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# Graduation from Subsistence to Commercial Aquaculture: Evidence on Household Welfare

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This paper investigates the possibilities of subsistence homestead aquaculture producers to commercialise using a two-wave panel data of 518 households in Bangladesh. A binary endogenous switching regression model is applied to explore opportunities and constraints of commercialisation and a counterfactual analysis to estimate the effects of commercialisation on income and poverty. The study finds that while there is good potential for commercialisation, only a few households do that. Households who engage in commercial aquaculture achieve higher per capita income and are less likely to be poor. The study also finds that subsistence fish farmers who transform towards commercialised producers tend to receive support from non-government organisations, are members of fish farmers' associations, and have better access to local fish markets. A major constraint to aquaculture transformation is the lack of government attention to the subsistence-oriented homestead fish producers, thus forgoing a huge potential for reducing poverty and increasing welfare. The paper suggests that fisheries extension services should develop and implement a specifically-targeted aquaculture commercialisation program in cooperation with the agricultural extension.

**Keywords:** Aquaculture, Commercialisation, Household Welfare, Endogenous Switching Regression, Correlated Random Effect

**JEL Classification:** Q22, M31, D60, C34, C33

## I. INTRODUCTION

Aquaculture has become the fastest-growing food-producing sector in the world, with an annual growth rate of 5.8 per cent, and accounted for over 50 per cent of total fish consumed globally in 2016 (FAO, 2018a, 2018b). It is projected that the share of aquaculture in global fish consumption will increase to more than

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60 per cent by 2030 (FAO, 2014). The growth trend in aquaculture is so significant that it has started commonly been termed as the "blue revolution." This growth is more prominent in developing countries compared to developed countries (FAO, 2018a).

Aquaculture in developing countries, however, is largely dominated by smallholders. Smallholder aquaculture is mainly subsistence fish farming, where aquaculture is considered a part of households' diverse livelihood activities with important employment effects for the rural population (Phillips, Beveridge, Weirowski, Rogers, & Padiyar, 2011). Household-level subsistence production mainly supports family nutrition (Béné et al., 2016; Bogard et al., 2015; Thilsted, 2012), ensures a food safety net for the poor making fish available year-round (Castine et al., 2017), and improves household livelihoods through enhanced and diversifying income sources (Phillips et al., 2011).

In Bangladesh, aquaculture is one of the fastest-growing rural sectors, with enormous opportunities for rural households (Ali & Haque, 2011). Pond aquaculture in Bangladesh accounts for 79.19 per cent of total aquaculture production in 2019-20, where 20,46,258 metric tons of production originates from ponds out of 25,83,866 metric tons originating from aquaculture (DoF, 2021). The majority of the recorded production from the homestead is for home consumption, with occasional sales for surplus producers to complement the cash income of the poor (Edwards, 1999). However, more recently, small-scale homestead ponds are transforming into more commercial-type enterprises where better-off farmers are expanding their ponds and increasing the use of production inputs (Sarker et al., 2017).

Pond-based aquaculture is crucial for rural households in Bangladesh. This production system is growing and transforming very rapidly (Hernandez et al., 2018). However, previous studies have addressed this issue primarily (not exclusively). This paper makes a novel contribution to the empirical literature by applying rigorous econometric analysis to examine the possibilities of smallholder aquaculture farmers in Bangladesh to more effectively contribute to fish production when transforming from subsistence-type of home-pond producers towards a more modern, commercialised small-scale aquaculture system.

The remainder of this paper is organised as follows. Section II explains the implications of aquaculture commercialisation on household welfare. Section III provides the theoretical framework. Section IV describes the details of the estimation procedures. Section V presents the data and descriptive statistics. In section VI, the results of the empirical models are presented and discussed. Section VII concludes and offers some policy recommendations.

## II. AQUACULTURE COMMERCIALISATION AND ITS IMPLICATIONS FOR HOUSEHOLD WELFARE

Commercialisation has been defined to mean the progressive shift of production at the household level from home consumption to sales in accessible markets. Such a shift requires households' production and input decisions to align with the profit maximisation principle with participation in output and input markets (Olwande, Smale, Mathenge, Place, & Mithöfer, 2015). According to Pingali and Rosegrant (1995), commercialisation is a sequence of transformations where households move from subsistence to semi-commercial and finally to a fully commercialised production system (Table I).

TABLE I

**PRODUCTION SYSTEM WITH INCREASING COMMERCIALISATION**

| Level of market orientation | Farmers' objective | Input sources | Product mix | Income sources |
|---|---|---|---|---|
| Subsistence system | Food self-sufficiency | Household generated (non-traded) | Wide range | Predominantly agricultural |
| Semi-commercial systems | Surplus generation | Mix of traded and non-traded inputs | Moderately specialised | Agricultural and non-agricultural |
| Commercial systems | Profit maximsation | Predominantly traded inputs | Highly specialised | Predominantly non-agricultural |

**Source:** Pingali and Rosegrant (1995, p. 172).

In many developing countries, smallholder commercialisation is central to the inclusive development process, considered an effective way to bring welfare benefits of market-based economies to households (Arias, Hallam, Krivonos, & Morrison, 2013). In this sense, there is rarely a complete subsistence producer. Instead, producers are mostly semi-commercial with low input and low productivity. According to Olwande et al. (2015), these production systems are critical for poverty alleviation. However, the literature on the role of smallholder agricultural commercialisation on the welfare of the poor remains a large mix. For example, there is a large strand of literature that found that agricultural commercialisation significantly increases household income and welfare for households in sub-Saharan Africa (Muriithi & Matz, 2015; Poulton, Kydd, & Dorward, 2006; Timan, Makenzi, Laltaika, & Ubwani 2004). On the other hand, commercialisation driven by smallholder producers has been criticised for its role in widening the income inequalities among the poorest households in rural areas (Pingali & Rosegrant, 1995; Pingali, Khwaja, & Meijer, 2005).

However, while this literature may be varying and inconclusive on the role of agricultural commercialisation in general, most of these studies are limited to traditional agricultural sectors, such as crops and livestock, with little or no direct research in aquaculture commercialisation. This lack is in spite of the considerable interest by policymakers and development agents in aquaculture as a sustainable strategy for reducing poverty and food insecurity in many developing countries, e.g., Bangladesh (Toufique, 2015; Béné et al., 2016).

## III. THEORETICAL MODEL OF THE HOUSEHOLD MARKET PARTICIPATION DECISION TO COMMERCIALISE

This paper models the household market participation decision using a non-separable agricultural household model (AHM). The AHM considers households' market participation behaviour of selling fish to commercialise aquaculture under the condition that prices are endogenous to decision-making and determined by transaction costs (Barrett, 2008; Alene et al., 2008; Boughton et al., 2007).

Following the works of Barrett (2008), Alene et al. (2008), and Boughton et al. (2007), the households' market participation decisions as a seller can be expressed as $M^{cs}$. Where $M^{cs}$ is a binary indicator and takes a value of one if the household sells its product in the market and zero otherwise. The observed decision is a function of observed market prices and the vector of fish and household-specific transaction costs. Similarly, the decision not to participate in the market as a buyer is defined as, $M^{cb}$, which takes value one if the household elects to buy any crop and zero otherwise.

Household's market participation decision can thus be expressed as an optimisation problem as follows:

$$Max\ U(F^c, T) \qquad (1)$$

Subject to:

Cash budget constraint

$$P^T T + \sum_{c=1}^{n} M^{cb} P^{c*} F^c = \sum_{c=1}^{n} M^{cs} P^{c*} \int^{c} (K^c, S) + O_f \qquad (2)$$

Asset allocation constraint

$$K = \sum_{c=1}^{n} K^{c} \tag{3}$$

$$\left(1 - M^{cb}\right) F^{c} \leq \int^{c} (K^{c}, S) \qquad \forall\ c = 1,2,3 \ldots \ldots \ldots n \tag{4}$$

where $F^{c}$ (c=1, 2, 3,…….., n) is the consumption of a vector of agricultural commodities; $T$ is the Hicksian composite of other tradable goods; $C$ is the production of goods and services from farm sources that are consumed at home and possibly sold in the market; $O_f$ is off-farm sources; $f_c(K^{c}, S)$ is crop-specific production technology, which is a function of quasi-fixed assets ($K^{c}$) and public goods and services ($S$); $P^{m}$ is the parametric market price for fish ($c$); $\tau^{c}(H, S, K, O_f)$ is household and fish-specific transaction costs that depend on public goods and services ($S$), household-specific characteristics ($H$), household assets ($K$), and liquidity from off-farm income sources ($O_f$).

