Welfare Impacts of Fisheries Co-management System at Oxbow Lakes in Bangladesh

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Abstract. Fisheries co-management starts with the premise that stakeholders have the innate capacity to improve resource condition as well as the welfare of the society. If this is true, there is a need for rapid and substantial devolution of fisheries management institutions. The main purpose of this study was to examine net welfare change to society as a result of the co-management system at Oxbow Lakes in Bangladesh. The simultaneous equation model consisting of supply, demand and identity equations were estimated and Marshallian surplus measurement was used to estimate the welfare change before and after the co-management system. The pooling technique proposed by Kmenta (1971; 1986) was utilized for the estimation. The analysis showed that the co-management program had caused a welfare gain to society.

Key words: Fisheries co-management, Oxbow Lake, Producer Surplus, Consumer Surplus.

1.1 INTRODUCTION:

Fish is a valuable natural resource in Bangladesh that contributes significantly to the national economy. Fisheries account for about 3.27 percent of the country's GDP. It is an important source of animal protein in Bangladesh where it contributes 60 percent of the animal protein supply of the country. Nearly one tenth (11 million) of the country's population is involved in fishery and fishery related activities. The importance of inland fisheries in Bangladesh has been well documented in the literature. Bangladesh has nearly 4.5 million ha of inland water bodies which includes marshes, reservoirs, Oxbow Lakes, natural depressions, rivers and estuaries (BBS, 1997) that offer an extensive opportunities for inland fishery. In 1997 the inland fishery employs some 1.2 million full time fishers (FFYP, 1997; BBS, 1997), with a total fish production of 1.07 million metric ton.

In Bangladesh, most of the inland fishery exploitation activities are small-scale and traditional in nature. For a long time, the inland fisheries have been managed by a group of middlemen or powerful individuals in the society, who managed to secure yearly leases from the government through auctions; otherwise, government officers managed the fisheries within the framework of a government management system. In both cases, fisher participation in decision-making was ignored and they participated only in fish harvesting as mere laborers. These systems however had failed to serve the national interest of conserving the fisheries and protecting the economic fortune of the fishers (Aguero, 1989). Instead, it created unequal power structures that kept poor fishing communities at the mercy of lease holders and encourage resource overexploitation (Ahmed et al., 1997). Pressures from an increasing fishing dependent population, huge fishery management costs and an excess of fishing effort relative to the availability of fish stock have contributed to declining catches of some species, and the subsequent decline in fishing incomes (Ahsanullah, 1989).

In response to these problems, the government in 1988 established a new management system, known as "co-management" in which the management task and responsibility are shared between the government and fishers. The objective of introducing this new management system was mainly to redirect potential benefits of the fishery to genuine fishers[1] and improve the productivity of the fish stocks on a sustainable basis. The economic consequences of this new management system are yet to be addressed. The understanding of the impacts of the fishery co-management institutions as an alternative management regime is necessary from the policy point of view to improve decisions on policy reforms. The evaluation was carried out in this study at the Oxbow Lake fisheries in the southwestern part of Bangladesh.

In real world situations, a policy change will greatly affect the production and price of goods and services. A policy change towards fisheries co-management system will inevitably affect the production and consumption structures of the economy. Changes in the imbedded factors of fisheries production (technological change, credit support, fishers' decision in fishing operation and

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[1] Government of Bangladesh in New Fisheries Management Policy (NFMP) defines a genuine fisher as one who devotes 9 months of the year in fishing or gets 90 percent of his income from fishing.

management) in a co-management system will affect the overall fish supply. Theoretically it has an impact on the welfare of the producers and consumers. The decision making ability of the fishermen in the fisheries co-management system can possibly lead to increase production and producers' welfare. At the same time, consumers can also gain from adequate supplies of fish at a suitable price. The primary objective of this paper is therefore to develop a framework to examine the net welfare impacts resulting from the intervention of the co-management system at Oxbow Lake fisheries in Bangladesh.

This paper comprises of five sections. The next section provides a brief discussion on the Oxbow Lakes and fisheries co-management experience on Oxbow Lake fisheries of Bangladesh. The section three explains the theoretical framework and data used in the analysis. The results of the econometric estimates of supply and demand and the welfare impact of the co-management are presented in fourth section. The conclusions and recommendations are discussed in the final section.

