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Impact of Integrated Aquaculture-agriculture Value Chain Participation on Welfare of Marginalized Indigenous Households in Bangladesh: A Panel Data Analysis

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In the light of on-going debates about the sustainable agricultural intensification and sustainable development paradigms, this paper examined the linkages between integrated aquaculture-agriculture (IAA) value chain participation dynamics and the welfare of marginalized extremely poor indigenous households using a three-wave household panel dataset from Bangladesh. The distributional effect of IAA participation was also investigated by examining impacts across different value chain actors. We applied pooled Ordinary Least Squares, Random-Effects, and Standard Fixed-Effects, Heckit panel, and control function approaches to control for endogeneity of IAA participation and unobserved heterogeneity. We found that IAA value chain participation is positively correlated with household income, expenditure and the consumption frequency of certain foods, especially fish consumption, and the benefits continue to accrue after discontinuing participation in the value chain. The results reveal that IAA value chain participation has higher impacts on the welfare of relatively wealthier households involved in production related IAA value chain activities than on landless, extremely poor households that were involved in upstream and downstream IAA value chain activities.

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JEL Codes: O33, I31

#96



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Abstract

In the light of on-going debates about the sustainable agricultural intensification and sustainable development paradigms, this paper examined the linkages between integrated aquaculture-agriculture (IAA) value chain participation dynamics and the welfare of marginalized extremely poor indigenous households using a three-wave household panel dataset from Bangladesh. The distributional effect of IAA participation was also investigated by examining impacts across different value chain actors. We applied pooled Ordinary Least Squares, Random-Effects, and Standard Fixed-Effects, Heckit panel, and control function approaches to control for endogeneity of IAA participation and unobserved heterogeneity. We found that IAA value chain participation is positively correlated with household income, expenditure and the consumption frequency of certain goods, especially fish consumption, and the benefits continue to accrue after discontinuing participation in the value chain. The results reveal that IAA value chain participation has higher impacts on the welfare of relatively wealthier households involved in production related IAA value chain activities than on landless, extremely poor households that were involved in upstream and downstream IAA value chain activities.

Key words: Integrated Aquaculture-agriculture (IAA), Welfare Impact, Value Chain Participation, Panel data methods, Marginalized extremely poor indigenous households; Bangladesh.

JEL Classification: O13, O33, Q22, Q12

1. Introduction

Despite the decreasing trend in the incidence of extreme poverty, hunger and malnutrition in Asia this region remains home to the largest number of poor, hungry and malnourished people in the world (FAO/IFAD/WFP, 2013; ADB, 2014a). Most of these people live in rural areas furthest from roads, markets, schools, and public health services, are less likely to be educated, often belong to minority and other marginalized social groups, and most of them are either directly or indirectly engaged in agriculture as their primary source of livelihood (Ahmed et al., 2007; IFAD, 2003, 2011). Markedly, agricultural intensification through the innovations of the Green Revolution, such as high-yield seed varieties, chemical fertilizers, and modern irrigation technologies over the past several decades led to a dramatic increase in agricultural production, improved livelihoods, and radically transformed the course of agricultural development in South and East Asia (Pender, 2007). But the impacts of the Green Revolution have also been criticized for the negative long term environmental and social equity impacts and recently rice yields have been declining or stagnant in many parts of Asia (Pimentel and Pimentel, 1990; Pingali and Rosegrant, 1994; Kerr and Kolavalli, 1999; Das 2002; Pingali, 2012).

Like many other Asian countries, the economy of Bangladesh also largely depends on agriculture. Agriculture accounts for close to half of employment, 20% of GDP, and is the basis of food security for the entire population. Even with steady and commendable progress poverty is still widespread and continues to be largely a rural phenomenon, accounting for 84% of the nation's poor. Bangladesh also faces many challenges to food security, including, but not limited to, climate change, population growth, vulnerability to price shocks, increasing natural resource scarcity, persistent poverty, and malnutrition. Most of the rural poor who struggle to achieve food security are either directly or indirectly engaged with agriculture for their livelihood, thus fostering agricultural development and sustainable rural natural resource management are crucial for reducing poverty and improving food security in Bangladesh (ADB, 2014b; Cortijo, 2014).

The people of Bangladesh are commonly referred to as '*macche-bhate bangali*' ('the people made of fish and rice'). Like many other Asian countries rice and fish have been an essential part of Bangladeshi culture from time immemorial as household staple foods. Rice is the main source of dietary carbohydrates and fish (as well as aquatic crustaceans) as the main source of dietary animal protein (Dey et al., 2013). Rice is the leading agricultural crop, in fact so much so that in Bangladesh food security is mainly defined in terms of access to rice (Ahmed et al., 2013). The demand for rice and fish in the country is constantly increasing due to mounting population growth (Chowdhury, 2009). Like many other Asian countries rice production in Bangladesh is threatened due to land degradation (caused by overuse of fertilisers and pesticides), decreased arable land area, the effects of climate change, and other environmental problems (Alauddin and Tisdell, 1991; Ali et al., 1997; Rahman, 2003a, 2003b; Sarker et al., 2012). However, IAA¹ technologies potentially offer a sustainable solution to this problem by contributing to food security, income, and dietary nutrition (FAO, 2000; Ahmed and Garnett, 2011). Bangladesh has two to three million hectares of land that is suitable for rice-fish based IAA production (ADB, 2005; Dey and Prein, 2006; Ahmed and Garnett, 2010; Dey et al., 2013). Recent estimates indicate that approximately 4.27 million households in the country (approximately 20% of all rural households) own a homestead pond that is suitable for IAA based fish production (Belton and Azad, 2012). However, due to small farm sizes and low levels of investment in relevant social, economic, and policy dimensions, this potential is not being fulfilled. According to another recent estimate only about 180,000 ha are

¹ IAA is based on the concept of integrated resource management, utilizing synergies among subsystems that result in greater farm productivity. For detailed discussions of IAA related technologies see Edwards (1998), Prein (2002), and Pant et al. (2005).

currently under rice-fish based IAA production, well below the nation's potential. This raises the questions of whether the adoption and impacts of rice-fish based IAA systems are being adequately examined or not (Dey et al., 2013). Over many years Bangladesh's agricultural research and extension system, international organizations like the WorldFish, various domestic NGOs, private companies, and rural entrepreneurs have all contributed to extensive research and extension services in participatory manner to achieve the country's IAA potential. One such initiative of the WorldFish was the Adivasi² Fisheries Project, a food security oriented effort to diversify rural livelihood options for resource-poor, marginalized Adivasi communities in the north and northwest of Bangladesh. Through participatory processes the project set out to devise and disseminate IAA technologies and related enterprise options (using a value chain approach) to match the existing physical and human asset bases, and the social and economic contexts and aspirations needs, resources, and capabilities of Adivasi households (Pant et al., 2014). Thus participation in IAA value chains by indigenous households was not random.

Based on three rounds of panel data (2007, 2009, and 2012) on indigenous households, this study assessed the impacts of IAA value chain participation on the welfare of marginalized poor indigenous rural households in Bangladesh. We also examined the distributional impacts of IAA value chain participation by examining impacts across different groups of value chain actors by disaggregating production activity participants from up and downstream participants. Given the potential importance of IAA systems in Bangladesh this research mostly focused on rice-fish based IAA and the biophysical and technical feasibility aspects rather than socio-economic aspects. There have been previous socio-economic research efforts on IAA in Bangladesh (Ahmed and Garnett, 2011; Ahmed et al., 2011; Jahan and Pemsil, 2011; Dey et al., 2013) and elsewhere (Prein, 2002; Pant et al., 2005; Dey et al., 2010), but all of these efforts used cross-sectional data that makes it very difficult to control for unobserved heterogeneity and endogeneity.

