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Can Integrated Rice-Fish System Increase Welfare of the Marginalized Extreme Poor in Bangladesh? A DID Matching Approach

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Abstract

Although Integrated Rice-Fish farming (IRFF) system is a potential technology but the adoption of IRFF farming system is very low and even decreasing. This raises the question of whether the returns and adoption of rice-fish systems are being adequately investigated. Most micro-level impact studies so far are based on cross-sectional data, which can lead to unreliable impact estimates, and also focus on productivity of IRFF systems, not its impact. This article presents results of a two-year panel survey with adopting and non-adopting indigenous farm households in Bangladesh to estimate the impact of adopting IRFF on small-scale indigenous farmers' overall welfare. Using propensity score matching with a difference-in-difference estimator we found that adopting IRFF has a positive and statistically significant effect on household total income and expenditure, total farm income, number of days fish is consumed in a month and the quantity of fish consumption per day in a month.

Keywords**:** Bangladesh; Integrated Rice Fish Farming System; Indigenous People; Difference-in-Difference; Propensity Score Matching; Impact.

JEL codes: O13; O33; Q16; Q22; Q01

IAAE

1. Introduction

Despite immense progress in poverty reduction in the developing world there are still about 1 billion people living below $1.25 per day in 2013 and another 162 million people live in ultra-poverty of less than 50 cents a day. Many people under the upper $1.25 line are vulnerable (Chen and Ravallion, 2012; Ahmed et al., 2007a). Similarly, more than 1 billion people in the world are chronically undernourished and food-insecure and most of them live in Asia and the Pacific Region (FAO, 2010). So food security and poverty reduction remains a daunting challenge for most of the developing counties including Bangladesh. Bangladesh is one of the poorest, densely populated (964/Sq. Km) and climate-change affected small country where 150.6 Million people live in an area of 147570 Sq. Km (BER, 2012). Agriculture is still the backbone of the country which employs 47.30 percent of the population and contributes 19.29 percent to GDP. It is important to have a profitable, sustainable and environmental friendly agricultural system in order to ensure a long-term food security in Bangladesh (BER, 2012). Similar to most of Asia, Bangladeshis consume rice as their staple food with ample amounts of vegetables, tubers and pulses, and a fair amount of animal protein, mostly fish and meat. Two traditional proverbs regarding food consumption behaviour are commonly said in Bangladesh. The first one is the old Bengali proverb *masse-bhatee Bangali* (i.e. rice and fish makes a Bengali), and the second one is *dal-bhate Bangali*, which refers to a meal of rice with pulses is considered a poor man’s good dish (Dey et al., 2010a). So rice and fish are integral part of the Bangladeshi food culture like in many Asian food culture. Rice is the dominant crop with a total annual production of around 33.9 million metric tonnes (MT) while the total fish production is about 3.3 million MT (BER, 2012). Due to mounting population there is a challenge to meet up the widening demand gap for both rice and fish. On the other hand there is no chance for horizontal expansion of land. Rather there is further threat of reduction of land due to diversification, urbanization and infrastructure demand for the growing population. Besides, the existing land suffers from stagnant production due to soil degradation (due to overuse of fertilizer and pesticides), ground water depletion and climate change effects. In such a situation, only solution is to intensify production on the land in a sustainable way to produce more food per drop of water. Integrated rice-fish farming systems broadly integrating agriculture with aquaculture (IAA) could be a sustainable solution which yields rice and fish together to meet the long term food and nutrition security in the developing country particularly in Bangladesh (Ahmed et al.2011; Ahmed and Garnett, 2011; Dey et al., 2010b). Integrated rice-fish farming system utilizes the scarce land and water resources rationally and it could be a sustainable source for animal protein, extra income and employment (Pullin, 1985; Frei and Becker 2005; Haroon and Pittman, 1997). Integrated rice-fish farming system contributes to diversification, intensification, productivity, profitability, environmental health, and sustainability (Nhan et al. 2007; Ahmed et al. 2007b; Rothuis et al., 1998 and 1999).

Since the 1990s, the World Fish Center, formerly known as ICLARM (International Center for Living Aquatic Resources Management), has been working with different national research organizations and universities in Bangladesh to promote integrated rice-fish farming, broadly IAA-based aquaculture technologies for generating an appropriate and sustainable low cost intensification option for smallholder rural farmers. The total area under paddy cultivation in Bangladesh is about 11.3 million ha of which 2.834 million hectares are inundated with seasonal rice fields and remains under water for 4 to 6 months (WRS, 2013). The Asian Development Bank (2004) reported that about 147, 280,000 ha of irrigated rice fields or 0.6% of the total irrigated land is suitable for rice-fish farming. The carrying capacity of this land and water are not fully utilized; there exists potential scope for integrating aquaculture with agriculture (Ahmed and Garnet, 2011; DOF, 2010; Wahab et al., 2008). Although rice-fish technology has been demonstrated successfully through various projects, adoption rates are still relatively marginal and not widely practiced in Bangladesh due to lack of technical knowledge, and an aversion to the risks associated with flood and drought, socio-economic, environmental, technological, and institutional constraints (Nabi 2008; Ahmed and Garnet, 2011; Ahmed et al., 2011). A few studies which analyzed the impact of integrated rice-fish farming systems in Bangladesh show mixed results. But no studies have been conducted on household income and expenditure, farm income and household food security impacts. Although the indigenous[1] people in Bangladesh and all over the world are socio-economically and ecologically marginalized, no studies on similar issues have been found. This study is the first of its kind in Bangladesh and is expected to generate valuable information on the impacts of integrated rice-fish farming systems. All other studies conducted in Bangladesh and elsewhere were based on cross sectional data and they indicated that the adoption and impact of the technology depended on technological

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[1] Indigenous, tribal and *Adivashi* are interchangeably used in this studies.

knowledge, drought, and sustained water availability (Nabi, 2008; Ahmed and Garnet, 2011; Ahmed et. al., 2011). Therefore, temporal impact variability may be projected. This makes integrated rice-fish farming system an interesting technology for impact assessment with panel data and improved econometric techniques in marginal people and marginal environmental settings.

