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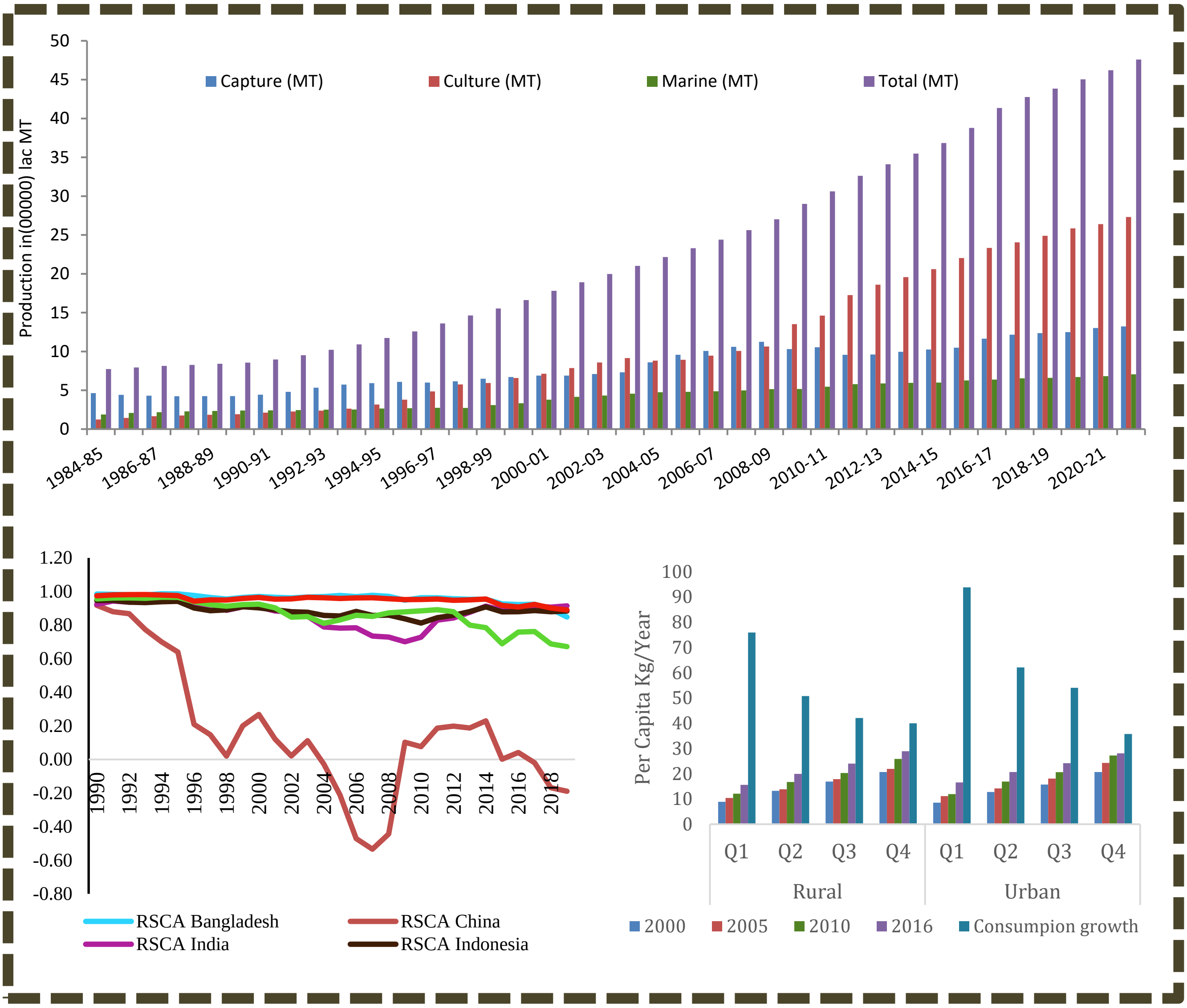

Strategies for Inclusive Aquaculture Value Chain in Bangladesh: Analysis of Market Access, Trade and Consumption Pattern

Fish Innovation Lab

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Prepared by:

Dr. Madan Mohan Dey

Dr. Md Akhtaruzzaman Khan

Dr. Md Takibur Rahaman

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Partners/Institutions

1. Texas State University,
   601 University Drive
   San Marcos, Texas 78666-4684
   Phone: 1-512-245-2111

2. Bangladesh Agricultural University,
   Mymensingh-2202, Bangladesh
   Phone : +880-1734 128911
   Fax : +880-91-66896
   Email : azkhan13@bau.edu.bd

3. Patuakhali Science and Technology University,
   Dumki, Patuakhali -8602, Bangladesh.
   Phone: +880 4427-56003

Abbreviations and Acronyms

ADF- Augmented Dickey–Fuller

ARDL- Auto Regressive Distributed Lag Model

BBS- Bangladesh Bureau of Statistics

COVID 19- Coronavirus disease 2019

DAM- Department of Agricultural Marketing

DEA- Data Envelopment Analysis

DoF- Department of Fisheries

FAOSTAT - Food and Agriculture Organization Corporate Statistical Database

FDI- Foreign direct investment

GDP- Gross Domestic Product

GI- Globalization Index

HIES- Household Income Expenditure Survey

IMF- International Monetary Fund

IQ- Institutional Quality

PCI- Problem Confrontation Index

PSM-Propensity Matrix Model

RCA- Revealed Comparative Advantage

RSCA- Revealed Symmetric Comparative Advantage

SFA- Stochastic Frontier Analysis

TC- Trade Credit

WDI- World Bank's World Development Indicators

WGI- Worldwide Governance Indicator

Glossary

Trade Credit: Trade credit is a business-to-business (B2B) agreement in which a customer can purchase goods without paying cash up front, and paying the supplier at a later scheduled date. Trade credit can be thought of as a type of 0% financing, increasing a company's assets while deferring payment for a specified value of goods or services to sometime in the future and requiring no interest to be paid in relation to the repayment period.

Gross Domestic Product (GDP)-Gross domestic product is a monetary measure of the market value of all the final goods and services produced in a specific time period by a country or countries. GDP is most often used by the government of a single country to measure its economic health.

World Development Indicators (WDI)- is the primary World Bank collection of development indicators, compiled from officially recognized international sources. It presents the most current and accurate global development data available, and includes national, regional and global estimates.

Foreign Direct Investment (FDI)- is a category of cross-border investment in which an investor resident in one economy establishes a lasting interest in and a significant degree of influence over an enterprise resident in another economy.

World Bank Worldwide Governance Indicators (WGI) provides a ranking of 215 countries and territories based on six dimensions of governance, including political stability, government effectiveness, and control of corruption.

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Abstract

The aquaculture industry in Bangladesh has experienced a significant growth in production over the past three decades, and more than 90% of the aquaculture production is destined for domestic consumption. However, consumption of fish differs significantly between households in rural and urban areas as well as between various socioeconomic categories. In addition, all farmers, fishers, and traders do not have similar access to key inputs, particularly financing, in Bangladesh. On the other hand, the COVID-19 pandemic has affected aquaculture and fisheries sector of Bangladesh. The country is also losing export competitiveness for major exporting fish like shrimp. Therefore, the project is aimed at analyzing economic implications of increased aquaculture production in terms of food and nutrition security, market access, and trade pattern.

To accomplish the objectives of the study, both primary and secondary data were utilized and several relevant econometric analyses were performed. Based on Bangladesh National Household Income Expenditure Survey (HIES) Data from 2000 to 2016, the study found that fish consumption has increased over the studied period for every category of household- rural, urban, and income quantiles. However, the lowest income quantile i.e., the poorest household has experienced the fastest growth in fish consumption. Low-income households have a strong demand for low-value cultured fish species, while high-income households mostly consume high-value cultured and captured fish species. The findings indicate that aquaculture is contributing to improving fish consumption patterns irrespective of income groups and residential status of households, especially of the lowest income quantile. Conversely, with the limited availability of captured fish, there has been a notable rise in prices, hence impacting the accessibility and consumption of many nutritious, micronutrient-rich, fish among the poorest households.

Results related to trade credit show that users of trade credit are equally technically efficient as non-users. Trade credit enables farms to use improved production technology with a positive trade-off between benefits and costs. Furthermore, convenience, interest rate, collateral, documentation, number of suppliers, and revenues influence trade credit decisions. The trade credit supports farms' continuity and adoption of the best technology in the industry.

Regarding the nexus between inputs and output price, among the price factors, the price of corn, soybean, and oilcake, and fisheries wage rate have a favorable significant impact on fish price in both the short and long term. In addition, among the non-price drivers, GDP per capita,

inflation rate, and fish consumption all have a significant positive influence on fish price in the long run, whereas total production has a detrimental effect on fish prices in the long run.
Furthermore, the findings indicate that because of COVID-19 income and employment across value chain were severely affected with a drastic fall in the market demand, coupled with a severe drop in fish consumption. As market demand declined, fish farmers had to extend the culture period, eventually increasing cost of production. The price of all the major cultured and captured species plunged, leading to a depressing return to farmers, while inputs price underwent a significant increase except labor and fingerling. During the COVID-19 period, some of the main obstacles for fish production and selling are but not limited to higher transportation costs, labor shortage, inability to pay for the wage, reduced consumer demand across the value chain.

The results from the shrimp export competitiveness analysis shows that all the competing countries (Bangladesh, China, India, Indonesia, Thailand, and Vietnam) seem to have some degree of shrimp export competitiveness during 1990 to 2019, whereas China has entirely lost its export competitiveness after 2004. However, Bangladesh's shrimp export competitiveness has dipped marginally in recent years, despite continuous growth in competitor countries such as India, Indonesia, and Vietnam. Further, economic globalization, institutional quality, trade openness, number of trade agreements, and trade freedom all have a favorable impact on Bangladesh's shrimp export competitiveness in the long-run, whereas the international or exporting price of shrimp has a detrimental influence in short-and long-run.

The study used Policy Analysis Matrix (PAM) to assess the export potentiality and Domestic Resource Cost (DRC) criteria to examine comparative advantage of different fish species such as pangasius, tilapia and rohu. The value of DRC indicates that Bangladesh has comparative advantage in pangasius, tilapia and rohu fish production. However, producers of pangasius and rohu are unprotected through policy interventions while tilapia producers are protected through the policy interventions. In addition, the commodity system of selected three fish species are competitive at producer level. This project recommends increasing output support while maintaining input support for aquaculture species to enhance nutritional security and be more competitive on the global market, which ultimately can make it easier for producers to reach markets.

Introduction

Fish is the most frequently consumed animal-source food in Bangladesh (Belton, van Asseldonk and Thilsted, 2014), accounting for more than 60 percent of the animal-sourced protein consumed (Dey et al., 2005; Dey, Alam and Paraguas 2011). Recent growth in fish consumption has been made possible by jump in aquaculture production from 787,000 MT in 2001-02 to 2,731,070 MT in 2021-22 (DoF 2021-22). Over 90% of the aquaculture production in Bangladesh is destined for domestic consumption (Hernandez et al., 2018). Shrimp aquaculture and trade is an important foreign exchange earning activity. About 60 percent by quantity, and about 80 percent by value, of seafood exported from Bangladesh is of farmed shrimp (Rashid, Minot and Lemma 2019). Thus, aquaculture has played an important role from an equity point of view (by improving the food and nutritional security of vulnerable sections) and also in wealth creation (through foreign exchange earnings).

Aquaculture value chain needs to be more inclusive to be effective in meeting the goals of *promoting pro-poor and inclusive growth*, stated in the Eighth Five Year Plan of the Government of the Peoples Republic of Bangladesh. Access to markets is an important dimension of inclusiveness: improved access to safe and nutritious food for all consumers, and enhanced access to inputs and output markets for producers. The Government's plan of promoting private sector in aquaculture can be realized by removing barriers to market access in the sector.

On the consumption side, capacity of the aquaculture sector in meeting the food and nutritional security of vulnerable sections needs to be analyzed in greater detail. On the production side of aquaculture, farming techniques are transforming from mostly subsistence production towards more commercial/intensive production. Commercial aquaculture makes intensive use of high-quality inputs such as floating feed, fingerlings, land, labor, machinery, fertilizer, and medicines etc. However, these inputs are more expensive and require more capital in order to purchase them. Feed cost itself constitutes over 70% of total production cost (Belton et al. 2011). Access to inputs and output market are disparate, with small farmers facing limited access into inputs market, limiting their production (Khan, Guttormsen and Roll 2018). Output market is also power-driven by large farmers, with small farmers compelled to sell in local market at lower price, limiting their revenue. Moreover, as aquaculture becomes more intensive, it becomes more interlinked with input markets such as feed-grains (corn, soybeans etc.). Therefore, aquaculture producers become more vulnerable to shocks in input markets with increased intensification. Given the market disruption caused by the novel coronavirus pandemic of 2019 (COVID-19), an analysis of the impacts of the pandemic on market prices of farmed fish and impacts on fish farmers' business operations is important.

While only a small proportion of the aquaculture production in Bangladesh is currently exported, export of aquaculture products could play an increasingly important role in the coming years. The country's aquaculture sector has performed spectacularly in meeting the increased final/consumer demand in the domestic market. However, recent studies such as Dasgupta et al. (2017) have reported a *status bias* in fish consumption in Bangladesh such that as household income increases other animal protein sources like eggs and meat are favored over fish. Under such scenarios of adverse trends in final demand for fish, increased aquaculture supply in the domestic market would lead to market surplus. Therefore, the viability of exports of major aquaculture products needs to be explored for their capacity in absorbing additional aquaculture supplies.

Project Objectives

The overall goal of this project is to analyze economic implications of aquaculture value chain development in Bangladesh in terms of food security and market access, and thus to improve market access for consumers and producers. Specific objectives are as follows:

1. Analyze the food and nutritional security impacts of increased aquaculture production
    a. Can inland aquaculture continue to contribute to food and nutritional security of poorer households, as measured by nutritional elasticities?
    b. How does poorest households' expenditure on fish, as disaggregated by species and/or source of production, differ from richer households as measured by the income elasticity?

c. How does the expenditure on fish compare to expenditure on other major food items across households of different income levels? How true and/or strong is the aforementioned *status bias* in fish consumption?

2. Evaluate constraints in the aquaculture input markets that influence domestic market access for aquaculture producers

   a. Determinants of availability of trade credits to fish farmers
   b. How does volatility in input prices (corn price, soybean price etc.) influence prices of farmed fish?
   c. What are the impacts of COVID-19 on aquaculture business operations- particularly those of small and marginal farmers, and on market prices of major aquaculture species at different geographical markets?

3. Analyze the export market competitiveness of major aquaculture products of Bangladesh (such as pangasius, tilapia, shrimp and major carps) for different scale and intensity of farming operations.

Research Methods

The study employed standard economics research techniques appropriate for each of the objectives using both primary data and secondary data sources. The research encompassed both desk-based analysis and fieldwork.

Approach for Objective 1

For objective 1-a, Household Income and Expenditure Survey (HIES) data from years 2000, 2005, 2010, and 2016 were collected from the Bangladesh Bureau of Statistics (BBS). Based on the available data, an estimation was made regarding the pattern of fish consumption across various income levels, distinguishing between rural and urban areas, as well as different species. In addition, nutritional elasticity with respect to fish consumption was estimated over time by income groups to analyze the contribution of aquaculture to nutritional security. Nutritional elasticities are numerical measures of responsiveness of nutrient consumption at household level to changes in fish prices and income levels. Nutritional elasticities were estimated using a suitable demand model such as Quadratic Almost Ideal Demand System (QAIDS). Derivation of nutritional elasticities requires matching of consumption information in HIES with nutritional contents of the consumed fish species. Nutritional information on Bangladeshi food items were taken from the *Food Composition Table for Bangladesh* (Shaheen et. al., 2013).

For objectives 1-b and 1-c, econometric modeling of consumption data (HIES) was used, and the outputs from both objectives would be elasticities. Main difference between analyses required for the two objectives would be in terms of product aggregation level. For objective 1-b, analysis was at the level of fish species and/or fish production environment of the species (aquaculture/capture or freshwater/coastal/marine). For objective 1-c, products are aggregated at a broader level, for example, chicken meat, poultry eggs, meat (beef & mutton), and fish. This makes use of the economics concept of *weak separability of preferences* to allow products to be categorized into different groups with decisions to consume them occurring in successive stages. QAIDS model also used for these objectives.

Approach for Objective 2

To analyze the determinants of trade credit availability and COVID-19 impact on the fisheries value chain, a survey was conducted to assess the existing constraint to access in the input and output market by the aquaculture farmers. Three stage stratified random sampling techniques were used for selecting the fish farmer. First, Mymensingh, Rajshahi, Bogura, Khulna, Jessore, Cumilla, Chattogram and Dhaka districts were selected purposively (Figure 1, Appendix 2) for primary data collection as the production volume is higher in these districts compare to others (DoF 2017-18). Secondly, total 18 sub-district (Upazila) from above 3 districts were selected. Finally, 820 fish farmers and value chain actors were selected following simple random sampling techniques from the list collected from Upazila Fisheries Office (UFO). Fish species combination, farmers' age (both young and aged), scale of operation, culture intensity and gender were considered for the sample representative. A semi-structured questionnaire was prepared with relevant information of access to input and output market and the effects of COVID-19 on business operations including input and output prices. The questionnaire was tested on a pilot-scale on 10 farmers, and subsequently modified to improve clarity and reliability by carrying out a reliability test to determine the consistency and stability of the questionnaire.

To analyze the impacts of input price volatility on the prices of farmed fish, secondary data for the periods of 1990 to 2019 were collected on the prices of corn, soybean, pangasius and tilapia from the online database available from the website of the Department of Agricultural Marketing (DAM) under the Ministry of Agriculture of the Government of Bangladesh. These are time-series data available for different commodities and at different resolutions of geographic units (from the Divisional level to specific marketplace). Time-series econometric modeling was used to analyze how changes in input price levels and volatilities impact fish price dynamics.

Approach for Objective 3

Both primary and secondary data were needed to assess the international market competitiveness. This study assessed the export market competitiveness of five major fish exporting countries namely Vietnam, Thailand, India, Indonesia, and China with Bangladesh. This study used Revealed Symmetric Comparative Advantage (RSCA) index to compute the export competitiveness of Bangladeshi shrimp over time and compare it to that of other major shrimp exporting countries. To determine the drivers of shrimp export competitiveness of Bangladesh, we also employed Auto Regressive Distributed Lag (ARDL) simulation approach. A detail description of the models is given in the Appendix 3. Policy analysis matrices (PAM) were developed and used to derive domestic resource cost (DRC) coefficients for different fish species (carps, pangas, and tilapia) to estimate the comparative advantages.

Research Results

Consumption pattern of aquaculture species

This investigation looked into the levels of fish intake across various groups of individuals from 2000 to 2016 in order to evaluate the consumption and nutritional security of fish among Bangladeshi people. The results revealed that there has been an overall increase in fish consumption among both rural and urban populations over the study period. However, it is worth noting that rural families exhibit higher levels of fish consumption compared to urban. Nonetheless, the fish consumption by poorest segment has been increasing more during the studied period may be because of increasing supplies of cultured fish pushing the price down (Figure 2, in Appendix 2). Fish consumption growth rate is lowest in the richest quantile which may be because of the quality of fish or the dietary shift with more preferences for substitutes like meat.