A household's net market position determines each household-specific crop price as follows:

$$P^{c*} = P^{cm} + \tau^{c}(H, S, K, O_f) \qquad \text{if } c > \int^{c} \tag{5}$$

$$P^{c*} = P^{cm} - \tau^{c}(H, S, K, O_f) \qquad \text{if } c < \int^{c} \tag{6}$$

$$P^{c*} = P^{a} \qquad \text{if } c = \int^{c} \tag{7}$$

where $P^{a}$ is the autarkic (i.e., non-tradable) shadow price, which exactly equates household demand and supply.

The model explained above is expressed in reduced form as a function of exogenous variables as follows:

$$M_i = M_i\left(P, H, K, S, O_f\right) \tag{8}$$

where $M_i$ indicates the market participation decision to sell fish by household ($i$). $P$ is the observed market price of fish. $H$ represents household characteristics. $K$ captures variables of household assets such as mobile and means of transport equipment. $S$ captures village-level infrastructure such as market distance, extension authority, and association of fish farmers.

The identification strategy for equation (8) follows a two-step procedure to determine market participation decision and welfare impact attributable to this participation.

## IV. ESTIMATION STRATEGY

This section explains the empirical model based on the specification of the agricultural household model defined in section III.

### 4.1 Modelling Commercialisation Decision to Assess Welfare Impact on Smallholders

There are several challenges while assessing the impacts of commercialisation. First, the treatment is not randomly assigned as households self-select themselves to be commercialised and non-commercialised. This introduces a self-selection bias in the outcome variable. Second, the impact of commercialisation on household welfare could be different for the treated and untreated households due to the structural difference in household and farm characteristics (Kassie, Jaleta, & Mattei, 2014; Shiferaw, Kassie, Jaleta, & Yirga, 2014). Third, the treatment variable (e.g., aquaculture commercialisation) is potentially endogenous.

This study develops a counterfactual group following a two-step framework to address these challenges. The first step estimates a probit selection equation to determine the drivers of commercialisation decisions. Then a selection bias correction term is calculated from the first step probit model and added as a generated regressor in the outcome equation. The second step implements a counterfactual analysis based on the outcome equation by calculating the average treatment effects on the treated and untreated groups to estimate the impact of commercialisation on household welfare. Following Di Falco and Veronesi (2013), Di Falco, Veronesi, and Yesuf (2011), and Teklewold, Kassie, Shiferaw, & Köhlin (2013), the selection bias corrected regression is defined as an endogenous switching regression model (ESR). This model not only helps correct for self-selection bias but also helps control for both observed and unobserved heterogeneity between different commercialisation strategies (Mansur, Mendelsohn, & Morrison, 2008).

**Step 1: Probit Selection Equation to Estimate Determinants of Commercialisation**

The market participation decision depends on the expected utility of the household that depends on the observed ($X_{it}$) and unobserved characteristics ($U_{it}$) (Boughton et al., 2007; Alene et al., 2008). As utility is unobservable, it can be expressed as a function of observable household characteristics ($X_{it}$) and the error terms ($\eta_{it}$) in the form of a latent variable model as follows:

$$C_{it} = \alpha_{it} X_{it} + \eta_{it} \text{ where, } C_{it} = \begin{cases} 1 \; if \; C^{*}{}_{it} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{9}$$

where $C_{\mathrm{it}}$ is the binary indicator variable for commercialisation which equals 1 if household $i$ is commercialised, 0 otherwise, $\alpha_{it}$ is vector of parameters to be estimated, $\mathrm{X}_{\mathrm{it}}$ is vector of observable explanatory variables, and $\eta_{\mathrm{it}}$ is the error term.

The ESR model is estimated using the outcome functions conditional on the household's commercialisation decision to evaluate the impact of commercialisation on welfare as follows (Kassie et al., 2014; Shiferaw et al., 2014):

$$W_{1it} = \beta_1 X_{1it} + \varepsilon_{1it} \qquad \text{if } C_{it} = 1 \tag{10a}$$

$$W_{0it} = \beta_0 X_{0it} + \varepsilon_{0it} \qquad \text{if } C_{it} = 0 \tag{10b}$$

The error terms $\eta, \varepsilon_1, \varepsilon_0$ are assumed to have a trivariate normal distribution with zero mean and covariance matrix as follows:

$$\boldsymbol{Cov}(\eta, \varepsilon_1, \varepsilon_0) = \begin{bmatrix} \sigma_\eta^2 & \sigma_{\eta\varepsilon_1} & \sigma_{\eta\varepsilon_0} \\ \sigma_{\eta\varepsilon_1} & \sigma_{\varepsilon_1}^2 & .. \\ \sigma_{\eta\varepsilon_0} & .. & \sigma_{\varepsilon_0}^2 \end{bmatrix} = \begin{bmatrix} 1 & \sigma_{\eta\varepsilon_1} & \sigma_{\eta\varepsilon_0} \\ \sigma_{\eta\varepsilon_1} & \sigma_{\varepsilon_1}^2 & .. \\ \sigma_{\eta\varepsilon_0} & .. & \sigma_{\varepsilon_0}^2 \end{bmatrix} \tag{11}$$

where $W_{1it}$ and $W_{0it}$ are outcome variables, representing households' welfare indicators such as household income, poverty, and income diversification for commercialised and non-commercialised households respectively at time period $t$, $X$ represents observed vectors of covariates, which determines outcome variable for commercialised and non-commercialised households respectively, at time period $t$, $\beta$ is the vectors of parameters, and $\varepsilon$ is the error terms that are normally distributed with zero mean and constant variance, $\sigma_\eta^2$ is $var(\eta)$, $\sigma_{\varepsilon_1}^2$ is $var(\varepsilon_1)$, $\sigma_{\varepsilon_0}^2$ is $var(\varepsilon_0)$, $\sigma_{\eta\varepsilon_1}$ and $\sigma_{\eta\varepsilon_0}$ are $cov(\eta, \varepsilon_1)$ and $cov(\eta, \varepsilon_0)$, respectively.

There are three issues that need to be addressed before estimating the model. ***First,*** For the ESR model to be identified, at least one selection instrument needs to be incorporated into the section model without the $X_{it}$ variables. Following the empirical literature (Muricho, Manda, Sule, & Kassie, 2017; Mazengia, 2016), we use distance to the village market and a binary indicator showing the membership of the fish farmers association as instruments. ***Second,*** There is selection bias in the ESR model. Therefore, the expected values of the error terms in equations (10a) and (10b) conditional on commercialisation decision are non-zero as follows:

$$E(\varepsilon_{1it} | C_{it} = 1) = \sigma_{\varepsilon_1\eta} \frac{\phi(X_i,\alpha)}{\Phi\,(X_i,\alpha)} = \sigma_{\varepsilon_1\eta}\, \lambda_{1it} \quad \text{where } \lambda_{1it} = \frac{\phi(X_i,\alpha)}{\Phi\,(X_i,\alpha)} \tag{12a}$$

$$E(\varepsilon_{0it} | C_{it} = 0) = \sigma_{\varepsilon_0\eta} \frac{\phi(X_i,\alpha)}{1-\Phi\,(X_i,\alpha)} = \sigma_{\varepsilon_0\eta}\, \lambda_{0it} \quad \text{where } \lambda_{0it} = \frac{\phi(X_i,\alpha)}{1-\Phi\,(X_i,\alpha)} \tag{12b}$$

where $\phi(.)$ is the standard normal probability density function, $\Phi(.)$ is the standard normal cumulative density function, $\lambda_1$ and $\lambda_0$ are the inverse mills' ratio (IMR), $i \; and \; t$ represent household and time period, respectively.

As the expected values of the error terms are non-zero, $\lambda_1$ and $\lambda_0$ are computed from the selection equation (9) and included in welfare equations (10a) and (10b) to account for the selection bias (Maddala, 1983):

$$W_{1it} = \beta_1 X_{1it} + \sigma_{\varepsilon_1 \eta} \, \lambda_{1it} + e_{1it} \qquad \text{if } C_{it} = 1 \tag{13a}$$

$$W_{0it} = \beta_0 X_{0it} + \sigma_{\varepsilon_0 \eta} \, \lambda_{0it} + e_{0it} \qquad \text{if } C_{it} = 0 \tag{13b}$$

where $e_{1it} = \varepsilon_1 + \sigma_{\varepsilon_1 \eta} \, \lambda_{1it}$ and $e_{0it} = \varepsilon_0 + \sigma_{\varepsilon_0 \eta} \, \lambda_{0it}$ are the error terms, with conditional mean equal to zero. In equations (13a) and (13b), the standard errors are bootstrapped to account for the heteroscedasticity arising from the generated regressors $(\lambda)$.