Several studies have been undertaken on agricultural technology adoption and impact. These studies found out the factors affecting adoption and underlying impact on poverty alleviation, food insecurity reduction and rural development in developing countries (Feder et al., 1985; Feder and Umali, 1993; Doss, 2006; Sunding and Zilberman, 2001; Mendola, 2007; Amare, e tal., 2012; Minten and Barrett, 2008; Becerril and Abdulai, 2010). Most of these studies use cross-section observational data. For impact assessment, such data can be associated with non-random selection bias and cannot analyze temporal impact variability as well as address the broader policy questions and distributional effects (Doss, 2006). In addition, through cross section data, potential impact dynamics could not be evaluated (Besley and Case, 1993). Panel data can significantly tackle these problems, but panel data are rarely available and costly for impact assessment. In this study, two years' (2007 and 2009) panel data sets and appropriate statistical techniques were used for a more robust and trustworthy impact assessment. Using a difference in difference (DID)-propensity score matching method, this paper contributes to a growing impact evaluation and integrated farming systems literature in at least two ways. The first contribution of the paper is to identify casual effect of an integrated rice-fish system (IRFS) on household's welfare in terms of income, expenditure and food security in developing country's marginal people settings such as Indigenous people in Bangladesh by controlling for nonrandom selection bias (control for heterogeneity across households). The second contribution is its use of unique panel data sets (that almost cover all plain land inhabited by indigenous people) in Bangladesh, which were collected in two rounds in 2007 and 2009, and using DID-matching method for impact evaluation. The results provide valuable insights for other indigenous as well as non-indigenous people and farming systems research in many of the developing countries with similar socio-economic, agro-ecological and institutional settings. The empirical data for this study were obtained from a panel survey of 84 adopter and 147 non-adopter households from 14 sub-districts under 5 districts in Southwestern Bangladesh of the plain land where indigenous people are concentrated.

This paper is organized as follows: After the introduction the background on integrated rice- fish farming system in Bangladesh is presented in Section 2; the theoretical model, identification strategy and data, descriptive statistics and study area are discussed in Section 3; results of estimations by DID-matching and robustness checks are presented in Section 4; and Section 5 closes by highlighting the conclusion and recommendation.

2. Integrated Rice-Fish Farming System in Bangladesh

The production and harvesting of fish in rice fields is a traditional integrated farming practice in Asia such as China, Thailand, the Philippines, Vietnam, Cambodia, Malaysia, India, Bangladesh and Indonesia (David et al., 1996; Haroon and Pittman, 1997; Mackay, 1995; Lu and Li, 2006; Halwart et al., 1996). Recently it is selected as a "globally important agricultural heritage system" (GIAHS) by the Food and Agriculture Organization (FAO), United Nations Development Programme (UNDP), and Global Environment Facility (GEF) (Jian et al., 2011). Similarly in Bangladesh many farmers traditionally harvest a substantial amount of naturally occurring small indigenous species (SIS) of fish from rice fields for their own consumption. Some poor farmers even sell the harvest in the nearby market for income generation. But like with many other Asian countries due to introduction of green revolution technologies (GRT) in the 1970s, many of Bangladesh's traditional integrated rice–fish farming systems have transformed. As a result natural fish habitat have been destroyed, thereby reducing the SIS fish harvesting from the rice field, which in turn reduced an important source of both nutrition and income for many small-scale poor rural farmers and extreme poor households (Halls et al., 1998; Hoggarth et al., 1999; Shankar et al., 2004; Dey et al., 2013)[2].

To address the transformation brought by GRT, different national and international agricultural research and extension organizations, non-governmental organizations (NGOs), private companies, and rural entrepreneurs in Bangladesh piloted research and thereby explored

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[2] Klemick and Lichtenberg shows in Mekong Delta region of Vietnam, Green Revolution associated with pesticides have adverse effects on wild fish and other aquatic animals in rice fields (2008).

numerous alternative improved integrated rice–fish farming practices since the mid-1980s. Many of the Bangladeshi farmers stock fish in the rice filed in various forms like concurrently with, or subsequent to, rice cultivation depending on their farming environments and resource endowments (Dey et al., 2013; Halwart and Gupta, 2004; Gupta et al., 1998).

Since the introduction of improved integrated rice–fish farming practices in Bangladesh not so many comprehensive researches have been undertaken. So far research on integrated rice–fish farming practices in Bangladesh focused on experimentation and feasibility evaluation but the socio-economic research on rice–fish systems is relatively limited although several studies indicated its potential to improve agricultural production and food security by increasing resource utilization, diversity, productivity and efficiency in both rainfed and irrigated environment (Dey et al., 2013; Ahmed and Garnet, 2010; Ahmed et al., 2011; Edwards, 2000). Dey et al. (2013) did meta-analysis based on 29 published articles and unpublished reports, and indicated that so far research on rice-fish system focused mainly on biological and technical issues. Most of the studies dealt with location and season specific biophysical and technical feasibility of rice-fish technologies, rather than feasibility at a system level or across an entire agricultural year. Socio-economic, policy, and institutional dimensions of rice–fish systems research is scanty. Interestingly, it is now acknowledged that no research has been conducted on extreme poor and marginal people like indigenous peoples in Bangladesh. Furthermore, most of the previous studies do not explicitly point to a causal effect of integrated rice-fish system adoption on farm household wellbeing, or, in other words, they failed to establish an adequate counterfactual situation and identify the true causality of rice-fish system adoption[3]. But to assess the impact of a new technology on wellbeing, the counterfactual situation is necessary (Mendola, 2007). Against these backdrops, the main aim of this study is to examine the likelihood impact of integrated rice-fish farming system on farm household wellbeing in marginalized extreme poor indigenous people setting in Bangladesh by using various quantitative micro-econometric evaluation techniques.

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[3] They did not control for the potential endogeneity (due to selection bias and endogenous program/project placement) of the rice-fish system adoption.

3. Methodology of the Study

3.1 Study Area and Data with Descriptive Statistics

Of the total 163 million people in Bangladesh more than 2.5 million (1 to 2 %) are indigenous people of different ethnic groups. These groups are characterized as: mostly poor, food and nutrition insecure and lack safe drinking water and sanitary facilities; marginalized in terms of socio-economic, ecological and political; face discrimination and are subject to extortion by land grabbers; and having dependencies on natural resources. But excessive population pressure, resource depletion and dwindling aquatic and terrestrial habitats continue to threaten *Adivasis'* traditional livelihoods. The Bangladesh Poverty Reduction Strategy Paper (PRSP) identified the challenges of indigenous communities (IC) as: remoteness, low food production, lack of institutional mechanism, understanding of the problems of the indigenous communities, and lack of census and statistical data. The indigenous communities are excluded from mainstream development activities even from social safety net programs (SSNP). The political economy hypothesis also stated that there is a negative association between ethnic heterogeneity and public good provision (CIA, 2013; AFP, 2010; PRSP, 2008; Habyarimana et al., 2007; Ahhmed, 2012). The Adivasi Fisheries Project (AFP) implemented by the World Fish Center (WFC) with different national partner organizations was aimed at increasing fish production, household nutrition, income and alternative employment opportunities of vulnerable Adivasi *(*Indigenous) people through the promotion of small-scale aquaculture and aquaculture enterprise development activities. It was also aimed to find new and more sustainable livelihoods option in the northern and north-western regions of Bangladesh from January 2007 to December 2009.