1.2 FISHERIES CO-MANAGEMENT SYTEM AT OXBOW LAKES

Oxbow Lakes are sections of meandering rivers that died down or changed their courses over time. Both ends of the Oxbow Lakes get silted up, thus becoming semi-closed water bodies in the dry season. Water is replenished from the flood plains draining into the Oxbow Lakes during the rainy season. Oxbow Lakes are connected with the flood plain of the river by inlets and outlets. By screening the inlets and outlets, an Oxbow Lake can be converted into a culture-based fishery. The name of "Oxbow" refers to its shape, which is like a horseshoe or Oxbow. Oxbow Lake (commonly referred to as Baor) falls into a category of common pool resources as it has the two characteristics of substractability and non-excludability of a common pool resource (IFAD, DANIDA and UNOPS, 1994). There are more than 600 hundred Oxbow Lakes in south-western Bangladesh, covering an area of about 5500 ha, each ranging from 10 to 500 ha. The number of villages on the shores of a Lake ranges from one to seven (DOF, DANIDA and BRAC, 1996). Though these Lakes cover only about 0.37 percent of inland water area in Bangladesh but it can ensure increased fish production through fish farming and aquaculture in the future (UNOPS, 1997). Rough estimates by UNOPS (1997) indicated that, through culture-based fisheries and efficient use of Oxbow Lakes, it would be possible to obtain fish production of about 700 Kg/ha/year.

Although the Oxbow Lakes had an immense potential for fish production and the Lakes have been through a number of management regimes such as private management, co-operative management and government

management in Bangladesh, however, low levels of production was the common picture of these Lakes (IFAD, DANIDA and BRAC, 1994). It was observed that fish production in the Oxbow Lakes was about 301 kg/ha/year (BBS, 1997), which was far below the expected level of production. Since fishing was the major means of livelihood of the Oxbow Lake fishers, low productivity has caused fishers to remain poor. Huge management costs due to lack of participation of fishermen in the management activities and low level of investment for fingerling stocking, poaching by the outsiders, traditional technology of fish culture were identified by the policy makers as the major reason for the low level of production in the Oxbow Lakes (IFAD, DANIDA and BRAC, 1994). Under these management systems, fishers participated only in catching fish, but they did not get the ownership of the fish harvested. They worked in the Lakes as mere day laborers and received a portion of catch income. This system has led to inequitable distribution of benefits among users of the Lakes, which has deteriorated the economic condition of the fishers (Aguero, 1989).

Under the pretext of the above problems, the Oxbow Lake Co-management project (OLP II) was designed in 1988 following the guideline of the New Fisheries Management Policy (NFMP)[2] and was completed in July 1997. The project was funded by International Fund for Agricultural Development (IFAD) with Technical Assistance grant from Danish International Development Agency (DANIDA). In the literature, fisheries co-management is defined as a partnership arrangement in which government, the community of local resource users (fishers) and external agents (non-governmental organizations) share the responsibility and authority for decision making over the management of a fishery (Pomeroy and Williams 1994). Fishers therefore not only participate in the decision making process but also have the authority to make and implement regulatory decisions on their own (Abdullah et al., 1998). The co-management arrangement that is followed in these Oxbow Lakes is a partnership arrangement between the government and the fishers. In these Lakes the government and an NGO, Bangladesh Rural Advancement Committee (BRAC) work together to ensure proper institutional, organizational and adequate technical and financial supports to the fishers.
Fishers in each Lake are organized in a group known as the Lake Management Group (LMG). The fishers elect

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[2] Government of Bangladesh introduced the New Fisheries Management Policy (NFMP) in 1986. The strategy of the NFMP was to abolish the system of leasing water bodies to middlemen or non-fishers and replaces it with the licensing system in order to establish the access rights of genuine fishers.

their LMG committee (president, secretary, cashier and fishing team leader). Management activities such as releasing fingerling, distributing income, keeping records and seeing the official matters (court cases, communication with government and NGO officers) are usually undertaken by the LMG committee after consultation with fisher members. All other management duties such as harvesting, guarding the Lakes against poachers, selling and marketing activities are equally performed by all the fishers (Figure 1).
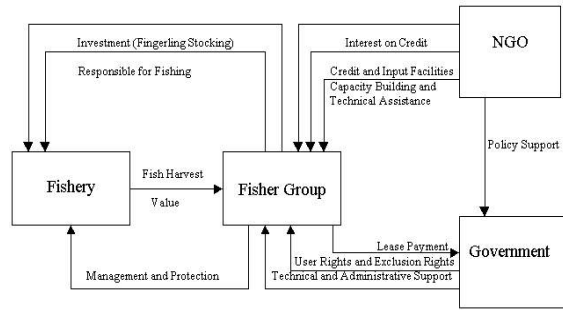

Figure 1: Production relationships, rights allocation and distribution of benefits under fisheries co-management

1.3 THEORETICAL FRAMEWORK AND DATA

1.3.1 Theoretical Consideration

Prices play a very important role in the dynamics of a fishery, as they determine the way in which fishers allocate their effort, in addition to determining revenue and profit. The determination of fish market price stipulates jointly dependent variables between the quantities of fish supplied and demanded in the market. In the fisheries economics literature, prices are considered as exogenously determined and, therefore, are fixed, or can be variable in response to supply and demand conditions. In general, the former is appropriate if prices are determined on an international basis, or landings represent a very small share of the overall market (Tai and Heaps, 1996). In this study, prices are considered to be endogenous and, when prices are endogenous, any policy changes in the fishery affect not only producers but, also, consumers.