Using a large and unique three-wave panel dataset and different panel analysis methods such as Fixed-Effects (FE) model, Random-Effects (RE) model, bias corrected FE model (Heckit panel), and control function approaches, the analyses presented in this chapter contribute to the growing body of literature on the impacts evaluation in at least three ways. First, is the identification of the casual effects of IAA value chain participation on household welfare in marginal, extreme poverty settings with due consideration for both observed and unobserved heterogeneity and endogeneity of IAA value chain participation. Second, is the consideration of backward and forward linkages along IAA value chains for a comprehensive impact assessment that documents the evidence of heterogeneous treatment effects of IAA value chain participation. Third, is that this study took into account the impacts of the dynamics of IAA value chain participation, which is not possible using cross-sectional data and is seldom considered in many panel data based impact evaluation studies. This appears to be the first impact assessment of IAA technologies using a large, three-wave panel dataset. The results of the analyses presented in this chapter provide valuable insights for other developing countries with similar agro-ecological, socioeconomic, and institutional settings for efforts to address extreme poverty and marginality problems through IAA systems.

² The terms Adivashi, indigenous, ethnic minority and tribal are used interchangeably in this study. In Bangladesh Adivasi communities are typically the most marginalized and extremely poor segments of society; live in densely populated border areas; face dispossession and eviction from their ancestral lands; are often excluded from social safety net programs; are frequently trapped in poverty; and a significant proportion of them live below the absolute national poverty line (Pant et al., 2014).

The rest of the chapter is organized as follows. Section 2 briefly describes the data and descriptive statistics. The empirical approaches are used in this paper are presented in section 3. In section 4 we present the results and discussion, and in section 5 we conclude with the highlights of the key findings and policy implications.

2. Data and descriptive statistics

2.1 Data

Data used in this study come from three wave nationally representative survey of plain land indigenous rural farm households in Bangladesh. The first and second waves of data comes from the Adivasi Fisheries Project (AFP) household survey, a survey conducted in 2007 and 2009 respectively, that covers 12 sub districts in 5 districts in northwest and southwest region of Bangladesh (see in figure 1), collected by the World Fish (WF) Bangladesh researchers. At the first and second round, 657 IAA value chain participators and non-IAA value chain participators were interviewed using a structured questionnaire. The IAA value chain participators were selected randomly from the Adivasi Fisheries Project (AFP) participants list and non-IAA participants also selected randomly, who opted not to participate in the IAA intervention made by AFP or lived in nearby villages (AFP, 2010; Pant et al., 2014). The third wave of data re-surveyed in 2012, by the author himself with trained enumerators. Despite significant efforts, some of the IAA participants and non-participants from the first and second round could not be met again. Of the 657 households in revisited areas, 571 were found for re-interview in third round, which gives us an attrition rate of 13.09% between first, second and third round. We tested for attrition bias and found it is random. Therefore, we end up using a non-balanced panel of a total of 1,885 observations (detail in Table 1).

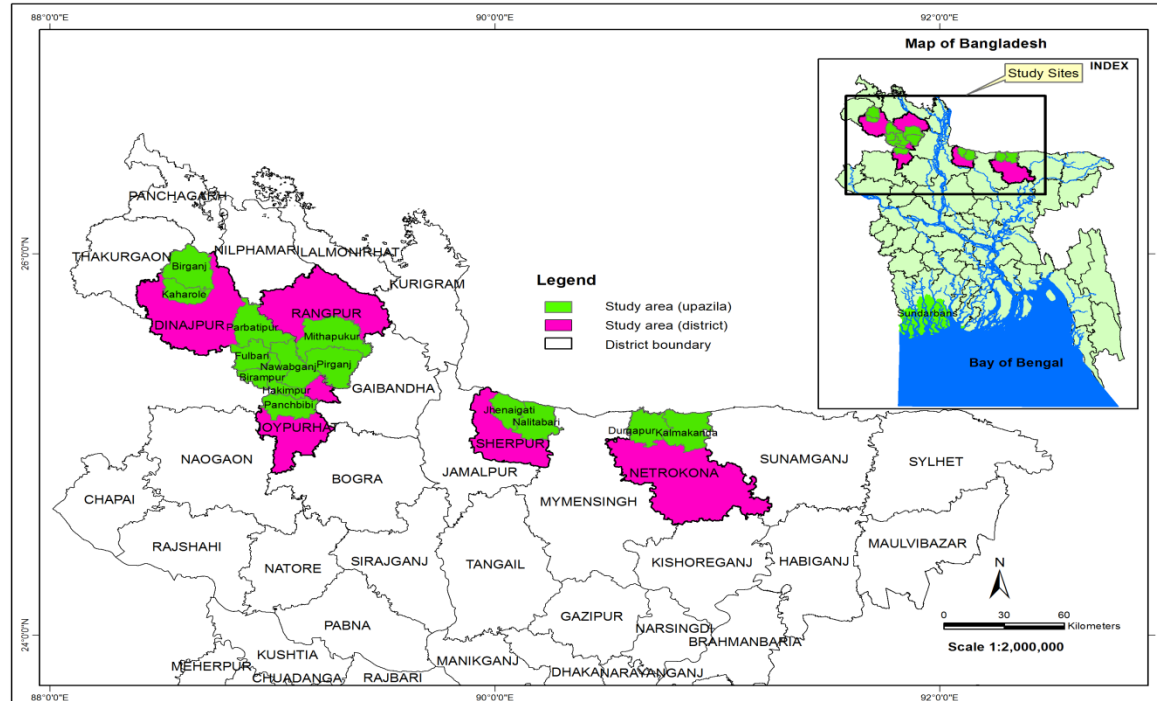


Figure 1. Map of the study area indicating the geopolitical districts (purple) and sub-districts (green)

Table 1. Sample size of the panel survey of IAA participating and non-participating households in Bangladesh

Survey round	Year	IAA value chain non-participants	IAA value chain participants	IAA value chain dis-participants	Total	Attrition (%)
1 st Wave	2007	147	510	-	657	-
2 nd Wave	2009	148	509	-	657	-
3 rd Wave	2012-2013	121	234	216	571	13.09

2.2 Descriptive statistics

2.2.1 Who participated in IAA value chains in Bangladesh?

Descriptive statistics of the socio-economic explanatory variables used in this analysis are shown in Table 2 by IAA participation category. Households participating in IAA value chains are, on average, headed by younger and more educated farmers. In addition, IAA value chain participants have larger families. This is consistent with the higher labour requirements of IAA value chain activities relative to rice monoculture. This implies that family labour has an important role in participation and possibly indicates that subsistence pressure is part of the IAA value chain participation decision-making process. There were proportionately more male-headed households among participants than in the non-participant group.