This study was conducted in the 8 Upazilas of Dinajpur, Rangpur and Joypurhat Districts in the north-western region and in 4 Upazilas of Netrokona and Sherpur Districts in the northern region where Adivasi Fisheries Project (AFP) was implemented by WFC through EU funding (Figure 1). Although the project offered several technological and enterprises development options for the Adivasi households, this paper dealt with the data on only those who participated in integrated rice-fish technologies (treatment group) and non-project participants (control group). The households who have potential resources for aquaculture i.e. having rice fields were used as main criterion for selection of households for the project. The selection of household was based on Participatory Rural Appraisal (PRA) in the communities and a preliminary survey of all the households was conducted in the selected communities using a checklist. Of the total 5537 Adivasi households living in 120 communities, 3650 Adivasi households of poorer categories were finally selected as the project participants. Among the 3650 households, 533 households were selected for integrated rice-fish technology depending on the availability of resources for integrated rice-fish farming. The project provided initial financial and advocacy support (to develop rice fields by renovating rice fields for fish culture) together with technical know-how through the formation of Farmer Field Schools (FFSs) and training of project staff, capacity building programs and exchange visits of the project beneficiaries, farmers field day, and formation of a network forum for Adivasi communities involved in the project (AFP, 2010)[4]. Thus adoption or participation in the integrated rice-fish farming system was not random which could have led to the problem of self-selection. This problem is tested and accounted for in this article.

For the purposes of the study in the first round of survey, a total of 84 farmers (who were later absorbed in the project) were randomly selected (treatment group) from four AFP working areas (in Fig-1) in 2007 before the project was implemented as a baseline. In addition to this 147 households were randomly selected from the same four working areas and in the same year as non-project farmers (control group) to whom no technical support was given and no one was practicing integrated rice-fish farming system and no project interventions promoting integrated rice-fish farming technologies had taken place in the past. The second round of the survey on the same project (treated) and non-project (control) households were conducted in 2009 at the end of the project period. In both surveys, an equal number of respondents was interviewed; so this analysis is based on a balanced panel sample, that is, for this study 231 farm households for which two rounds of data were available were used. Out of these, around 36% were integrated rice- fish adopters, and 64% non-adopters (see Table 1 for sample distribution). Both surveys used detailed structured household questionnaires for data collection, and cross validation was done by different key informants related to integrated rice- fish farming, research and extension.

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[4] See Pant et al 2014 for detail the processes followed in identifying appropriate intervention options, planning and implementing activities and baseline as well as end line survey of sample households of Adivashi fisheries project in Bangladesh.

To the best of our knowledge, this is the only panel survey of integrated rice- fish farming system in a developing country.

The Table 2 reports the descriptive statistics of the key independent variables by adoption status for 231 surveyed households. These characteristics are the explanatory variables of the estimated models that are presented further on, selected on the basis of the theoretical discussion. As Table 2 shows, adopters and non-adopters had group mean differences among several observed pre-adopting covariates. For example, the gender of the head of the household of adopter was significantly more male-dominated than non-adopters. Head of the adopter households were also more likely to be literate and also to possess more land and more non-farm income. Furthermore, size of irrigated landholding and likelihood of having more information (about market place, price etc.) were larger among the adopter households. Interestingly, the adopter households were more likely to have more working age population in their households. Compared to the non-adopter households, the adopter households had significantly greater access to irrigation and more marketing engagement. As expected, the adopter households had more frequency of contact with extension media and less conflict with other villagers and less shock affected the households compared to the non-adopters. Integrated rice-fish farming system adopters and non-adopters were similar with regard to age of the household head, household size, and access to credit and extension. These were the factors which were also shown in other studies that determined technology adoption behaviour (Mendola, 2007; Murshed-E-Jahan and Pemsl, 2011).

Mean values for the outcome variables of interest, namely annual household's income, expenditure, food expenditure, farm income[5], number of days fish consumed in a month, total meal with fish per month and household fish consumption per day in a month, are shown in Table 3 for 2007 and 2009. From the descriptive analysis in Table 3, it is evident that both adopters and non-adopters had significantly higher annual household income, expenditures, number of days fish consumed in a month, total meal with fish per month and household fish consumption per day in a month in 2009 as compared to 2007. Similarly, annual household farm income and food expenditures were also higher in 2009 than in 2007, but the difference is statistically significant only for the adopters. However, this comparison may be misleading, so it

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[5] The entire income and expenditure figures of 2007 are inflation adjusted to take into account the price effect.

should not be overly interpreted. Because, these descriptive results one cannot tell whether or not the difference or no difference is due to the adoption of integrated rice-fish farming system or some other factors. In fact, documentation of a casual effect cannot be possible before taking care of the influences of confounding factors. In the subsequent section the article present the DID matching method and derive the integrated rice-fish farming system treatment effect by controlling this matter.

3.2 Econometric Approach

This study aims to quantify the impact of integrated rice-fish farming system adoption on income, expenditure and food security (broadly welfare impact) in Bangladesh. But how can one be sure that the better welfare of the adopters as compared to the non-adopters is caused by integrated rice-fish farming system adoption? To answer this question we need counterfactual situation as experiment can provide this information. But this is not the case in our study so our impact evaluation problem is a missing data problem (Blundell and Costa Dias, 2000; Heckman, Ichimura and Todd, 1997; Smith and Todd, 2005). In order to answer the question we have to differentiate the integrated rice-fish farming system impact from other socio-economic determinants of outcome variables. So it's a self-selection problem i.e. households (partly) determine whether they adopt the integrated rice fish farming systems and their decision may be related to the expected utility deriving from it. In other words, the relationship between integrated rice-fish farming system adoption and welfare is likely to be a two-way relation (reverse causality) whereby technology (rice-fish farming system) can help wellbeing and wellbeing can affect adoption. Thus, it is difficult to establish the causal effect of integrated rice-fish farming system on welfare, but at the same time this is necessary to better understand the effectiveness (e.g. in terms of poverty and food security impact) of any new technology e.g. Integrated rice-fish farming system (Mendola, 2007).