***Third***, to solve the presence of unobserved time-invariant individual heterogeneity in the ESR model, a correlated random effects (CRE) approach is applied using the *Mundlak–Chamberlain* device (Mundlak, 1978; Chamberlain, 1982) to estimate the welfare equations in (13a) and (13b). The CRE framework, including the farm variant variable, can be modelled as follows:

$$T_i = \pi + \theta \bar{X}_i + \gamma_i \tag{14}$$

where $\pi$ is a scale coefficient, $\bar{X}$ is the average value of fish yield, $\theta$ is the coefficient vector, $\gamma_i$ is a normally distributed error term assumed to have zero mean, equal variance, and not correlated with $\bar{X}_i$ (Di Falco & Veronesi, 2013).

Finally, the ESR model is expressed in reduced form as follows:

$$W_{it} = \delta_t^* + \beta X_{it} + \theta \bar{X}_{it} + \sigma \, \lambda_{it} + \omega Z_i + \upsilon_{it} \tag{15}$$

where $W_{it}$ is the outcome variable representing households' welfare indicators for commercialised and non-commercialised households at time period $t$, $\delta_t^*$ is intercept coefficient which is equal to $(\delta_t + \pi)$, $X_{it}$ represents observed vectors of covariates for commercialised and non-commercialised households, respectively, at time period $t$, the vectors of parameters are $\beta, \theta, \sigma, \omega$ , $\bar{X}$ is the average value of fish yield, $Z_i$ is a vector of time-invariant explanatory variables, $\lambda_{it}$ is the inverse mills' ratio, and $\upsilon_{it}$ is the error term which is equal to $(\gamma_i + e_{it})$ and are normally distributed with zero mean and constant variance.

**Step 2: Counterfactual Analysis for Treatment Effects**

Using the above framework, a counterfactual analysis is formulated to estimate the expected welfare outcomes for commercialised and non-commercialised households. Following Di Falco and Veronesi (2013) and Di Falco, Veronesi, and Yesuf (2011), the average treatment effect on the treated (ATT) and untreated (ATU) groups are estimated as follows:

Commercialised household with commercialisation (actual scenario):

$$E(W_{1i}|C_i = 1; X) = \beta_1 X_{1i} + \sigma_{\varepsilon_1\eta}\,\lambda_{1i} \tag{16a}$$

Non-commercialised household without commercialisation (actual scenario):

$$E(W_{0i}|C_i = 0; X) = \beta_0 X_{0i} + \sigma_{\varepsilon_0\eta}\,\lambda_{0i} \tag{16b}$$

Commercialised households had they decided not to commercialise (counterfactual):

$$E(W_{0i}|C_i = 1; X) = \beta_0 X_{1i} + \sigma_{\varepsilon_{01}\eta}\,\lambda_{1i} \tag{16c}$$

Non-commercialised households had they decided to commercialise (counterfactual):

$$E(W_{1i}|C_i = 0; X) = \beta_1 X_{0i} + \sigma_{\varepsilon_1\eta}\,\lambda_{0i} \tag{16d}$$

Using the conditional expectations, the average welfare outcome is computed by calculating the outcome difference between commercialised and non-commercialised households as follows:

The effect of commercialisation on households who commercialise (The average treatment effect on the treated ATT):

$$ATT = E(W_{1i}|C_i = 1; X) - E(W_{0i}|C_i = 1; X) = (\beta_1 - \beta_0)X_{1i} + (\sigma_{\varepsilon_1\eta} - \sigma_{\varepsilon_{01}\eta})\,\lambda_{1i} \tag{17}$$

The effect of commercialisation on households who do not commercialise (The average treatment effect on the untreated ATU):

$$ATU = E(W_{1i}|C_i = 0; X) - E(W_{0i}|C_i = 0; X) = (\beta_1 - \beta_0)X_{0i} + (\sigma_{\varepsilon_1\eta} - \sigma_{\varepsilon_{01}\eta})\,\lambda_{0i} \tag{18}$$

## 4.2 Choice of Outcome Variables for the Model

### *4.2.1 Commercialisation*

Commercialisation is measured at the household level and is given as the percentage of the total marketed output of a product to total production (Mather, Boughton, & Jayne, 2013; Otieno, Omiti, Nyanamba, & McCullough, 2009). However, there is always some amount of output that even a subsistence farmer would sell. Therefore, just taking the percentage of sales without a threshold can result in subsistence households being wrongly classified as commercial households (Abafita, Atkinson, & Kim, 2016). The literature on commercialisation uses different thresholds of 10, 20, and 50 per cent depending on the location (Doppler, 1991; Ruthenberg, 1971; Gebreselassie & Sharp, 2007). Therefore, this study also uses different levels of thresholds to capture the impact at different levels of commercialisation.

#### *4.2.2 Household Welfare Indicators*

This study uses three welfare indicators, i.e., net household income, poverty status, and income diversification. Net household income considered in nominal terms is the total income from all sources such as crops, livestock, wage and salaries, business, remittances, pension, and social benefits in the calculation process.

Moreover, household expenditure is used to calculate the economic position of a household by identifying the poverty status. The poverty line threshold applied here is jointly used by the Bangladesh Bureau of Statistics (BBS) and the World Bank, and it is considered the 'official methodology' to determine the incidence of poverty. Any household with per capita expenditure below the threshold is considered as poor and above as non-poor. Additionally, the income diversification of households is calculated using the Simpson index (Hirschman, 1945; Simpson, 1949) as follows:

$$ID_i = 1 - \sum_{j=1}^{N} \left(S_{i,j}\right)^2 \quad (19)$$

where $ID$ is the income diversification index, $S$ refers to the share of income sources, $j$ is the number of income sources, $i$ is the number of households, and $N$ is the total number of income sources.

## V. DATA AND DESCRIPTIVE STATISTICS

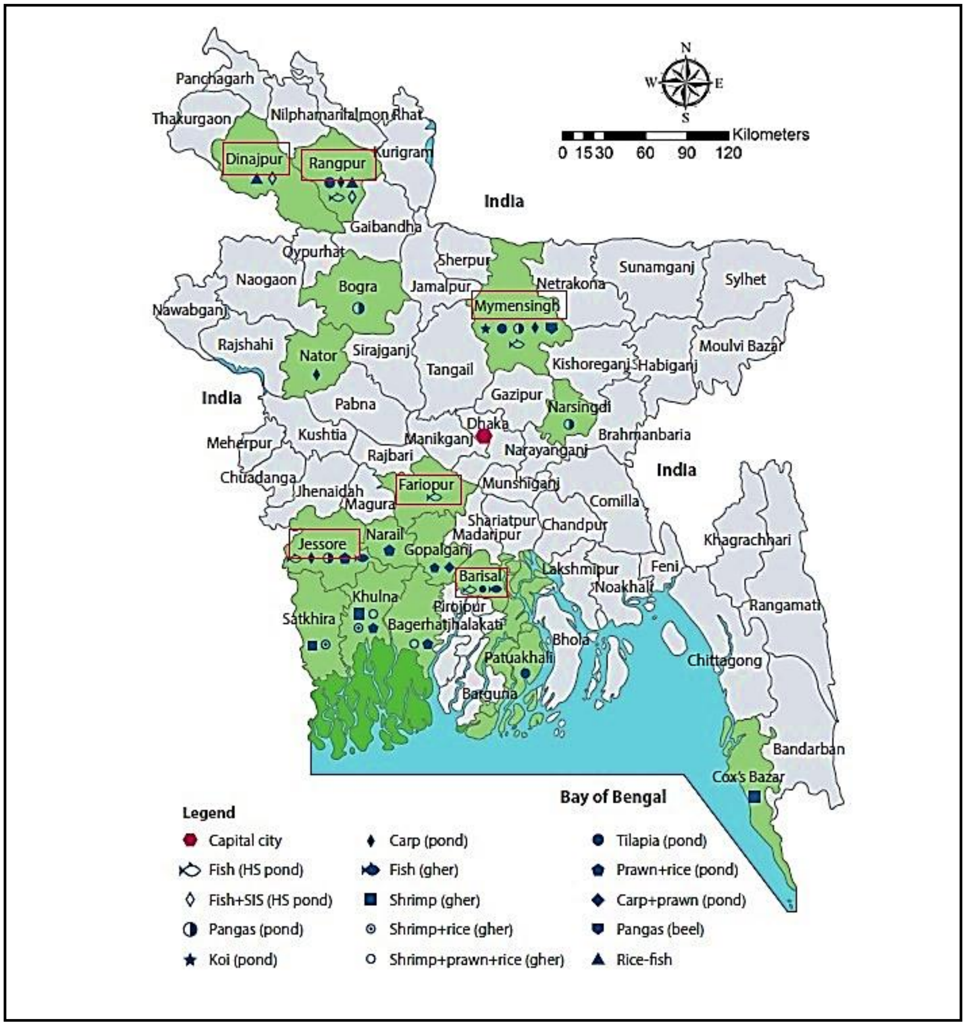
### 5.1 Data

This study uses two-wave panel data collected from households engaged in homestead pond aquaculture in Bangladesh. The first round of data was collected in 2011, while the second round was in 2016. A total of 518 households were surveyed in both rounds, while 494 were successfully resurveyed in the second round in 2016, with an attrition rate of 4.6 per cent.