Table 2. Descriptive statistics (mean and standard deviation) of explanatory variables

Variables	Definition and measurement	2007		2009		2012		
		Non-participant	Participant	Non-participant	Participant	Non-participant	Dis-participant	Participant
Gender of HH head	Dummy (1 if Household head is male, 0 otherwise)	0.90 (0.30)	0.95 (0.21)	0.91 (0.28)	0.95 (0.22)	0.88 (0.33)	0.92 (0.28)	0.93 (0.26)
Age of HH head	Continuous (Age of household head in years)	46.08 (11.73)	43.65 (12.23)	47.93 (12.21)	46.03 (13.40)	50.10 (12.73)	47.85 (13.69)	48.33 (12.17)
HH size	Continuous (Total number of household members)	4.42 (1.51)	4.53 (1.62)	4.40 (1.61)	4.61 (1.58)	4.54 (1.69)	4.44 (1.54)	4.80 (1.57)
Farm size	Continuous (Total land area in decimals)	103.75 (107.34)	102.89 (122.86)	125.23 (187.71)	107.94 (117.76)	115.67 (172.72)	79.49 (117.07)	119.59 (123.52)
Non-farm income	Continuous (Per year in BDT)	21650.92 (16983.5)	21551.08 (15664.5)	30944.82 (28988.8)	28453.48 (24363.9)	28343.01 (44566.2)	32931.94 (50380.2)	36867.74 (54930.9)
Participation in a CBO	Dummy (1 if household head is a member of a CBO, 0 otherwise)	0.40 (0.49)	0.98 (0.14)	0.58 (0.50)	1.00 (0.04)	0.18 (0.39)	0.13 (0.34)	0.24 (0.43)

Access to extension services	Dummy (1 if household had access to government or NGOs extension services)	0.94 (0.24)	0.93 (0.25)	0.93 (0.25)	0.95 (0.22)	0.41 (0.49)	0.38 (0.49)	0.52 (0.50)
Irrigation	Dummy (1 if irrigated crop land last year, 0 otherwise)	0.70 (0.46)	0.61 (0.49)	0.66 (0.47)	0.65 (0.48)	0.60 (0.49)	0.42 (0.49)	0.60 (0.49)
Access to credit	Dummy (1 if able to access credit, 0 otherwise)	0.92 (0.27)	0.91 (0.29)	0.78 (0.41)	0.86 (0.34)	0.79 (0.41)	0.71 (0.45)	0.75 (0.44)
Access to market information	Dummy (1 if agricultural market information available, 0 otherwise)	0.82 (0.39)	0.83 (0.38)	0.62 (0.49)	0.69 (0.46)	0.55 (0.50)	0.47 (0.50)	0.69 (0.46)
Marital status of HH head	Dummy (1 if the household head is married, 0 otherwise)	0.86 (0.34)	0.93 (0.25)	0.92 (0.27)	0.93 (0.26)	0.92 (0.28)	0.92 (0.28)	0.92 (0.27)
Main occupation of HH head	Dummy (1 if main occupation of household head is agriculture, 0 otherwise)	0.38 (0.49)	0.37 (0.48)	0.46 (0.50)	0.39 (0.49)	0.48 (0.50)	0.37 (0.48)	0.47 (0.50)
Education of HH head	Continuous (Number of years that household head attended school)	3.15 (3.93)	3.24 (3.83)	3.43 (3.83)	4.06 (4.08)	3.40 (3.80)	2.50 (3.43)	4.57 (3.99)
Number and percentage (in parentheses) of observations		147 (22.37)	510 (77.63)	148 (22.53)	509 (77.47)	121 (21.19)	216 (37.83)	234 (40.98)

Evaluation of the change in household IAA value chain participation status over the years 2007–2012 showed that the probability of continued IAA value chain participation was lower than the probability of discontinuing participation and non-participation. Only 41% of households who participated in IAA value chains continued to participate in the subsequent period, while 38% of households dis-participate in subsequent periods and the rate of discontinuing is quite high among the up and down stream segment IAA value chain participants relative to production process participants. Dis-participants differed from both non-participants and continuous participants in terms of almost all characteristics reported in Table 2.

2.2.2 Relationship between IAA value chain participation dynamics and household welfare

The IAA value chain participator groups are distinguishable in terms of welfare based on total income from land, other assets, off-farm income, and non-farm income. In the baseline (2007) incomes and expenditures among IAA value chain participator were lower than non-participants, but in the subsequent survey year incomes and expenditures were higher for participator, a difference that was significant between participants and non-participants (Figure 2).

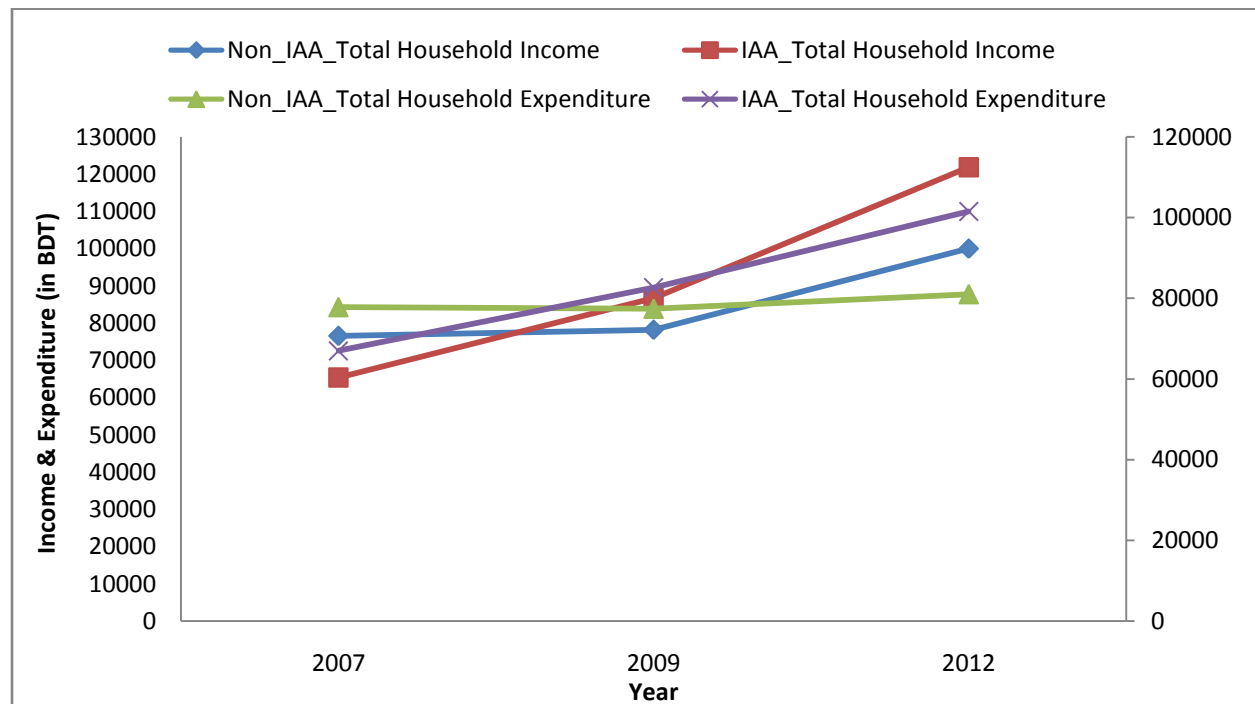


Figure 2. Household income and expenditure for IAA value chain participants and non-participants in Bangladesh

2.2.3 Distributional impacts of IAA value chain participation

The welfare effects of IAA value chain participation may not be the same for all actors irrespective of their participation status. To test for income variability among participation groups, we disaggregated the IAA value chain participants into two groups: production activity participants and up and down stream (non-production) segment participants. The IAA production activity group was comparatively better off than up and downstream IAA value chain participants. Figure 3 presents the welfare outcomes by group and year. Welfare gains among IAA value chain participants increased over time for both groups, but the rate for production activity participants was much higher than for up and down stream participants. The details of the outcome differences between the two major groups are also calculated but not reported here to save the space. Those details also show that IAA production participants had significantly greater total income than non-participants. In order to be able to infer whether income differences were due to IAA value chain participation or other factors we applied a rigorous analytical model to identify if mean welfare outcomes were due to IAA value chain participation or not after controlling for confounding factors.