In case of program or technology evaluation, main interest is quantifying the impact of a treatment on the treated (Heckman et al., 1997, 1998). In a counterfactual framework (i.e. if technology is randomly assigned to households like an experiment), the average treatment effect is defined by Rosembaum and Rubin (1983) as

Δ=E (Yi^1-Yi^0) (1)

i.e. the mean impact of a treatment on the treated is the difference between mean values of the outcome variable of interest for the treatment and control groups.

The fundamental evaluation problem is that both of these outcomes (Yi^1 and Yi^0) in equation (1) cannot be observed for the same household at the same time. For example if treatment status for adopter and non-adopter are denoted "1" and "0" respectively. Outcomes are (Y^1 and Y^0). Let D = 1 if a person is in state "1"; D =0 otherwise. What we can observe from equation (1) is as follows

$Y= Di\, Yi^1 + (1-Di)\, Yi^o$ Di=0, 1. (2)

The gain from moving an individual from the state "without treatment" to the state "with treatment" is

$\Delta = Yi^1 - Yi^0$. *(3)*

Unfortunately, the difference between Yi^1 and Yi^0 cannot be observed for the same farm household, because adopters have adopted and we do not know what their outcome would have been had they not adopted (i.e. missing data problem) (Todd, 2007).

If integrated rice fish-farming system was randomly assigned to households, the average treatment effect could be computed by taking the difference in means of the outcome variable between those who adopted and those who did not (Heckman et al., 1998). However, this procedure cannot be applied in our present case because as stated earlier *Adivasi* fisheries project followed a non-random process for targeting of its beneficiaries. So adoption of integrated farming system by indigenous households in Bangladesh is non-random; that is, subject to self-select into treatment. The treatment effect i.e. outcome difference between adopter and non-adopter may be due to systemic difference rather than integrated rice-fish farming system adoption. This would lead to selection bias problem, and the impact of integrated rice-fish farming system adoption would be overestimated or underestimated, depending on the type of bias.

The problem can be solved through different parametric and non-parametric methods. In such a case an appropriate non-experimental method (see Blundell and Costa-Dias, 2000; Smith and

Todd, 2005 for advantages and disadvantages of different non-experimental methods) is commonly used for impact evaluation. A popular non-experimental method is propensity score matching (PSM), which is sufficient to remove bias due to all observed covariate but not for unobserved heterogeneity (Rosenbaum and Rubin, 1983; Becerril and Abdulai, 2010; Mendola, 2007). Another method is instrumental variables estimator (IV), which can deal with unobserved heterogeneity (Greene, 2008). IV has the advantage to generate a ‘‘natural experiment’’ (Mendola, 2007). But basic requirements of using this method are that the set of valid instruments, Z, must be relevant and exogenous and at the same time we would assume an ‘untestable condition’, such as the exclusion restriction and a linear functional form assumption. However, it is often very difficult to find a strong instrument and perfect control of the treatment assignment i.e. compliance, especially in cross section data (Mendola, 2007)[6]. In contrast to that, if panel data are available, fixed-effects models can be used (Krishna and Qaim, 2012). Fixed-effects estimators require sufficient within-group variability with respect to the treatment variable for impact analysis (Kikulwe, Kabunga and Qaim, 2012). Blundell and Costa-Dias, (2000) and Smith and Todd (2005) recommend in the presence of both baseline and follow-up survey data, a more robust procedure for impact evaluation would be a difference-in-difference (DID) or DID in combination with PSM. Similarly, Michalopoulos et al. (2004) showed that the propensity score method has some advantages in some cases because PSM combined with other methods can deal with unobserved heterogeneity, when repeated cross section or longitudinal data are available. We have two years’ panel data on baseline and end line (follow-up) survey from *Adivashi* fisheries project about the adopter and non-adopter of integrated rice-fish farming system households. Thus, we use PSM combined with a difference-in-difference (DID) estimator to analyse our two years’ panel data sets. Next, we first describe the PSM method as usual and introduce the DID estimator consequently.

The idea behind PSM is to match the non-adopter of integrated rice-fish farming system with adopters based on their observable characteristics (Rosenbaum and Rubin, 1983; Smith and Todd, 2001, 2005). The first step in the application of PSM is to estimate the propensity score (*p score*) which is defined as the conditional probability that a farm household adopts integrated

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[6] See also Heckman and Navarro-Lozano, 2004; Jalan and Ravallion, 2003 for broad discussion.

rice-fish farming system given a vector of observed farm household characteristics Z*i* *(*Rosenbaum and Rubin, 1983*)*. The propensity score can be estimated as follows:

$$P(Zi)=\text{Prob}\ (Bi=1|Zi) \qquad (4)$$

where B =(0,1) is an adoption dummy, and Zi is a vector of baseline covariates, including variables that can affect both adoption and outcomes. Logit or probit models can be used to estimate propensity scores (Maddala, 1983). Probit model is used in this study.

The balancing property and common support conditions are imposed for implementing PSM. A balancing score, b (z), is a function of the observed covariates z such that the conditional distribution of z given is the same irrespective of their treatment status i.e. households with the same (similar) propensity score should have the same distribution of Z, irrespective of the treatment status. It is crucial to reduce the influence of possible confounding factors (Rosenbaum and Rubin, 1983; Dehejia and Wahba, 2002). The common support, or overlap, condition assures the propensity score is bounded away from 0 and 1 i.e. the households with the same (or similar) characteristics have a positive probability of both adopting and non-adopting integrated rice-fish farming system (Heckman et al., 1997; Smith and Todd, 2005). This improves the quality of the matches as it is only performed for treated and control households that share a common support in their estimated propensity scores, excluding the tails of the distribution of P (Z), but this is done at the cost that sample may be considerably reduced. However, Rubin and Thomas (2000) mentioned that, impact estimates based on full samples yields less reliable, more biased estimates than those based on matched samples. Other than these, PSM also allows to compute heterogeneous treatment effects since it does not impose any assumption on the data (Abebaw, Fentie and Kassa, 2010).