The baseline data (2011) come from Cereal Systems Initiative for South Asia in Bangladesh (CSISA-BD) project implemented by WorldFish, Bangladesh. The follow-up survey (May and June 2016) was jointly conducted by the University of Hannover, Germany, and WorldFish, Malaysia, through a household survey in Bangladesh.

A purposive random sampling technique was used following a multi-stage process to select the households that are practising different aquaculture technologies in Bangladesh (Jahan, Belton, Ali, Dhar, & Ara, 2015). The WorldFish survey collected information on five major aquaculture production systems containing 14 aqua- culture technologies in Bangladesh (Figure 1).

FIGURE 1: **Study Areas in Bangladesh (within red rectangles)**




**Source:** Jahan et al. (2015, p. 19).

Among the production systems, homestead pond aquaculture was the only non-commercial aquaculture production system and the only system where a major proportion of the aquaculture production was used for household consumption. Thus, to fulfil the objective of this study, households practising homestead pond-based aquaculture production systems were selected from the CSISA-BD project, which comprised 518 households, and was resurveyed independently in 2016 through a household survey to collect the necessary information.

## 5.2 Descriptive Statistics

### *5.2.1 Extent of Commercialisation among the Fish Farmers in Bangladesh*

The data shows that homestead fish farming in Bangladesh is still at a low level of commercialisation (on average, 23 per cent of output is marketed). Also, between 2011 and 2016, total marketed output only increased by seven percentage points (an increase of 28 per cent). However, the observed increase is driven by households selling above 50 per cent of their product. Moreover, graduation to a higher commercialisation level is observed among the sample households selling below 25 per cent of their produced fish. Additionally, a highly commercialised group selling above 75 per cent of produced fish was observed to be operated in 2016, capturing 5 per cent of the total sample. Depending on the threshold that is used for commercialisation (above 25 per cent of output), it is seen that there is a progressive shift from subsistence production to a more market-oriented homestead production.

TABLE II

**LEVEL OF COMMERCIALISATION AMONG THE HOMESTEAD FISH**

| Level of commercialisation | Number of households (%) | | | | Output sold (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | 2011 | 2016 | Change | Total | 2011 | 2016 | Change |
| No sell | 47.64 | 51.50 | 43.78 | -7.72 | 0 | 0 | 0 | 0 |
| Up to 10% | 6.44 | 8.58 | 4.29 | -4.29 | 8.96 | 9.90 | 7.08 | -2.82 |
| 11-25% | 7.30 | 7.51 | 7.08 | -0.43 | 18.84 | 19.23 | 18.42 | -0.81 |
| 26-50% | 18.67 | 14.38 | 22.96 | 8.58 | 38.61 | 40.33 | 37.53 | -2.8 |
| 51-75% | 14.70 | 11.37 | 18.03 | 6.66 | 62.88 | 61.93 | 64.39 | 2.46 |
| Above 75% | 5.26 | - | 10.52 | - | 85.90 | - | 85.90 | - |
| Total | 100.00 | 100.00 | 100.00 | 0 | 22.92 | 19.26 | 26.58 | 7.32 |

**Source:** Own calculation based on the household survey, 2011 and 2016.

In terms of levels of fish output from the homestead, the total production of fish increased by about 150 per cent between 2011 and 2016. Similarly, the overall volumes sold increased in the same period. However, the volume traded by households below the 50 per cent threshold of produced fish fell while that for those above the 50 per cent threshold increased in the period (Table II). It implies that farmers practising subsistence and low levels of commercialisation used the increased output produced for home consumption, as shown in Table III, where home consumption for households below the 50 per cent threshold increased while that for those above the threshold decreased. It implies that when production increases, consumption at the households who produce at the subsistence and low commercialisation level increases more than the marketed output. This type of relationship between marketed output and the consumed product is not unusual in a farming system dominated by poor smallholders (Gebreselassie & Sharp, 2007, p. 67).

TABLE III

**PRODUCTION AND CONSUMPTION AT DIFFERENT COMMERCIALISATION LEVELS**

| Level of commercialisation | % of households | Production (Kg/year) | | | Consumption (%) | | |
|---|---|---|---|---|---|---|---|
| | | 2011 | 2016 | % change | 2011 | 2016 | % change |
| No Sell | 47.64 | 68 | 101 | 48.53 | 100.00 | 100.00 | 0.00 |
| 1- 10% | 6.44 | 82 | 151 | 84.15 | 90.1 | 92.92 | 2.82 |
| 11-25% | 7.30 | 142 | 148 | 4.23 | 80.77 | 81.58 | 0.81 |
| 26-50% | 18.67 | 82 | 115 | 40.24 | 59.67 | 62.47 | 2.8 |
| 51-75% | 14.70 | 119 | 282 | 136.97 | 38.07 | 35.61 | -2.46 |
| Above 75% | 5.26 | - | 955 | - | - | 14.1 | - |
| Total | 100.00 | 86 | 220 | 155.81 | 80.74 | 73.42 | -7.32 |

**Source:** Own calculation based on the household survey, 2011 and 2016.

### *5.2.2 Definition of the Variables Used in the Econometric Analysis*

Table IV describes the variables used in the econometric analysis. The total household income is calculated from seven different sources: crop production, livestock and poultry, aquaculture activities, self-employment activities, wage-earning, pension and salary, and remittances. The Simpson index used in the analysis is constrained to lie between zero and one. A value of zero indicates that a household's income is completely specialised in one source, while a value of one implies that the income sources are highly diversified.

TABLE IV

**DEFINITION OF VARIABLES USED IN REGRESSION ANALYSIS**

| Name of Variables | Description of the variables |
|---|---|
| *Dependent variables* | |
| Total income per capita (in Taka) | Household income per capita adjusted for inflation using CPI 2016 (Tk./Year) |
| Poverty headcount rate (%) | The fraction of households whose income falls below the poverty line |
| Income diversification index | How diversified is household income (range between 0 and 1) |
| Commercialise | If the household is commercialised (yes = 1 and no = 0) |
| *Independent variables* | |
| Age | Age of the household head in years |
| Age square | Square of household head's age |
| Gender | Gender of household head (female-0 and male=1) |
| Education | Completed years of schooling of the household head |
| Household size | Total number of family members |
| Dependency ratio | The total household members below 15 and above 65 divided by the total household member aged 15 to 64 |
| Total land holding | Area of land under possession by a household in hectare |
| Have farm income (yes=1) | If the household has income from the sale of crop, livestock, and farm-related goods (yes = 1 and no = 0) |
| Have off-farm income (yes=1) | If the household has income from non-farm self-employment activities, wage-paying activities and other services (yes = 1 and no = 0) |
| Have livestock? (yes=1) | If the household has livestock (yes = 1 and no = 0) |
| Experience shock in pond (yes=1) | If the household experience any kind of shocks related to production in the pond. (yes = 1 and no = 0) |
| Aquaculture experience (years) | Experience in homestead aquaculture production of the household head in years |
| Fish Yield | Total fish production (kg/year) |
| Distance to market (km) | Distance from household to nearest village market in kilometre |
| Credit access (yes=1) | If the household receives credit for fish production (yes = 1 and no = 0) |
| Received support from fisheries officers (yes=1) | Received any kind of support related to fish production from fisheries officers (yes = 1 and no = 0) |
| Received support from NGOs (yes=1) | Received support from NGOs related to fish production (yes = 1 and no = 0) |
| Member of farmers association (yes=1) | If the household is a member of any fish farmers association (yes = 1 and no =0) |
| Fish price | Weighted average market price of fish by species and by year in taka per kilogram (at district level) |
| Regional dummy (yes=1) | If the household belongs to a particular aquaculture cluster (yes = 1 and no = 0) |

**Source:** Own calculation based on the household survey, 2011 and 2016.

Table V presents the descriptive statistics of variables used in the two-step estimation procedure. About 33 per cent of the surveyed households were commercialised and participated in the market to sell fish in 2011, which increased to 45 per cent in 2016. The per capita income of homestead fish farmers increased between 2011 and 2016, although households that did not commercialise have a lower per capita income than the commercialised households. Moreover, commercialised households had higher per capita annual income and lower poverty headcount rates than their non-commercialised counterparts.