During the investigated time, the production of farmed fish increased greatly, particularly that of pangasius, punti, tilapia, and exotic carps. Eventually, the supply expanded at increasingly reduced prices, and both demand and consumption also significantly increased. Due to its lower price compared to other competing farmed and captured fish species, the pangasius has contributed the most to the development of aquaculture production over the past two decades and is mostly consumed by low-income people throughout the region. Although this species is regarded as a poor man's fish, households with higher income quantiles had higher per capita intake of pangasius. It's because households in higher income quantiles generally consume more fish per capita than households in lower income quantiles (Figure 3, in Appendix 2). Besides, because of higher buying capacity, consumption per capita is higher for higher-income quantiles households but it does not indicate that higher-income quantile people prefer these fish more than that of lower-income quantile households.

Like pangasius another two popular species are punti (Thai/China punti) and tilapia. These two species are also consumed more by higher income quantiles than lower income quantiles and the consumption growth is increasing across the income quantiles (Figure 4, in Appendix 2). The consumption growth steeper for higher income quantiles than that of lower income quantiles may be due to decreasing purchasing power of these households. The consumption of punti/tilapia and pangasius fish has increased especially for the most improvised people (Figure 4, in Appendix 2). However, consumption of these species by higher income quantiles has sharply increased, indicating rising market demand (Figure 4, in Appendix 2).

The next popular fish species for consumers is exotic carps. In Figure 5, (in Appendix 2), poor households consume more of these fish species and wealthy urban families are not consuming more of them. It is because of *status bias* preferring high-priced, better-quality fish over cheaper fish. Consumption of exotic carps is more among the richest quantile of households in rural areas compared to urban areas.

Along with the above-mentioned species, the consumption pattern of rohu/katla/mrigel is presented in Figure 6, in Appendix 2 and it shows an increasing trend in consumption of these species. Initially, rohu/katla/mrigel was capture fish species, now the majority of rohu is produced through aquaculture. Since there hasn't been a significant advancement in technology, despite being an aquaculture species, production could not increase significantly.

Consumption Pattern of capture fish

There has been a fall in the overall capture fish consumption among the poorest and poor households. Most of the production of fish species has been substituted by aquaculture. Prices rise due to a limited supply, which in turn reduces the purchasing power of those in the lowest income quantile. For instance, Hilsa is one of the most expensive and popular fish species in the country which is beyond buying capacity of the lowest quantile household. The consumption pattern of the fish is presented in Figure 7, in Appendix 2. The quantity of hilsa consumption is either the same or is decreasing. For the richest quantile, the quantity of hilsa consumption is decreasing significantly. Most of the fishes are exported, and the prices of hilsa are high which makes it beyond the affordability of the poor households.

Fish species like shol/gajar, taki, magur, and shing, which were previously common and abundant in all open waterbodies, are now extremely rare in catch fisheries. The consumption pattern of these species are given in Figure 8 and Figure 9 in Appendix 2. Small fishes especially mala/kachi/chapila used to be main sources of protein to the poor households. Given shortage of supply due to the unavailability of floodplains and wetlands, the consumption of these species of small fish decreased among the poor households over the years (Figure 10, in Appendix 2).

Demand for fish at the aggregate level and disaggregated level

The results of the QUAIDS model are divided into two levels: aggregate level and disaggregated level. At the aggregate level, we investigate the demand for fish with other sources of protein that include meat, poultry, and poultry eggs. Meat consists of beef, buffalo, and mutton. Poultry and poultry eggs are comprised of hen and duck. On average, the own-price elasticities of sources of protein vary from -0.32 to -3.79 (Table 1, in Appendix 1), demonstrating the heterogeneity of demand of protein across the years. The own-price elasticities of the fish can be considered almost unitary elastic, except for the year 2000. The protein elasticities of fish can also be considered inelastic. The observed inelastic demand for fish suggests that most of the population in Bangladesh are less responsive to the changes in the prices of fish. The reason behind this can be attributed to the significant role of fish in the Bangladeshi diet, as at least 60% of the animal protein comes from fish (FAO and WHO, 2014, FRSS 2017). For poultry, poultry eggs and meat, the own-price protein elasticities are inelastic. The inelasticities are explained by the crucial impact the poultry industry has on attaining food and nutrition security offering an economical and stable source of protein for the growing population in Bangladesh. To calculate the expenditure elasticity, we have divided the Household Income Expenditure Survey (HIES) data into four quantiles. The four quantiles are segregated based on the yearly expenditure of the households. The first and the fourth quantiles are used to describe the lowest and the highest income groups. From most of the Marshallian cross-price elasticities and cross-price protein elasticities, presented in Tables 2 and 3 (in Appendix 1), indicate that (1) fish, meat, poultry, poultry eggs are substitutes, (2) meat and poultry are complements of fish in the year 2005, (3) poultry and meat are found to be complements to poultry egg for the year 2010, fish and poultry egg are complements to poultry. The estimated expenditure elasticities and expenditure protein elasticities by income quantiles are presented in Tables 4 and 5 (in Appendix 1). From the income elasticities presented in these tables, it can be observed that the expenditure elasticities of all sources of protein are positive, indicating that fish, meat, poultry, and poultry egg is considered a normal good by households, regardless of their wealth status.

The own-price elasticities and own-price protein elasticities of the fish across the species are presented in Table 6 (in Appendix 1). At the disaggregate level, the own-price elasticities of fish species produced through aquaculture, puti/ tilapia, pangasius, and exotic carps though are greater than one, they follow a downward trend across the years. Their own-price protein elasticities are less than 1, indicating that they are inelastic, a very small decline in demand with a change in price. In addition to this, own-price elasticities of hilsa, and Indian carps, are greater than one, however, they decline across the years. The own-price protein elasticities of Indian carps and hilsa are inelastic, their inelasticities do not decline much across the years. This behavior reflects that the population of Bangladesh normally consumes and draw protein in their diets. Though hilsa is an expensive fish species, these species have an inelastic demand, owing to preferences by people who can afford them. Most of the cross-price elasticities and cross-price protein elasticities of fish across the speices, presented in Tables 7 and 8 (in Appendix 1), are positive implying that maximum fish species are substitutes to each other. On the other hand, fish species like exotic carps, shol/gojar/taki, tilapia/puti, small fish species (mala/kachi/chapila) are found to be complements with pangasius and airbreathing fish[1] for years 2000 and 2005. Expenditure elasticities and expenditure protein elasticities of fish across the species of 4 years are reported in Tables 9 and 10 (in Appendix 1). The expenditure elasticities of fish across species are found to be positive, indicating that fish in general is considered as the normal good in Bangladesh. However, expenditure elasticities of hilsa are elastic with a value greater than one. This suggests that hilsa is a luxury fish in Bangladesh.

Access to trade credits and its determinants

Fish farmers are compelled to purchase feed on credit due to lack of capital. The sources and size of drain and gain of trade credit (TC) are presented in Table 11 (in Appendix 1). The estimated production metrics show that there is only gain for using TC to small scale aquaculture farms. The gains are in terms of more harvest and more revenues may be because of longer culture period and higher feed conversion ratio (FCR) (Table 11, see in Appendix 1).

[1] Airbreathing fish is composed of Magur, shing and Koi fish.

It means that more access to trade credit allows fish producers to keep the fish in the pond for a longer period (culture period is higher for user of TC), which is critical to get more harvest and higher price per kgs of fish and generates more revenues.

The trade credit users can feed fish more intensively than the non-users of trade credit thus the FCR is higher for users than the non-users of trade credit. However, it requires more money to drain out as indicated by a higher amount of feed costs ($16291/hectare) for users than the non-users ($10722/hectare) of trade credit (Table 12, in Appendix 1). Apart from this, the technical efficiency of users and non-users are 0.79 and 0.67, respectively when compared against their own group frontier. However, when compared against meta-frontiers the estimated efficiency scores are the same for users and non-users of trade credit (0.79) (Table 13, in Appendix 1), which indicate that the users and non-users of trade credit are equally technically efficient indicating that they can produce the same quantity of fish with a given level of inputs. The estimated Technology Gap Ratio (TGR) are 0.99 and 0.88 for users and non-users of trade credit respectively which indicate that the production technology followed by users of trade credit is representative to the technology of the whole industry, however, the production technology used by non-users of trade credit is lag behind the best technology in the industry.

The determinants of trade credit are reported in Table 14 (in Appendix 1). The collateral required for formal credit is statistically significant determinant of trade credit. Because of poor credit worthiness and lack of collateral access to formal credit are limited for small-scale fish producers in Bangladesh which forces fish producers to enter into trade credit contracts.

Furthermore, the number of suppliers offering is a statistically significant determinant of trade credit. It is because fish producers may have more bargaining power over terms of trade credit if there are more suppliers. The finding shows that feed cost is an important determinant of trade credit which is significant at a 5% level. To those fish producers who are spending more on inputs, mainly feed in this case to achieve economies of scale, the suppliers typically give additional credit at softer terms. It may also mean that those who use trade credit consume feed more heavily than others who do not. Finally, the education of fish producers can be considered as an important determinant of trade credit because education reflects the ability to acquire and apply technological advances in the production process that might induce suppliers to extend more credit.

The effect of inputs (feed ingredients, wage, inflation, economic growth etc.) on fish price

To investigate the effect of feed ingredients and other macroeconomic factors on fish price, the long-run elasticity was estimated using the dynamic ARDL (DARDL) simulations model. The results are presented in Table 15 (in Appendix 1) indicating that, a 1% increase in the corn price will raise the price of fish by 0.342% in the long run and 0.109% in the short run. Furthermore, a 1% hike in the soybean price will push up the price of fish by 0.320% and 0.038% in the long and short term, respectively. In addition, fish prices will go up by 0.208% in the long run and 0.298% in the short term for every percent increase in the mustard price. It is worth mentioning that protein, fat, and mineral substances of fish feed are the essential nutrient elements, which come from the raw materials such as soybean cake, corn, rice bran, wheat bran, and so on (Rana et al., 2009). However, corn (including maize, wheat, rice barn), soybean, and mustard are commonly used as main feed components in both handmade and manufactured pelleted feed in Bangladesh (Rana et al., 2009). As a result, if the cost of these inputs rises, farmers' production costs will rise as well.

The results also demonstrated that the fisheries wage rate index has a considerable positive influence on the price of major carp fish, with the positive impact being stronger in the long run than in the short run. This means that fish producers do not quickly raise their fish prices in response to a change in wage rate, but they are more sensitive in the long run if wage rates continue to climb.

Fish consumption and GDP per capita have a considerable impact on fish pricing. The increase in fish consumption can be linked to an increase in demand; the more fish consumed, the higher the demand. The rate of inflation has a significant impact on the price of fish. As a result of increased inflationary pressure, customers require to pay more for the same quantity of products, such as fish in this example; hence, the price level for fish rises effortlessly.

Finally, in the long term, total major carp production has a detrimental impact on market pricing; the fish price drops by 0.219% for every percent rise in total major carp production.

The "Law of Supply" backs up this conclusion. When there is an oversupply of fish in the market compared to demand, the market price will fall because customers have more negotiating power and more options for obtaining fish.

Effects COVID-19 on aquaculture and fisheries value chain, and adaptation strategies

People who work in the fisheries and aquaculture sector depend primarily on income from it to support their families. However, COVID-19 greatly impacted their earning; it is observed that fish farmers' and traders' income from fisheries fell by nearly half, while fisher's income dropped by 32.80% on average (Table 16, in the Appendix 1).

Comparing fish farmers and fishers, results revealed that fish traders cut the most employees, with labor hiring dropped by 60.55% (Table 16, in Appendix 1). In addition, self-employment of fish traders was reduced by almost 80% since there were less fish trading activities with fewer buyers and sellers to deal with due to lockdown and other movement restrictions. On the other hand, since revenue and employment have plummeted, all actors in the aquaculture and fisheries sectors have lowered their fish consumption, with traders' households being the hardest hit (27.78%), followed by fishers (22.66%).

During the pandemic, fish producers in Bangladesh have to stocked mature fish in their ponds for a longer period, expecting to sell them at a higher price once the market demand returned to normal (FAO, 2021). Fishers and traders, on the other hand, used ice to keep unsold fish frozen until they could be sold later (Table 17, see in Appendix 1). It was observed that fish farmers applied 29.80% more feed than usual, while the fishers and traders used 5.5% and 7.95% of more ice, respectively (Table 17, see in the Appendix 1). For fish farmers, the total cost of per kg fish production increased by 32.63%, in which feed costs increased by nearly two-thirds.

The pandemic has a considerable impact on the price of farm inputs, causing some to rise and others to fall in price (Figure 11, in the Appendix 2). Results revealed that commercial pelleted feed price increased by one-fourth of than regular price. Commercial pelleted feeds are made from a range of raw materials by feed mills, and most of the raw materials are imported from other countries. Feed mills were unable to acquire these raw supplies due to the closure of the border during the lockdown, resulting in an upsurge in feed prices. The survey respondents noted that the transportation cost increased by 32.95% compared to business as usual. A substantial price reduction was observed for fingerling (15.23%) and labor (24.65%). Demand for fingerling has dropped considerably because of farmers' uncertainty and incapacity to empty their ponds. During pandemic low-value cultured fish species, such as pangas, mrigal, common carp, grass carp, tilapia, and silver carp, saw the most substantial price decline among cultured species (Table 18, in the Appendix 1) with a 40% decline of pangas fish price. The price of tilapia was reduced by one-fourth of the regular situation. Similarly, low-value captured fish species had a greater price decline. Tengra, mola punti, shol, baila and taki experienced the significant price drops among the capture species, whereas high-value captured species like hilsha and shrimp had the lowest price drops (Table 18, in Appendix 1). Normally, high-value fish species are purchased by higher-income consumers, however during the pandemic, their income may be reduced, but their consumption habits may not change significantly.

Bangladesh relies heavily on foreign input supply of feed ingredients. Due to the international shipping ban and transportation barriers, the fish farmers found it the most troublesome to get an adequate feed supply (Table 19, in the Appendix 1). Movement restriction also took a heavy blow to the fishers as they could not reach their fishing sites. Furthermore, the travel bans also squeezed the supply of cocksheets and containers; therefore, they were unable to preserve fish in anticipation of a greater price at a later period. The most significant issue that traders experienced was the high transportation cost and unavailability of transportation.

The prime issues for fish farmers and fish traders were low fish prices, followed by the closure of auction places led by *arat (a local wholesale place)*, lack of bargaining power, limited numbers of buyers resulting in lower demand (Table 20, in Appendix 1). The fish traders, however, faced a more diversified range of issues in the fish sale. Due to transportation restrictions, buyers could not move to the market, which was the most severe problem reported by the traders. Besides, because of lockdown measures, traders found it difficult in opening their *arats*.

Strategies followed by the fish farmers and fishers to deal with market force disruption are depicted in (see Figure 12, in the Appendix). Results revealed that approximately half of the respondents followed the direct selling approach to local consumers over the phone. Retail marketplaces have become heavily regulated to provide physical distance and other sanitary norms, which prevent consumers from entering the market. Many small-scale fish farmers and fishers have adopted home delivery by taking orders over the phone to combat this situation. Roughly 40% of the farmers reduced the number of employees as an adoption strategy. Because of labor layoff and stocked of mature fish in the pond, approximately 35% of farmers did not start their new production cycle. The survey also found that respondents were planning to switch to other supplementary income sources (22%), which are easier to adopt. Some respondents were compelled to acquire financial assistance in the form of loans (12%) to cope with decreasing sales and market demand during the pandemic, while others (15.45%) were looking for new markets to sell their fish.

Results revealed that more than half of the sampled fish traders reduced the number of employees to survive during the pandemic. However, when they could handle buyers from local or distant marketplaces, some traders (34.75%) directly contacted fish farmers for fish harvesting. Often, they took less commission than usual time to attract the buyers. Due to the closure of *arat* and fish business, many fish traders (22.45%) were seeking alternative means of income; therefore, they were forced to other off-farm income such as shop keeping, driving, migration to cities, etc. To deal with the capital deficit, some traders (16%) take out loans and seek government assistance (Figure 13, in the Appendix 2).

Shrimp export competitiveness and its determinants

To investigate the shrimp export competitiveness and compare it with the other rivalry countries, this project use revealed symmetric comparative advantage (RSCA) formula. Table 21 (in the Appendix 1) depicts the shrimp export competitiveness of Bangladesh, China, India, Indonesia, Thailand, and Vietnam for the period of 1990 to 2019, based on the findings of the RSCA index. The results reveal that, in 1990, all of the aforementioned countries had nearly the same degree of comparative advantage in shrimp export. Bangladesh, Indonesia, and

Vietnam have been consistent in their shrimp export performance as the RSCA values ranged above 0.90 throughout the period. On the other hand, India and Thailand underwent a declining trend in their competitiveness. However, China, initially being the leading shrimp exporter, completely lost its export potential since their RSCA values went below 0 in recent years (Figure 14, in the Appendix).

Bangladesh has been successful in exploring its shrimp export avenues in the foreign market. The high RSCA value reflects the position of Bangladesh in shrimp exporting throughout the past decades. A plethora of factors can be attributed to Bangladesh's success: Firstly, in recent years, the shrimp production process in Bangladesh has transitioned to organic, giving it a distinct flavor and thereby, increasing exports. Following the EU organic regulations, only 1800 shrimp farmers were certified in 2012 (Hensler, 2013); however, in 2020, the number of HACCP-regulated farms has been raised to approximately 60% of total shrimp farmers (DoF, 2020). However, the RSCA value has dropped below 0.9 in recent years, indicating that there are some difficulties that need to be addressed. The majority of the shrimp farms still rely on natural shrimplings which are prone to infectious diseases. The adoption rate of pathogen-free shrimp and larvae is quite low, which is affecting the quality and quantity of Bangladeshi shrimp. Bangladesh needs to adopt the updated technologies, sound logistics, and innovation for maintaining the international standards regarding food safety and human health issues.

India continues to thrive with its large shrimp export. The main destination of Indian shrimp is the US market. Some reasons can be identifiable for the boom in India's shrimp performance. Firstly, back in 2009, the prevalence of early mortality syndrome among the shrimps of south-east Asian countries curtailed the exporting volume from these countries. This eventually gave India an avenue to expand its shrimp export. Second, India has endeavored to adopt technological changes in the production process, especially, the import of Specific Pathogen-Free (SPF) *vannamei* brood stock helped them upgrade and extend their shrimp production both in quantity and quality aspect.

The finding for China is understandable because, in recent years, China has minimized its shrimp export, while increasing the volume of imports. China's share of shrimp exports to EU member states has decreased somewhat over the previous six years, and the rejections number from the US and EU markets has been a considerable issue (Geetha et al., 2020). The observed decrease in shrimp exports from China to the USA and the EU could be linked to rising seafood consumption in domestic markets due to increased awareness of food safety and raising income (Zhang et al. 2017), as well as weakened importer demand (Yang et al., 2021). Despite the fact that Indonesia was severely affected by the several infectious diseases that afflicted its shrimp, it somehow managed to overcome the challenges. The high tariffs on Chinese and Vietnamese shrimp imports may have offered an opening for Indonesian shrimp to enter the US market, which is the world's largest shrimp consumer (WTO, 2021). Vietnam has also been highly competitive throughout the last decades. Shrimp accounts for 75% of the total aquaculture exports of Vietnam, and it's the third largest shrimp exporter after India and Ecuador (Export Genius, 2018). However, the latest figure indicates that Vietnam's shrimp slightly lost its competitive advantage in the global market with an RSCA value of 0.88. This is due to the fact that the US and the EU recently banned the use of antibiotics and other drugs that are often used in Vietnamese shrimp production (Chin, 2018).