In case of cross-section data, single difference matching estimator is used to address the so called missing data problem i.e. selection bias. After estimating the propensity score, the ATT is estimated as follows:

$$ATT= \{E\ (Y^1-Y^0|P(Z)\} = \{E\ (Y^1|B=1, P(Z)\} - \{E\ (Y^0|B=0, P(Z)|B=0\} \qquad (5)$$

This ATT estimator cannot control possible differences between adopters and non-adopters that are due to unobserved factors. However, when panel data are available, as in our case, it is possible to control the unobserved heterogeneity. In panel data case, PSM can be combined with a DID estimator, which cancel out time-invariant unobserved factors (Smith and Todd, 2005). Hence, a combination of PSM and DID can improve the quality of non-experimental evaluation to a great extent (Blundell and Costa Dias, 2000; Benin et al., 2011). Thus this study use combination of PSM and DID i.e. difference-in-difference (DID) matching (Abadie, 2005; Heckman, Ichimura, and Todd, 1997; Smith and Todd, 2005) to estimate the ATT and to eliminate selection bias. DID-matching combines a non-parametric matching procedure with first-differencing with respect to a pre-treatment period. Matching eliminates selection bias due to observed covariates by comparing adopter farm households to similar non- adopters. First-differencing eliminates selection bias due to time-invariant unobservable heterogeneity. Thus this estimator eliminates time-invariant differences in outcomes between participants and non-participants that cross-sectional matching fails to do (Smith and Todd, 2005). Combination of matching and DID can weaken the underlying assumptions of both methods (Blundell and Costa-Dias, 2008). In PSM the conditional independent assumption (CIA) is quite strong if individuals are expected to decide according to their forecasted outcome. The DID matching as proposed in Heckman, Ichimura, and Todd (1997) can accommodate time invariant unobserved determinants of the non-treated outcome affecting participation. DID matching can be used when treated and non-treated are observed over time with at least one observation before and one after the treatment, as in our case (Blundell and Costa- Dias, 2008).

With our panel data, the ATT of integrated rice fish farming system adoption is then calculated by comparing the changes in individual outcomes among adopters ($Y^1_{2009} - Y^1_{2007}$) with the changes among their non-adopting matches ($Y^0_{2009} - Y^0_{2007}$). So ATT defined is as follows:

$$ATT=E\,\{(Y^1_{2009} - Y^1_{2007} | B=1, p(Z)) - (Y^0_{2009} - Y^0_{2007} | B=0, p(Z) \mid B=0)\}$$

$$=1/Ni\,\{\sum^{Ni}_{t=1} (Y^1_{2009} - Y^1_{2007}) - \sum^{Ni}_{t=1} (Y^0_{2009} - Y^0_{2007})\} \qquad (6)$$

Where N_i is the number of matches.

There are different matching algorithms available for PSM and the choice of a matching method is a tough exercise and mostly depends on the nature of the data. There are different statistical tests for comparing quality of matching (see Caliendo and Kopeinig, 2008; Abadie and Imbens, 2006; Becker and Ichino, 2002; Leuven and Sianesi , 2003 for details). Kernel matching and nearest neighbor (NN) matching are the most commonly used ones. Kernel matching calculates treatment effects by subtracting from each outcome observation in the treatment group a weighted average of outcomes in the control group. On the other hand, NN matches adopters with non-adopters based on the nearest propensity score, while controlling for differences between adopters and non-adopters (Abadie and Imbens, 2006). Caliendo and Kopeinig (2008) reported that a good matching estimator does not exclude too many of the original observations from the final analysis while at the same time it should produce statistically equal covariate means for households in the treatment and control groups. This study use kernel matching with band widths (BW=0.03 and BW=0.06) and NN matching with (NN=1 and NN=5). Analyses are based on common support and caliper, reflecting that the distributions of integrated rice fish farming system adopters and non-adopters were closely alike in terms of observable characteristics. As a balancing test, we test for significant differences in terms of independent variables between integrated rice fish farming system adopters and non-adopters before and after matching (Dehejia and Wahba, 2002).

For ATT estimation, this study use bootstrapping methods for robust standard errors, NN matching was implemented with replacement. NN matching contributes to bias reduction and it is also an important approach in small sample size study such as this study (see further details Dehejia and Wahba, 2002). The outcome variables considered are total household income, farm income, total household expenditures, household food expenditures, household fish consumption frequency per month.

4. Results and Discussion

4.1 Propensity Score Matching

Before identifying and quantifying the impact of integrated rice-fish farming system on different outcome variables, we need to appropriately specify[7] and estimate the propensity score that a household had been included in integrated rice-fish farming system. Caliendo and Kopeinig (2008) stated that estimating a valid propensity score should include the covariates of those who

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[7] Should include the explanatory variables that affect outcome as well as adoption of integrated rice fish farming system.

are exogenous and unaffected by the adoption. Pre-adoption/intervention characteristics are used to fulfill this condition in our study. We use a probit model to predict the probability to adopt the integrated rice-fish farming system and we include different ranges of characteristics as explanatory variables that was already discussed in Table 2. In Table 4, the estimation results from the best specifications[8] of the propensity scores equation are presented. The dependent variable in the probit model is coded as 1 for adopter and 0 for non-adopters. The estimated model is statistically significant at the 1% level. Significant coefficients in the probit model indicate that adopter and non-adopter households are different with respect to the corresponding variables. The estimated probit models suggest that farm size, age of the household head, household size, frequency of extension media contact, non-farm income, access to agricultural information and conflict with the villagers are important determinants of integrated rice-fish farming system adoption by indigenous people in Bangladesh. The results are more or less similar in direction with earlier adoption research for integrated rice-fish farming system and other agricultural technology in smallholders in developing countries (Feder et al., 1985; Doss, 2006; Murshed-E-Jahan and Pemsl, 2011: Nabi 2008; Dey et al., 2010b; Ahmed and Garnet, 2011; Ahmed et al., 2011). We imposed common support and the balancing property condition, both condition were satisfied which indicates reasonable goodness-of-fit of the estimated model.

4.2 Average Treatment Effects on the Treated (ATT)

Several researchers (e.g. Smith and Todd, 2005; Dehejia and Wahba, 2002; Caliendo and Kopeinig, 2008) recommend to use different algorithms[9] to estimate ATT and to check robustness of the result. The impact of integrated rice-fish farming system on different outcomes of indigenous rural households is estimated through different methods, i.e., the Nearest Neighbour Matching (NNM), the Kernel-Based Matching (KBM) methods and radius matching. The ATT, estimated with the DID estimator and different matching algorithms, are presented in

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[8] Although we tried different specifications but here reported the best fitting one in terms of larger number of variables are statistically significant with expected sign, larger pseudo-R2.Other specifications also tried to check the robustness of our result.