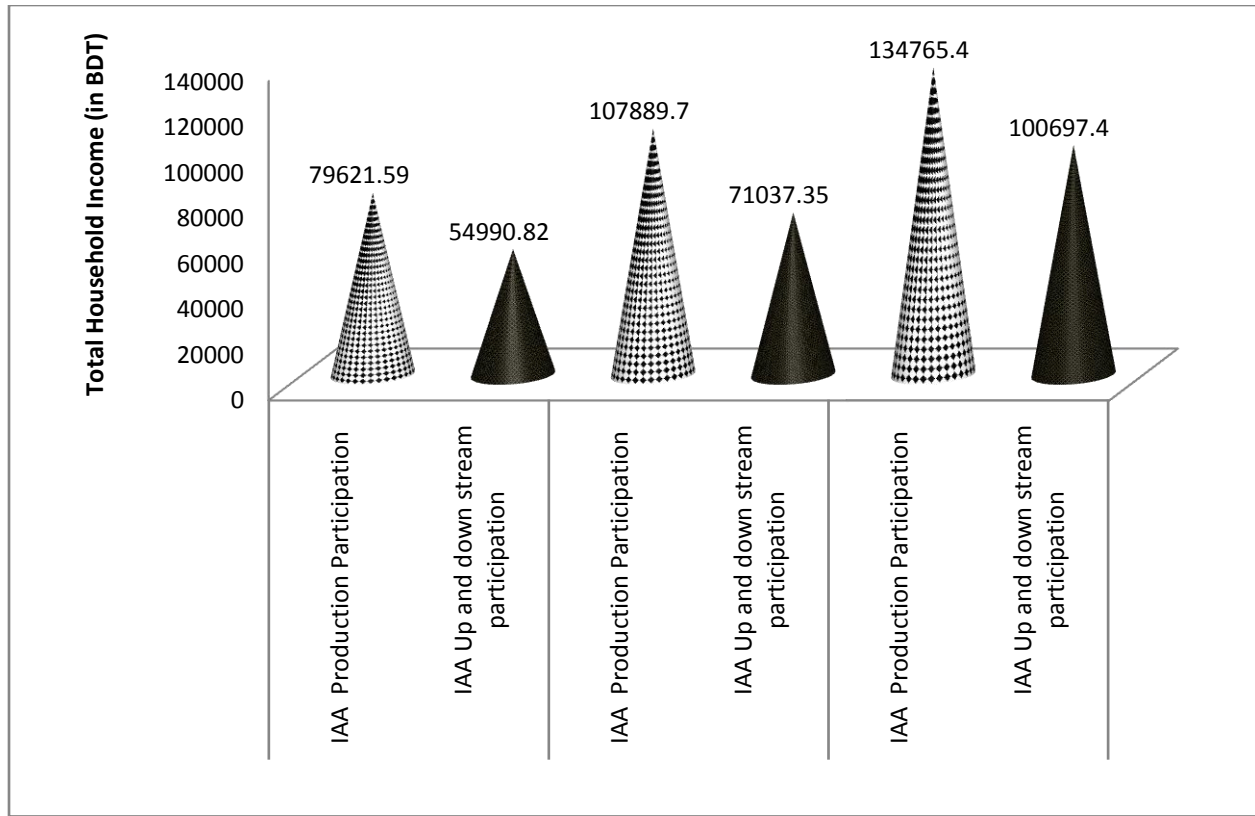


Figure 3. Distribution of income effects among IAA value chain participants in Bangladesh

3. Estimation Issue and Strategy

The decision of whether or not to participate in IAA value chains is not random, thus the outcome of IAA value chain participants and non-participants are not directly comparable. This presents some challenges to estimating the welfare functions, particularly regarding how the unobserved heterogeneity and potential endogeneity of some variables are addressed in the models. In this section we discuss the estimated models and how these issues were treated.

In any given year the decision by a household to participate in IAA value chains or not will be determined by its expected utility or the relative costs and benefits associated with either option. Participation in IAA value chains was expected to have important positive impacts on household welfare through direct and indirect pathways that were discussed in the context of the conceptual framework. The indicators of household welfare outcomes for this analysis were annual household income, expenditure and the consumption frequency of different food items measured at the household level. Another suitable welfare indicator, asset holdings (the value of household assets), was not an option because these data were not collected during the first two survey efforts. The welfare equation is simple and relatively straightforward. We defined welfare (income or expenditure or consumption) (Y_{it}) as a function of IAA value chain participation ($IAAp_{it}$), IAA value chain dis-participation ($IAAd_{it}$), and a vector of relevant covariates (Z_{it}), that may include both time-variant and time-invariant factors.

The generic specification for impact evaluation is expressed as:

$$Y_{it} = \alpha + Z_{it}\beta_1 + IAAp_{it}\beta_2 + IAAd_{it}\beta_3 + T_t\gamma + c_i + \epsilon_{it} \quad (1)$$

In this impact model the dynamics of participation are shown by analysing whether the gains from IAA value chain participation persist over time, and what the economical impacts of dis-participation from IAA value chain participation. The coefficients (β_2 and β_3) of the two participation status dummy variables in this model represent the impacts of being in the particular category on welfare as compared to non-participation in IAA value chains, which was the reference category. β_2 indicates whether the range of welfare outcomes among IAA participators and non-participators increases or decreases over time for households that remain in their particular category. β_3 is the effect of dis-participation in comparison to non-participation in IAA value chains. The coefficients difference ($\beta_2 - \beta_3$) provides the welfare effects of dis-participation in comparison to IAA value chain participation. A dummy variable representing the year data were collected (T_t) was used to control for time fixed effects, c_i is an individual-specific effect, and ε_{it} is an idiosyncratic error term. Explanatory variables included in Z that are likely to affect household welfare are based on extensive theoretical and empirical literature review on technology, or innovation, or high value chain participation impact studies, which are shown in Table 4.1 and discussed in section 4.4.1.

At the beginning it was assumed that IAA value chain participation is exogenous (i.e. the decision to participate in IAA value chains is independent of material outcome) and there are presumably no factors that simultaneously affect IAA value chain participation and household welfare. We used a Pooled Ordinary Least Squares (POLS) estimator to estimate Equation 2.

$$Y_{it} = \alpha + Z_{it} \beta_1 + IAAp_{it} \beta_2 + IAAd_{it} \beta_3 + T_t \gamma + \varepsilon_{it} \quad (2)$$

The POLS estimator ignores the panel structure of the data and simply estimates the coefficients by using OLS regression and by assuming that ε_{it} , the idiosyncratic error term, is uncorrelated with the explanatory variables in Equation 2.

It is very unlikely, however, that IAA value chain participation is exogenous. IAA value chain participation is a decision variable and hence may be correlated with the error term in the welfare equations. It may also result from unobserved heterogeneity between IAA value chain participators and non-participators. Such heterogeneity is very likely, as households self-select the IAA value chain participation category they belong to. Households that self-select IAA value chain participation may do so on the basis of unobservable characteristics that also determine the household welfare (Heckman and Hotz, 1989). Households with greater resources, skills, capabilities, and motivation (which are all also likely to affect household welfare) may decide to participate in IAA value chains, while those that do not have or that have fewer resources may not participate in IAA value chains and vice versa. If this is the case the impact of IAA value chain participation estimated with Equation 1 will be either over- or underestimated.

Panel data models that allow IAA value chain participation decisions to be correlated with unobservable effects on outcome variables control this problem (Heckman and Hotz, 1989; Berhane and Gardebroek, 2011). We used three such empirical approaches to exploit the panel nature of the data: the Standard FE model, the Heckit panel model, and a control function approach. An important issue in estimating panel models is how to deal with the unobserved heterogeneity effect, c_i . Following a strict exogeneity assumption (i.e. the time invariant unobserved heterogeneity, c_i , is not correlated to any of the other covariates) then $v_{it} = c_i + \varepsilon_{it}$ can be considered as a composite error and the following equation can be estimated through a RE model.

$$Y_{it} = \alpha + Z_{it} \beta_1 + IAAp_{it} \beta_2 + IAAd_{it} \beta_3 + T_t \gamma + v_{it} \quad (3)$$

However, the strict exogeneity assumption is very strong and it is very unlikely that the unobserved heterogeneity will be orthogonal and uncorrelated to the other covariates (Bezu et al., 2014). If this is the case and it is not controlled for, this could lead to selection bias in the estimated welfare effects of IAA value chain participation. Literature suggests that a common and straightforward way to control the selection bias problem is to use a household FE estimator (Wooldridge, 2002; Greene, 2008). Recent empirical research efforts frequently use an FE estimator to control for the selection bias problem (Crost et al., 2007; Jorgenson and Birkholz, 2010; Berhane and Gardebroeck, 2011; Kouser and Qaim, 2011; Kathage and Qaim, 2012; Bezu et al., 2014; Muriithi and Matz, 2015).