The potential factors influencing shrimp export competitiveness of Bangladesh are presented in Table 22 (in Appendix 1), economic globalization intensifies the export competitiveness of shrimp export in the long run. Economic globalization increases the diversity of nations, widens transportation radii, minimizes the influence of distance on flows, and improves export allocation to importing countries' earnings (Johansson and Nilsson, 2012). Transport costs, as well as tariffs, have decreased considerably because of economic globalization. Therefore, if Bangladesh increases its economic globalization index, it will benefit with trade advantage including exports of not only shrimp but also other items (A. Giles and Williams, 2000).

Furthermore, the export price of Bangladeshi shrimp and the competitiveness of shrimp exports appear to be negatively related. More precisely, any increase in Bangladeshi export price hurts shrimp export competitiveness both in the long-run and in the short-run. As exporting price of a commodity increases, the demand is reduced and export volume narrows (Narayan and Bhattachrya, 2019), which in turn, may make export disadvantaged.

The institutional quality improves the shrimp export competitiveness of Bangladesh in both long-run and short-run. This influences the overall market condition and macroeconomic stability. As a result, if Bangladesh can ensure high institutional quality by providing traceability throughout the shrimp value chain, it will be able to compete more effectively in the shrimp export market. Bangladesh recently implemented block chain technology in the shrimp value chain by strengthening institution quality, allowing buyers and importers to track each stage of the shrimp value chain (Khan et al., 2022).

In addition, trade openness seems to exert positive long-run impact on the shrimp export competitiveness of Bangladesh. The most prevalent sort of trade impediment is regulatory obstacles. However, regulatory barriers in importing countries, particularly in terms of production, can also lead to greater comparative advantage in emerging countries, such as Asia, because they place less emphasis on regulations (Abate et al., 2016). Similarly, number of trade agreements showed propelling effect on shrimp export competitiveness, both in the long-run and short-run. Bangladesh is an active member of the World Trade Organization (WTO) and has recently signed Preferential Trade Agreement (PTA), and Free Trade Agreement (FTA) with several countries (Juventia et al., 2019). It also has other bilateral and regional trade agreements to enhance the trade volume, and eventually export competitiveness.

Moreover, the trade freedom has a positive effect on shrimp export competitiveness both in the long-run and short-run. The less export duties and restrictions a country has, the greater trade freedom it has. As trade freedom grows, exporting any commodity to a specified region becomes easier and more viable.

Comparative advantage of major aquaculture species

This project tried to assess the export potentiality of three most prevailing aquaculture species of Bangladesh i.e., pangasius, tilapia and rohu. Data were collected from 820 aquaculture farmers in Bangladesh and different secondary sources. The study used Policy Analysis Matrix (PAM) to assess the export potentiality and Domestic Resource Cost (DRC) criteria was used to examine comparative advantage. Results indicated that the producers are not discouraged significantly through the existing policy interventions and average market prices for the inputs are less than the world prices. Regarding the output price, results indicated that the prices of pangasius and tilapia are less than the international price while the price of rohu is higher than the international price. However, producers of pangasius and rohu are unprotected through policy interventions while tilapia producers are protected through the policy interventions. The commodity system of selected three fish species are competitive at producer level. The value of DRC indicates that Bangladesh has comparative advantage in pangasius, tilapia and rohu fish production (Figure 15, in Appendix 2).

Outputs and Conclusions

Aquaculture production in Bangladesh has experienced significant growth over the past thirty years. It is crucial that the aquaculture value chain adopt a more inclusive strategy to successfully meet the goals of improving health and nutrition, as well as decreasing poverty while generating employment. Significant disparities exist in the availability of supplies from diverse sources and the consumption patterns of different species among households, which are influenced by their income levels and geographic locations. The availability of fish, particularly those derived from aquaculture, is subject to many market and non-market forces. These forces include elements such as market accessibility, fluctuations in input and output prices, macroeconomic variables, and disruptions in the supply chain caused by unexpected events like the COVID-19 pandemic. However, for fish species with an export orientation that need to be competitive to survive in the global market over the long term, the enabling environment in the domestic market might not be enough. Therefore, this project aimed at (i) contributing to the debate on which fisheries sectors capture or culture to be promoted with critical analysis of fish consumption patterns over time (2000-2016) based on HIES datasets of Bangladesh; (ii) evaluating how access to credit especially trade credit contributes to overall performance of the fish farmers; (iii) measuring effects of price and non-price factors influencing aquaculture sectoral performance; (iv) examining impacts of COVID 19 like pandemic on supplies and consumption of fish; (v) identifying the factors affecting export competitiveness of shrimp relative to its competitors in the world market based on collected data from reliable secondary sources while measuring the export potentiality of major fish species in Bangladesh i.e., pangasius, tilapia and rohu using the survey data. The major findings and outputs are listed below which may support decision making of industry operators and policy makers.

- ✓ The richest urban households are opting to replace fish consumption with poultry and poultry eggs. Due to the presence of *status bias*, affluent urban households refrain from consuming inexpensive aquaculture species such as exotic carps. Conversely, with the limited availability of captured fish, there has been a notable rise in prices, hence impacting the accessibility and consumption of fish among the most poor households.

- ✓ The poorest, moderately poor, and non-poor households have increased their consumption of some cheaper cultured fish species, such as silver carps, mirror carps, and grass carps, while the richest households have decreased their consumption, suggesting a "*status bias*" towards more expensive and higher-quality fish species.
- ✓ There exists a favorable tradeoff between the benefits and costs of trade credit for fish producers. The utilization of trade credit offers advantages in terms of yield, income, and cost savings per kilogram of feed inputs. These benefits can potentially arise as a consequence of extended culture periods and increased feeding intensity.
- ✓ The documentation (complex paperwork), collateral, and interest rates are required for financing from formal sources which induce fish producers to enter into trade credit contracts. Besides, the convenience of availing trade credit and number of suppliers willing to offer trade credit are important determinants of trade credit.
- ✓ The escalation of corn, soybeans, mustard seeds, and the sectoral wage index has a significant impact on the increase in fish prices, both in the short and long run.
- ✓ Non-price factors such as per capita fish consumption, GDP and inflation rate result in a considerable increase in the market price of fish in the long run.
- ✓ An unprecedented disruption caused by COVID 19 resulted in labor and capital shortage, higher input prices, unavailability of input, and elimination of intermediaries, decrease in demand, extending the culture period pushing costs up.
- ✓ The findings in relation to shrimp competitiveness indicate that Bangladesh, Indonesia, and Vietnam have maintained a similar level of shrimp export performance, while India and Thailand's competitiveness has dipped marginally from 1990.
- ✓ Bangladesh's shrimp export competitiveness has slightly dropped, although competing countries such as India, Indonesia, and Vietnam have continued an upward trend in the recent years.

- ✓ Economic globalization, institutional quality, trade openness, and trade freedom are factors that have a long-term impact on shrimp competitiveness. Trade freedom and institutional quality also have a short-term impact on Bangladesh's shrimp export competitiveness. However, the export price of Bangladeshi shrimp has a negative short- and long-term impact on Bangladesh's competitiveness in the shrimp export market.
- ✓ Bangladesh has comparative advantage in pangasius, tilapia and rohu fish production. However, producers of pangasius and rohu are unprotected through policy interventions while tilapia producers are protected through the policy interventions. In addition, the commodity system of selected three fish species are competitive at producer level.

The following policy recommendations are made to help future policies make the aquaculture industry more sustainable, robust to shocks like the COVID-19 pandemic, and inclusive to all participants in the value chain. In order to promote inclusivity in the field of aquaculture, it is imperative for future policies to take into account several elements such as the variety in consumers' income, dietary preferences, quality of fish and inputs, as well as the price of both fish and inputs. This consideration is necessary due to the observed variations in fish consumption patterns across these aforementioned characteristics.

- ❖ The potential for mitigating *status bias* can be enhanced through technology advancements and interventions implemented at the farm and processing levels, which can lead to improvements in the quality, taste, and acceptability of these fish and fish products. .
- ❖ In addition to the development of aquaculture, it is imperative to prioritize the enhancement of capture fisheries. This is because specific micronutrients are exclusively found in particular high-value fish species obtained through catch, such as Mala, Katchci, etc. This approach aims to mitigate the potential consequences of an increase in fish production that may inadvertently lead to inadequate micronutrient intake.

- Small-scale producers require assistance in the form of access to institutional credit, relaxation of collateral and documentation requirements, and provision of aquaculture insurance. Trade finance plays a pivotal role in facilitating farm operations and enabling the adoption of enhanced agricultural technologies.
- Future policies may prioritize conducting additional market research to accurately assess the demand and supply of inputs. Additionally, they may involve offering financial assistance to mitigate the losses incurred as a result of pandemics similar to COVID-19. Furthermore, the establishment of cooperative societies among farmers, fishers, and fish traders might alleviate the burden imposed by pandemics through the enhancement of input availability, marketing activities, credit accessibility, and overall resilience capacity.
- Policies supporting indirect lending may play a critical role to small scale young and financially constrained farmers stay in the industry in the long run. It means that institutional lenders may be encouraged to lend feed manufacturers so that they can extend in-kind finance to small-scale producers.
- A meticulously designed and effectively administered public buffer stock strategy for feed ingredients has the potential to contribute to the maintenance of domestic price stability for key inputs, hence impacting the price of fish, irrespective of the prevailing conditions inside a given country.
- Policies aimed at promoting domestic production of key ingredients for fish feed have the potential to decrease import dependency, resulting in reduced production costs and lower fish prices.
- To develop a rational fish pricing policy, authorities must strike a balance between supply and demand. As a result, a continuous supply of fish to high-demand locations from the production regions must be assured, allowing both producers and consumers to adhere to rational pricing without fear of oversupply and insufficient demand or overdemand and insufficient supply.

- The government should prioritise the strengthening of current trade agreements and the expansion of preferential and free trade agreements. Additionally, it may be beneficial to reduce export levies or trade barriers associated with fish in order to enhance competitiveness in global markets.
- Fish "branding" (quality) is critical to expanding internationally. Favourable production settings, such as traceability, transparency, and accountability of value chain stakeholders, should be increased. In this case, "Blockchain Technology" may be used in the value chain of shrimp production.
- In order to be more competitive on the global market, major aquaculture species (pangasius, tilapia and major carps) which have export potentiality should see an increase in output support while retaining input support. This would eventually make it simpler for producers to reach not only domestic markets but also international markets; thus, the export potential of the fish species can be fully explored.

Technologies/Innovations developed, and what phase was achieved

In this study we develop several policies which emphasize the strategic use of policy-making processes as a means to achieve specific goals or outcomes of the aquaculture sector. Similar to a technological solution, aquaculture policy addressing consumption pattern considering fish species, consumers' income, location and gender, input constraints, financial barriers, resilience capacity and export potential will be used to address aquaculture challenges.

Key Beneficiaries

The key beneficiaries of the projects are the actors of the value chain including consumer, fish farmers, policy makers, Department of Fisheries, Bangladesh Fisheries Research Institute, market regulators and lending agencies. Since, the Government of Bangladesh plans to further develop aquaculture through production intensification, species diversification, private sector participation. Therefore, the benefits and costs of aquaculture development highlighted in this study will provide important information to policy makers. Which will help to develop more equitable and accessible markets of inputs and outputs for all irrespective of size, scale, income, gender and ages.

How the scientific results were disseminated?

The project organized a variety of activities aimed at publicizing the scientific findings of the study. The initiative engages in many activities to effectively communicate and distribute its scientific findings.

- Three scientific articles have been published, one more is accepted, two are under review in peer reviewed indexed journals (i.e., in Aquaculture, Aquaculture Economics and Management, and World Aquaculture Society journal) and two more are on progress.
- Three scientific papers have been presented in Bangladesh Fisheries Research Forum (BFRF) Biannual Conference and in Annual Conference of Bangladesh Agricultural Economics Association (BAEA) in Dhaka, Bangladesh. Besides, the project team has conducted three training for fish producers, hatchery and nursery owners on scientific farm and business management system in three different districts in Bangladesh.
- Scientific results have also been presented both in Aquaculture America 2023 at New Orleans, USA.
- Organized Bangladesh Sector Meeting 2022 at Bangladesh Agricultural University, Mymensingh to share the scientific results among policy makers, industry operators, scientific communities and funding agency.
- Organized policy workshop with participation of the State Minister of Planning of the People Republic of Bangladesh, industry operators, academics, researchers and other relevant ministry and institution.

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Appendices

Appendix 1: Tables

Appendix 2: Graphs

Appendix 3: Analytical Techniques

Table 1: Own-Price Elasticity (Aggregated)

Food Category	Price Elasticity			
	2000	2005	2010	2016
Fish	-1.51	-1.09	-0.85	-1.08
Poultry	-3.30	-1.81	-1.19	-1.07
Poultry egg	-2.32	-3.02	-1.66	-1.76
Meat	-2.72	-2.19	-0.32	-3.79
	Price Protein Elasticity			
	2000	2005	2010	2016
Fish	-1.09	-0.80	-0.61	-0.73
Poultry	-0.21	-0.16	-0.15	-0.18
Poultry egg	-0.18	-0.21	-0.14	-0.16
Meat	-0.36	-0.23	-0.02	-0.26

Table 2: Cross-Price Elasticities (Aggregated)

	Fish	Poultry	Poultry egg	Meat
	2000			
Fish	**-1.51**	0.20	0.13	0.34
Poultry	1.49	**-3.30**	0.14	0.02
Poultry egg	1.30	0.19	**-2.32**	0.14
Meat	1.08	0.01	0.001	**-2.72**
	2005			
Fish	**-1.09**	0.04	0.16	0.10
Poultry	-0.24	**-1.81**	0.06	0.45
Poultry egg	1.69	0.16	**-3.02**	0.48
Meat	-0.23	0.31	0.18	**-2.19**
	2010			
Fish	**-0.85**	-0.003	0.15	-0.10
Poultry	-0.39	**-1.19**	-0.07	0.30
Poultry egg	1.49	-0.02	**-1.66**	-0.40
Meat	-1.77	0.27	-0.45	**-0.32**

		2016		
Fish	**-1.08**	-0.03	0.02	0.26
Poultry	-0.28	**-1.07**	-0.004	0.30
Poultry egg	0.24	0.04	**-1.76**	0.74
Meat	0.84	0.31	0.46	**-3.79**

Table 3: Cross-Price Protein Elasticities (Aggregated)

	Fish	Poultry	Poultry egg	Meat
		2000		
Fish	**-1.09**	0.14	0.10	0.24
Poultry	0.09	**-0.21**	0.009	0.001
Poultry egg	0.10	0.015	**-0.18**	0.01
Meat	0.14	0.002	0.0001	**-0.36**
		2005		
Fish	**-0.80**	0.03	0.11	0.07
Poultry	-0.02	**-0.16**	0.006	0.041
Poultry egg	0.12	0.011	**-0.21**	0.03
Meat	-0.02	0.032	0.0191	**-0.23**
		2010		
Fish	**-0.61**	-0.002	0.10	-0.07
Poultry	-0.05	**-0.15**	-0.009	0.038
Poultry egg	0.13	-0.001	**-0.14**	-0.03
Meat	-0.13	0.019	-0.0323	**-0.02**
		2016		
Fish	**-0.73**	-0.02	0.01	0.17
Poultry	-0.05	**-0.18**	-0.001	0.051
Poultry egg	0.02	0.004	**-0.16**	0.07
Meat	0.06	0.022	0.0313	**-0.26**

Note: Elasticities are calculated as the percentage change in the protein demand of row food category due to the percentage change in the price of the column food category.

Table 4: Expenditure Elasticities (Aggregated)

	Quantile 1	Quantile 2	Quantile 3	Quantile 4
		2000		
Fish	0.871	0.853	0.841	0.797
Poultry	2.247	1.791	1.642	1.430
Poultry egg	0.776	0.705	0.638	0.626
Meat	2.125	1.730	1.608	1.413
		2005		
Fish	0.850	0.822	0.791	0.745
Poultry	2.049	1.657	1.459	1.366
Poultry egg	0.723	0.707	0.701	0.675
Meat	2.524	2.076	1.885	1.671
		2010		
Fish	0.863	0.830	0.800	0.740
Poultry	1.724	1.413	1.283	1.203
Poultry egg	0.583	0.556	0.542	0.635
Meat	3.158	2.606	2.274	1.893
		2016		
Fish	0.883	0.858	0.834	0.793
Poultry	1.158	1.070	1.025	0.978
Poultry egg	0.553	0.642	0.790	1.006
Meat	3.032	2.556	2.157	1.761

Table 5: Expenditure Protein Elasticities (Aggregated)

Food Category	Quantile 1	Quantile 2	Quantile 3	Quantile 4
		2000		
Fish	0.701	0.647	0.614	0.482
Poultry	0.058	0.085	0.106	0.162
Poultry egg	0.076	0.057	0.043	0.044
Meat	0.151	0.195	0.222	0.301
		2005		
Fish	0.705	0.634	0.562	0.468
Poultry	0.089	0.119	0.155	0.191
Poultry egg	0.053	0.050	0.050	0.046
Meat	0.136	0.176	0.211	0.272
		2010		
Fish	0.688	0.626	0.564	0.456
Poultry	0.120	0.154	0.187	0.213
Poultry egg	0.057	0.046	0.041	0.052
Meat	0.107	0.141	0.169	0.235
		2016		
Fish	0.638	0.594	0.553	0.479
Poultry	0.149	0.177	0.187	0.194
Poultry egg	0.061	0.058	0.066	0.083
Meat	0.115	0.130	0.153	0.203

Table 6: Own-Price Elasticity (Disaggregated)

Fish Category	Price Elasticity			
	2000	2005	2010	2016
Hilsa	-2.74	-1.41	-1.41	-1.46
Rohu/Mrigel/Katla	-2.92	-2.40	-1.77	-1.64
Pangasius	-7.06	-2.86	-1.55	-1.52
Airbreathing fish	-4.69	-3.79	-3.88	-2.63
Exotic Carps	-2.42	-1.99	-1.84	-1.60
Shol/Gajar/Taki	-2.56	-2.39	-1.52	-2.05
Puti/Tilapia	-1.42	-1.47	-1.17	-0.96
Mala/Kachi/Chapila	-2.21	-2.42	-2.12	-2.11
Shrimp	-1.10	-0.86	-1.44	-1.01
Dried fish	-1.82	-1.55	-1.83	-1.11
Baila/Tapashi/Tangra/Other	-3.07	-4.72	-4.44	-2.80
Sea fish	-6.18	-4.26	-4.70	-2.56
	Price Protein Elasticity			
	2000	**2005**	**2010**	**2016**
Hilsa	-0.20	-0.07	-0.08	-0.06
Rohu/Mrigel/Katla	-0.31	-0.29	-0.24	-0.20
Pangasius	-0.11	-0.18	-0.20	-0.23
Airbreathing fish	-0.15	-0.07	-0.11	-0.11
Exotic Carps	-0.25	-0.29	-0.23	-0.20
Shol/Gajar/Taki	-0.17	-0.13	-0.06	-0.07
Puti/Tilapia	-0.24	-0.28	-0.23	-0.20
Mala/Kachi/Chapila	-0.21	-0.23	-0.16	-0.10
Shrimp	-0.11	-0.05	-0.07	-0.03
Dried fish	-0.18	-0.14	-0.14	-0.07
Baila/Tapashi/Tangra/Other	-0.34	-0.37	-0.26	-0.28
Sea fish	-0.23	-0.16	-0.15	-0.10

Note: The own-price elasticities are uncompensated (Marshallian) elasticities.