In this section, a model is developed to estimate the welfare effect of fishers (as producers) and fish consumers in the western part of Bangladesh, after the implementation of the co-management system. The net social benefit is evaluated using producer surplus (PS) and consumer surplus (CS) measurements. These surplus estimations are obtained from the structural equations of supply and demand for fish. In an ideal market, demand and supply curves are believed to be stable and at any

particular price the quantity produced by an industry is equal to the quantity purchased. The quantities of fish supplied and demanded are related to the same price of fish in the market. Thus, the equilibrium price and quantity determined by the intersection of these curves equates the consumers "willingness to pay" and the producers "willingness to sell" at that price. Demand and supply analyses carried out in this study are essentially guided by an economic model using the price quantity theory, which can be written as:

$$\text{Supply } Q_S = a_0 + a_1p \qquad (1)$$
$$\text{Demand } Q_D = b_0 + b_1p \qquad (2)$$
$$Q_S = Q_D \qquad (3)$$

Where,
Q_s and Q_D = quantity supplied and demanded at price p
a_o and b_o = intercept terms for supply and demand functions
a_1 and b_1 = slopes of the supply and demand functions
$a_1 \geq 0$ and $b_1 \leq 0$

The net benefits derived from the intervention of the co-management system should include a measure of satisfaction which producers derive from the exploitation of the fishery and consumers from the consumption of various quantities of fish. In welfare economics literature, concepts such as Producer Surplus (PS) and Consumer surplus (CS) are very frequently used to measure such benefits. In 1844, Dupuit developed the formulation for welfare measurement and used the notion of consumer surplus. Subsequently, these concepts were further developed by Marshall in the early 20th century, and have since formed the basis for most empirical analyses. Here, consumer surplus refers to the area above the equilibrium price line, but below the demand curve, and Producer surplus refers to the area below the equilibrium price line, but above the supply curve (Figure 2).

When $a_0 \geq 0$; PS is a + b and CS is d_1
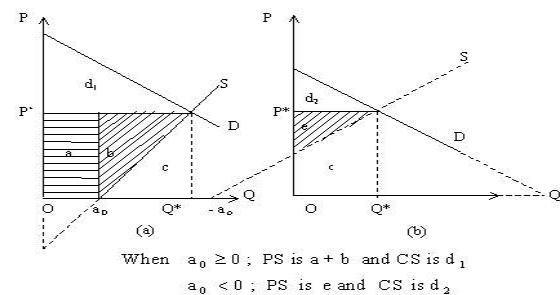$a_0 < 0$; PS is e and CS is d_2

Figure 2: Consumers surplus and producers surplus with different intercept values of supply function

The PS, which is defined as the area under the equilibrium price, but above the supply function, can be obtained by using the integral calculus approach. The shaded area (a + b; e) represents the PS with different

intercept value (a_0) of the supply function in Figure 2. The PS is calculated as follows:

$$PS = \int_{P=0}^{P=P^*} f(P_s) dP_s \qquad \text{When } a_0 \geq 0 \qquad (4)$$

$$PS = P^*Q^* - \int_{Q=0}^{Q=Q^*} f(W_s) dQ_s \qquad \text{When } a_0 < 0 \quad (5)$$

The CS is defined as the area under the demand curve, but above the equilibrium price. It is shown by the area of triangles d_1 and d_2 in Figure 2, and may be calculated as follows:

$$CS = \int_{Q=0}^{Q=Q^*} f(Q_D) dQ_D - P^*Q^* \qquad (6)$$

When there is no spill over benefit in other markets, and if the market participants are considered as belonging to the same society, the total gains to society may be measured by the sum of both PS and CS.