[9] That algorithm should use which one produce statistically identical covariate means for both groups (Caliendo and Kopeinig, 2008), that provides low pseudo-R^2 value (Sianesi, 2004) and statistically insignificant likelihood ratio test of all regressors after matching (Smith and Todd, 2005). On the other hand, a good matching estimator should accommodate relatively larger observations for evaluating the impact of an intervention (Moreno-Serra, 2009).

Table 5[10]. Overall, matching estimates show that integrated rice-fish farming system adoption has a positive and robust effect on total annual household income and expenditure, annual farm income, number of days fish is consumed in a month, total meal with fish per month and household fish consumption per day in a month.

During the period of investigation integrated rice-fish farming system increased significantly the total annual household income and expenditure, annual farm income, number of days fish is consumed in a month, total meal with fish per month and household fish consumption per day in a month. These results are quite different from the simple comparison of adopter farmers' total annual household income and expenditure, annual farm income, number of days fish consume in a month, total meal with fish per month and household fish consumption per day in a month in Table 3, confirms that there is significant positive selection bias. That is farmers with higher income, expenditures are more likely to adopt integrated rice-fish farming system compare to average income and expenditures categories farmers. Therefore, a simple comparison between adopters and non-adopters overestimates the integrated rice-fish farming system's treatment effect. This selection bias is controlled for by the PSM and DID methodology. Most of the estimates in Table 5 are significant, underlining the robustness of the causal effect of integrated rice-fish farming system adoption on total annual household income and expenditure, annual farm income, number of days fish is consumed in a month, total meal with fish per month and household fish consumption per day in a month.

In evaluating the reliability of the above results, we carried out the balancing test by pstest after psmatch2 command (developed by Leuven and Sianesi, 2003) before and after matching but not reported here to save space. The test shows, adopters and non-adopters have statistically similar characteristics and group means test shows that there is no statistically significant difference after matching. Furthermore, the percentages of bias for all covariates are below after matching. The test results show that all significant differences between adopters and non-adopters in the unmatched sample were eliminated after matching. The distributions of the estimated propensity scores for adopters (treatment) and non-adopters (control) are shown in Fig. 2. As expected, it shows that the two groups have substantial overlap in their propensity score distributions.

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[10] The data and econometric code used to generate the results are available upon request.

5. Conclusion and Recommendation

Although the relationship between agricultural technology and farm household's welfare is complex, this study evaluated the impact of integrated rice-fish farming system on annual household income, expenditure, food expenditure, farm income, number of days fish is consumed in a month, total meal with fish per month and household fish consumption per day in a month, using two years' panel survey data from Adivashi project areas, in the north-western and northern regions of Bangladesh. The Adivashi fisheries project was implemented between 2007–2009 by the world fish center in association with partner NGOs and different national research organizations. The main research question of the study was ‘‘what would have been the welfare of the indigenous household (in terms of annual household's income, expenditure, food expenditure, farm income, number of days fish consume in a month, total meal with fish per month and household fish consumption per day in a month) had the households not adopted the integrated rice-fish farming system?"

Improving agricultural productivity through sustainable intensification is one of Bangladesh's policy priorities especially in the agricultural sector. In this respect, integrated rice-fish farming system is expected to play an important role through complementary use of scarce land and water resources in achieving sustainable growth in agriculture sector. However, to the best of our knowledge, no quantitative micro-econometric studies have examined whether or not the integrated rice-fish farming system have impacted farm households welfare in terms of annual household's income, expenditure, food expenditure, farm income, number of days fish is consumed in a month, total meal with fish per month and household fish consumption per day in a month in Bangladesh. Particularly, impact studies with panel data on integrated rice-fish farming system in marginal people settings have not been done yet, in Bangladesh and elsewhere. But from a policy perspective, this is crucial since integrated rice-fish farming system is expected to improve the stagnant agricultural productivity in a sustainable fashion in the country. This paper is an attempt to fill this gap by investigating the impact of integrated rice-fish farming system on annual household's income, expenditure, food expenditure, farm income, number of days fish is consumed in a month, total meal with fish per month and household fish consumption per day in a month in Bangladesh. To this end, two years panel data and a combination of DID and PSM technique were used to measure and quantify the impacts.

Unlike the previous impact studies on integrated rice-fish farming system and other agricultural technologies, most of which were based on cross-section data, this study used panel data covering two time periods (baseline and follow up survey). This allowed us to combine propensity score matching with a difference-in-difference estimator to control for observed as well as unobserved heterogeneity and established causality by solving the selection bias problems. The estimation results show that adoption of integrated rice fish farming system has positive impacts on almost all outcome variables. The projected effects are very large. In this study, although we emphasize the importance of methodological issues in evaluating causal relationships, but our analysis also highlights the potential role of integrated rice-fish farming system to rural development in the Bangladesh particularly the small farm households and indigenous people.

Our analysis also highlighted that as integrated rice-fish farming system is a knowledge-intensive technology, thus successful adoption and diffusion requires proper extension and access to proper agricultural information (see table 4). May be these are also the reasons why integrated rice-fish farming system adoption is still relatively marginal in Bangladesh. Thus our results put emphasis that strong extension efforts to deliver the system technologies to smallholder particularly to the marginal indigenous farm households should be strengthened.

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Tables and Figures

Table 1: Number of sampled farm households in two survey waves

Adopter categories	Year of survey	
	2007	2009
IRF adopter	84 (36.36)	84 (36.36)
Non-adopter	147 (63.64)	147 (63.64)
All	231(100)	231 (100)

NB: In bracket is percentage (%)

Table 2. Descriptive statistics for IRF system adopters and non-adopters (2007)