Table 7: Cross-Price Elasticities (Disaggregated)

	Hilsa	Indian Carps	Pangasius	Airbreathing fish	Exotic Carps	Shol/Gajar/Taki	Puti/Tilapia	Mala/Kachi/Chapila	Shrimp	Dried fish	Baila/Tapashi/ Tangra/Other	Sea fish
2000												
Hilsa	**-2.74**	0.63	0.33	0.02	0.10	0.02	-0.02	-0.22	0.05	0.17	-0.31	0.18
Indian Carps	0.50	**-2.92**	0.20	0.11	-0.38	0.10	0.12	0.04	0.0228	0.0497	0.3042	0.41
Pangasius	1.52	1.19	**-7.06**	0.57	-0.45	-0.20	-0.31	0.43	0.30	0.47	0.75	1.01
Airbreathing fish	0.07	0.34	0.28	**-4.69**	0.08	-0.07	-0.40	0.01	-0.09	0.36	1.17	1.50
Exotic Carps	0.17	-0.35	-0.063	0.058	**-2.42**	0.080	0.143	0.259	0.029	0.299	0.357	0.661
Shol/Gajar/Taki	0.090	0.236	-0.048	-0.03	0.11	**-2.56**	-0.166	0.397	0.252	0.071	0.084	0.560
Puti/Tilapia	0.083	0.170	-0.017	-0.0708	0.098	-0.047	**-1.42**	0.25	0.16	0.023	0.094	-0.049
Mala/Kachi/Chapila	-0.110	0.118	0.098	0.027	0.259	0.249	0.3742	**-2.21**	0.012	-0.486	0.18	0.03
Shrimp	0.126	0.097	0.071	-0.011	0.022	0.155	0.227	0.011	**-1.10**	-0.110	0.1039	-0.428
Dried fish	0.335	0.20	0.16	0.254	0.500	0.095	0.088	0.252	-0.146	**-1.82**	0.647	-1.087
Baila/Tapashi/Tangra/Other	-0.149	0.3607	0.136	0.405	0.30	0.05	0.100	0.146	0.087	0.326	**-3.07**	0.427
Sea fish	0.568	1.477	0.570	1.775	2.028	1.029	-0.232	0.10	-1.34	-2.108	1.559	**-6.18**
2005												
Hilsa	**-1.41**	0.19	-0.31	-0.0223	-0.64	-0.22	-0.09	0.58	0.32	-0.04	0.02	-0.34
Indian Carps	0.13	**-2.40**	0.06	0.06	-0.07	0.12	0.18	0.04	0.0906	0.0333	0.3235	0.10
Pangasius	-0.26	0.11	**-2.86**	0.36	0.11	0.21	0.29	0.225	-0.07	-0.24	0.416	0.363
Airbreathing fish	-0.033	0.277	0.884	**-3.79**	-0.236	-0.068	-0.659	-0.205	-0.301	0.380	1.476	0.611
Exotic Carps	-0.208	0.017	0.092	-0.020	**-1.99**	0.104	-0.065	0.222	0.086	0.320	0.389	0.332
Shol/Gajar/Taki	-0.208	0.347	0.279	-0.018	0.232	**-2.39**	-0.603	0.123	0.385	-0.052	0.004	0.847
Puti/Tilapia	0.046	0.205	0.146	-0.071	-0.049	-0.156	**-1.47**	0.216	0.107	0.251	0.031	0.032
Mala/Kachi/Chapila	0.422	0.109	0.177	-0.032	0.285	0.073	0.358	**-2.42**	0.140	-0.209	0.475	0.032
Shrimp	0.366	0.223	-0.053	-0.107	0.146	0.315	0.245	0.206	**-0.86**	-0.198	-0.259	-1.051
Dried fish	0.053	0.168	-0.191	0.186	0.729	-0.017	0.746	-0.741	-0.170	**-1.55**	0.730	-0.492
Baila/Tapashi/Tangra/Other	0.081	0.538	0.343	0.467	0.602	0.010	0.027	0.552	-0.184	0.512	**-4.72**	0.863
Sea fish	-0.569	0.453	0.753	0.512	1.397	1.352	0.168	0.108	-2.032	-0.966	2.269	**-4.26**
2010												
Hilsa	**-1.41**	-0.36	-0.23	0.0365	-0.39	-0.23	-0.35	0.19	0.32	0.10	0.30	0.03
Indian Carps	-0.15	**-1.77**	0.09	0.12	-0.16	0.05	0.005	0.15	0.1617	0.1038	0.1058	0.11
Pangasius	-0.071	0.13	**-1.55**	-0.04	-0.17	0.18	0.18	0.08	0.05	-0.07	0.319	-0.026
Airbreathing fish	0.099	0.349	-0.188	**-3.88**	-0.050	0.172	-0.603	0.185	0.081	0.047	1.627	0.511
Exotic Carps	-0.153	-0.119	-0.138	0.022	**-1.84**	0.163	0.140	0.311	0.196	0.263	-0.050	0.531
Shol/Gajar/Taki	-0.390	0.213	0.537	0.200	0.453	**-1.52**	-0.628	-0.397	-0.494	-0.196	0.646	0.575
Puti/Tilapia	-0.048	0.064	0.150	-0.093	0.083	-0.123	**-1.17**	0.162	0.057	0.234	-0.056	0.004
Mala/Kachi/Chapila	0.274	0.290	0.141	0.122	0.429	-0.184	0.348	**-2.12**	-0.139	-0.020	0.539	-0.278
Shrimp	0.552	0.425	0.097	0.083	0.389	-0.372	0.131	-0.239	**-1.44**	0.343	-0.666	-0.416
Dried fish	0.262	0.359	-0.115	0.080	0.619	-0.130	0.875	-0.385	0.380	**-1.83**	0.035	-0.685
Baila/Tapashi/Tangra/Other	0.452	0.260	0.606	1.033	-0.120	0.398	-0.191	0.682	-0.534	0.009	**-4.44**	0.941
Sea fish	0.166	0.595	-0.098	0.780	2.311	0.846	0.0002	-0.851	-0.801	-1.334	2.246	**-4.70**
2016												
Hilsa	**-1.46**	-0.03	-0.14	-0.0804	-0.18	0.02	-0.34	-0.01	0.028	-0.061	0.17	0.09
Indian Carps	0.04	**-1.64**	-0.02	0.09	-0.06	0.05	0.04	0.14	0.0588	0.0443	0.0962	0.10
Pangasius	0.002	-0.02	**-1.52**	0.10	-0.07	0.04	-0.06	-0.052	0.01	0.02	0.428	-0.014
Airbreathing fish	-0.073	0.123	0.227	**-2.63**	-0.213	0.124	-0.276	-0.066	0.164	-0.014	0.810	0.119
Exotic Carps	-0.012	-0.003	-0.005	-0.044	**-1.60**	0.077	-0.001	0.173	0.112	0.123	0.303	0.362
Shol/Gajar/Taki	0.093	0.164	0.214	0.242	0.190	**-2.05**	-0.175	-0.044	-0.130	0.001	0.177	0.151
Puti/Tilapia	-0.036	0.076	0.027	-0.028	-0.013	-0.015	**-0.96**	0.106	0.014	0.133	0.149	-0.089
Mala/Kachi/Chapila	0.061	0.359	-0.134	-0.029	0.356	-0.019	0.352	**-2.11**	-0.072	0.007	0.362	0.076
Shrimp	0.083	0.138	-0.022	0.259	0.230	-0.123	-0.073	-0.123	**-1.01**	0.094	-0.128	-0.770
Dried fish	0.0003	0.178	0.171	0.045	0.313	0.021	0.572	-0.034	0.115	**-1.11**	-0.504	-0.309
Baila/Tapashi/Tangra/Other	0.148	0.099	0.606	0.384	0.208	0.051	0.151	0.129	-0.017	-0.179	**-2.80**	0.306
Sea fish	0.229	0.345	-0.051	0.236	1.129	0.153	-0.537	0.101	-0.840	-0.411	1.185	**-2.56**

Note: Elasticities are calculated as the percentage change in the demand of row fish category due to the percentage change in the price of the column fish category.

Table 8: Cross-Price Protein Elasticities (Disaggregated)

	Hilsa	Indian Carps	Pangasius	Airbreathing fish	Exotic Carps	Shol/Gajar/Taki	Puti/Tilapia	Mala/Kachi/ Chapila	Shrimp	Dried fish	Baila/Tapashi/ Tangra/Other	Sea fish
							2000					
Hilsa	**-0.20**	0.05	0.02	0.001	0.01	0.001	-0.001	-0.02	0.004	0.01	-0.02	0.01
Indian Carps	0.05	**-0.31**	0.02	0.01	-0.04	0.01	0.01	0.004	0.0024	0.0052	0.0319	0.04
Pangasius	0.02	0.02	**-0.11**	0.01	-0.01	-0.003	-0.005	0.01	0.005	0.01	0.01	0.02
Airbreathing fish	0.002	0.01	0.01	**-0.15**	0.003	-0.002	-0.01	0.0003	-0.003	0.01	0.04	0.05
Exotic Carps	0.02	-0.04	-0.006	0.006	**-0.25**	0.008	0.015	0.026	0.003	0.030	0.036	0.067
Shol/Gajar/Taki	0.006	0.015	-0.003	-0.002	0.01	**-0.17**	-0.011	0.026	0.016	0.005	0.005	0.036
Puti/Tilapia	0.014	0.028	-0.003	-0.0118	0.016	-0.008	**-0.24**	0.04	0.03	0.004	0.016	-0.008
Mala/Kachi/Chapila	-0.010	0.011	0.009	0.003	0.024	0.023	0.0353	**-0.21**	0.001	-0.046	0.02	0.003
Shrimp	0.013	0.010	0.007	-0.001	0.002	0.016	0.023	0.001	**-0.11**	-0.011	0.0106	-0.044
Dried fish	0.033	0.02	0.02	0.025	0.049	0.009	0.009	0.025	-0.014	**-0.18**	0.063	-0.106
Baila/Tapashi/Tangra/Other	-0.016	0.0397	0.015	0.045	0.03	0.01	0.011	0.016	0.010	0.036	**-0.34**	0.047
Sea fish	0.021	0.055	0.0212	0.0662	0.0757	0.038	-0.009	0.004	-0.050	-0.079	0.058	**-0.23**
							2005					
Hilsa	**-0.07**	0.01	-0.01	-0.001	-0.03	-0.011	-0.004	0.03	0.015	-0.002	0.001	-0.02
Indian Carps	0.02	**-0.29**	0.01	0.01	-0.01	0.02	0.02	0.005	0.0111	0.0041	0.0395	0.01
Pangasius	-0.02	0.01	**-0.18**	0.02	0.01	0.013	0.019	0.01	-0.005	-0.02	0.03	0.02
Airbreathing fish	-0.001	0.01	0.02	**-0.07**	-0.005	-0.001	-0.01	-0.0040	-0.006	0.01	0.03	0.01
Exotic Carps	-0.03	0.002	0.013	-0.003	**-0.29**	0.015	-0.009	0.032	0.012	0.046	0.056	0.048
Shol/Gajar/Taki	-0.011	0.019	0.015	-0.001	0.01	**-0.13**	-0.033	0.007	0.021	-0.003	0.0002	0.047
Puti/Tilapia	0.009	0.039	0.028	-0.0136	-0.009	-0.030	**-0.28**	0.04	0.02	0.048	0.006	0.006
Mala/Kachi/Chapila	0.040	0.010	0.017	-0.003	0.027	0.007	0.0339	**-0.23**	0.013	-0.020	0.04	0.003
Shrimp	0.020	0.012	-0.003	-0.006	0.008	0.018	0.014	0.012	**-0.05**	-0.011	-0.0145	-0.059
Dried fish	0.005	0.01	-0.02	0.016	0.065	-0.002	0.066	-0.066	-0.015	**-0.14**	0.065	-0.044
Baila/Tapashi/Tangra/Other	0.006	0.0419	0.027	0.036	0.05	0.001	0.002	0.043	-0.014	0.040	**-0.37**	0.067
Sea fish	-0.022	0.017	0.0291	0.0198	0.0539	0.0522	0.006	0.004	-0.078	-0.037	0.088	**-0.16**
							2010					
Hilsa	**-0.08**	-0.02	-0.01	0.002	-0.02	-0.013	-0.019	0.01	0.018	0.01	0.02	0.001
Indian Carps	-0.02	**-0.24**	0.01	0.02	-0.02	0.01	0.001	0.020	0.0218	0.0140	0.0143	0.01
Pangasius	-0.01	0.02	**-0.20**	-0.005	-0.02	0.022	0.024	0.01	0.006	-0.01	0.04	-0.003
Airbreathing fish	0.003	0.01	-0.01	**-0.11**	-0.001	0.005	-0.02	0.0052	0.002	0.001	0.05	0.01
Exotic Carps	-0.02	-0.01	-0.017	0.003	**-0.23**	0.020	0.018	0.039	0.025	0.033	-0.006	0.066
Shol/Gajar/Taki	-0.016	0.009	0.022	0.008	0.02	**-0.06**	-0.026	-0.017	-0.021	-0.008	0.027	0.024
Puti/Tilapia	-0.009	0.013	0.030	-0.0185	0.016	-0.024	**-0.23**	0.03	0.01	0.047	-0.011	0.001
Mala/Kachi/Chapila	0.021	0.023	0.011	0.010	0.033	-0.014	0.0271	**-0.16**	-0.011	-0.002	0.04	-0.022
Shrimp	0.026	0.020	0.005	0.004	0.018	-0.017	0.006	-0.011	**-0.07**	0.016	-0.0311	-0.019
Dried fish	0.019	0.03	-0.01	0.006	0.046	-0.010	0.065	-0.029	0.028	**-0.14**	0.003	-0.051
Baila/Tapashi/Tangra/Other	0.026	0.0151	0.035	0.060	-0.01	0.02	-0.011	0.039	-0.031	0.001	**-0.26**	0.054
Sea fish	0.0051	0.018	-0.0030	0.0242	0.0716	0.0262	0.000005	-0.0264	-0.0248	-0.0414	0.0696	**-0.15**
							2016					
Hilsa	**-0.06**	-0.002	-0.01	-0.003	-0.01	0.001	-0.015	-0.0004	0.001	-0.003	0.01	0.004
Indian Carps	0.005	**-0.20**	-0.002	0.01	-0.01	0.01	0.01	0.017	0.0071	0.0053	0.0115	0.01
Pangasius	0.0003	-0.004	**-0.23**	0.02	-0.01	0.006	-0.009	-0.01	0.001	0.002	0.06	-0.002
Airbreathing fish	-0.003	0.01	0.01	**-0.11**	-0.009	0.005	-0.01	-0.0027	0.007	-0.001	0.03	0.005
Exotic Carps	-0.002	-0.0004	-0.001	-0.005	**-0.20**	0.009	-0.0001	0.021	0.014	0.015	0.037	0.044
Shol/Gajar/Taki	0.003	0.006	0.007	0.008	0.01	**-0.07**	-0.006	-0.002	-0.005	0.00005	0.006	0.005
Puti/Tilapia	-0.008	0.016	0.006	-0.0059	-0.003	-0.003	**-0.20**	0.02	0.003	0.028	0.031	-0.019
Mala/Kachi/Chapila	0.003	0.017	-0.006	-0.001	0.017	-0.001	0.0169	**-0.10**	-0.003	0.0003	0.02	0.004
Shrimp	0.002	0.004	-0.001	0.007	0.006	-0.003	-0.002	-0.003	**-0.03**	0.003	-0.0035	-0.021
Dried fish	0.0002	0.01	0.01	0.003	0.019	0.001	0.036	-0.002	0.007	**-0.07**	-0.031	-0.019
Baila/Tapashi/Tangra/Other	0.015	0.0099	0.061	0.038	0.02	0.01	0.015	0.013	-0.002	-0.018	**-0.28**	0.031
Sea fish	0.0006	0.0137	-0.0020	0.00935	0.04471	0.00606	-0.0213	0.00402	-0.03326	-0.01628	0.0469	**-0.10**

Note: Elasticities are calculated as the percentage change in the protein demand of row fish category due to the percentage change in the price of the column fish category.