 The above measure will be used to estimate the consumers surplus and producers surplus in this study. This approach has also been widely used in many other empirical studies on fish demand and supply as in Ahmed (1971); Foster et al. (1986); Olson and Trapani (1984); Frech and Samprone (1980); Indah (1991); and Tai and Heaps (1996). However, in literature, the Dupuit-Marshallian triangle method for measuring welfare has been criticized primarily for two reasons. One of the major criticisms is on the assumption that marginal utility of income is constant. If the marginal utility of income is constant, as assumed by Marshall, then, there is a one-to-one correspondence between utility and the areas to the left of the demand curve. Another problem related with the ceteris paribus assumptions of price changes are that there are interactions between different goods. This is generally known as path dependency problem. If two goods are substitutes or complements, a rise or fall in the price of the first commodity will lead to a shift in the demand curve for the other; if the shift in the demand curve for the second good results in a change in its price, consumer surplus will be affected. These problems have led economists to be concerned with the conditions under which change in consumer surplus could measure a true surplus of utility. Hicks (1956) had proposed measuring consumers surplus by taking areas under compensated or Hicksian demand curves and over a price rather than quantity change. The resulting Consumers surpluses are known as compensating variation (CV) and equivalent variation (EV). Detailed discussions of these various measures of consumer surplus can be found in, for example Ahmad (1989). There are much debates over which concept provides the best measure of welfare. The problem of path dependency can be overcome by estimating either the CV or EV of price changes under the compensated demand curve. In practice the compensated demand curve are unobservable but they can be derived from expenditure functions. However, data on household expenditures are not available for estimating the expenditure functions. Thus it is not possible to estimate CV and EV in this study. Willig (1976) and Just et al. (1982) however, have shown that the measurement error between the consumer surplus using and the CV and EV is likely to be small if the income effects are small. Furthermore, in comparing the effects of consumer surplus between two different periods may not be serious if a path is consistently followed.

1.3.2 Specification of the Theoretical Model

In the real world, many factors are at work in influencing the location of supply and demand curves. A simultaneous equation model is developed in this study to examine factors affecting supply and demand for fish in the market.

The model employed for the empirical study is as follows:

Supply: $LnQS_t = f(LnP_t, LnF_t, LnC_t, LnT)$ (7)

Demand: $LnQD_t = f(LnP_t, LnP_{Ht}, LnP_{Ct}, LnY_t)$ (8)

Identity: $LnQS_t = LnQD_t$ (9)

Where,

$LnQS_t$ = the log of quantity of fish supplied in the open market in period t (Kg)

$LnQD_t$ = the log of quantity of fish demanded in open market in period t (Kg)

LnP_t = the log of aggregate price of fish in period t (Tk.)

LnF_t = the log of aggregate price of carp fingerling in period t (Tk/1000' pieces)

LnC_t = the log of total amount of credit given to the fishers in period t (Tk)

LnT = the log of the trend variable (T=1 for 1991-92 and T=7 for 1997-98) which reflect the technological advancement

LnP_{Ht} = the log of the price of Hilsha fishes in period t (Tk/Kg)

LnP_{Ct} = the log of the price of chicken in period t (Tk/Kg)

LnY_t = the log of the income factor of the consumer in period t (Tk)

1.3.3 Data Considerations

To estimate the annual supply and demand functions of carps, data on carps production, carps consumption, price of carps, prices of substitutes / complementary goods (chicken and Hilsha fish), average income of society, fingerling price and credit support to fishers before and after co-management, were collected from published statistics and project reports provided by BRAC, DANIDA and DOF. The trend variable was used in the supply function to determine the impact of technological change. The study was conducted on 15 of the 22 co-

management Lakes. The co-management project started its operation from 1989/90 in the western part of Bangladesh, although the actual steps in undertaking co-management, that is, group formation, institution building, training of fishers and credit operation started in full swing from 1993/94 when all the Lakes came under the umbrella of the co-management project. As there is no baseline information about these Lakes before 1991/92, DOF, DANIDA and BRAC used the year 1993/94 in 1997 to assess the project effect in their studies. In this study, the time period considered for the welfare analysis is from 1991/92 to 1997/98. The data used for the before co-management periods were from 1991/92 to 1993/94 and for the after co-management the period were from 1994/95 to 1997/98.

Data availability restricted the analysis to only six major carp species. There are several approaches to aggregate catch data. As the fish species cultured in the Oxbow Lakes are carp species and there is no major gear differences to catching fishes, a simple additive approach is used in this study to aggregate the catch data.

The quantity of fish produced by fishers is used as a proxy for the fish supplied to society. In other words, the total fish caught is considered as fish supplied by fishers. The domestic consumption for carp fishes is considered, in this study, as a proxy of the quantity of carp fishes demanded by consumers. The consumption by households, restaurants and institutions (for instance hostels, hospitals) are considered as domestic consumption. Since these data are not available, fish production data could also be used as proxy for domestic consumption, assuming that all the carp fishes produced by the fishers are consumed by the society. Indah (1991) and Dirijen and UGM (1979) also used these assumptions in their studies. Moreover, these assumptions imply that $LnQD_t = LnQS_t$, thereby fulfilling the simultaneity condition. In addition, the time taken to distribute fish from producers to consumers is quite short i.e. immediately after harvesting, in the Oxbow Lakes. This result in a minimal difference in the price received by producers and the price paid by the final consumers, i.e. marketing margins are negligible.