This Standard FE model allows for individual heterogeneity, c_i , to be correlated with the vector of explanatory variables, Z_{it} . The Standard FE estimator provides a consistent estimate of welfare effects by differencing out all time-invariant unobserved heterogeneity effects (Wooldridge, 2002). We estimated the welfare outcome Equation 1 by using a FE model because these are linear models. Some of the outcome variables are censored at zero or count variables. For such outcome variables (such as consumption frequency) in the welfare equation we estimated the equation by using a Poisson estimator, otherwise the linear specification will lead to a biased estimate (Wooldridge, 2002). We also used a Hausman test to compare the FE and RE model results and to detect unobserved heterogeneity, although it is neither necessary nor a sufficient condition to test (Snijders, 2005; Greene, 2008). Both the RE and FE model results are reported, but an interpretation is only given for the FE estimate³.

As already discussed, the IAA value chain participation and dis-participation in Equation 1 may be correlated with the error term. We also used a framework similar to Heckman's two-stage model with panel settings to control for possible endogeneity of the selection of participation in IAA value chains and checked the robustness of the above results with a FE estimator. The first step involves estimating the IAA participation and dis-participation selection equations using a pooled Probit model for different T by including the exclusion restriction variables and then computed the T inverse Mills ratios (λ_{1it} and λ_{2it} for participation and dis-participation respectively). In the second step the Mills ratios were plugged into the welfare outcome equation to control for possible self-selection into IAA value chain participation and dis-participation, which was then estimated using a standard household FE model by excluding the exclusion restriction variables. The welfare outcome Equation 1 was amended as follows:

$$Y_{it} = \alpha + X_{it} \beta_1 + IAAp_{it} \beta_2 + IAAd_{it} \beta_3 + \lambda_{1it} + \lambda_{2it} + T_t \gamma + c_i + \varepsilon_{it} \quad (4)$$

where X_{it} contains Z_{it} , but three variable less, that affect IAA value chain participation and dis-participation, but not household welfare, which is what the identification of the causal effect hinges on. Furthermore a control function approach was used to control for possible endogeneity of selection in IAA value chain participation and to check the robustness of the above results with a different estimator. This approach also involves two steps; the first step it involves estimating the reduced form (like the selection model) of the IAA participation and dis-participation model by using a RE probit model

³ Within-group variability with respect to the treatment variable (in this case IAAp and IAAd) is necessary in order to estimate an efficient FE model (Kikulwe et al., 2014). Thus, there needs to be a sufficient number of households that participate in IAA value chains or that discontinued participation in the first year of the survey, but not in another year. Such variability is present in the data, especially between the survey wave one (2007) and three (2012), and between years two (2009) and three (2012), because in the third wave a large number of IAA value chain participators became dis-participators.

by including the exclusion restrictions and then computing the generalized residuals (δ_{1it} and δ_{2it} for participation and dis-participation respectively). In the second step the generalized residuals were included in the welfare outcome (structural) equation to control for possible endogenous selection of IAA value chain participation, which is then estimated using a standard household FE model by removing the exclusion restriction variables. A significance test on the coefficients (δ_1 and δ_2) of the residuals tests for endogeneity of the IAA value chain participation and dis-participation (Bezu et al., 2014). The welfare outcome Equation 1 was amended as follows:

$$Y_{it} = \alpha + X_{it} \beta_1 + IAAp_{it} \beta_2 + IAA_{d_{it}} \beta_3 + \delta_{1it} + \delta_{2it} + T_t \gamma + c_i + \varepsilon_{it} \quad (5)$$

In the Heckit model and control function approach ‘Access to market information’, ‘Access to Extension’ and ‘CBO membership status’ are used as exclusion restrictions. These variables may influence household participation and dis-participation in IAA value chain. These variables are considered as viable exclusion restrictions because the first two variables are kind of universal access now in Bangladesh. Like for information access, now almost everybody, irrespective of income have mobile phone that they can use to get access to information easily. Similarly, extension in Bangladesh is merely public, irrespective of income farmers can access to it. CBO membership is expected to represent social capital at the individual and village levels because these are voluntary membership organizations and among indigenous people participation in this type of organization is very high and they have high degree of social cohesion (Pant et al., 2014). Thus these three variables were included in the participation equation to satisfy the exclusion restriction in the above two models, which are not included in the welfare outcome equations. These variables were not expected to affect the welfare outcome equations directly after controlling for IAA participation and dis-participation.

4. Results

4.1 IAA value chain participation dynamics and household welfare

4.1.1 Standard Fixed-Effects model

We applied the FE models⁴ to reveal the relationship between IAA participation dynamics and household welfare. The selected indicators for welfare outcomes are annual household income, expenditure and household consumption frequency of selected food items. Household consumption frequency was computed by counting the number of times that a household consumed a particular food item over the course of a day, or week, or month depending on the food item. Household income includes income from crops, livestock, fisheries, non-farm activities, and off-farm activities. Household expenditures also computed by summing-up all the household annual expenses for food, clothing, health, education, house repair or construction, festivals, land and furniture purchase or rent, inputs for livestock, fisheries and crops, farm equipment, loan repayment etc.

Table 3. Fixed-Effects model results for the relationship between IAA value chain participation dynamics and household income and expenditure in Bangladesh

Variables	Income		Expenditure	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
Participation in IAA value chain	18.88***	6.63	17.54***	5.96

⁴ Pooled OLS and Random effects model were also estimated but the results are not reported here to save the space.

Dis-participation from IAA value chain	5.46	7.33	15.54***	6.21
Year 2009	14.73***	2.02	10.24***	1.72
Year 2012	40.89***	4.39	19.07***	3.70
Age	0.37*	0.20	0.27*	0.16
Total family size	8.65***	1.79	7.51***	1.56
Farm Size	0.08***	0.03	0.08***	0.02
Access to extension	2.94	3.92	2.51	3.28
Irrigation	1.41	3.56	3.44	3.10
CBO Membership	0.03	0.02	0.03	0.02
Access to Credit	3.69	4.03	8.52***	3.36
Access to Market information	-0.98	3.20	-2.84	2.48
Constant	-17.64	14.96	-9.21	10.59
Rho		0.34		0.40
R-sq overall		0.31		0.33
Number of observations		1885		1885
Number of groups		657		657

Notes: † The total household income (dependent) variable is in thousands, * significant at 10%, ** significant at 5%, *** significant at 1%

Table 3 and 4 presents the results of the FE models of the impacts of IAA participation on household income, expenditure and consumption respectively. IAA value chain participation had a large positive and significant effect on household income and expenditure. The FE estimates show that, controlling for other factors, IAA participation was associated with an increase of approximately 19,000 BDT and 18,000 BDT in household income and expenditure respectively and the time FE results show that this effect has increased over time. This is a sizable impact given the fact that sample households are indigenous, which are one of the mostly marginalized and extremely poor socio-ethnic groups in Bangladesh with typically small land holdings, and sustainable intensification using IAA is a potential option for increasing food production in Bangladesh. Quite surprisingly, dis-participation from IAA value chain also affect positively to household income and expenditure, but the magnitudes of income and expenditure are comparatively lower than participation and these are as expected. These results indicate that dis-participation from IAA leads to an income loss compared to staying in the IAA value chain, suggesting that the dis-participation decision is not due to economic superiority (Table 3). We also ran a Hausman test and the results reject the RE model results in favour of the FE model results.