Variables	Type	Definition and measurement	Adopter categories	Mean	Std. Dev.	dif
Sex	Dummy	=1 if male-headed	Non-Adopter	0.898	0.304	0.090***
			Adopter	0.988	0.109	
			All	0.931	0.254	
Age	Continuous	Age of household head in years	Non-Adopter	46.082	11.733	1.073
			Adopter	47.155	12.671	
			All	46.472	12.066	
Marital status	Dummy	=1 if the household head is married	Non-Adopter	0.864	0.344	0.065
			Adopter	0.929	0.259	
			All	0.887	0.317	
Education	Continuous	Schooling of household head in Years	Non-Adopter	3.150	3.926	1.172**
			Adopter	4.321	4.421	
			All	3.576	4.142	
Total working people in the household	Continuous	Total number of people age between 15 to 64 in the household	Non-Adopter	2.741	1.153	0.306*
			Adopter	3.048	1.241	
			All	2.853	1.192	
Household size	Continuous	Total Number of household members	Non-Adopter	4.422	1.512	0.126
			Adopter	4.548	1.731	
			All	4.468	1.593	
Farm size	Continuous	Total land area in decimal	Non-Adopter	103.746	107.342	76.296***
			Adopter	180.042	160.761	
			All	131.490	134.140	
Access to irrigation	Dummy	=1 if irrigated crop land last year	Non-Adopter	0.701	0.460	0.168***
			Adopter	0.869	0.339	
			All	0.762	0.427	
Irrigated area	Continuous	Irrigated land last year (in decimal)	Non-Adopter	59.190	74.046	45.101***
			Adopter	104.292	128.731	
			All	75.591	99.666	
Non-farm income	Continuous	Annual income from non-farm sources (in Taka[11])	Non-Adopter	21650.920	16983.490	6182.406***
			Adopter	15468.510	14941.680	
			All	19402.770	16508.930	

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[11] One US dollar equal to 68.80 Bangladeshi Taka (i.e. 1$=68.80 Bangladeshi Taka i.e. BDT) (BB, 2009) http://www.bb.org.bd/openpdf.php

Marketing	Dummy	=1 if engaged in marketing	Non-Adopter	0.837	0.371	0.128***
			Adopter	0.964	0.187	
			All	0.883	0.322	
Access to credit	Dummy	= 1 if able to access credit	Non-Adopter	0.918	0.275	0.034
			Adopter	0.952	0.214	
			All	0.931	0.254	
Information	Dummy	=1 if get agricultural information	Non-Adopter	0.823	0.400	0.165***
			Adopter	0.988	0.109	
			All	0.883	0.335	
Access to extension	Dummy	=1 if have access to GO or NGOs extension	Non-Adopter	0.939	0.241	0.037
			Adopter	0.976	0.153	
			All	0.952	0.213	
Extension media contact	Continuous	Frequency of contact with extension media	Non-Adopter	0.612	0.489	0.376***
			Adopter	0.988	0.109	
			All	0.749	0.435	
Conflict with other villagers	Dummy	=1 if face conflict with villagers before survey	Non-Adopter	0.429	0.497	-0.167***
			Adopter	0.262	0.442	
			All	0.368	0.483	
Shocks	Dummy	=1 if face any shocks before survey	Non-Adopter	0.857	0.351	-0.095*
			Adopter	0.762	0.428	
			All	0.823	0.383	

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table 3. Descriptive statistics for outcome (dependent) variables

Dependent Variables	Unit	Adopter categories	2007		2009		difference
			mean	Sd.	mean	Sd.	
Total household Food expenditures	BDT[12]	Adopter	27556.01	9020.514	30810.59	11691.29	3254.58**
		Non-adopter	26704.93	9930.47	28231.07	11134.74	1526.136
		All	27014.42	9598.478	29169.08	11383.07	2154.661**
Total household income	BDT	Adopter categories	51847.6	24599.11	87050.18	49636.11	35202.58***
		Non-adopter	50711.24	30143.5	60880.53	49572.27	10169.29**
		All	51124.46	28203.74	70396.76	51070.33	19272.31***
Household total expenditures	BDT	Adopter	56290.17	25883.05	83822.14	53475.73	27531.98***
		Non-adopter	51527.54	30712.13	60271.46	42758.84	8743.918**
		All	53259.41	29082.28	68835.35	48181.42	15575.94***
Farm income	BDT	adopter	35160.87	25142.58	57146.45	39485.86	21985.58***
		Non-adopter	28058.48	28183.83	28749.59	39502.33	691.1054
		All	30641.17	27277.7	39075.72	41720.4	8434.552***
Number of days fish consume in a month	No of days in a month	adopter	7.547619	3.977057	13.89286	5.812363	6.35***
		Non-adopter	4.768707	3.094556	9.911565	5.730148	5.142857***
		All	5.779221	3.685306	11.35931	6.059551	5.580087***
Total meal with fish per month	Total meal with fish per month	adopter	11.45238		26.7381		15.28571***
		Non-adopter	7.421769	5.748049	18.15646	13.3692	10.73469***
		All	8.887446	6.717619	21.27706	14.57041	12.38961***
Fish consumption per day in a month	Consumption per day (in Kg.)	adopter	2.990893	2.36188	6.124524	3.716176	3.133631***
		Non-adopter	2.337075	1.56738	3.885884	2.732367	1.54881***
		All	2.574827	1.916223	4.699935	3.299622	2.125108***

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

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[12] Bangladeshi Taka (1$=68.80 in 2009)

Table 4. Probit estimates for propensity (or factors determining) to adopt integrated rice fish farming system (2007)

Variables	Coef.	Std. Err.	P>z
Sex	0.807	0.840	0.337
Age	-0.109	0.066	0.098*
Age square	0.001	0.001	0.075*
Marital status	0.770	0.566	0.174
Education	-0.114	0.096	0.236
Education square	0.014	0.009	0.135
Total working people in the household	0.051	0.118	0.664
Household size	-0.177	0.088	0.045**
Farm size	0.004	0.002	0.070*
Farm size square	0.000	0.000	0.443
Access to irrigation	-0.112	0.337	0.740
Irrigated area	-0.001	0.001	0.452
Non-farm income	0.000	0.000	0.028**
Marketing	-0.134	0.641	0.834
Access to credit	0.130	0.496	0.793
Information	1.747	0.670	0.009***
Access to extension	0.841	0.558	0.132
Extension media contact	2.487	0.542	0.000***
Conflict with other villagers	-0.508	0.229	0.026**
Shocks	-0.408	0.289	0.159
_cons	-2.841	1.812	0.117
Log likelihood		-98.497	
LR chi2(20)	=	105.840	
Prob > chi2	=	0.00	
Pseudo R2	=	0.350	
Number of observation		231	

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table 5. Average treatment effect on the treated (ATT) of integrated rice fish farming system (2007-2009)