Based on the economic theory, price influences the quantity of fish supplied and demanded. At the same time, price of fish also depends upon the size, species and freshness of fish. Since the fish cultured in Oxbow Lakes are carp fishes and there are no major price differences between them, average price of the carp fishes is used in the analysis. Average price is also used in the case of fingerling prices, as the price difference between different fingerling species is small.

One of the important factor recognized by policy makers to realize higher fish production and higher income from Oxbow Lake is the timely availability of the credit.

BRAC has been charged with the responsibility of establishing credit delivery and recovery schemes in the co-management of Oxbow Lakes by the government and international donor agencies. Credit is issued to the fishers to buy fingerlings, fishing boats and gears. The information on credit was collected from BRAC statistics for this study. The credit operation of BRAC started in 1992-93. The credit information before 1992-93, that is for 1991-92 period was collected from Bangladesh Krishi Bank (BKB), Thana Fisheries Office, fisher co-operatives and from entrepreneurs who were the owners of the Lakes.

Technological improvements can cause the supply function to shift, as there is a positive relationship between technological advancement and fish supply. The technological shift may be the result of the adoption of an improved polyculture technology in carp fish production and the technical knowledge among fishers as a result of training and extension programs. To account for these technological improvements, a simple time trend variable: T=1 for 1991-92 to T=7 for 1997-98 is used.

The prices of Hilsha fish and chicken are used as proxies for other complementary or substitute commodities. The price data of these commodities were collected from the Thana Fisheries Office (TFO), District Office and a market survey carried out by the researcher in 1997-98. The price of these commodities was derived by aggregating large, medium and small size of Hilsha fish and chicken.

Annual income data, which represents the purchasing power of society, was utilized in this study to estimate the demand function. Since data on society's income was not readily available, Indah (1991), in her study, used the Gross Regional Domestic Product (GRDP) as a proxy for the society's income. Since this study has used the pooling technique to estimate the model, and all the Lakes are concentrated in the same region, the use of GRDP in this case may cause the problem of non-variability in the income data. This can cause a serious problem in the econometric estimation. To overcome this problem fisher's income per year from the selected co-management Lakes were used as a proxy of society's income. However, it needs to be mentioned here that the average income per fisher per year in Oxbow Lakes is about the same level as the regional per capita GDP, except for the years 1991-92 and 1992-93. In these two years the average fishers income from Oxbow Lakes were 30 percent lower than the regional GDP. These years represented the first two years before the development of co-management arrangement for culturing carps in the Oxbow Lakes.

1.3.4 Econometric Framework

As in other studies that utilize the simultaneous equation approach, the model used in this study was first checked for the identification problem, and it was found overidentified. The 2SLS estimation technique using single equation approach was employed to estimate the structural parameters of the model.

In this study, 15 out of 22 co-management Lakes were selected for the analysis. These selections were based on the availability of data from 1991-92. This data is only for three years (1991-92 to 1993-94) for the before co-management project, and only four years (1994-95 to1997-98) for the after co-management assessment. For such a short data series and different intercepts of the Lakes[3], the pooling technique was adopted to obtain consistent estimates of supply and demand functions.

Estimation of economic relationships using data on a set of economic units (a cross section, e.g. Lake) that are observed more than one point in time (a time series) is a problem frequently encountered in econometrics (Griffiths et al., 1993). Pooling methods can be used as a mechanism to combine cross-section and time series data. Suppose there are N cross-sectional units, which are observed over T time periods to give a total of N x T observations. With data Y_{it} and X_{it} (explanatory variable) the regression equation can be written as:

$$Y_{it} = X'_{it} \beta + \varepsilon_{it} \qquad (10)$$

Where β is a K x 1 vector of unknown parameters and ε_{it} is random error.

An approach for handling pooled data was suggested by Kmenta (1971; 1986). The approach was found suitable for this study. The Kmenta method employed a set of assumptions on the disturbance covariance matrix and this method is a special case of Generalized Linear Regression (GLR). A consistent estimate is obtained here by a Generalized Least Squares (GLS) procedure. As an approach for pooling data, this method was widely used in studies by Baltagi et al. (1992); van der Gaag et al. (1977); Griffin (1982) and Larson and Wlaters (1993).

The particular characteristics of this model are:
$E(\varepsilon_{it}^2) = \sigma_i^2$ (heteroskedasticity)
$E(\varepsilon_{it} \varepsilon_{jt}) = 0 \ (i \neq j)$ (cross-sectional independence)
$\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + \mu_{it}$ (autoregression)
Where $\mu_{it} \sim N(0, \sigma_{ui}^2)$,
$\varepsilon_{it} \sim N(\sigma_{ui}^2 / 1 - \rho_i^2)$
$E(\varepsilon_{i,t-1} \mu_{jt}) = 0$ for all i,j.