TABLE V

**DESCRIPTIVE STATISTICS OF THE VARIABLES BY YEAR AND COMMERCIALISATION STATUS**

| Variables | Total | Year | | Commercialisation status | |
|---|---|---|---|---|---|
| | | 2011 | 2016 | C | NC |
| *Dependent variables* | | | | | |
| Commercialise | 0.39 | 0.33 | 0.45 | 1.00 | 0.00 |
| | (0.49) | (0.47) | (0.49) | (0.00) | (0.00) |
| Total income per capita | 27.92 | 22.50 | 33.33 | 30.24 | 26.43 |
| (in ’000 Tk.) | (22.00) | (18.79) | (23.61) | (11.58) | (21.52) |
| Headcount ratio | 0.80 | 0.89 | 0.71 | 0.78 | 0.82 |
| | (0.40) | (0.31) | (0.45) | (0.41) | (0.39) |
| Diversification index | 0.41 | 0.41 | 0.42 | 0.41 | 0.41 |
| | (0.19) | (0.18) | (0.20) | (0.19) | (0.19) |
| *Independent variables* | | | | | |
| Age of head (years) | 48.70 | 47.19 | 50.21 | 49.13 | 48.73 |
| | (12.97) | (12.66) | (13.11) | (12.49) | (13.26) |
| Gender of head (male=1) | 0.97 | 0.98 | 0.95 | 0.97 | 0.97 |
| | (0.18) | (0.15) | (0.21) | (0.19) | (0.18) |
| Education of head (years) | 5.26 | 5.24 | 5.29 | 5.24 | 5.27 |
| | (4.83) | (5.35) | (4.26) | (4.11) | (5.25) |
| Household size | 5.07 | 4.92 | 5.23 | 5.21 | 4.98 |
| | (1.86) | (1.73) | (1.98) | (1.87) | (1.85) |
| Dependency ratio | 0.58 | 0.57 | 0.58 | 0.64 | 0.54 |
| | (0.54) | (0.53) | (0.56) | (0.61) | (0.50) |
| Total land holding (hectare) | 0.72 | 0.77 | 0.67 | 0.74 | 0.71 |
| | (0.83) | (0.98) | (0.65) | (0.75) | (0.88) |
| Have farm income (yes=1) | 0.94 | 0.99 | 0.89 | 0.92 | 0.96 |
| | (0.23) | (0.06) | (0.31) | (0.27) | (0.20) |
| Have off-farm income (yes=1) | 0.71 | 0.60 | 0.83 | 0.74 | 0.70 |
| | (0.45) | (0.49) | (0.37) | (0.44) | (0.46) |
| Have livestock (yes=1) | 59.12 | 0.77 | 0.41 | 0.62 | 0.55 |
| | (0.49) | (0.42) | (0.49) | (0.49) | (0.50) |
| Experience shocks (yes=1) | 0.13 | 0.10 | 0.16 | 0.14 | 0.12 |
| | (0.34) | (0.30) | (0.37) | (0.35) | (0.32) |
| Experience in aquaculture (years) | 13.27 | 13.80 | 12.75 | 14.53 | 11.32 |
| | (8.61) | (8.49) | (8.71) | (8.77) | (7.99) |
| Fish yield (Kg) | 153.00 | 85.89 | 220.11 | 246.58 | 93.03 |
| | (353.29) | (59.44) | (487.17) | (544.27) | (77.89) |
| Credit access (yes=1) | 0.15 | 0.015 | 0.18 | 0.15 | 0.00 |
| | (0.07) | (0.05) | (0.09) | (0.07) | (0.00) |
| Received support from NGOs (yes=1) | 0.86 | 0.87 | 0.83 | 0.80 | 0.88 |
| | (0.36) | (0.34) | (0.37) | (0.40) | (0.32) |
| Received support from FO (yes=1) | 0.12 | 0.13 | 0.12 | 0.11 | 0.13 |
| | (0.33) | (0.33) | (0.32) | (0.31) | (0.34) |
| Fish price (Tk./Kg) | 0.33 | 91.66 | 134.92 | 115.58 | 111.82 |
| | (0.47) | (38.57) | (74.21) | (79.81) | (49.21) |

*(Contd. Table V)*

| Variables | Total | Year | | Commercialisation status | |
|---|---|---|---|---|---|
| | | 2011 | 2016 | C | NC |
| *Selected instruments* | | | | | |
| Distance (Km) | 1.86<br>(0.80) | 1.86<br>(0.80) | 1.86<br>(0.80) | 1.77<br>(0.86) | 1.90<br>(0.76) |
| Member of farmers association (yes=1) | 0.49<br>(0.50) | 0.54<br>(0.49) | 0.45<br>(0.49) | 0.90<br>(0.31) | 0.23<br>(0.42) |
| Observations | 932 | 466 | 466 | 568 | 364 |

**Note:** (a) Standard deviations are in parentheses. (b) Regional dummies statistics are omitted for brevity. (c) Standard deviations are in parentheses. (d) C and NC represent commercialised and non-commercialised households, respectively, using a threshold above 25 per cent sales to define a commercial production system.
**Source:** Own calculation based on the household survey, 2011 and 2016.

It has been found that the majority of the surveyed households were male-headed, and there is less difference between the commercialised and non-commercialised households. It might indicate that female-headed households have less involvement in aquaculture activities either due to barriers to participation in markets as sellers or for prioritising household activities.

Overall, almost 50 per cent of the surveyed households were found to be members of the fish farmers' association, and the majority of the commercialised households had membership in the fish farmers' association.[1] Public support service from local government through fisheries officers seems less attractive in the survey area as the majority of the fish farmers received all needed support services from the local non-government organisations (NGOs).

### *5.2.3 Input-output Data of Production in Homestead Pond*

Table VI presents the input and output data of production in homestead ponds for commercialised and non-commercialised households. The total cost of production includes the fixed costs and the operating costs of production. The fixed costs in the pond include pond repairs, equipment, rental costs, etc. In contrast, the operating costs include the cost associated with purchasing fry and fingerlings, fertilisers, feed, and costs related to hiring labour, marketing, irrigation, and water exchange.

[1] Farmers participated in different types of formal institutions such as cooperative societies and district or upazila-level farmers' associations. Many farmers are also involved in informal or semiformal institutions such as market committees and traders' associations. Usually, these types of associations provide necessary training and advice to the fish farmers and also disseminate information about the market condition and market price of fish among the members.

TABLE VI

**INPUT-OUTPUT PARAMETERS BY YEAR AND BY COMMERCIALISATION STATUS**

| Details | 2011 | | | 2016 | | |
|---|---|---|---|---|---|---|
| | C | NC | Mean diff | C | NC | Mean diff |
| Pond area (in hectare) | 0.07 | 0.05 | 0.02*** | 0.14 | 0.08 | 0.06*** |
| | (0.003) | (0.002) | (0.004) | (0.01) | (0.01) | (0.01) |
| Fish yield (kg) | 102.53 | 77.83 | 24.71*** | 449.51 | 111.82 | 337.69*** |
| | (4.53) | (3.35) | (5.76) | (59.01) | (5.81) | (48.08) |
| Sold (%) | 52.16 | 3.32 | 48.83*** | 55.25 | 2.65 | 52.59*** |
| | (1.09) | (0.36) | (0.92) | (1.45) | (0.38) | (1.39) |
| Selling price (per kg) | 133.25 | 136.91 | -3.65 | 85.83 | 94.48 | -8.65** |
| | (2.96) | (6.67) | (6.90) | (1.95) | (2.46) | (3.79) |
| Total cost (per kg) | 63.69 | 67.39 | -3.70 | 49.75 | 86.81 | -37.06* |
| | (6.61) | (4.72) | (8.20) | (3.74) | (17.63) | (22.09) |
| Total income (Tk./year) | 13924 | 13166 | 757 | 42048 | 14504 | 27543*** |
| | (1824) | (2052) | (3212) | (5107) | (707) | (4729) |
| Net income (Tk./year) | 7246 | 7756 | -509 | 25675 | 9370 | 16304*** |
| | (1013) | (1476) | (2237) | (3639) | (682) | (3406) |
| % of household income | 6.96 | 6.83 | - | 13.58 | 5.73 | - |
| Observations | 152 | 314 | | 212 | 254 | |

**Note:** (a) C and NC represent commercialised and non-commercialised households, respectively. (b) standard deviations are in parentheses. (c) ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.
**Source:** Own calculation based on the household survey, 2011 and 2016.

The results show that there exist significant differences in terms of costs and benefits between the two groups of households. On average, commercialised farmers sold more than 50 per cent of their produced fish in the market. The net income was highest for commercialised households than their counterparts despite the fact that they had significantly lower (in 2016) selling prices. The production cost per kilogram was lowest for commercialised farmers, which explains that commercialised farmers generate higher revenue with minimum production costs.