Outcome	Matching algorithm					
	Kernel (BW=0.03)	Kernel (BW=0.06)	Nearest-neighbor (NN=1)	Nearest-neighbor with the bias adjustment (NN=5)	Radius matching (caliper = 0.05)	Radius matching Caliper = 0.1
Household total annual income	20604.213***	19624.391**	21762.08**	26523.76**	22952.934***	24377.025***
Total annual farm income	28987.625***	28024.443***	24367.01***	23893.86***	25344.098***	25203.051***
Household annual total expenditures	1750.939	4226.842	20672.67**	17246.38**	16456.902***	18373.799***
Household annual food expenditure	1154.034	2057.430	1621.961	2995.8	1531.947	1900.624
Total number of days fish consume per month	1.687**	1.762***	1.74494***	1.393155**	1.710***	1.695 ***
Quantity of fish consumption per day in a month	1.971*	1.853	2.369048**	1.392878	1.839*	1.688 *

Notes: ATT estimates of nearest neighbor matching were obtained by applying ‘nnmatch’ command using the bias adjustment option (in case of NN=5) in Stata (Abadie et al., 2004) and ATT estimates of radius and kernel matching (based on Epanechnikov kernel) were obtained by implementing the ‘attk and attr’ command (Becker and Ichino, 2002). Bootstrapped standard errors (number of replications = 1000) also estimated for kernel and radius matching estimators. With the kernel and radius matching estimators common support condition and balancing condition are imposed and satisfied and the matched sample includes 84 adopter and 96 non-adopters of integrated rice fish farming system.

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

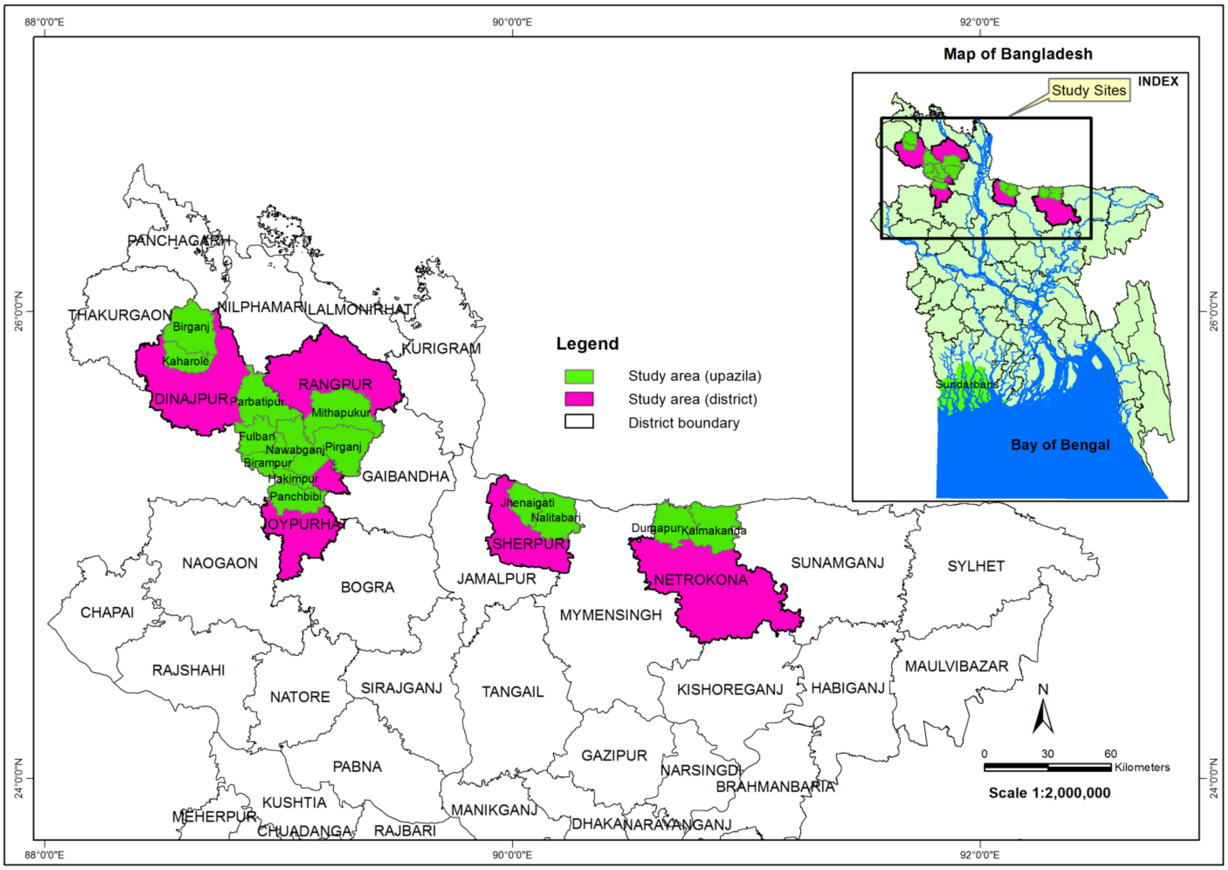

Fig. 1. Study areas: districts and sub-districts are shows by different colours

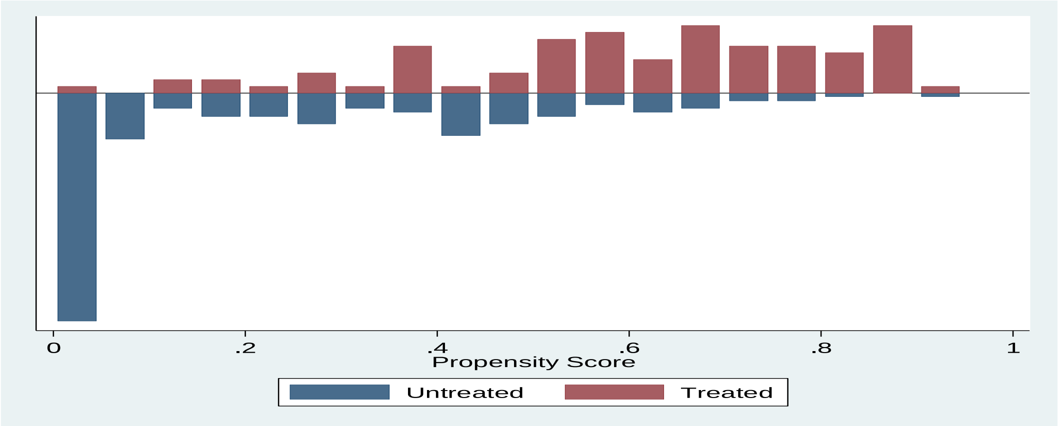

Fig. 2. Distribution of propensity scores.