To obtain the feasible GLS estimators of regression coefficients, the following steps are followed: In the first step, OLS residuals are used to obtain consistent estimates of the ρ_i. Next, a Paris-Winsten transformation procedure is applied using the estimated ρ_I to derive a consistent estimate of Σ from the resulting residuals. This Paris-Winsten transformation is designed to remove autoregression. In the last step, GLS is applied to the Paris-Winsten transformed model using the consistent estimate of Σ. This transformation is performed to remove heteroskedasticity. The disturbance term thus obtained is asymptotically non-autoregressive and homoskedastic. To apply the Kmenta approach in 2SLS estimation procedure data are first stacked and the reduced form equation in the first stage is estimated by OLS method[4]. In the next stage, the predicted endogenous variable is substituted in the original equations and estimated using the Kmenta technique of pooling.

The Chow test (1960)[5] proved that the estimated relationships before and after were significantly different. The model was estimated in linear and log-linear forms using the data in terms of deflated values. The log-linear form gave the better fit.

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[3] Griffiths et al. (1993) and Judge et al. (1988) stated that if all the intercepts are identical for the N cross sectional units and other assumptions of the model continue to hold, then there is no basis for differentiating the time-series cross-sectional nature of the data, and for estimation purposes, the data can be treated as one sample of NT (N = number of cross-sectional units, T = time periods) observations and can be estimated using the OLS Procedure. Based on F-test described in Judge et al. (1988), in this study it was found that the calculated F value before co-management was 4.97 (14, 26 degrees of freedom) and after co-management it was 22.04 (14, 41 degrees of freedom) in case of supply function. Thus, we reject the null hypothesis that the intercepts of the 15 Lakes supply functions were not all the same.

[4] Maddala (1977) stated that in 2SLS estimation procedure in application of pooling technique, in the first stage OLS is applied to estimate the reduced form parameters, as at this stage it is only necessary to get consistent estimates rather than efficient estimates.

[5] The Chow test (1960) was employed to verify whether the structure of the supply and demand was indeed different before and after co-management. The test of equality was only carried out for supply function, while demand function is assumed to adjust accordingly to the simultaneity nature. The results of the Chow test indicated that ($F^*_{5,95}$ (calculated value) = 13.03 > $F_{5,95}$=2.25 at 5 percent level) there is a structural change in demand and supply of fish before and after the co-management system.

1.4 RESULTS AND DISCUSSIONS

1.4.1 Estimates of Demand and Supply Equations

The estimates of supply and demand models before and after co-management system are presented in Tables 1 and 2. The interpretations of the results are presented in the following sub-sections. Hypothesis testing in 2SLS is complicated by the unknown distributions. This causes the normal t test to be invalid, because they lack empirical content in simultaneous models. To correct the t-ratio, a correction factor[6] proposed by Gujrati (1995) was used in this study.

The significant levels of estimated parameters in the supply model were fairly good, except for the fingerling price variable before co-management. The statistical results (Wald Test) indicated that all the variables were jointly significant in each equation. All the variables specified in the supply model had the expected signs, except the fingerling price after co-management, which was positive. As for the demand function, all variables were significant except the price of chicken before co-management and price of Hilsha after co-management. All coefficients in the demand function had the expected signs.

Table 1: Estimated Supply Model
LnQS = f (LnP, LnF, LnC, LnT)

Variable Name	Estimated Coefficient	T - Ratio
Before:		
Constant	-15.430	-1.72 ***
LnP (price of carp fish)	5.781	2.67 ***
LnF (price of fingerling)	-0.453	-1.16
LnC (credit support)	0.584	3.95 *
LnT (technology)	1.354	3.31 *
After:		
Constant	-15.241	-2.46 **
LnP (price of carp fish)	5.175	3.95 *
LnF (price of fingerling)	0.232	2.28 **
LnC (credit support)	0.301	7.91 *
LnT (technology)	1.46	5.11 *

Notes: * Significant at 1 percent level **Significant at 5 percent level, ***Significant at 10 percent level

The results of the supply function (Table 1) showed that the price of fish, technology and credit support were the significant variables of the supply of fish before co-management, whereas the price of fish, technology, credit support and fingerling price were the significant

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[6] The corrected standard error is calculated by multiplying the standard errors of the coefficient estimated in the second stage regression with $\sigma^2_u / \sigma^2_{u*}$. Here, σ^2_u is the true variance of the disturbance term u calculated by using the estimated coefficient of the second stage regression, and σ^2_{u*} is the variance of the disturbance term obtained from the second stage regression Gujrati (1995).