Table 9: Expenditure Elasticities (Disaggregated)

	Quantile 1	Quantile 2	Quantile 3	Quantile 4
		2000		
Hilsa	2.651	2.031	1.776	1.546
Indian Carps	1.566	1.556	1.463	1.382
Pangasius	2.832	2.332	1.968	1.525
Airbreathing fish	1.381	1.454	1.478	1.432
Exotic Carps	0.847	0.808	0.763	0.641
Shol/Gajar/Taki	1.009	1.003	0.998	0.993
Puti/Tilapia	0.833	0.743	0.674	0.566
Mala/Kachi/Chapila	0.899	0.865	0.804	0.745
Shrimp	0.921	0.870	0.818	0.709
Dried fish	0.296	0.454	0.650	1.007
Baila/Tapashi/Tangra/Other	0.970	0.908	0.846	0.739
Sea fish	6.461	1.007	0.504	-0.160
		2005		
Hilsa	3.273	2.257	1.914	1.686
Indian Carps	1.379	1.362	1.358	1.278
Pangasius	1.445	1.356	1.326	1.316
Airbreathing fish	1.748	1.645	1.732	1.594
Exotic Carps	0.813	0.767	0.707	0.550
Shol/Gajar/Taki	1.061	1.059	1.051	1.041
Puti/Tilapia	0.799	0.734	0.686	0.581
Mala/Kachi/Chapila	0.952	0.897	0.841	0.726
Shrimp	1.016	1.023	1.028	1.043
Dried fish	0.471	0.547	0.593	0.744
Baila/Tapashi/Tangra/Other	0.983	0.932	0.888	0.841
Sea fish	2.140	1.073	0.544	-0.243
		2010		
Hilsa	2.999	2.484	1.978	1.663
Indian Carps	1.101	1.193	1.198	1.201
Pangasius	1.039	1.002	0.978	0.929
Airbreathing fish	1.685	1.647	1.675	1.635
Exotic Carps	0.780	0.709	0.636	0.491
Shol/Gajar/Taki	1.001	1.000	0.999	0.996
Puti/Tilapia	0.785	0.761	0.734	0.659
Mala/Kachi/Chapila	0.872	0.855	0.817	0.764
Shrimp	1.067	1.098	1.117	1.153
Dried fish	0.517	0.505	0.541	0.642
Baila/Tapashi/Tangra/Other	0.963	0.926	0.875	0.841
Sea fish	3.287	1.263	0.570	-0.425
		2016		
Hilsa	2.881	2.304	1.906	1.736
Indian Carps	0.948	1.029	1.079	1.100
Pangasius	1.197	1.151	1.125	1.115
Airbreathing fish	1.880	1.765	1.655	1.628
Exotic Carps	0.625	0.566	0.451	0.339
Shol/Gajar/Taki	1.127	1.149	1.171	1.194
Puti/Tilapia	0.718	0.663	0.597	0.527
Mala/Kachi/Chapila	0.834	0.827	0.842	0.859
Shrimp	1.420	1.439	1.452	1.441
Dried fish	0.377	0.475	0.640	0.827
Baila/Tapashi/Tangra/Other	0.982	0.940	0.897	0.849
Sea fish	1.997	1.263	0.674	0.194

Table 10: Expenditure Protein Elasticities (Disaggregated)

	Quantile 1	Quantile 2	Quantile 3	Quantile 4
2000				
Hilsa	0.064	0.104	0.143	0.209
Indian Carps	0.086	0.126	0.168	0.228
Pangasius	0.008	0.019	0.029	0.053
Airbreathing fish	0.029	0.040	0.049	0.068
Exotic Carps	0.106	0.092	0.076	0.046
Shol/Gajar/Taki	0.072	0.063	0.067	0.057
Puti/Tilapia	0.187	0.130	0.100	0.069
Mala/Kachi/Chapila	0.093	0.093	0.068	0.060
Shrimp	0.100	0.102	0.084	0.056
Dried fish	0.038	0.048	0.058	0.067
Baila/Tapashi/Tangra/Other	0.119	0.114	0.089	0.064
Sea fish	0.061	0.025	0.030	-0.009
2005				
Hilsa	0.048	0.077	0.106	0.146
Indian Carps	0.093	0.134	0.168	0.249
Pangasius	0.059	0.081	0.096	0.110
Airbreathing fish	0.017	0.028	0.033	0.051
Exotic Carps	0.126	0.121	0.105	0.063
Shol/Gajar/Taki	0.064	0.057	0.056	0.056
Puti/Tilapia	0.192	0.145	0.124	0.087
Mala/Kachi/Chapila	0.103	0.091	0.079	0.055
Shrimp	0.064	0.058	0.059	0.048
Dried fish	0.059	0.059	0.046	0.035
Baila/Tapashi/Tangra/Other	0.088	0.069	0.064	0.064
Sea fish	0.058	0.044	0.024	-0.010
2010				
Hilsa	0.062	0.084	0.118	0.173
Indian Carps	0.097	0.126	0.171	0.239
Pangasius	0.129	0.140	0.136	0.103
Airbreathing fish	0.029	0.041	0.049	0.066
Exotic Carps	0.126	0.095	0.074	0.044
Shol/Gajar/Taki	0.047	0.046	0.041	0.033
Puti/Tilapia	0.162	0.159	0.148	0.118
Mala/Kachi/Chapila	0.079	0.073	0.059	0.047
Shrimp	0.050	0.052	0.052	0.053
Dried fish	0.058	0.042	0.034	0.027
Baila/Tapashi/Tangra/Other	0.064	0.056	0.043	0.047
Sea fish	0.060	0.036	0.022	-0.016
2016				
Hilsa	0.059	0.075	0.099	0.117
Indian Carps	0.086	0.110	0.132	0.174
Pangasius	0.176	0.183	0.180	0.156
Airbreathing fish	0.047	0.062	0.079	0.093
Exotic Carps	0.096	0.077	0.050	0.031
Shol/Gajar/Taki	0.036	0.041	0.042	0.043
Puti/Tilapia	0.165	0.145	0.121	0.101
Mala/Kachi/Chapila	0.044	0.038	0.039	0.040
Shrimp	0.032	0.038	0.042	0.046
Dried fish	0.030	0.031	0.038	0.037
Baila/Tapashi/Tangra/Other	0.110	0.096	0.085	0.077
Sea fish	0.073	0.047	0.028	0.008

Table 11: Descriptive Statistics

	Overall			Users			Non-users		
Number of farms		280			64			216	
	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Determinants of trade credit:									
Documentation Problem (Yes/No)	0.00	0.61	1.00	0.00	0.70	1.00	0.00	0.62	1.00
Collateral Problem (Yes/No)	0.00	0.61	1.00	0.00	0.69	1.00	0.00	0.59	1.00
TC Convenient (Yes/No)	0.00	0.59	1.00	0.00	0.66	1.00	0.00	0.57	1.00
TC Interest low (Yes/No)	0.00	0.46	1.00	0.00	0.55	1.00	0.00	0.47	1.00
Alternative Available (Yes/No)	0.00	0.45	1.00	0.00	0.48	1.00	0.00	0.46	1.00
Number of suppliers offering TC	0.00	1.19	5.00	1.00	2.00	5.00	0.00	1.00	5.00
Sellers Willing to offer TC (Yes/No)	0.00	0.44	1.00	0.00	0.45	1.00	0.00	0.45	1.00
Sales return possible (Yes/No)	0.00	0.40	1.00	0.00	0.43	1.00	0.00	0.41	1.00
Lower quality Lower Price (Yes/No)	0.00	0.37	1.00	0.00	0.42	1.00	0.00	0.37	1.00
Covariates:									
Age (Years)	18.00	41.00	75.00	18.00	42.00	75.00	18.00	41.00	75.00
Education (Years)	1.00	**9.00**	18	1.00	9.00	18.00	1.00	**10.00**	18.00
Experience (Years)	4.00	12.00	40.00	4.00	13.00	40.00	4.00	12.00	40.00
Farm Size (Hectare)	0.40	1.54	10.12	0.40	1.54	10.12	0.40	1.53	10.12
Household Income ($)	700	24208	213125	700	23680	21313	1125	23960	187500
Outcome variables:									
Feed quantity (Kg.)	2400	33543	160000	2400	34191	160000	2400	33804	160000
Feed Cost ($)	1563	16725	67500	1615	16712	67500	1563	16641	67500
Culture Period (days)	90.00	213.00	420.00	90.00	216.00	420.00	90.00	213.00	420.00
Yield (Kgs)	2150	22043	155000	2280	22369	99400	2280	22293	155000
Gross sales value ($)	1688	25305	111788	1688	25480	111000	1688	25337	111000
Cost per Kg. of feed ($)	0.15	0.53	0.90	0.15	0.51	0.90	0.15	0.54	0.84
Feed Conversion Ratio (FCR)	0.24	1.56	5.00	0.24	1.57	5.00	0.24	1.56	5.00
Technical Efficiency	0.41	0.79	0.93	0.41	0.80	0.93	0.41	0.80	0.93

Table 12: Sources and size of drain and gain of trade credit to small scale aquaculture farms

	Means Treated (Users of TC)	Means Control (Non-users of TC)	Std. Mean diff.	eCDF	Var. Ratio
Impacts of trade credit:					
Culture period (days)	221.00	197.00	0.25	0.06	1.58
Yield (Kgs)	21243.00	14359.00	0.08	0.05	0.76
Revenues ($)*	21881	17813	0.17	0.05	0.91
Feed Quantity (Kgs)	33094.00	20875.00	0.08	0.03	0.68
Feed Cost ($)*	16291	10722	0.18	0.04	0.53
FCR	1.68	1.54	0.16	0.06	1.60
Feed cost Per Kg. ($)*	0.50	0.53	0.05	0.04	0.56
Efficiency	0.79	0.79	0.01	0.05	1.61
Sample Sizes:					
	Control	**Treated**			
All	64	216			
Matched	64	64			
Unmatched	0	152			
Discarded	0	0			

Table 13: Efficiency scores of users and non-users of trade credit

	Meta frontier efficiency scores		Group frontier efficiency scores		Technology gap ratio	
	Users	Non-Users	Users	Non-user	Users	Non-users
Minimum	0.41	0.49	0.37	0.26	0.91	0.28
1st quartile	0.76	0.75	0.75	0.56	0.99	0.65
Median	0.80	0.79	0.80	0.71	0.99	0.90
Mean	0.79	0.79	0.79	0.67	0.99	0.88
3rd quartile	0.84	0.84	0.84	0.78	1.00	1.00
Maximum	0.93	0.91	0.93	0.91	1.00	1.00

Table 14: Determinants of trade credit

Response variable: Taken Trade Credit: Yes/No	Estimate	Std. Error	t value	Pr(>|t|)	Marginal Effects
(Intercept)	0.79*	0.38	2.10	0.03	0.11
Documentation is problem :Yes/No	0.11**	0.04	2.63	0.00	0.037**
Collateral is problem: Yes/No	0.04*	0.04	1.11	0.08	0.018*
Trade credit is convenient than formal: Yes/No	0.08**	0.04	2.40	0.017	0.015**
Trade credit int. is lower than formal: Yes/No	0.12***	0.03	3.53	0.00	0.026***
Feed sellers willing to give trade credit: Yes/No	0.00	0.03	0.05	0.96	-0.003
Feed can return if bought on credit: Yes/No	-0.01	0.04	-0.41	0.69	-0.002
Lower payment for lower quality feed: Yes/No	0.01	0.03	0.37	0.71	0.018
Number of suppliers offering Trade credit	0.23***	0.01	16.98	< 2e-16	0.070***
Age	0.01	0.06	0.13	0.90	0.000
Education	0.06**	0.02	1.76	0.00	-0.001**
Farm size	0.04	0.03	-1.30	0.19	-0.001
Household Income	0.01	0.02	0.35	0.73	-0.001
Log (Years of Farming)	-0.02	0.03	-0.53	0.60	-0.000
Log (Culture period)	-0.01	0.04	-0.13	0.90	-0.050
Log (Revenues)	-0.08**	0.03	-2.96	0.00	-0.023**
Log (Feed costs)	0.07**	0.02	2.76	0.00	0.027**
Overall model significance and model fit	Pseudo R^2			0.52	
	LR chi-square			201.66	
	Prob. > chi-square			<2.2e-16	
Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

Table 15. Long and short-run coefficient estimates from the DARDL model.

Variables	Coefficient	Std. Error	Prob.
lnCP	0.342[b]	0.138	0.022
ΔlnCP	0.109[a]	0.028	0.000
lnSP	0.320[a]	0.071	0.000
ΔlnSP	0.038[a]	0.011	0.000
lnMP	0.208[b]	0.081	0.016
ΔlnMP	0.298[a]	0.065	0.000
lnFWR	0.492[a]	0.149	0.000
ΔlnFWR	0.147[a]	0.031	0.000
lnFC	0.094[a]	0.022	0.000
ΔlnFC	0.014	0.126	0.569
lnGDP	0.012[a]	0.002	0.000
ΔlnGDP	0.021	0.032	0.453
lnIF	0.019[c]	0.011	0.085
ΔlnIF	0.001	0.002	0.498
lnPRD	-0.219[a]	0.027	0.000
ΔlnPRD	-0.081	0.189	0.631
Cons.	1.170[a]	0.220	0.000
ECT (-1)	-0.561[a]	0.210	0.000
R^2	0.958	Adjusted R^2	0.965
F- Statistics [Prob.]	346.23 [0.000]	Simulation	5000
Diagnostic test			
Jarque-Bera (JB) test	χ^2: 0.514 (Prob: 0.723)		
Breusch-Godfrey (BG) serial correlation LM	F-stat: 0.021 (Prob: 0.882)		
Breusch-Pagan- Godfrey (BPG) test	F-stat: 0.892 (Prob: 0.598)		
Ramsey RESET test	F (1): 0.673 (Prob: 0.431)		

Note: [a, b, and c] denote statistical rejection level at 1% level 5% and 10% level.

Table 16. COVID-19 effects on income, employment, and trading activities of fish farmers, fishers, and traders.

Particulars	Change (%)		
	Fish farmers	Fishers	Traders
Income from fisheries	-42.75	-32.80	-49.75
Self-employment	+28.5	-55.75	-78.25
Hired labor	-35.69	-55.90	-60.55
Household fish consumption	-15.55	-22.66	-27.78
Frequency of transport use	-30.35	-39.40	-70.55
Market demand (no. of customers/traders)	-42.75	-58.00	-72.54
Average amount of fish trade (buy and sell)	-63.55	-33.60	-70.30
Amount of unsold fish	+40.00 [a]	+19.50 [b]	+12.00

Note: "+" sign indicates positive change (increase), while "-" sign denotes negative change (decrease).

[a] change in the amount of unsold mature fish, [b] change in unsold catch fish.

Table 17. Information of mature fish stocking in pond during COVID-19.

Particulars	Fish farmers	Fishers	Traders
Mature fish stocking in pond or icing of fish after harvest during COVID-19 (% of respondents)	68.44	17.60	14.64
Mature fish stocking in pond or icing of fish after harvest during COVID-19 (no. of days)	118	3	14
Quantity of feed/ice application increased for further stocking of mature fish or icing of fish after harvest (%)	29.80	5.5	7.95
Feed/ice cost increased for further stocking/icing of mature fish (%)	21.62	6.05	7.55
Change in others cost* (%)	11.01	1.65	3.35
Cost increase per kg of fish production/sell for further stocking/icing (%)	32.63	7.70	10.9

Note: Mature fish stocking strategy used by fish farmers while the fishers and traders used ice for preserving the fish.
* Other cost includes inputs those are required for farm operation except feed/ice.

Table 18. Changes in fish price during COVID-19 (USD/kg).

Fish species	Fish price (pre- COVID)	Fish price (During COVID)	Mean change (%)	t-value
Culture				
Rui (*Labeo rohita*)	2.71	2.29	-15.56	0.84
Catla (*Catla catla*)	2.23	1.81	-18.92	1.01
Silver Carp (*Hypophthalmichthys molitrix*)	1.81	1.33	-26.67	1.98[c]
Common Carp (*Cyprinus carpio*)	1.81	1.20	-33.33	2.11[b]
Mrigal (*Cirrhinus cirrhosis*)	1.69	1.20	-28.57	1.97[c]
Tilapia (*Oreochromis mossambicus*)	1.45	1.08	-25.00	1.84[c]
Pangas (*Pangasius hypophthalmus*)	1.51	0.90	-40.00	2.61[a]
Grass Carp (*Ctenopharyngodon Idella*)	1.81	1.20	-33.33	2.12[b]
Prawn/ Golda (*Macrobrachium rosenbergii)*	8.43	7.23	-14.29	0.72
Capture				
Hilsha (*Tenualosa ilisha*)	9.04	8.13	-10.00	0.66
Shrimp/Bagda (*Penaeus monodon*)	6.02	5.42	-10.00	0.65
Tengra (*Batasio batasio*)	1.45	0.84	-41.67	2.64[a]
Rida (*Rita rita*)	3.61	3.61	-0.00	0.02
Mola punti (*Puntius guganio)*	1.45	0.96	-33.33	2.11[b]
Baila (*Awaous guamensis*)	4.82	3.61	-25.00	1.82[c]
Shol (*Channa striata*)	4.82	3.01	-37.50	2.09[b]
Taki (*Channa punctate)*	1.45	0.96	-33.33	1.97[c]
Ayre (*Bagarius bagarius*)	7.23	6.02	-16.67	0.92
Bata (*Labeo bata*)	1.20	0.96	-20.00	1.23
Boal (*Wallago attu*)	3.61	3.01	-16.67	0.91

Notes: "-" sing indicates negative change (reduction) of fish price during the pandemic period. [a, b] and [c] indicates the significance at 1%, 5% and 10% level, respectively.

Table 19. Major problems faced by fish farmers, fishers, and traders for input supply.

Problems of inputs accumulation	Extent of problem (%)			Total	Rank
	Low (1)	Medium (2)	High (3)	PCI	
Fish farmers					
Raised the feed price due to deficient supply	15 (10)	55 (36.67)	80 (53.33)	365	1
Lack of quality fingerling and fry due to the closure of hatchery business	37 (24.67)	21 (14)	92 (61.33)	355	2
Unable to sell fish but have to pay the lease value of land	32 (21.33)	43 (28.67)	75 (50)	343	3
Inadequate labor supply	39 (26)	44 (29.33)	67 (44.67)	328	4
Price rise of locally made feed ingredients	122 (81.33)	16 (10.67)	12 (8)	190	5
Fishers					
Unable to catch fish due to movement restriction	12 (8)	45 (30)	93 (62)	381	1
Inadequate cocksheet/container supply	34 (22.67)	55 (36.67)	61(40.67)	327	2
High rope price	67 (44.67)	46 (30.67)	37 (24.67)	270	3
Difficulties in purchasing fishing nets	97 (64.67)	23 (15.33)	30 (20)	233	4
Fish traders					
Unavailability of transport and high cost	9 (9)	24 (24)	67 (67)	258	1
Lack of capital and credit support	12 (12)	33 (33)	55 (55)	243	2
Labor shortage	33 (33)	29 (29)	38 (38)	205	3
Inadequate ice supply and high price of ice	27 (27)	52 (52)	21 (21)	194	4

Notes: Figure shown in the parenthesis indicates the percentage of respondents in each category.

Table 20. Major issues faced by fish farmers, fishers, and traders for fish sale.

Problems of fish sale	Extent of problem (%)			Total PCI	Rank
	Low (1)	Medium (2)	High (3)		
		Fish farmers			
Low fish price	7 (4.67)	24 (16.0)	119 (79.33)	412	1
Closure of *arat* (auction place)	12 (8)	39 (26)	99 (66)	387	2
Lack of bargaining power	34 (22.67)	55 (36.67)	61 (40.67)	327	3
Limited number of buyers	37 (24.67)	69 (46)	44 (29.33)	307	4
Lower demand	55 (36.67)	59 (39.33)	36 (24)	281	5
		Fishers			
Closure of *arat* (auction place)	9 (6)	17 (11.33)	124 (82.67)	415	1
Low fish price	12 (8)	18 (12)	120 (80)	408	2
Limited number of buyers	27 (18)	23 (15.33)	100 (66.67)	373	3
Transportation problem	77 (51.33)	12 (8)	61 (40.67)	284	4
		Fish traders			
Limited number of buyers from distant market	12 (12)	8 (8)	80 (80)	268	1
During a lockdown, the administrative difficulty of *arat* opening	18 (18)	32 (32)	50 (50)	232	2
Shorter market duration	23 (23)	29 (29)	48 (480	225	3
Lack of *bepari* and wholesaler (*paikar*)	20 (20)	55 (55)	25 (25)	205	4
Unavailability of sufficient labor	56 (56)	22 (22)	22 (22)	166	5
Low volume of fish to sell	44 (44)	49 (49)	7 (7)	163	6
Unavailability of transport	43 (43)	55 (55)	2 (2)	159	7

Notes: Figure shown in the parenthesis indicates the percentage of respondents in each category.

Table 21. Kaplan-Meier survival rates for the RSCA index and tests for equality of survival functions.