## VI. RESULTS FROM THE TWO-STEP ENDOGENOUS SWITCHING REGRESSION MODEL

This section identifies the micro-economic determinants of household market participation decision to commercialise (or not commercialise). The relationship between household commercialisation status and household-level factors is established using the household survey data, assuming the macroeconomic conditions remain constant.

### 6.1 Determinants of Commercialisation

Table VII provides a list of variables from the results generated from the *probit* selection equation using the first stage of the binary endogenous switching regression (ESR) technique to identify the determinants of commercialisation based on the significant variables.[2] The results show that 'households' total land holding,' 'farmer's experience in aquaculture production,' 'household's membership in farmers' association,' and 'distance to the nearest village market' are the most important determinants of smallholder commercialisation decisions, which hold true for any commercialisation level. The explanatory variables such as total land holding, experience in aquaculture production, and members of farmers' associations positively and significantly influence the farmers' decision to participate in the market to sell fish. In contrast, the variable distance to the village market has a significant negative association with farmers' decision to participate in the market.

TABLE VII

**DETERMINANTS OF COMMERCIALISATION AMONG HOMESTEAD FISH FARMERS**

| Name of variables | Model 1 (Sell > 10 %) | Model 2 (Sell >25 %) | Model 3 (Sell >50 %) |
|---|---|---|---|
| Age of head | X | $0.06^{**}$ (0.03) | X |
| Age squared | X | $-0.001^{**}$ (0.00) | X |
| Dependency ratio | X | X | $-0.23^{**}$ (0.11) |
| Total land holding (log) | $0.24^{***}$ (0.06) | $0.12^{*}$ (0.07) | $0.25^{***}$ (0.06) |
| Have farm income (yes=1) | $-0.47^{**}$ (0.22) | X | X |
| Have off-farm income (yes=1) | $0.23^{*}$ (0.13) | X | X |
| Experience in aquaculture (years) | $0.02^{**}$ (0.01) | $0.03^{***}$ (0.01) | $0.01^{*}$ (0.01) |
| Credit access (yes=1) | X | $0.78^{**}$ (0.40) | $1.52^{***}$ (0.58) |
| Received support from NGOs (yes=1) | X | $0.24^{**}$ (0.12) | $0.26^{**}$ (0.12) |
| Received support from FO (yes=1) | X | X | $0.29^{*}$ (0.16) |
| Distance to village market (log) | $-0.69^{***}$ (0.21) | $-0.51^{**}$ (0.23) | $-0.10^{***}$ (0.04) |
| Member of farmers' association (yes=1) | $1.82^{***}$ (0.12) | $2.22^{***}$ (0.14) | $1.50^{***}$ (0.14) |
| Regional and time dummy | | | |
| Rangpur (yes=1) | $0.85^{***}$ (0.18) | $0.74^{***}$ (0.20) | $0.67^{***}$ (0.24) |

*(Contd. Table VII)*

[2] The tables of *probit* selection equation using the first stage of the binary endogenous switching regression (ESR) technique using a threshold above 10% and 50% sales will be available upon request.

| Name of variables | Model 1 (Sell > 10 %) | Model 2 (Sell >25 %) | Model 3 (Sell >50 %) |
|---|---|---|---|
| Mymensingh (yes=1) | 0.74*** (0.21) | 0.54** (0.23) | 0.56** (0.27) |
| Faridpur (yes=1) | 0.77*** (0.18) | 0.82*** (0.19) | 0.58** (0.24) |
| Time (year=2011) | 0.59*** (0.11) | 0.49*** (0.12) | 0.33** (0.16) |

**Note:** (a) Robust standard errors are in parentheses. (b) X represents coefficients that are not significant in appendix table A1. (c) Base category is the Jessore region; ***, **, and * indicate significance at 1%, 5%, and 10% levels, respectively.
**Source:** Own calculation based on the household survey, 2011 and 2016.

Land holding is statistically significant and has a positive influence on the market participation of households. It implies that land is important for smallholder fish farmers. Land ownership is considered as a proxy of household wealth, as household land holding increases, the probability of the decision to commercialise increases. This result is in line with Olwande and Smale (2014) and Muricho et al. (2017), who report a positive relationship between landholding and commercialisation probability within the household. Moreover, the information provided by informal associations of farmers' had a positive and significant effect on the commercialisation of homestead fish farmers in Bangladesh. Membership in farmers' associations is likely to facilitate access to information, increase the market bargaining power of smallholders and open the opportunity to enter into lucrative markets that they could not have been able to access if they were not members (Shiferaw et al., 2014).

In addition, this study finds a significant negative association between aquaculture commercialisation and the distance to the nearest village market. A shorter distance from farm to market reduces the transaction cost and thus increases the probability of selling more fish in the market (Muricho et al., 2017). This finding highlights the importance of market access, transaction costs, and remoteness in curtailing farming households from commercialising their aquaculture product.

The other important variables for smallholder commercialisation are access to credit for aquaculture production, NGOs' support, and support from fisheries officers. However, these variables are significant at the higher commercialisation level, such as households who sell above 25 and 50 per cent of their produced fish in the market. Finally, some regional dummies correlate with household commercialisation decisions reflecting the ecological differences among different aquaculture clusters.

The later part of the appendix Table A1 presents the endogenous switching regression model results to show the determinants of household welfare outcomes. To select the appropriate functional form for the switching model, different functional specifications, such as linear–linear, log–linear, and log–log specification, have been implemented. Following Di Falco and Chavas (2009), Akaike's information criteria (AIC), as well as the Bayesian information criteria (BIC), have been used to select the log-log specification for the income equation. The validity of chosen instruments is tested based on the falsification test suggested by Di Falco et al. (2011). The Wald test statistics on selection instruments are jointly statistically significant, which implies that selected instruments affect household commercialisation decisions but no longer affect the welfare outcomes of the non-commercialised farmers. It validates their use to identify the outcome equations and makes the econometric model more robust.[3]

The results from the ESR model show that, as expected, a bigger household size significantly reduces household income per capita and increases households' probability of being poor, which is applicable for both commercialised and non-commercialised farm households. Moreover, household landholding is positively and significantly associated with income per capita and income diversification while negatively associated with the poverty rate of non-commercialised households. It implies that land holding is important for determining the welfare of non-commercialised households.

At the household level, it is found that off-farm income and ownership of livestock are important for both commercialised and non-commercialise households. These variables have positive and significant effects on household income per capita and income diversification; however, they have a negative association with the poverty headcount rate. It implies that households that have more off-farm income and livestock will have higher per capita income and lower poverty rates. These households will also be more diversified in terms of their income sources.

Moreover, access to credit turns out to be an important indicator of household welfare for non-commercialised households who do not either participate in the market or sell a minimum amount of their harvested products. Most importantly,

[3] The results of the falsification test will be available upon request.

fish production increases the welfare of both commercialised and non-commercialised fish farmers. Moreover, average fish yield is significant for income diversification of commercialised farmers. The significance of fish yield variable indicates the presence of unobserved heterogeneity in the selected welfare outcomes. Therefore, applying Mundlak's fixed effects through mean fish yield helps us control the presence of unobserved factors in the ESR model.

However, the selection bias correction terms (inverse mills ratio) in all equations are not statistically significant, indicating that commercialisation will have the same impact on the farm households who are still non-commercialised if they choose to be commercialised.

**6.2 Commercialisation Impacts Using Counterfactual Estimations**

Table VIII and Table IX provide the results of the counterfactual analysis and the estimated impacts of selling fish generated from the ESR model. The ATT effect of income shows that selling fish positively and significantly impacts household income. Households that are commercialised would have earned less had they not been commercialised. However, the fall in income varies at different commercialisation levels. Farm households that are in the low commercialisation level (i.e., 10 per cent) would have earned 10 percentage points less had they not commercialised. The fall in income is higher for households who sell above 25 and 50 per cent of their fish. For them, the loss of income equal to 23 percentage points and 59 percentage points, respectively, had they not commercialised. Correspondingly, the ATU effect of income shows that if non-commercialised households choose to be commercialised, they can increase their income between 19 and 39 percentage points. It is found that non-commercialised households who are subsistence producers and operating at a low commercialisation level can achieve a high-income level by selling additional fish. However, the income effect is lower if the households who sell half of their produced fish in the market decide to sell more than existing using their current resource endowment.