determinants after co-management. The elasticity of fish supply with respect to price was higher (5.78) before co-management compared with after co-management (5.17). Theoretically, it implies that when the price of fish increases, fishers would be encouraged to catch more fish. However, after co-management, the results indicated that the increase of supply with respect to price was marginally less than before the co-management. However, the catch statistics of these Lakes showed that the increase in fish production after co-management was much higher than before co-management. This indicated that Lakes' fishers were less price sensitive after co-management as opposed to before co-management period. This resulted in the low price elasticity of supply for fish after the co-management period. The signs of the trend variable were positive and greater (1.46) after co-management than before (1.35), and this indicated that improvement in technology had a notable effect on production. Technology adoption appears to be faster during the co-management period. The credit elasticity of supply was found less elastic (.30) after co-management than before (0.58) co-management. This drop in the elasticity of credit with respect to supply of fish could be due to the wide spread availability of credit under the co-management arrangement. The number of fishers unable to obtain credit during co-management was smaller than before co-management. Finally, the sign of fingerling price variable was not consistent with a priori expectation, being negative before co-management and became positive after it. This unexpected result could be due to the institutional credit support to fishers. Increased fish production at Oxbow Lake was dependent upon fingerling stocking. Fishers here paid less attention to the price of fingerling. More over, in order to reduce the gestation period between stocking and harvesting, they preferred large fingerlings compared to those before the co-management regime, which was more costly.

Table 2: Estimated Demand Model (Carp fish)
LnQD = f (LnP, LnP$_H$, LnP$_C$, LnY)

Variable Name	Estimated Coefficient	* T - Ratio
Before:		
Constant	10.271	1.79 ***
LnP (price of carp fish)	-2.251	-5.00 *
LnP$_H$ (price of Hilsha fish)	-2.253	-3.92 *
LnP$_C$ (price of chicken)	1.563	1.46
LnY (income)	1.168	17.88 *
After:		
Constant	5.26	1.20
LnP (price of carp fish)	-1.344	-2.62 **
LnP$_H$ (price of Hilsha fish)	-0.623	-1.30
LnP$_C$ (price of chicken)	1.237	1.66 ***
LnY (income)	0.868	10.40 *

Notes: *Significant at 1 percent level * *Significant at 5 percent level, *** Significant at 10 percent level

The estimates for the demand function (Table 2) indicated that the prices of carps and Hilsha fish and income were the major determinants of carp demand in the pre co-management period. However, in the post co-management period only prices of carps, chicken and income were

significant. The elasticity of the fish demanded with respect to its own price was greater (-2.25) before co-management than after co-management (-1.344). This implies that, when the price of carps increased, consumers decreased the carp consumption by a lower amount after co-management than before co-management. The signs of the estimated coefficients for Hilsha fish and chicken were negative and positive, respectively. This meant that Hilsha was complementary and chicken was a substitute to carps. Lastly, the income elasticity of demand for fish tended to be more elastic before co-management (1.16) than after co-management (0.86). This implied that consumers were not spending more on carp fish during co-management period. As income increases, people could probably spend more on non-food items such as clothing and housing.

The disturbances in the models estimated using Kmenta (1971; 1986) approach proved to be asymptotically non-autoregressive and homoskedastic. Diagnostic checking, such as normality and multicollinearity, were performed in the demand and supply models before and after co-management to get consistent estimates. Based on Jarque-Bera normality test and Variance Inflation Factor (VIF) and Tolerance Factor (ToL) multicollinearity tests, it was found that in both equations the disturbance terms were normally distributed and that multicollinearity was minor.

1.4.2 Estimation of Welfare Impact

The estimation of the supply and demand models was carried out for two separate periods, before and after co-management. From these results, two welfare estimates were obtained, the difference of which formed the net welfare change resulting from the co-management intervention.

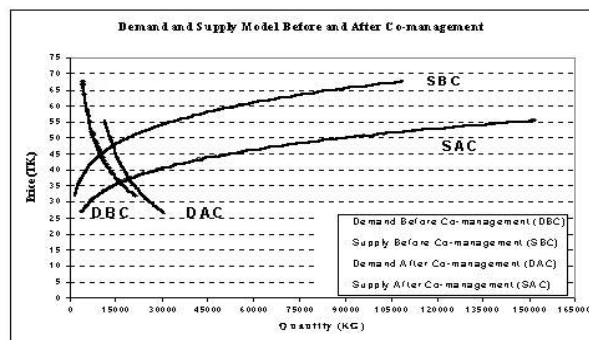#### 1.4.2.1 Equilibrium Price and Quantity:

Figure 3: Equilibrium price and quantity before and after co-management

Figure 3 illustrates the structural change of the estimated supply and demand functions before and after co-management, as well as their respective prices and quantity equilibria. The estimated supply curve has shifted down to the right after the co-management program was launched. The demand for fish after co-management has also shifted up, following its supply. The respective equilibrium quantity Q_0^* increased from 10046.71 Kg to 19528.50 Kg at Q_1^*, and the equilibrium price fell to 37.20 at P_1^* from 45.75 Tk. at P_0^*.