Similarly, the FE model results for the relationship between IAA participation and household consumption frequency show that IAA participation was significantly and positively associated with increased fish, pulse and vegetable consumption frequency and that the consumption continued to increase over the course of the year (Table 4). Surprisingly, dis-participation from IAA value chain also have positive and significant on fish and pulse consumption and negative and significant effect on egg and vegetables consumption. This result suggests that even after dis-participation consumption effect of IAA participation continue to some extent.

Table 4. Fixed-Effects model results for the relationship between IAA value chain participation dynamics and household consumption frequency in Bangladesh

Variables	Consumption frequency of						
	Rice	Fish	Meat	Egg	pulse	fruits	vegetables
Participation in IAA value chain	0.00 (0.02)	0.72*** (0.08)	-12.83 (843.32)	-11.86*** (1.02)	0.95*** (0.08)	0.85*** (0.32)	-0.08** (0.04)
Dis-participation from IAA value chain	-0.03 (0.02)	0.35*** (0.10)	-13.04 (843.32)	-12.13*** (1.02)	0.77*** (0.09)	0.33 (0.39)	-0.17*** (0.05)
Year 2009	0.00 (0.00)	0.64*** (0.03)	0.49*** (0.05)	0.07 (0.06)	0.05 (0.03)	0.27*** (0.10)	-0.01 (0.01)
Year 2012	-0.04*** (0.01)	0.55*** (0.05)	0.43*** (0.07)	0.38*** (0.10)	0.25*** (0.05)	0.14 (0.18)	-0.04 (0.03)
Age	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00** (0.00)	0.01 (0.01)	0.00 (0.00)
Total family size	0.00 (0.00)	0.03** (0.02)	0.01 (0.02)	0.00 (0.03)	0.02 (0.02)	0.01 (0.05)	0.00 (0.01)
Farm Size	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)
Access to extension	-0.01 (0.01)	-0.07 (0.05)	-0.12* (0.07)	-0.14 (0.10)	0.04 (0.05)	-0.09 (0.17)	0.01 (0.03)
Irrigation	0.00 (0.01)	0.01 (0.05)	0.05 (0.07)	-0.17* (0.10)	0.10** (0.05)	-0.04 (0.19)	-0.01 (0.02)
CBO Membership	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)
Access to Credit	0.00 (0.01)	0.09* (0.05)	-0.03 (0.06)	0.12 (0.09)	0.05 (0.05)	-0.07 (0.17)	0.03 (0.03)
Access to Market information	-0.01 (0.01)	-0.12*** (0.04)	-0.08 (0.06)	-0.16** (0.08)	-0.05 (0.04)	0.08 (0.16)	0.02 (0.02)
Number of observations	1885	1885	1794	1666	1885	1019	1885
Number of groups	657	657	624	577	657	353	657

Note: Robust Standard Errors are in parentheses. * Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

4.1.3 Heckit panel and control function approaches

Further to check the robustness of the FE estimates and control for possible selection bias in IAA participation and dis-participation, we used a Heckman bias corrected FE model where the inverse Mills ratios from the first stage selection pooled probit are used to control for both individual-specific, time-variant observable and time-invariant unobservable characteristic related selection problems. We also used the control function approach to control for the possibility of endogenous selection of IAA participation and dis-participation. The generalized residuals from the first stage participation and dis-participation equations were included in the FE models to test and control for the endogeneity of IAA value chain participation and dis-participation. Both the Heckit FE and control function FE model results are reported in Table 5.

Table 5 Heckit panel and control function models results of the relationship between IAA participation dynamics and household income and expenditure in Bangladesh

Variables	Heckman				Control function			
	Income		Expenditure		Income		Expenditure	
	Coef.	Robst Std. Err.	Coef.	Robst Std. Err.	Coef.	Robst Std. Err.	Coef.	Robst Std. Err.
Participation in IAA value chain	26.01***	6.21	19.92***	5.60	41.56***	8.52	27.74***	6.45
Dis-participation from IAA value chain	11.95*	6.92	17.68***	6.20	28.34	20.88	11.51	15.31
Year 2009	14.90***	1.97	10.72***	1.74	15.64***	1.97	11.36***	1.73
Year 2012	34.90***	4.59	15.94***	4.60	46.43***	8.48	29.21***	6.74
Mills ratio (Participator)	-19.74*	10.71	-10.52	7.78	-	-	-	-
Mills ratio (Dis-participator)	-16.48**	7.05	-8.87*	5.11	-	-	-	-
Generalized residual(Participator)	-	-	-	-	-5.12***	1.36	-3.70***	1.08
Generalized residual (Dis-participator)	-	-	-	-	-11.48	11.78	1.30	8.55
Age	0.37*	0.21	0.26	0.16	0.35*	0.19	0.24	0.15
Total Family Size	8.60***	1.81	7.55***	1.60	8.46***	1.82	7.06***	1.58
Farm Size	0.09***	0.03	0.09***	0.02	0.08***	0.03	0.10***	0.03
Irrigation	8.33**	3.76	7.93**	3.38	2.07	3.26	2.98	2.76
Access to Credit	5.30	4.14	9.09***	3.32	3.67	3.92	8.35***	3.28
Constant	21.87	22.36	12.47	15.82	-39.19**	16.30	-20.81*	11.51
Rho	0.36		0.41		0.35		0.38	
R-sq overall	0.28		0.31		0.31		0.37	
Number of observations		1885		1885		1873		1873
Number of groups		657		657		657		657

Notes: † The total household income (dependent) variable is in thousands of BDT, * significant at 10%, ** significant at 5%, *** significant at 1%

The coefficient estimates of the inverse Mills ratios and generalized residuals for IAA value chain participation are statistically significant indicating that participation in IAA value chain is endogenous as expected and, therefore, our specification was necessary which control for selection into participation in IAA value chain. On the other hand, generalized residual for IAA value chain dis-participation are not statistically significant which ameliorates our concern for potential endogenous selection bias with regards to the dis-participation from IAA value chain.

The results reported in Table 5 indicate that IAA value chain participation is positively and significantly associated with household income and expenditure, which is consistent with the earlier FE results. Interestingly, the coefficients are higher in magnitude compared to the FE results presented in Tables 3. Specifically, due to IAA value chain participation household income and expenditure increased by about 26, 000 to 42, 000 BDT and about 20, 000 to 28, 000 BDT respectively depending on the model. Again

surprisingly, dis-participation from IAA value chain do not affect negatively rather it affect positively which suggest that benefit of IAA participation continue to accrue even after dis-participation. Thus the positive income effect of IAA participation is robust under different specifications.

4.2 Who benefits more from IAA value chain participation?

We calculated disaggregated results of the household income equation to compare comparatively wealthier households (that participated in IAA production related value chain activities, which consists of actors who require access to land) with poorer households (extremely poor households that participated in both up and down stream chain and some IAA production related activities, most of this group do not have access to land).

Table 6 Comparison of the Fixed-Effects model results of annual household income[#] for the IAA value chain actors by relative wealth in Bangladesh

Variables	IAA Value Chain Participation Stage/Status			
	Up and down stream value chain activity actors ^{††}		Production value chain activity actors [†]	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
IAA value chain participation	0.07	0.08	0.32***	0.13
Year 2009	0.12***	0.03	0.20**	0.04
Year 2012	0.37***	0.05	0.44**	0.06
HH head age	0.00	0.00	0.00	0.00
Total HH size	0.10***	0.02	0.09***	0.02
Farm size	0.00***	0.00	0.00***	0.00
Access to irrigation	0.05	0.05	0.05	0.06
Access to credit	0.05	0.05	0.10	0.07
Access to market information	0.02	0.04	0.07	0.06
Access to extension services	0.05	0.05	0.09	0.07
Constant	10.14***	0.15	10.14***	0.21
Rho	0.33		0.38	
Number of observations	1253.00		1048.00	
Number of groups	441.00		364.00	
R ² : overall	0.3030		0.2424	

Notes: [#] The annual household income (dependent) variable is a logarithmic term, [†] actors that participated in production activities include: integrated rice-fish producers and integrated pond-fish producers (comparatively wealthier households), ^{††} Upstream and downstream value chain actors include: fingerling traders, fish traders, fishermen, cage cultivators, and community based fish and aquatic animal producers (comparatively poorer/landless households), * significant at 10%, ** significant at 5%, *** significant at 1%.