TABLE VIII

**ATT EFFECTS AT DIFFERENT LEVELS OF COMMERCIALISATION**

| Outcome variables | Decision | | ATT= (a-c) |
|---|---|---|---|
| | (a) Actual (Commercialised) | (c) Counterfactual (Non-commercialised) | |
| *Income per capita (log)* | | | |
| Model 1 (sell above 10 %) | 11.53 | 11.43 | 0.10*** |
| | (0.04) | (0.05) | (0.03) |
| Model 2 (sell above 25 %) | 11.52 | 11.30 | 0.23*** |
| | (0.04) | (0.05) | (0.03) |
| Model 3 (sell above 50 %) | 11.73 | 11.14 | 0.59*** |
| | (0.04) | (0.06) | (0.03) |
| *Poverty headcount rate* | | | |
| Model 1 (sell above 10 %) | 0.79 | 0.84 | -0.06*** |
| | (0.01) | (0.01) | (0.01) |
| Model 2 (sell above 25 %) | 0.78 | 0.85 | -0.06*** |
| | (0.01) | (0.01) | (0.03) |
| Model 3 (sell above 50 %) | 0.76 | 0.88 | -0.11*** |
| | (0.02) | (0.01) | (0.01) |
| *Income diversification* | | | |
| Model 1 (sell above 10 %) | 0.42 | 0.42 | -0.001 |
| | (0.01) | (0.01) | (0.003) |
| Model 2 (sell above 25 %) | 0.41 | 0.42 | -0.001 |
| | (0.01) | (0.01) | (0.003) |
| Model 3 (sell above 50 %) | 0.46 | 0.50 | -0.03 |
| | (0.01) | (0.01) | (0.01) |

**Note:** (a) Standard errors are in parentheses. (b) ***, ** and * indicate significance at 1%, 5%, and 10% levels, respectively.

**Source:** Own calculation based on the household survey, 2011 and 2016.

TABLE IX

**ATU EFFECTS AT DIFFERENT LEVELS OF COMMERCIALISATION**

| Outcome variables | Decision | | ATU= (d-b) |
|---|---|---|---|
| | (d) Counterfactual (Commercialised) | (b) Actual (Non-commercialised) | |
| *Income per capita (log)* | | | |
| Model 1 (sell above 10 %) | 11.60 | 11.21 | 0.388*** |
| | (0.03) | (0.03) | (0.023) |
| Model 2 (sell above 25 %) | 11.45 | 11.25 | 0.207*** |
| | (0.03) | (0.03) | (0.023) |
| Model 3 (sell above 50 %) | 11.45 | 11.26 | 0.190*** |
| | (0.02) | (0.03) | (0.015) |
| *Poverty headcount rate* | | | |
| Model 1 (sell above 10 %) | 0.98 | 0.81 | -0.17*** |
| | (0.01) | (0.01) | (0.01) |
| Model 2 (sell above 25 %) | 0.76 | 0.81 | -0.05*** |
| | (0.01) | (0.01) | (0.01) |
| Model 3 (sell above 50 %) | 0.80 | 0.82 | -0.02*** |
| | (0.01) | (0.01) | (0.01) |

*(Contd. Table IX)*

| Outcome variables | Decision | | ATU= (d-b) |
|---|---|---|---|
| | (d) Counterfactual (Commercialised) | (b) Actual (Non-commercialised) | |
| *Income diversification* | | | |
| Model 1 (sell above 10 %) | 0.40 | 0.41 | -0.003 |
| | (0.004) | (0.01) | (0.003) |
| Model 2 (sell above 25 %) | 0.42 | 0.41 | 0.01** |
| | (0.004) | (0.004) | (0.003) |
| Model 3 (sell above 50 %) | 0.47 | 0.40 | 0.07** |
| | (0.004) | (0.004) | (0.003) |

**Note:** (a) Standard errors are in parentheses. (b) ***, ** and * indicate significance at 1%, 5%, and 10% levels, respectively.

**Source:** Own calculation based on the household survey, 2011 and 2016.

In the case of the poverty headcount rate, the ATT results show that selling fish positively and significantly impacts poverty reduction. There would have been an increase in poverty headcount rate among the commercialised households had they not commercialised. The poverty headcount rate will have increased from 5.5 percentage points to 11.2 percentage points at different commercialisation levels. It is found that households that sell more fish will suffer more from poverty if they do not sell fish. Similarly, the ATU effects show that if non-commercialised households participate in the market, it will reduce their poverty rate from 4.9 to 16.7 percentage points. However, the impact of selling fish will have a higher effect on the poverty headcount rate of the households that are more subsistence-originated.

Moreover, the ATT results for income diversification show that participation in the fish market has no significant impact on the diversification of income sources of commercialised farmers. It reflects the importance of aquaculture activities in the livelihood strategies of homestead fish farmers. Moreover, it also reveals that the commercialised households have already diversified across farm and off-farm income sources, which is reflected in Table V. On the other hand, the ATU effects find a positive and significant impact of commercialisation on the diversification of household income sources if households that are non-commercialised can sell more than 50 per cent of their produced fish in the market. It will have an effect of 7 percentage points on their income diversification. However, the impact is really low (i.e., 0.6 percentage points) if non-commercialised households manage to sell only above 25 per cent of their produced fish. It implies that a higher level of commercialisation can promote income diversification among non-commercialised households.

The overall results show that commercialisation significantly impacts household income and poverty both for commercialised and non-commercialised households. Across different commercialisation levels, the impact on income and poverty is larger for commercialised households who sell more fish and fall under the category of higher commercialisation level. However, the impact is smaller for more subsistence-oriented households selling less of their produced fish in the market. Moreover, across different commercialisation levels, for non-commercialised households, the impact on income and poverty is larger for more subsistence-oriented households if they commercialise. However, the impact results do not necessarily reflect that the added income benefit of commercialisation will directly translate to a welfare gain for non-commercialised households. It is because of the existence of significant differences between these two groups of households in terms of resource use, cost of production, and the price they receive. Table VI shows that the difference is significant in terms of production cost and benefit received. Commercialised farmers are generating higher revenue than their counterparts with minimum production costs and significantly lower selling prices of fish. It implies that commercialisation can be an intermediate outcome on the way to welfare gains if the resource returns or efficiency of the non-commercialised households can be improved up to the level of the commercialised households.

## VII. CONCLUSIONS AND POLICY IMPLICATIONS

This paper evaluates the welfare impact of commercialisation on smallholder fish farmers using panel household data collected from 518 homestead fish farmers in Bangladesh. The findings show that commercialisation remains low among homestead fish farmers in Bangladesh. The empirical findings show that 'household land holding,' 'farmer's experience in aquaculture production,' 'household membership in farmers' association, 'distance to the nearest village market,' 'access to credit for aquaculture production,' and 'support from NGOs' are the most important determinants of smallholder commercialisation and output market participation decision. Moreover, transaction costs are very important in determining aquaculture commercialisation among homestead fish farmers in Bangladesh.

In the case of impact, the ATU results show that households that are currently producing under subsistence stand to benefit more, and they were to transform from subsistence to a commercial production system. Therefore, there is huge potential for income growth and poverty reduction if homestead fish producers could be systematically targeted by policy to commercialise their production.

Moreover, the commercialisation of homestead aquaculture should be encouraged as a means to strengthen rural economies with greater welfare gains for smallholders. However, to do so, the observed knowledge gap between commercialised and non-commercialised households needs to be minimised by sharing knowledge and transferring information about the latest aquaculture production technologies to non-commercialised households.

Moreover, it is true that addressing only knowledge sharing alone cannot reduce the gap between commercialised and non-commercialised households. For smallholder commercialisation, proper strategies are needed to improve the support services from government fisheries officers who are responsible for Bangladesh's aquaculture sector development. These strategies can be, first, the creation of a separate cell to divide the dual responsibility of fisheries offices. The extension role with the intended technology adopters can be one separate cell/division. On the other hand, the enforcement of fisheries regulations can be another cell/division to monitor effectively and increase the coverage of beneficiaries (i.e., fish farmers). Second, at the field level, proper training and instruments need to be ensured for the fisheries offices as the field level officials are reported to lack proper training and field experience (Rahman & Ahmed, 2002, p. 243). Third, proper dissemination of information at the field level from the Department of Fisheries (DoF) needs to be arranged to facilitate the implementation of commercialisation strategies among smallholder fish farmers.

This study finding also highlights the role of aquaculture-specific umbrella organisations, such as fish farmers' associations in the context of Bangladesh, for the success of smallholder commercialisation. Therefore, strengthening the capacity of the fish farmers' association is an effective policy instrument to boost smallholder commercialisation.

To conclude, it can be said that homestead pond aquaculture is an important income-generating enterprise for smallholder farmers who produce and sell fish. Therefore, this study finding reinforces the call for interventions to expand the capacity of smallholder fish farmers in Bangladesh to produce for the market for a broader distribution of benefits (Danida, 2008; Olwande & Smale, 2014, p. 28).