Year	Survivor function	Bangladesh	China	India	Indonesia	Thailand	Vietnam
1990	0.9674	0.9851	0.9179	0.9238	0.9469	0.9558	0.9751
1991	0.9439	0.9830	0.8797	0.9437	0.9477	0.9607	0.9801
1992	0.9135	0.9803	0.8680	0.9368	0.9365	0.9616	0.9811
1993	0.8877	0.9793	0.7732	0.9428	0.9339	0.9596	0.9820
1994	0.8622	0.9866	0.6996	0.9531	0.9392	0.9658	0.9793
1995	0.8336	0.9854	0.6395	0.9447	0.9414	0.9653	0.9752
1996	0.8101	0.9767	0.2097	0.9201	0.9020	0.9390	0.9420
1997	0.7895	0.9649	0.1473	0.9075	0.8860	0.9209	0.9497
1998	0.7569	0.9550	0.0205	0.8880	0.8904	0.9129	0.9491
1999	0.7344	0.9647	0.2003	0.9084	0.9096	0.9218	0.9590
2000	0.7098	0.9703	0.2679	0.9083	0.9022	0.9243	0.9643
2001	0.6672	0.9654	0.1209	0.8837	0.8910	0.9023	0.9541
2002	0.6372	0.9616	0.0209	0.8781	0.8796	0.8473	0.9564
2003	0.6112	0.9673	0.1121	0.8526	0.8765	0.8509	0.9654
2004	0.6051	0.9700	-0.0278	0.7893	0.8575	0.8112	0.9632
2005	0.5793	0.9765	-0.2103	0.7825	0.8546	0.8306	0.9588
2006	0.5455	0.9694	-0.4707	0.7841	0.8809	0.8588	0.9622
2007	0.5128	0.9774	-0.5344	0.7349	0.8577	0.8519	0.9627
2008	0.4892	0.9713	-0.4441	0.7283	0.8595	0.8732	0.9571
2009	0.4663	0.9487	0.1027	0.7009	0.8369	0.8786	0.9521
2010	0.4205	0.9625	0.0758	0.7280	0.8122	0.8845	0.9529
2011	0.3952	0.9631	0.1862	0.8298	0.8439	0.8916	0.9553
2012	0.3599	0.9570	0.1982	0.8421	0.8589	0.8797	0.9478
2013	0.3150	0.9537	0.1871	0.8763	0.8805	0.7999	0.9505
2014	0.2795	0.9547	0.2296	0.9128	0.9082	0.7846	0.9548
2015	0.2562	0.9262	0.0014	0.8897	0.8786	0.6888	0.9172
2016	0.2298	0.9221	0.0412	0.8894	0.8800	0.7583	0.9074
2017	0.1983	0.9234	-0.0201	0.9136	0.8861	0.7613	0.9227
2018	0.1645	0.8964	-0.1682	0.9068	0.8800	0.6881	0.9016
2019	0.1205	0.8478	-0.1892	0.9144	0.8841	0.6718	0.8897
Log-rank test	0.0000						
Wilcoxon test	0.0000						

Table 22. Factors influencing export competitiveness of Bangladeshi Shrimp using dynamic ARDL simulations.

Variables	Coefficient	Standard Error	T-stat.
Cons	0.9721**	0.2488	2.39
GDP	-0.7160	0.6220	-1.15
△GDP	-0.0565	0.0622	-0.91
KOFEG	0.4250***	0.0448	2.95
△KOFEG	0.0846	0.0587	1.44
EPS	-0.0381**	.00335	-2.14
△EPS	-0.04327*	0.0539	-1.80
IQ	0.3681***	0.0423	3.87
△IQ	0.1229**	0.0399	2.58
TO	0.2284***	0.0346	3.82
△TO	0.011	0.093	0.12
TA	0.4104***	0.0182	3.57
△TA	0.0027	0.0020	1.32
TF	0.1044**	0.0233	2.19
△TF	0.1165**	0.0309	2.54
ECT(-1)	-0.6149***	0.1492	-4.68
R^2	0.6502	Prob > F	0.05**
Adjusted R^2	0.4456	N	30
Simulation	5000		

Note: ***, ** and * denotes significance at 1%, 5% and 10% level, respectively.

Appendix 2-Figures

Figure 1. Map location showing the study areas.

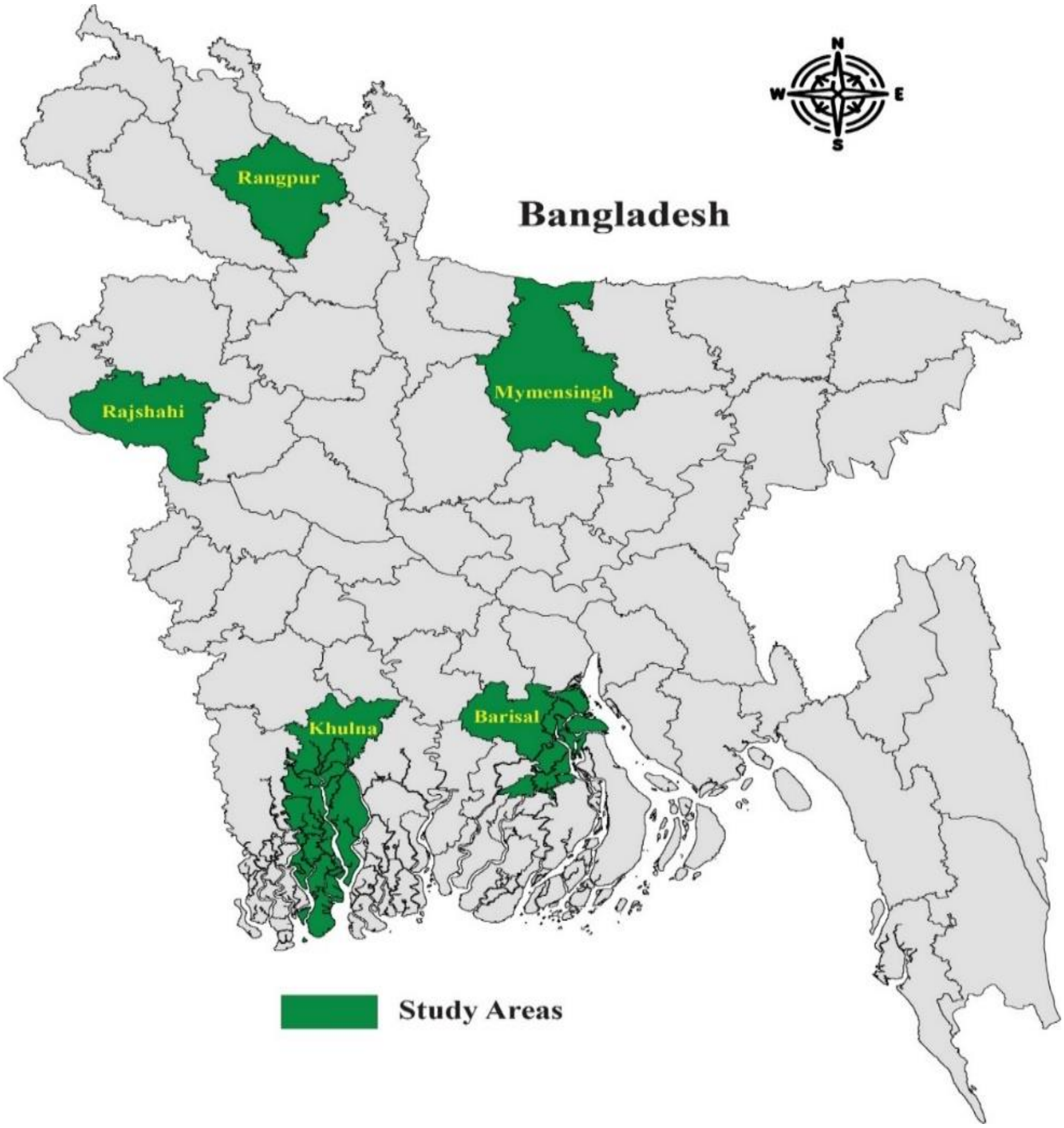


Figure 2: Fish consumption pattern over the years across income quantiles

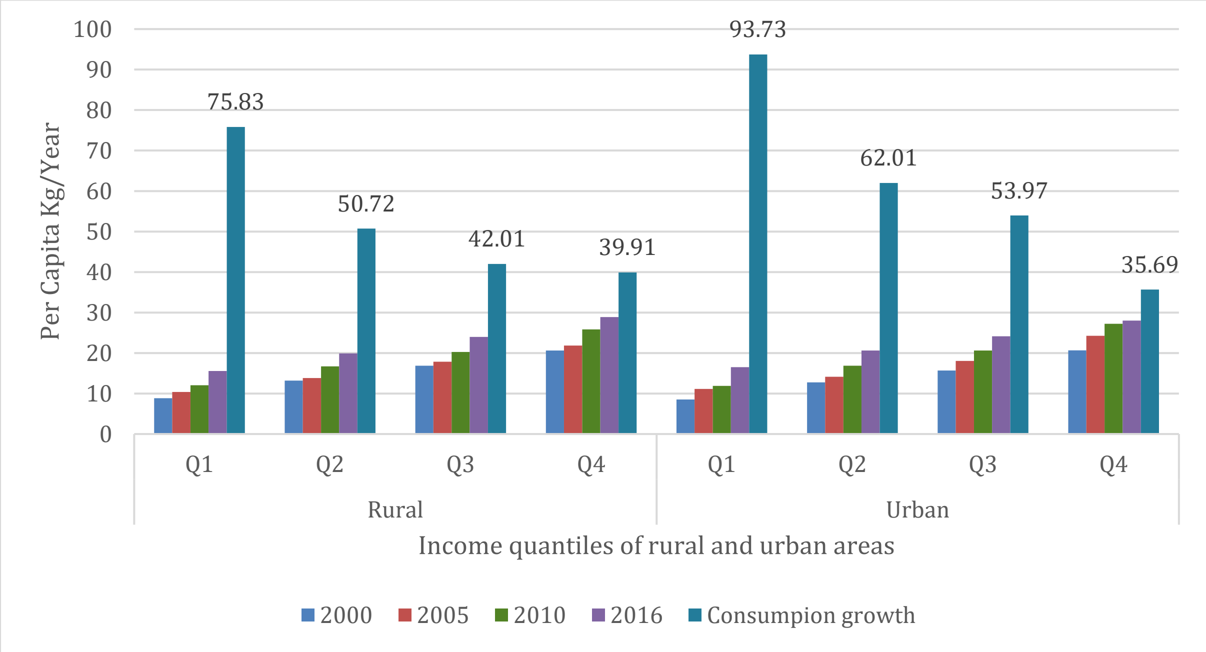


Figure 3: Pangasius consumption pattern across income quantile

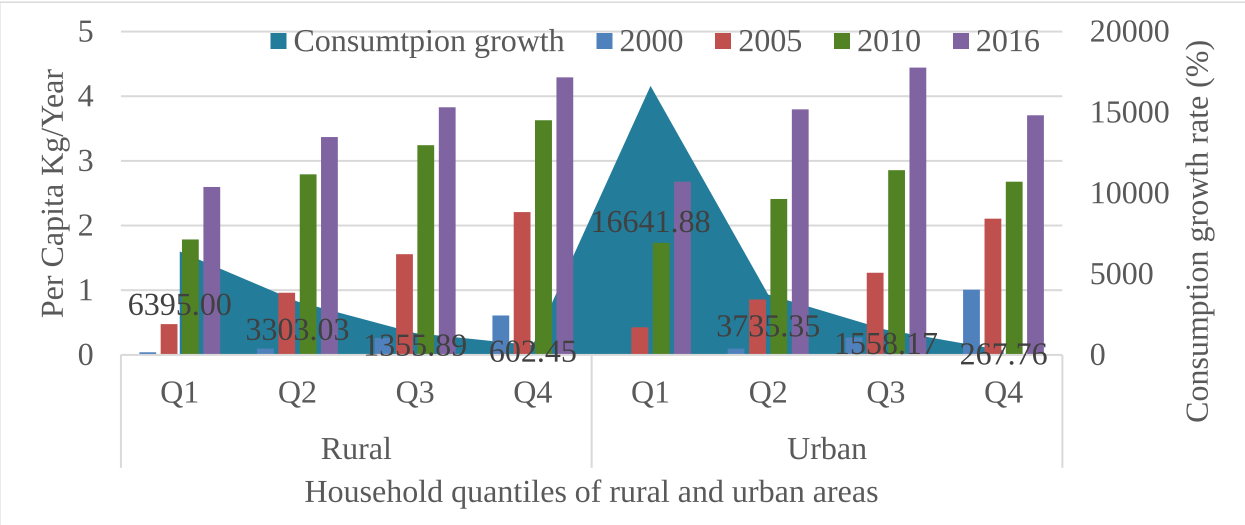


Figure 4: Tilapia/ Puti consumption pattern across income quantile

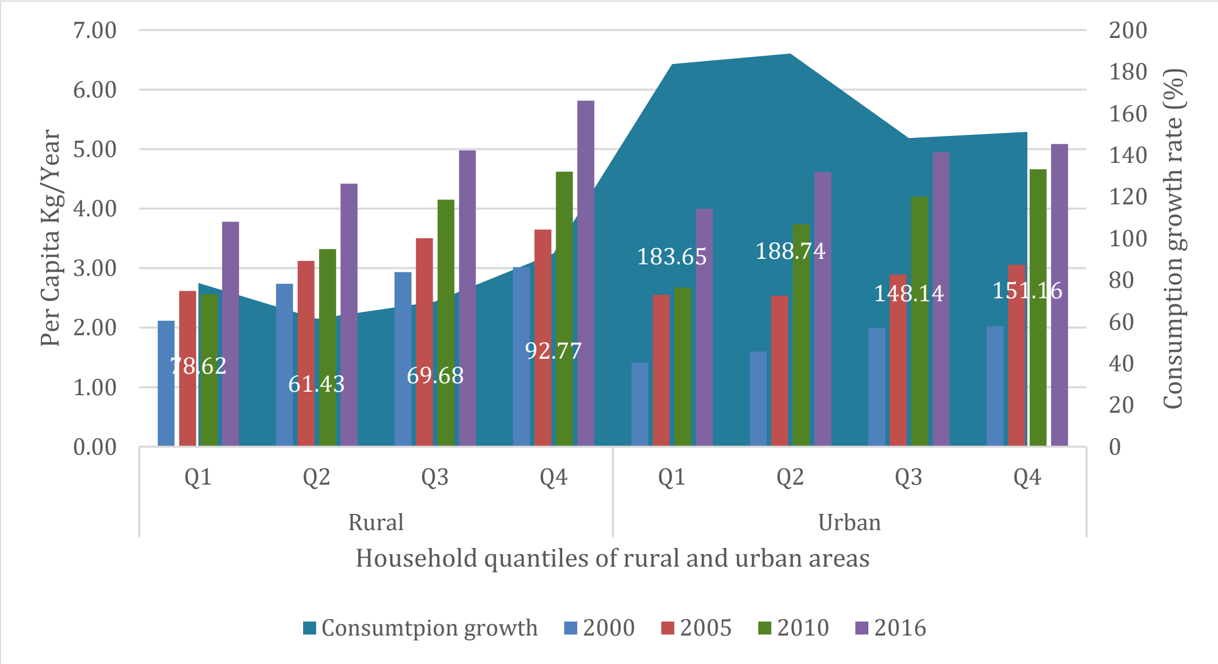


Figure 5: Exotic Carps Consumption Pattern across income quantile & geographic regions