Table 6 presents the results from a separate FE model of income for comparatively wealthier and poorer households. The estimated participation in IAA value chain coefficients shows that participation in IAA value chains was positive for all households regardless of the participation activities, but coefficients for production related IAA actors were significantly and comparatively greater than up and downstream IAA value chain actors. An increase in IAA value chain participation was associated with an increase in household income of 32% for production related actors and only 7% for non-productive segment other IAA value chain activities that do not require land. Greater income effects among households involved in

IAA production activities may reflect greater participation in IAA activities as these activities required land and higher capital investment than up and downstream activities. It seems that all IAA value chain actors do not have the same potential to capture benefits.

5. Conclusion

This study investigated the relationships between the IAA value chain participation dynamics among smallholders indigenous households and their economic wellbeing in order to contribute to the ongoing debate of whether or not IAA is a sustainable intensification option that can contribute to poverty reduction and food security in developing countries, especially in Asia. We used a large three-year panel dataset collected during the 2007–2012 period to systematically address these effects. In addition to using the panel data and exploiting the possibilities associated with this type of data, this study contributes to the relevant literature by examining the impacts of IAA value chain participation and dis-participation on three measures of household welfare: income, expenditure and consumption. This appears to be the first study that explores the dynamic impacts of IAA by considering all value chain actors.

We estimated the welfare impacts of IAA participation dynamics using different models (e.g. POLS, RE, FE, Heckit, and control function models) under different assumptions to control for unobserved heterogeneity and endogenous selection of IAA value chain participation dynamics. We started with a naive POLS model that assumes that IAA value chain participation and dis-participation are exogenous. Subsequently, we controlled for unobserved heterogeneity and endogenous selection to validate the results. Additionally, we applied FE models to sample households disaggregate by value chain activity among production related actors (who participated in production related IAA value chain activities and that require access to land) and up and downstream value chain actors (extremely poor households, most of which do not have access to land), to explore the distribution of IAA value chain participation benefits across all IAA value chain actors.

The results are robust across specifications, thereby justifying our concerns about unobserved heterogeneity with respect to participation in IAA value chains. We found consistent evidence of a positive relationship between IAA value chain participation and household income, expenditure and the consumption of fish and pulse. The results indicate that IAA value chain participation is associated with greater household income and expenditure, and this effect increased over time. Moreover, we found that IAA value chain participation was positively correlated with household income of both relatively poor (extremely poor households that participated in a variety of IAA value chain activities that did not require access to land) and wealthier households (that participated in IAA value chain production activities that required access to land), but that the benefits from IAA value chain participation were comparatively higher for the wealthier households. Considering participation dynamics, many of the former IAA value chain participants decided to discontinue participation, and dis-participation from IAA value chain impacts results are less stable than for participation in IAA value chain results. Dis-participation impact results indicated that dis-participation decision is not based on the economic superiority of alternative options, but due to other barriers to IAA value chain participation. Overall, we conclude that IAA value chain participation dynamics increase welfare of poor and marginalized indigenous households in Bangladesh. The results show the importance of IAA value chain activities for poor smallholders and how IAA value chain participation may contribute to food security and poverty reduction among rural smallholders. Cost effective agricultural policies that help to create an enabling environment for sustainable technology adoption and continuation can significantly contribute to improved food security and poverty reduction in rural areas.

Further research using other alternative welfare indicators, such as an asset index that considers the quantity of assets and their monetary value would be helpful to better understand changes in the capital stocks of households. In addition, technology adoption scenarios like IAA value chain participation not only have direct impacts, but also may have indirect impacts (e.g. spill over effects), which are beyond the scope of this study. Thus future research that takes into account these broader economy wide effects using appropriate economy wide modelling approaches (e.g. Subramanian and Qaim, 2009) would provide a better understanding of IAA participation's broader impacts.

References

- ADB (Asian Development Bank). *Key Indicators for Asia and the Pacific 2014. Special chapter: Poverty in Asia: A Deeper Look*. Philippines: Asian Development Bank, 2014a. <http://www.adb.org/sites/default/files/pub/2014/ki2014.pdf>
- ADB (Asian Development Bank). *Bangladesh quarterly economic update (QEU)*. Bangladesh resident mission, Dhaka, Bangladesh: Asian Development Bank, 2014b. <http://www.adb.org/sites/default/files/ban-qeu-2014-03.pdf>
- ADB (Asian Development Bank). *An Overview of Small-Scale Freshwater Aquaculture in Bangladesh. In: Special Evaluation Study on Small-scale Freshwater Rural Aquaculture Development for Poverty Reduction—Case Studies*. Manila: ADB, 2005.
- AFP (Adivasi Fisheries Project). *Fisheries and Aquaculture Enterprise Development for Adivasi (Tribal) Communities in the Northern and Northwestern Regions of Bangladesh*. The European Union's Food Security Programme for Bangladesh. Bangladesh and South Asia office, Dhaka, Bangladesh: WorldFish Center, 2010.
- Ahmed, A. U., Ahmad, K., Chou, V., Hernandez, R., Menon, P., Naeem, F., Naher, F., Quabili, W., Sraboni, E., Yu, B., Hassan, Z. *The Status of Food Security in the Feed the Future Zone and Other Regions of Bangladesh: Results from the 2011–2012 Bangladesh Integrated Household Survey*. Project report submitted to the US Agency for International Development. Dhaka: International Food Policy Research Institute, 2013. <<http://www.ifpri.org/publication/status-food-security-feed-future-zone-and-other-regions-bangladesh>> (accessed on 15.01.2014)
- Ahmed, N. and Garnett, S.T. "Sustainability of freshwater prawn farming in rice fields in southwest Bangladesh." *Journal of Sustainable Agriculture* 34 (2010): 659–679.
- Ahmed, N., Garnett, S. T. "Integrated Rice-Fish Farming in Bangladesh: Meeting the Challenges of Food Security." *Food Security* 3, 1(2011): 81-92.
- Ahmed, N., Wahab, M. A., Thilsted, S. H. "Integrated Aquaculture-Agriculture Systems in Bangladesh: Potential for Sustainable Livelihoods and Nutritional Security of the Rural Poor." *Aquaculture Asia*, 12, 1 (2007): 14–22.
- Ahmed, N., Zander, K. K., Garnett, S. T. "Socioeconomic Aspects of Rice-Fish Farming In Bangladesh: Opportunities, Challenges and Production Efficiency." *Australian Journal of Agricultural and Resource Economics* 55, 2 (2011): 199-219.
- Alauddin, M., Tisdell, C., *The Green Revolution and Economic Development: The Process and its Impact in Bangladesh*. London: Macmillan, 1991.
- Ali, M. M., Saheed, S. M., Kubota, D., Masunaga, T., & Wakatsuki, T. "Soil degradation during the period 1967–1995 in Bangladesh: II. selected chemical characters." *Soil Science and Plant Nutrition* 43, 4 (1997): 879-890.
- Belton, B., and Azad, A. "The characteristics and status of pond aquaculture in Bangladesh." *Aquaculture*, 358, (2012): 196-204.
- BER. *Bangladesh Economic Review*. Economic Adviser's Wing, Finance Dhaka, Bangladesh.: Division, Ministry of Finance, Government of the People's Republic of Bangladesh, 2014.