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## ***Appendix***

**Table A1: First Stage Estimates from the Endogenous Switching Regression**
(using a threshold of 25 per cent)

| Dependent variables | *Probit* estimates (C=1) | Household welfare outcomes | | | | | |
|---|---|---|---|---|---|---|---|
| | | Income per capita (log) | | Probability of being poor | | Income diversification | |
| | | C | NC | C | NC | C | NC |
| Age of head | 0.06** | 0.02 | 0.04 | -0.003 | -0.002 | 0.01 | -0.002 |
| | (0.03) | (0.04) | (0.04) | (0.01) | (0.007) | (0.004) | (0.003) |
| Age squared | -0.001** | -0.0002 | -0.0004 | 0.00003 | 0.00001 | -0.00005 | 0.00 |
| | (0.000) | (0.0004) | (0.0004) | (0.0001) | (0.0001) | (0.00004) | (0.00) |
| Gender of head (male=1) | 0.27 | 0.08 | 0.12 | -0.17 | -0.03 | -0.07 | -0.03 |
| | (0.23) | (0.32) | (0.62) | (0.12) | (0.11) | (0.06) | (0.04) |
| Education of head (years) | 0.01 | 0.01 | 0.01 | -0.01* | -0.004 | -0.003 | -0.002 |
| | (0.01) | (0.02) | (0.01) | (0.01) | (0.004) | (0.002) | (0.001) |
| Household size | -0.01 | -0.15*** | -0.17*** | 0.03** | 0.03*** | 0.003 | -0.003 |
| | (0.03) | (0.04) | (0.03) | (0.01) | (0.01) | (0.005) | (0.004) |
| Dependency ratio | -0.08 | -0.16* | -0.15 | 0.01 | 0.08*** | -0.002 | 0.00 |
| | (0.10) | (0.10) | (0.14) | (0.03) | (0.03) | (0.02) | (0.02) |
| Total land holding (log) | 0.12* | 0.07 | 0.24*** | -0.06** | -0.12*** | 0.02 | 0.03*** |
| | (0.07) | (0.10) | (0.08) | (0.03) | (0.02) | (0.01) | (0.01) |
| Have farm income (yes=1) | -0.23 | -0.03 | -0.79** | 0.01 | 0.37*** | 0.16*** | 0.07 |
| | (0.18) | (0.47) | (0.31) | (0.10) | (0.10) | (0.04) | (0.05) |
| Have off-farm income (yes=1) | 0.06 | 1.07*** | 0.82*** | -0.23*** | -0.18*** | 0.13*** | 0.17*** |
| | (0.14) | (0.19) | (0.22) | (0.05) | (0.04) | (0.03) | (0.02) |
| Have livestock (yes=1) | 0.02 | 0.24* | 0.43** | -0.06 | 0.01 | 0.06*** | 0.09*** |
| | (0.11) | (0.14) | (0.18) | (0.05) | (0.03) | (0.02) | (0.02) |
| Experience shocks (yes=1) | -0.01 | -0.20 | -0.10 | 0.05 | 0.04 | -0.02 | 0.04* |
| | (0.16) | (0.22) | (0.26) | (0.06) | (0.05) | (0.03) | (0.02) |
| Experience in aquaculture (years) | 0.03*** | -0.01 | -0.01 | 0.0001 | -0.001 | -0.000008 | 0.00 |
| | (0.01) | (0.01) | (0.01) | (0.003) | (0.002) | (0.001) | (0.001) |
| Fish price (Kg) | 0.0004 | 0.001 | 0.004 | -0.001 | -0.001** | 0.0001 | -0.00003 |
| | (0.001) | (0.003) | (0.003) | (0.001) | (0.001) | (0.0003) | (0.0002) |
| Fish yield (log) | - | 0.22*** | 0.39** | -0.04*** | -0.02 | 0.02*** | 0.02** |
| | | (0.08) | (0.17) | (0.01) | (0.02) | (0.01) | (0.01) |
| Credit access (yes=1) | 0.78** | 0.62 | -0.50** | -0.30 | -0.18*** | 0.12 | 0.28*** |
| | (0.40) | (0.49) | (0.23) | (0.24 | (0.06) | (0.08) | (0.03) |
| Received support from NGOs (yes=1) | 0.24** | 0.20* | 0.15 | -0.11** | -0.004 | 0.03 | -0.02 |
| | (0.12) | (0.13) | (0.21) | (0.05) | (0.04) | (0.02) | (0.02) |
| Received support from FO (yes=1) | 0.11 | 0.17 | 0.05 | -0.05 | -0.16** | -0.06 | -0.001 |
| | (0.18) | (0.31) | (0.21) | (0.11) | (0.07) | (0.04) | (0.03) |
| Regional and time dummy | | | | | | | |
| Rangpur (yes=1) | 0.74*** | -0.37* | -0.21 | 0.26*** | 0.20*** | -0.02 | -0.03 |
| | (0.20) | (0.23) | (0.26) | (0.09) | (0.05) | (0.04) | (0.02) |
| Dinajpur (yes=1) | -0.24 | -0.01 | -0.13 | 0.02 | 0.004 | -0.17*** | -0.07* |
| | (0.28) | (0.38) | (0.27) | (0.15) | (0.07) | (0.05) | (0.03) |
| Mymensingh (yes=1) | 0.54** | -0.75** | -0.24 | 0.29** | 0.03 | -0.09* | -0.01 |
| | (0.23) | (0.38) | (0.16) | (0.13) | (0.07) | (0.04) | (0.03) |
| Barisal (yes=1) | -0.02 | -0.32 | -0.45 | 0.19* | 0.07 | -0.08* | -0.08** |
| | (0.41) | (0.27) | (0.39) | (0.10) | (0.09) | (0.04) | (0.03) |
| Faridpur (yes=1) | 0.82*** | -0.22 | -0.14 | 0.14 | 0.09 | -0.03 | -0.06* |
| | (0.20) | (0.23) | (0.33) | (0.10) | (0.06) | (0.04) | (0.02) |
| Time (year=2011) | 0.59*** | 0.12 | -0.77*** | -0.17** | -0.04 | -0.02 | 0.03* |
| | (0.11) | (0.21) | (0.28) | (0.07) | (0.04) | (0.02) | (0.01) |
| Selection instruments | | | | | | | |
| Distance to village market (log) | -0.51** | - | - | - | - | - | - |
| | (0.23) | | | | | | |
| Member of farmers' association (yes=1) | 2.22*** | - | - | - | - | - | - |
| | (0.14) | | | | | | |
| Wald test on instruments ($\chi^2$) | 245.27*** | - | - | - | - | - | - |

*(Contd. Table A1)*

| Dependent variables | *Probit* estimates (C=1) | Household welfare outcomes | | | | | |
|---|---|---|---|---|---|---|---|
| | | Income per capita (log) | | Probability of being poor | | Income diversification | |
| | | C | NC | C | NC | C | NC |
| Mundalk's fixed effect | | | | | | | |
| Mean fish yield | - | 0.0002 | -0.0001 | -0.0001 | -0.00003 | 0.00005** | 0.00006 |
| | | (0.0001) | (0.0003) | (0.0001) | (0.0001) | (0.00002) | (0.0001) |
| Inverse mills ratio | - | 0.02 | -0.01 | -0.001 | 0.05 | -0.001 | -0.01 |
| | | (0.11) | (0.24) | (0.04) | (0.05) | (0.02) | (0.02) |
| Constant | -3.44*** | 9.04*** | 8.30*** | 1.15*** | 0.66** | 0.06 | 0.19* |
| | (0.74) | (1.34) | (1.72) | (0.29) | (0.27) | (0.13) | (0.12) |
| Model diagnosis | | | | | | | |
| Log pseudo likelihood | -339.06 | - | - | - | - | - | - |
| Wald $chi^2$ (25) | 317.32*** | 179.72*** | 292.16*** | 131.20*** | 180.95*** | 177.36*** | 2863.47*** |
| *Prob > $chi^2$* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $R^2$/ Pseudo $R^2$ | 0.46 | 0.31 | 0.19 | 0.26 | 0.24 | 0.32 | 0.29 |
| Number of observations | 932 | 364 | 568 | 364 | 568 | 364 | 568 |

**Note:** (a) For probit, robust standard errors are in parentheses. (b) Base category is the jessore region. (c) ***, ** and, * indicate significance at 1%, 5%, and 10% level, respectively. (d) N/A is to define the variable dropped during the estimation process. (e) For outcome variables, bootstrapped standard errors (1000 replications) in parentheses. (f) Fixed effects at panel level are included. (g) C and NC represent commercialised and non-commercialised households, respectively.
**Source:** Own calculation based on household survey, 2011 and 2016.