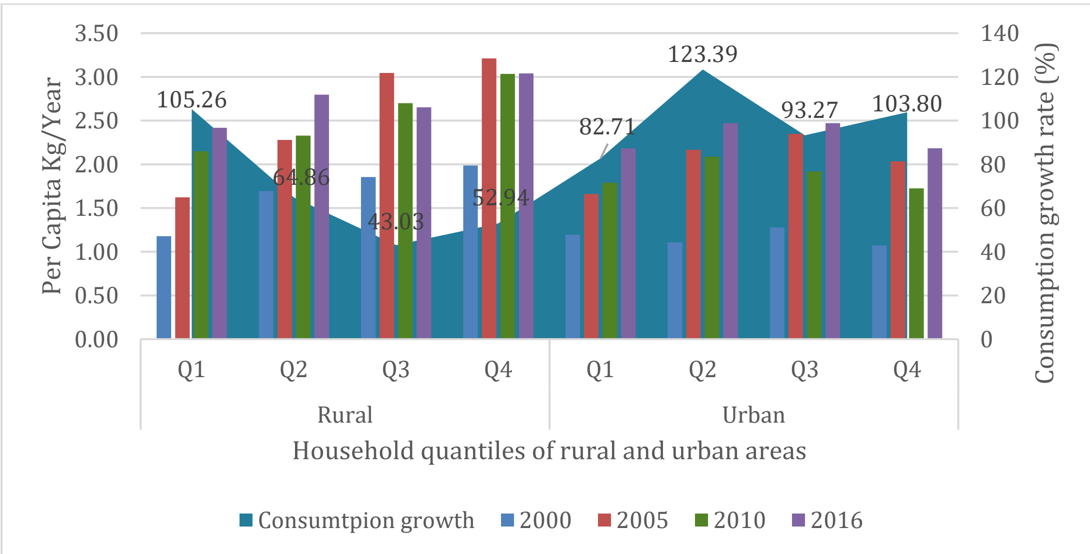


Figure 6: Rohu/Katla/Mrigel consumption pattern across income quantile

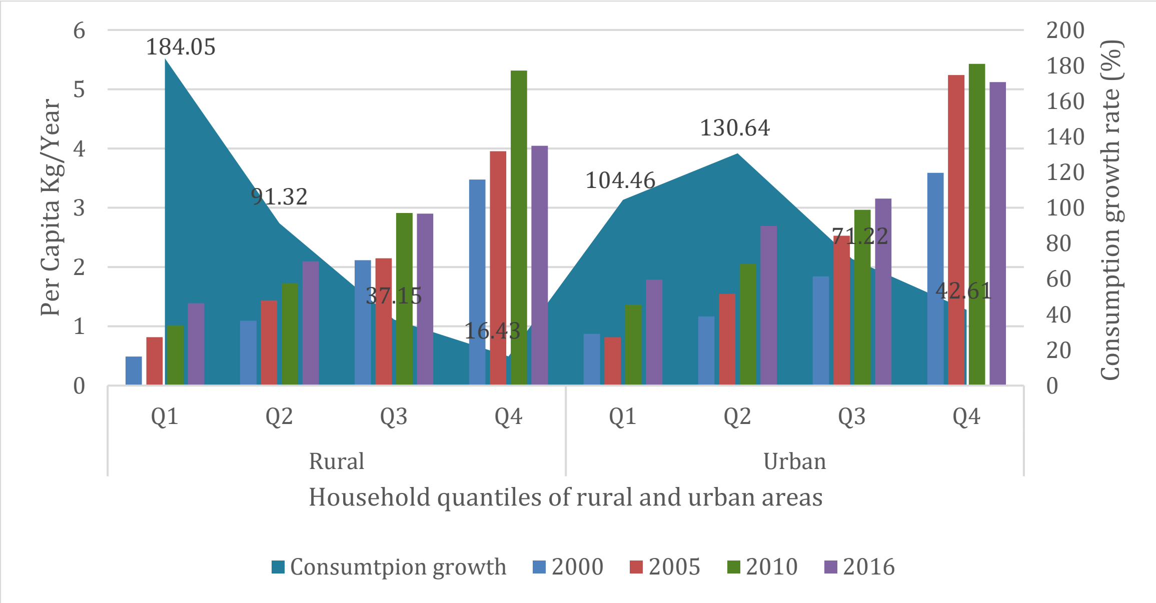


Figure 7: Hilsa consumption pattern across income quantile

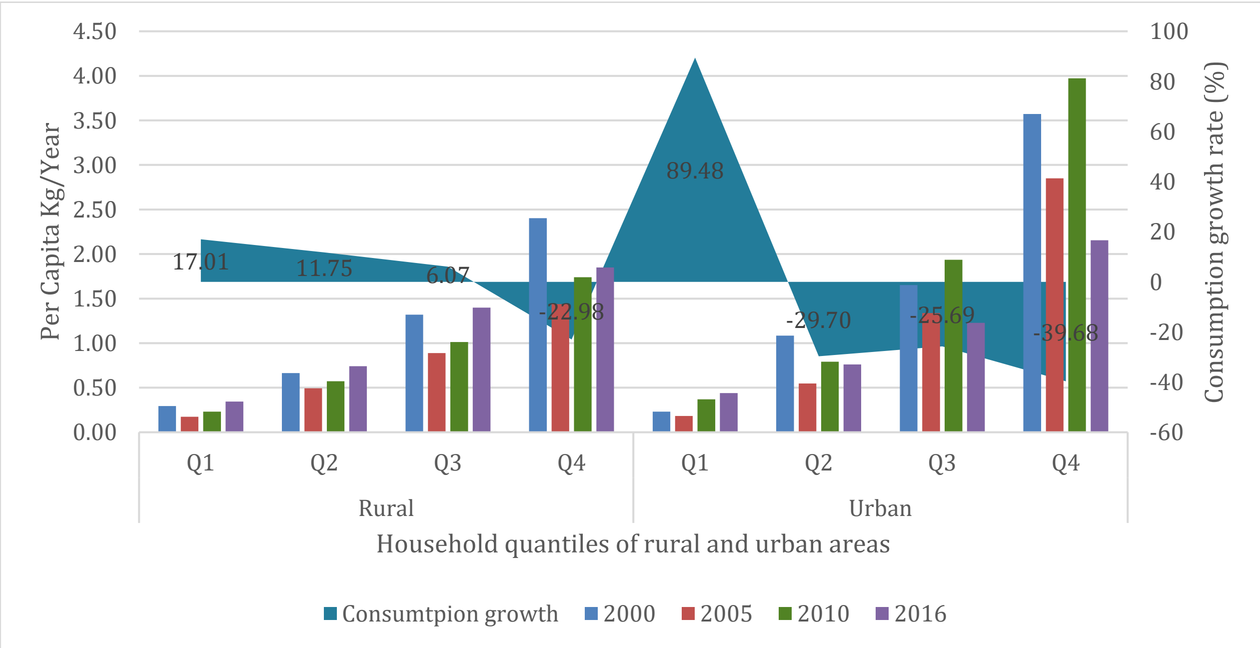


Figure 8: Shol/Gajar/Taki consumption pattern across income quantile

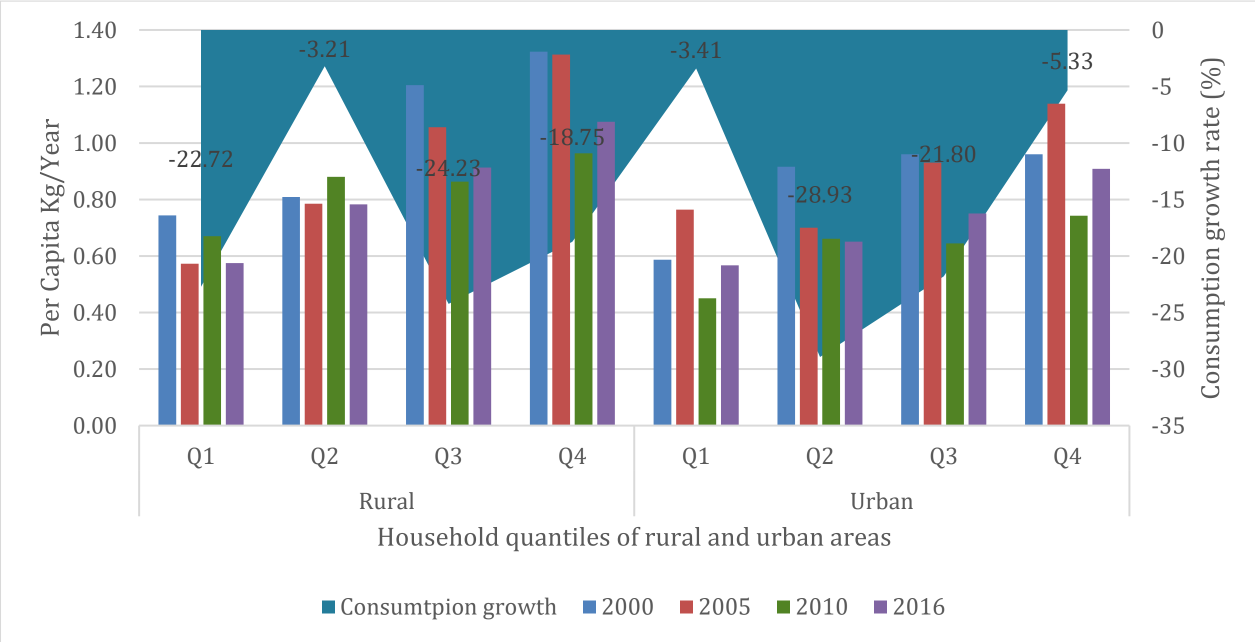


Figure 9: Magur/Shing consumption pattern across income quantile

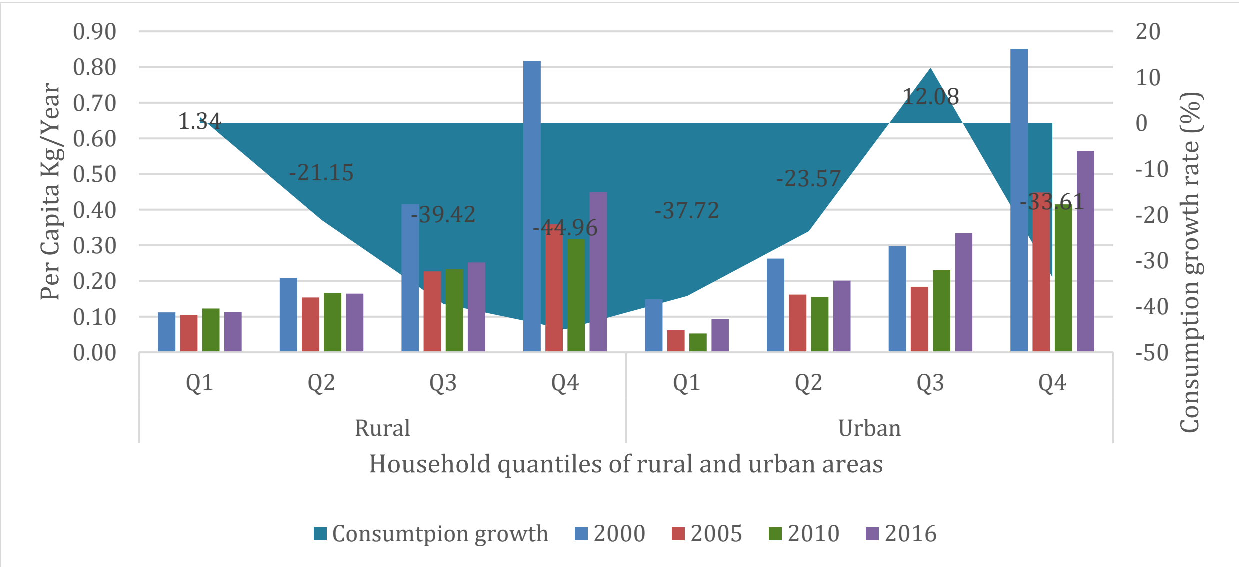


Figure 10: Mala/Kachki/Chapila consumption pattern across income quantile

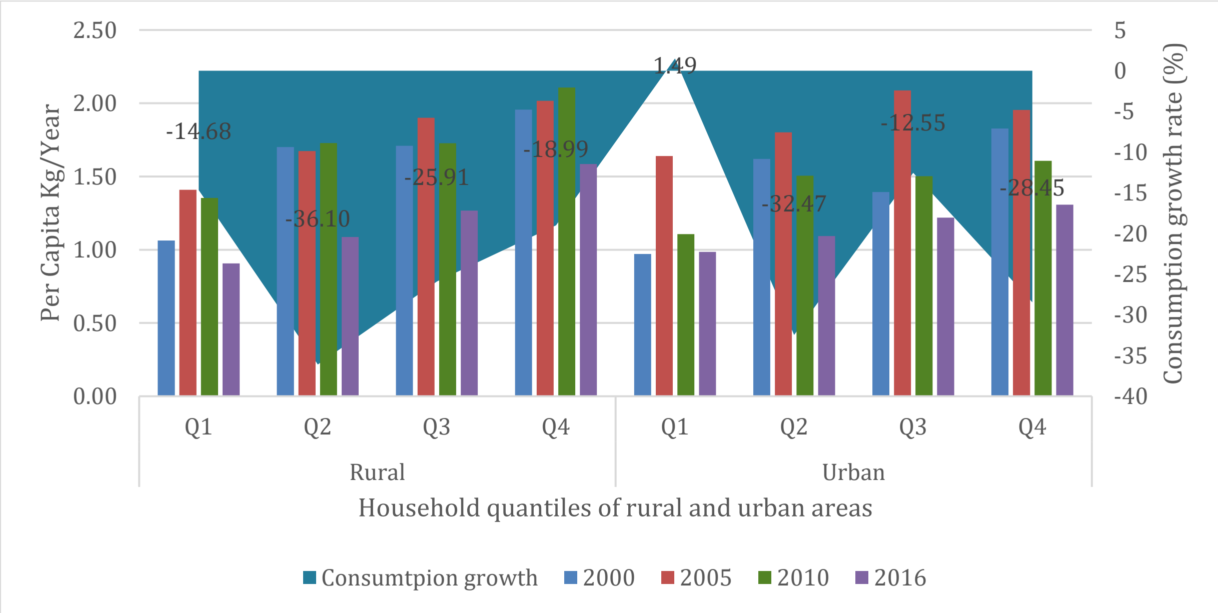


Figure 11. Changes in inputs price during COVID-19

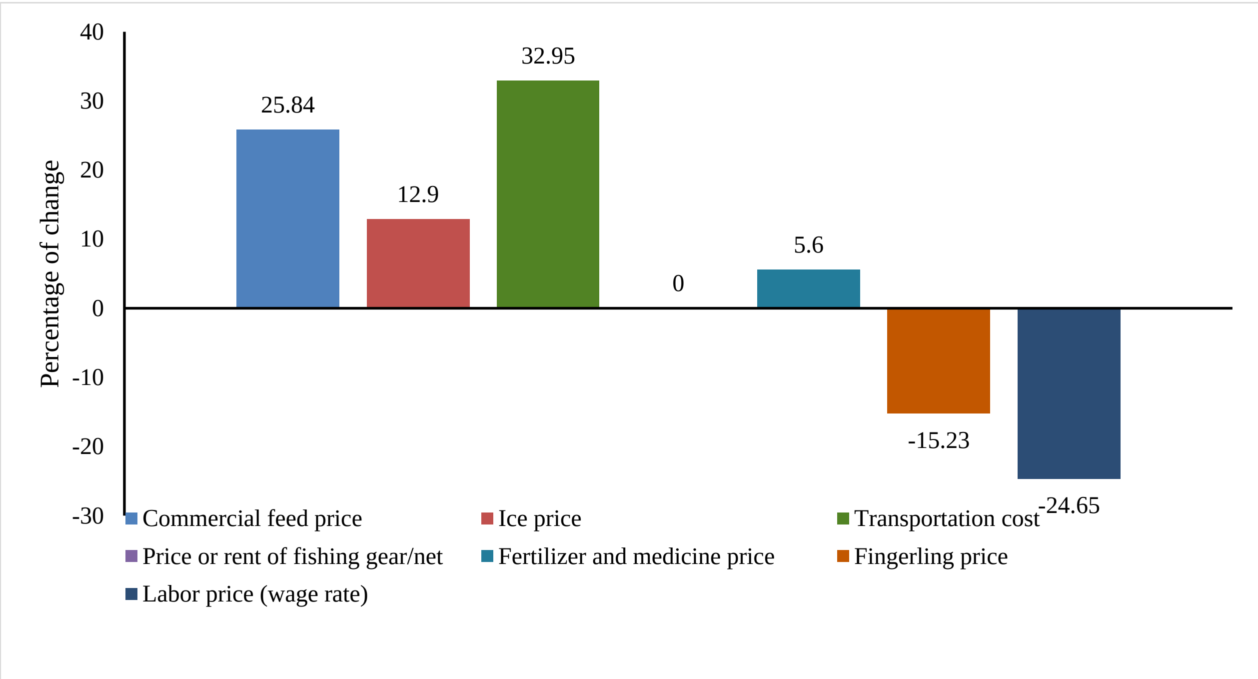


Figure 12. Strategies followed by the fish farmers and fishers to combat COVID-19.

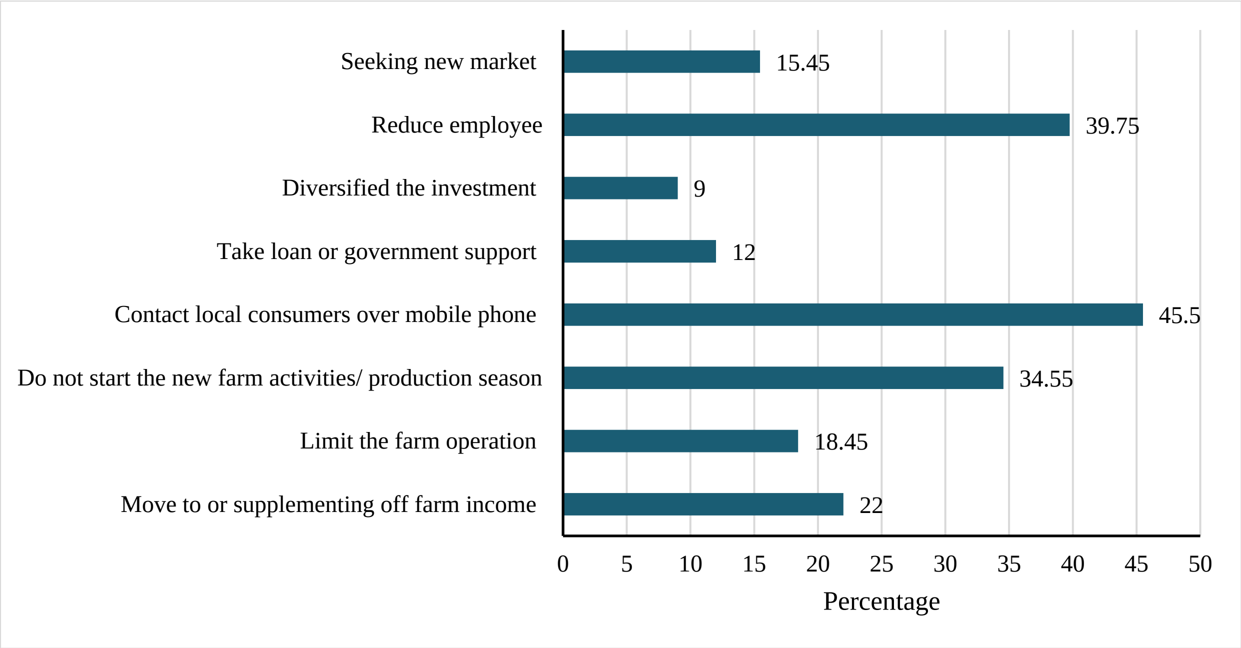


Figure 13. Strategies followed by the fish traders to handle the disruption of market forces

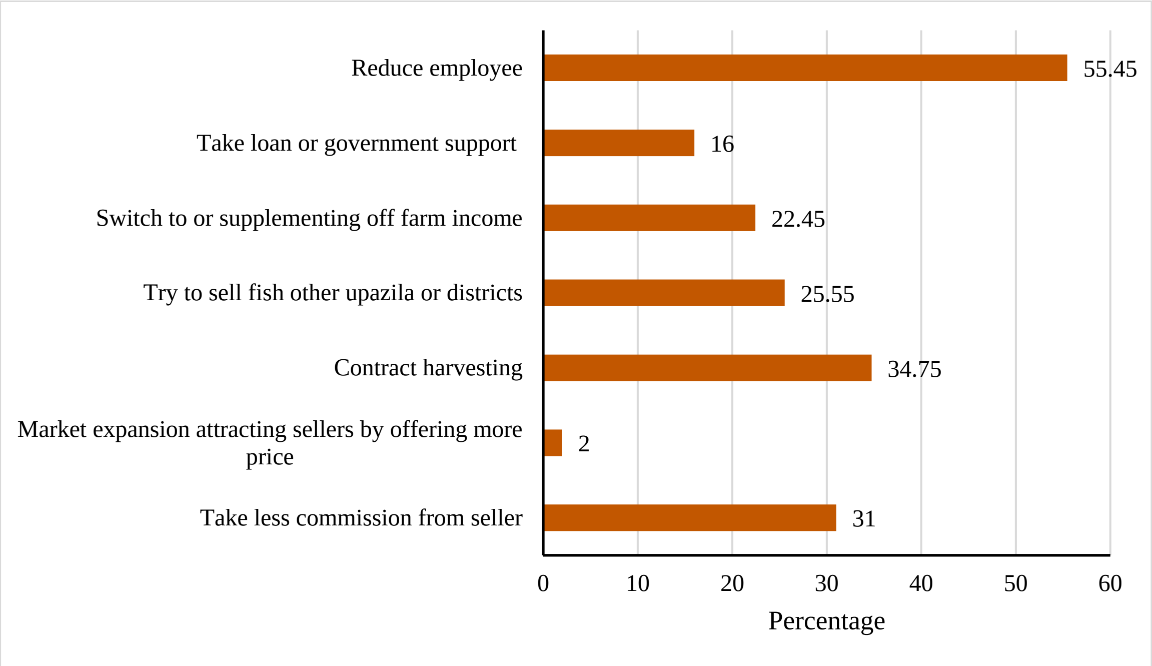


Figure 14. Shrimp export competitiveness of Bangladesh, China, India, Indonesia, Thailand, and Vietnam over the period of 1990 to 2019.