- Berhane, G., and Gardebroek, C. "Does microfinance reduce rural poverty? Evidence based on household panel data from northern Ethiopia." *American Journal of Agricultural Economics* 93, 1 (2011): 43-55.
- Bezu, S., Kassie, G. T., Shiferaw, B., & Ricker-Gilbert, J. "Impact of improved maize adoption on welfare of farm households in Malawi: a panel data analysis." *World Development* 59 (2014): 120-131.
- Chowdhury, M. R. *Population challenge facing Bangladesh*. CW Post Campus, New York: Long Island University, 2009.
- Cortijo, M.J.A. "Contributing to the eradication of hunger, food insecurity and malnutrition: lessons from Bangladesh." *ESA Working Paper No. 14-06*. Rome, FAO, 2014. <http://www.fao.org/3/a-i3868e.pdf>
- Crost, B., Shankar, B., Bennett, R., & Morse, S. "Bias from Farmer Self-Selection in Genetically Modified Crop Productivity Estimates: Evidence from Indian Data." *Journal of Agricultural Economics* 58, 1 (2007): 24-36.
- Das, R. "The green revolution and poverty: a theoretical and empirical examination of the relation between technology and society." *Geoforum* 33, 1 (2002): 55-72.
- Dey, M. M., Paraguas, F. J., Kambewa, P., and Pemsl, D. E. "The impact of integrated aquaculture-agriculture on small-scale farms in Southern Malawi." *Agricultural Economics* 41, 1(2010): 67-79.
- Dey, M. M., Spielman, D. J., Haque, A. B. M. M., Rahman, M. S., & Valmonte-Santos, R. "Change and Diversity in Smallholder Rice-fish Systems: Recent Evidence and Policy Lessons from Bangladesh." *Food Policy* 43(2013):108-117.
- Edwards, P. "A systems approach for the promotion of integrated aqua- culture." *Aquaculture Economics and Management* 2, 1 (1998): 1-12.
- FAO. "Integrated agriculture-aquaculture: A primer." *FAO Fisheries Technical Paper-407*, Rome, Italy: Food and Agriculture Organization of the United Nations, 2000. <http://www.fao.org/docrep/005/y1187e/y1187e00.htm#TopOfPage> (accessed on 05.05.2014)
- FAO, IFAD and WFP. *The State of Food Insecurity in the World 2013. The multiple dimensions of food security*. Rome: FAO, 2013. <http://www.fao.org/docrep/018/i3434e/i3434e.pdf>
- Greene, W.H. *Econometric Analysis*. Upper Saddle River, NJ: Prentice Hall, 2008.
- Heckman, J. J., & Hotz, V. J. "Choosing among alternative nonexperimental methods for estimating the impact of social programs: The case of manpower training." *Journal of the American statistical Association* 84, 408 (1989): 862-874.
- IFAD. *Indigenous Peoples and Sustainable Development*. Roundtable Discussion Paper for the Twenty-Fifth Anniversary Session of IFAD's Governing Council. Rome: IFAD, 2003. <http://www.ifad.org/gbdocs/gc/26/e/ip.pdf>
- IFAD. *Rural poverty report 2011. New realities, new challenges: new opportunities for tomorrow's generation*. Rome: IFAD, 2011. <http://www.ifad.org/rpr2011/report/e/rpr2011.pdf>
- Jahan, K. Murshed-E, & Pemsl, D. E. "The impact of integrated aquaculture-agriculture on small-scale farm sustainability and farmers' livelihoods: Experience from Bangladesh." *Agricultural Systems* 104, 5 (2011): 392-402.
- Jorgenson, A., and Birkholz, R. "Assessing the causes of anthropogenic methane emissions in comparative perspective, 1990-2005." *Ecological Economics* 69, 12 (2010): 2634-2643.
- Kathage, J., & Qaim, M. "Economic impacts and impact dynamics of Bt (*Bacillus thuringiensis*) cotton in India." *Proceedings of the National Academy of Sciences* 109, 29 (2012): 11652-11656.
- Kerr, K., and Kolavalli, S. "Impact of agricultural research on poverty alleviation: conceptual framework with illustrations from the literature." *EPTD discussion paper no. 56*. Washington, DC, USA:

- .International Food Policy Research Institute, 1999.
<http://impact.cgiar.org/sites/default/files/KerrKolavalli1999.pdf> (Accessed on 18.11.2011)
- Kikulwe, E. M., Fischer, E., & Qaim, M. "Mobile Money, Smallholder Farmers, and Household Welfare in Kenya." *PloS one* 9, 10 (2014): e109804.
- Kouser, S., & Qaim, M. Impact of Bt cotton on pesticide poisoning in smallholder agriculture: A panel data analysis. *Ecological Economics* 70, 11 (2011): 2105-2113.
- Muriithi, B. W., & Matz, J. A. "Welfare effects of vegetable commercialization: Evidence from smallholder producers in Kenya." *Food Policy* 50 (2015): 80-91.
- Pant, J., Barman, B. K., Jahan, K.M., Benjamin Belton, B., Beveridge, M. Can Aquaculture Benefit the Extreme Poor? A Case Study of Landless and Socially Marginalized Adivasi (ethnic) Communities in Bangladesh. *Aquaculture* 418 (2014): 1-10.
- Pant, J., Demaine, H., & Edwards, P. "Bio-resource flow in integrated agriculture–aquaculture systems in a tropical monsoonal climate: a case study in Northeast Thailand." *Agricultural systems* 83, 2 (2005): 203-219.
- Pender, J. "Agricultural Technology Choices for Poor Farmers in Less-Favored Areas of South and East Asia." *IFPRI Discussion Paper 00709*. Environment and Production Technology Division. Washington, DC: International Food Policy Research Institute, 2007.
<http://www.ifpri.org/sites/default/files/publications/ifpridp00709.pdf> (Accessed on 28.10.2011).
- Pimentel, D., & Pimentel, M. "Comment: Adverse environmental consequences of the Green Revolution." *Population and Development Review* 16 (1990): 329-332.
- Pingali, P. L. "Green Revolution: Impacts, limits, and the path ahead." *Proceedings of the National Academy of Sciences* 109, 31 (2012): 12302-12308.
- Pingali, P. L., & Rosegrant, M. W. "Confronting the environmental consequences of the Green Revolution in Asia." *EPTD discussion paper No. 2* Washington, DC, USA: International Food Policy Research Institute (IFPRI), 1994.
<http://www.ifpri.org/sites/default/files/publications/eptdp02.pdf>
- Prein, M. "Integration of aquaculture into crop–animal systems in Asia." *Agricultural Systems* 71, 1–2 (2002): 127–146.
- Rahman, S. "Environmental impacts of modern agricultural technology diffusion in Bangladesh: an analysis of farmers' perceptions and their determinants." *Journal of environmental management* 68, 2 (2003a): 183-191.
- Rahman, S. "Farm-level pesticide use in Bangladesh: determinants and awareness." *Agriculture, ecosystems & environment* 95, 1 (2003b): 241-252.
- Sarker, M. A. R., Alam, K., & Gow, J. "Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data." *Agricultural Systems* 112 (2012): 11-16.
- Snijders TAB. "Fixed and random effects." In: Everitt BS, Howell DC (eds.) *Encyclopedia of Statistics in Behavioral Science* 2 (2005): 664–665 (Wiley, Chichester).
- Subramanian, A., & Qaim, M. "Village-wide effects of agricultural biotechnology: The case of Bt cotton in India." *World Development* 37, 1 (2009): 256-267.
- Wooldridge, J.M. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: The MIT press, 2002.