The possible explanation for increased fish production could be the increased capital investment after co-management. One of the critical factors influencing fish production is the availability of credit and quality of fingerling. Also, the Oxbow Lake co-management project has developed the technical knowledge among fishers on fingerling stocking. Co-management system ensured fishers rights in the decision making process; for instance decisions on operating expenses, were made by their committees. As the poor fishers in Oxbow Lake were dependent on fish Production for their livelihood, they spent a major portion of their operating expenses in fingerling stocking. On average it accounted for about 62 percent of the total operating costs in 1996-97 (DOF, DANIDA and BRAC, 1997). Large-scale investment in fingerling stocking, adoption of the improved polyculture technology in fish culture and the proper timing of credit had positive effects on fish production in the Oxbow Lakes after the co-management program. These factors together had pushed the production frontier outward and hence the Maximum Sustainable Yield (MSY) curve.

1.4.2.2 Estimation of Producer's and Consumer's Surplus:

For the purpose of computing PS and CS, it was assumed that fish markets were competitive. Generally, in a competitive market, consumers increase their CS, measured by the difference between what they actually pay and what they are willing to pay. As mentioned earlier, the total revenues received by producers in the market must be equal to the total consumer expenditures. In this study, the amount of consumer's expenditure is assumed to be captured by producers' gains and producers' costs.

The results of welfare estimations are summarized in Table 3. The before co-management situation was considered as the reference point for comparing the changes in welfare. Table 3 also shows that fishers and consumers gained the PS and CS both before and after the co-management system. It is also observed that total consumers' welfare gain was higher (2471279 Tk.) than total producers' welfare gains (195219 Tk) through out the study period. The change in CS was also higher (487

percent) than the change in the PS (56 percent) after the implementation of co-management system. This could be because the consumers' paid lower prices to fishers during the post co-management period as compared to the pre co-management period (Figure 3). In the post co-management period fish production increased by a large amount. But because of lack of proper fish storage facilities, the fishers sold the fish at the time of harvest. This could be attributed to declining price of fish at the post co-management period. Although the producer gains welfare due to increase in production after co-management, it was however, lower than the consumer gains. This condition is favorable to the consumer, as the demand for fish is less elastic than its supply.

Table 3: Summary of welfare estimation results before and after co-management

Description	CS	PS	NSW	% Welfare Gain
Before (Tk.) %	CS_0: 359461 100 %	PS_0: 76216 100 %	NSW_0: 435677 100 %	16 [c]
After (Tk) %	CS_1: 2111818 587 [a]	PS_1: 119003 156	NSW_1: 2230821 512	84
Change (Tk) %	#CS :1752357 487	#PS: 42787 56 [b]	#NSW :1795144 412	
Total Welfare(Tk)	TCS:2471279	TPS: 195219	TNSW: 2666498	100

Note: #: change, TCS: Total Consumer Surplus, TPS: Total Producer Surplus, TNSW: Total Net Social Welfare, a: $\%CS_1 = CS_1 / CS_0$, b: #PS = #PS / PS_0, c: $\%NSW_0 = NSW_0 /$TNSW

The original net social welfare enjoyed by the society (NSW_0) before co-management was 16 percent of the total estimated welfare through out the study period. However, the welfare gains accrued to the society after the co-management was much bigger at 84 percent from the total net social welfare. This could be because the co-management system was successfully implemented in the Oxbow Lakes in the western part of Bangladesh. The change in fingerling stocking methods, credit schemes, monitoring by member fishers during stocking, the general willingness of the fishers to produce more fish and cooperation among them had resulted in the effective implementation of the co-management system.

1.5 CONCLUSIONS AND RECOMMENDATIONS

This analysis shows that the implementation of co-management system at Oxbow Lakes was successful in enhancing the fish production as well as the welfare of the society. Moreover, the analysis shows that the adoption of a new technology, like "carp polyculture technology" by the fishers has been successful in enhancing fish production.

The fishers in co-management Lakes have shown their capacity and motivation to innovate both with regards to management and technological matters. A national policy on transferring fishery management at Oxbow Lake and other inland water bodies of Bangladesh to fisher groups selected preferably from the poorest strata of society is needed in view of efforts devoted to poverty alleviation.

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