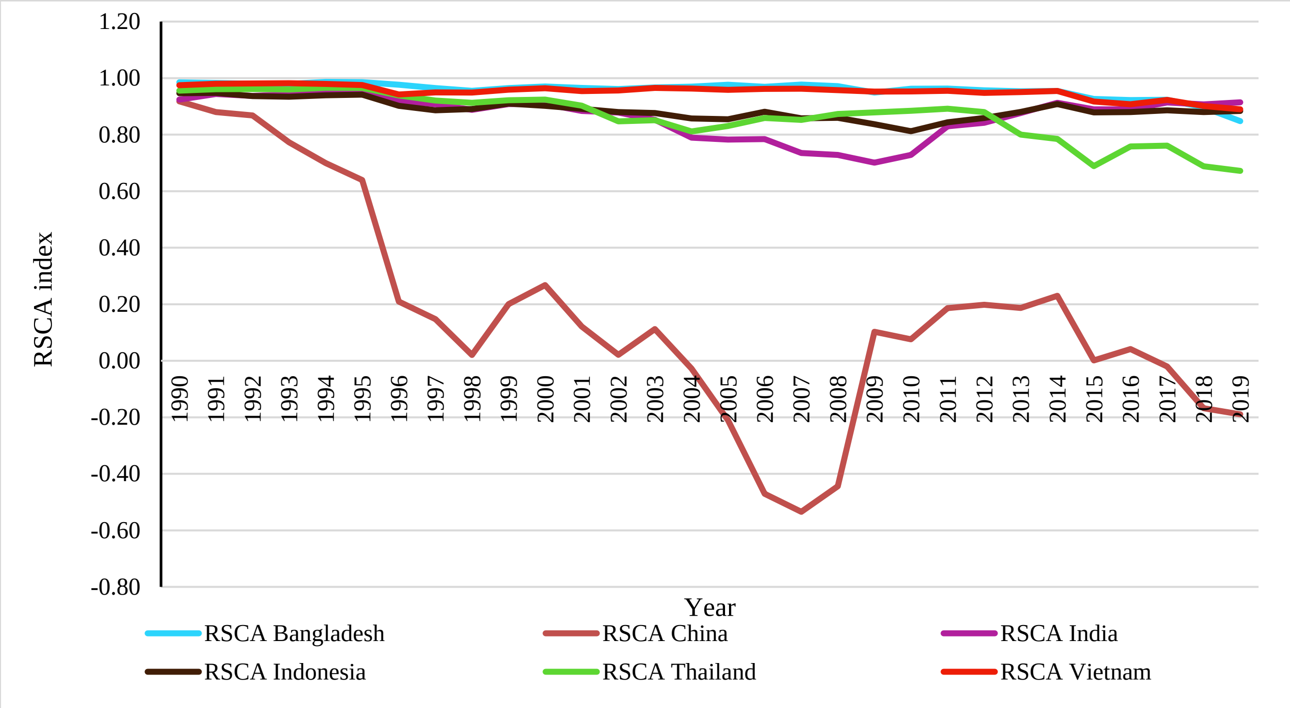
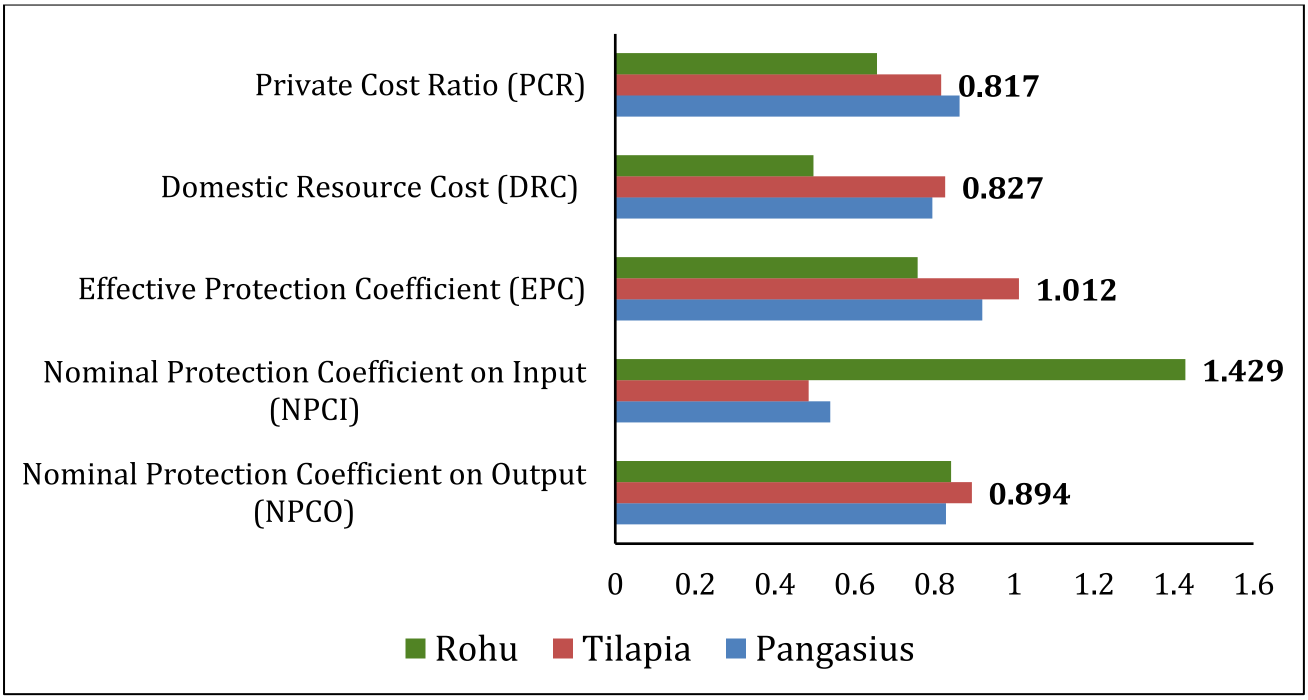


Figure 15. Export potentiality of pangasius, tilapia and major carp



Appendix 3: Description of Analytical Techniques and Econometric Models

1. Estimation of fish consumption and elasticity

We divide our estimation process into two stages. In stage one households are assumed to make their budget allocation on five sources of protein that include fish of all species group aggregated, meat, poultry and poultry eggs depending on their prices, per capita expenditure normalized by the Stone Price Index (SPI) of the protein sources, and the dummy variables of socio-demographic characteristics which are members of the households, age of the members, their gender, marital status of the household members, geographic locations of the households, rural or urban. In meat, we have considered beef, buffalo and mutton, poultry and poultry eggs constitute of hen and duck.

In stage two, we focus only on fish across the species group. We have incorporated the QUAIDS model in both stages of estimation. The QUAIDS model, with its quadratic nature, effectively captures the non-linear consumption behavior of households when it comes to various sources of protein. Simultaneously, it overcomes the limitations of linear demand functions, which assumed that marginal expenditures on commodities were identical for both affluent and less affluent households (Beach and Holt 2001). These assumptions restrict the categorization of goods solely as necessities or luxuries, disregarding the potential for some goods to be considered luxuries for individuals with lower incomes and necessities for those with higher incomes (Garcia et al. 2005). Given the fish, meat, poultry and poultry eggs market structures and consumption pattern in Bangladesh, we have developed the empirical model in two steps considering three main issues: i) weakly separable utility functions; ii) non-linearity in consumption behavior (i.e., quadratic income or expenditure terms); and iii) selection bias due to zero consumption. Following the approach used by Huang (1996), the nutrition elasticities are calculated. Preferences for fish, meat, poultry and poultry eggs have established a connection with the protein status of the households with the traditional framework of the demand estimation analysis.

Zero consumption of certain fish categories, as well as of fish as a group, and other protein sources is probable, and this can be attributed to three main factors: i) Differences in preferences among different groups of individuals (some households may choose not to consume certain fish species, meat, poultry and poultry eggs), ii) infrequent purchasing patterns, iii) misreporting of consumption data (Keen 1986). Furthermore, seasonal fluctuations are also responsible for the limited supply of certain fish species in the market, which consequently results in their non-consumption. The presence of zero observations causes selection bias in the estimation. As we have zero observations in the data, using standard continuous techniques will generate biased and inconsistent estimates due to the presence of random disturbances with non-zero means and correlations with the exogenous variables.

To deal with the sample bias owing to the presence of zero observations, we have followed the Tobit model. In this method the limited dependent variable model of Tobin (1958), provides a probability of observing zero consumption. The Tobit regression model determines the probability of household consumption of a particular fish species, fish as aggregated, meat, poultry, and poultry egg. The decision of a household to consume or not is defined as a dichotomous choice problem. The estimation of this dichotomous indicator is done using the Tobit model. The Tobit model, also known as the Tobin's probit model, provides a way to estimate the demand equation by accommodating the possibility of zero consumption. The probability is then used to calculate the Inverse Mills Ratio (IMR) of each household. We incorporate the estimated IMR in the demand estimation.

When all the system of demand equations are estimated jointly, the adding-up restriction implies that the disturbances will have a singular variance-covariance matrix. The reason behind this singularity problem is the sum of left-hand side variables of the equation is equal to the right-hand side variables owing to the adding-up restrictions. To overcome this problem of singularity, following the Barten (1969) method, we dropped one of the equations when estimating the system of equations. Estimating the system of equations, the equation for meat is dropped. And, for the estimation, equation for sea fish is dropped. The parameters of the dropped share equations are calculated residually from the remaining equations using the formula of the adding-up restriction. The models in the equations (1) and (2) are estimated using the Seemingly Unrelated Iterative Regression (ITSUR) method in STATA 16 software (StataCorp LP, College Station, TX).

The lnP_f is the Stone Price Index (SPI) (Stone 1953) of the sources of protein, computed as:

$$lnP_f = \sum_{j-1}^{m} w_j \, lnPfd_j$$

where w_j and Pfd_j are the budget shares and prices of food j.

A popular approach, quadratic extension of the AIDS (QUAIDS) model is utilized to estimate a set of demand equations for different species of fish, and sources of protein. Prior studies by Blundell, Pashardes, and Weber (1993), as well as Garcia, Dey, and Navarez (2005) have also used this approach, albeit no one has included various sources of protein, that include meat, poultry, and poultry eggs. Thus, in our study, we have considered two stages of estimation. In stage one, we have taken into account all sources of protein, fish, meat, poultry and poultry eggs in aggregated form. The functional form of the budget share of the sources of protein can be expressed as $S_i = f(P_f, P_M, \ P_P, P_{PE}, M/P, M/P^2, V)$. S_i is the budget share of fish, meat, poultry, and poultry eggs. $P_f, P_M, P_{Mu}, P_P, P_{PE}$ are the nominal prices of the sources of protein, fish, meat, poultry, and poultry eggs. M/P is the deflated per capita expenditure of fish, meat, poultry, and poultry eggs. It is deflated by the SPI of the expenditure. $(M/P)^2$ is the square term of the deflated per capita expenditure. V denotes the vector of aforementioned socio-demographics.

To correct the sample bias generated by the presence of the zero observations in the sample, Inverse Mills Ratio (IMR) are first generated from the Tobit model and incorporated in the QUAIDS model. The dependent variables of the Tobit model are binary that identifies whether the household will purchase any type of protein source or not. For instance, $Y_i = 1$ if the ith protein source that is consumed by a household, and $Y_i = 0$ otherwise, $i =$ aggregated protein sources like fish, meat, poultry, and poultry eggs. For the ith protein source, that a household will consume is defined as

$P[Y_i = 1] = f(P, F, H, G, A, C, T, R)$. P is the vector of prices of fish, meat, poultry and poultry eggs. F means the per capita expenditure of fish, meat, poultry and poultry eggs. H, G, A, C, T, R are the vectors of dummy variables for household members, gender, age, religion, marital status, and geographic areas. This probability is then used to calculate the IMR. The Inverse Mills Ratio (IMR) includes the truncation of latent variables when estimating demand systems. The Tobit is defined as:

$Q_i = X_i\delta + U_i$ if $X_i\delta + U_i > 0$

$Q_i = 0$ if $X_i\delta + U_i \leq 0$

where Q_i is the dependent variable, X_i is the vector of independent variables, δ is the vector of unknown coefficients, and U_i is an error term.

The IMR is generated from the Tobit model. It is defined as:

For $Y_i = 1$ $\qquad IMR_i = \frac{\emptyset(P[Y_i=1])}{\psi(P[Y_i=1])}$

For $Y_i = 0$ $\qquad IMR_i = \frac{\emptyset P[Y_i=1]}{\psi\left(1-(P[Y_i=1])\right)}$

where $\emptyset$ and ψ are the density and cumulative probability functions respectively.

We introduce the estimated IMRs in the estimations of share equations. Share equations are then specified as the quadratic extension of the AIDS[2] model or QUAIDS model:

$$w_i = \alpha_{i0} + \sum_{j-1}^{k} \mu_{ij} \ln P_j + \vartheta_{i1}\left[\ln\left({}^{M}/_{P}\right)\right] + \vartheta_{i2}\left[\left(\ln\left({}^{M}/_{P}\right)\right]^2 + \sum_{j-1}^{k} \delta_{ij} H_j + \sum_{j-1}^{k} \varphi_{ij} G_j + \sum_{j-1}^{k} \lambda_{ij} A_j + \sum_{j-1}^{k} \omega_{ij} C_j + \sum_{j-1}^{k} \tau_{ij} T_j + \sum_{j-1}^{k} \gamma_{ij} R_j + \pi_i IMR_i + \varepsilon_i$$

where w_i are the budget shares of the sources of protein at the aggregate level, fish, meat, poultry and poultry eggs, and fish across the species groups. P_j is the vector of prices consists of Stone-Lewbel

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[2] AIDS is the Almost Ideal Demand System Model, introduced by the Deaton and Muellbauber. To know more about the model please refer Deaton, Angus, and John Muellbauer. "An almost ideal demand system." The American economic review 70, no. 3 (1980): 312-326.

(SL) cross-section of prices of sources of protein at the aggregate level and fish across the species groups namely hilsa, Indian carps, pangasius, airbreathing fish (magur, shing and koi), exotic carps (silver carp, grass carp and mirror carp), shol-gajar-taki, tilapia-puti, small fish species (mala-kachi-chapila), shrimp, dried fish, baila-tapashi-tangra-other fish species, and sea fish. P is the Stone Price Index (SPI), and ${}^{M}/_{P}$ is the deflated expenditure for the sources of protein at the aggregate level and fish across the species, which is included in the linear and squared forms in the model. The parameters to be estimated are α, μ, ϑ, δ, φ, λ, ω, τ, γ and π.

Two restrictions are imposed on share equations: 1) homogeneity of zero in prices, and 2) symmetry. The homogeneity of degree zero in prices suggests that the consumers are unaffected by the illusion of money; instead, they respond to real prices, rather than just nominal prices. The symmetry restriction indicates that the effect of a change in the price of a fish species or any type of protein sources (fish in aggregated form, meat, poultry and poultry egg) i on the demand of fish species or any other type of protein sources *j* is the same as the effect of a change in the price of a fish species or any type of protein sources j on the demand of fish species or any other type of protein sources i that is $\mu_{ij} = \mu_{ji}$. In addition to this, symmetry restriction necessitates the ratio of the coefficients of income (ϑ_{i1}) and its squared term (ϑ_{i2}) must be equal to a constant, $\widetilde{\omega}$, that is $\frac{\vartheta_{i1}}{\vartheta_{i2}} = \widetilde{\omega}$. The homogeneity and symmetry restrictions are defined as:

Homogeneity: $\sum_{j-1}^{k} \mu_{ij} = 0$

Symmetry: $\mu_{ij} = \mu_{ji}, {}^{\vartheta_{11}}/_{\vartheta_{12}} = {}^{\vartheta_{21}}/_{\vartheta_{22}} = \cdots = {}^{\vartheta_{n1}}/_{\vartheta_{n2}} = \widetilde{\omega}$

Calculation of Elasticities

Expenditure Elasticity for sources of protein at the aggregate level; fish, meat, poultry and poultry eggs, individual species groups of fish (η_i):

$$\eta_i = 1 + ((\vartheta_{i1} + 2\vartheta_{i2} \ln y)/w_i)$$

Uncompensated price elasticity (Marshallian price elasticity):

$$\xi_{ij} = \left(\frac{b_{ij}}{w_i}\right) - (\vartheta_{i1} + 2\vartheta_{i2} \ln y) \left({}^{w_j}/_{w_i}\right) - k_{ij}$$

where k_{ij} denotes the Kronecker delta, which takes the value one for own-price elasticity (that is $i = j$) and zero for cross-price elasticity ($i \neq j$), and w_i are the budget shares of the sources of protein at the aggregate level, fish, meat, poultry and poultry eggs, and fish across the species groups. After the estimation of expenditure elasticity and uncompensated elasticity, the compensated (Hicksian) own-price and cross-price elasticities are calculated using the Slutsky equation in elasticity form:

$$\xi_{ij}^H = \xi_{ij} + w_j\eta_i$$

where ξ_{ij}^H represents the compensated or the Hicksian price elasticity.

Following the Huang's approach (1996), we have calculated the protein elasticities from the demand elasticities. The demand elasticities are calculated first, then multiplying those with nutrient (protein) consumption share of sources of protein at their aggregated level, and fish across the species, the protein (nutrient) elasticity is calculated. For instance, the general calculation of protein elasticity, say N, for ℓ nutrients and n sources of protein, can be obtained as a product of multiplying matrix S by matrix D as:

$$N = S * D$$

where N is the $\ell \times (n + 1)$ matrix of nutrient elasticties in response to changes of food prices and income, S is the $\ell \times n$ matrix with consumption share of protein of fish, meat, poultry, poultry eggs and fish across all species, and D is the $n \times (n + 1)$ matrix of demand elasticties. For nutrient, we have only considered protein.

2. Econometric model for analyzing effects of access to trade credit and its determinants

Stochastic Meta Frontier Model

The production performance of a farm mainly depends on how efficiently the production is managed and on the production technology in use. The used production technology (i.e., the means of converting inputs to outputs) is heterogeneous between the farms because of variation in scale and type of operation and knowledge of the producers, which are directly linked with the farms' financial ability. However, the traditional Stochastic or DEA based measurement of efficiency fails to reflect region, type, scale and other inherent attributes of decision-making unit (i.e., farms) while estimating technical efficiency. Thus, Stochastic Meta Frontier (SMF) is used to measure the technical efficiency differentials between groups (trade credit users and non-users) while emphasizing the heterogeneity of production technology to reflect type, scale and other unobserved inherent attributes of the farms. Therefore, all observed farms are divided into two groups assuming production technology heterogeneity between users and non-users of trade credit is because the access to credit stimulates the adoption of improved technology (Mitra et al., 2019; Tsinigo & Behrman, 2017 and Farrin & Miranda, 2015).

A general Stochastic Frontier for j^{th} group with N_j observed farms can be written as (for details see e.g., Orea and Kumbhakar, 2004 and Battese et al., 2004):

$$y_{ij} = f(x_{ij}, \beta)e^{(v_{ij}-u_{ij})}, i = 1,2, \dots \dots, N_j \qquad Eq. (1)$$

where, y_{ij} is the output of the i^{th} farm in the j^{th} group; x_i is a vector of inputs used by the i^{th} farm in the j^{th} group; $i = 1, 2, \dots \dots, N$ for farms; v_i is the error term; and u_i is the technical efficiency of farm i. Both v_i and u_i are assumed to be independent and identically distributed (iid) with variance $\sigma^2{}_v$ and $\sigma^2{}_u$ respectively, which means that the variables have the same probability of distribution and are mutually independent.

The Eq. (1) estimating the efficiency for j^{th} group can written as follows by omitting the subscript j for simplicity:

$$y_i = f(x_i, \beta)e^{(v_i-u_i)} \equiv e^{x_i\beta+v_i-u_i} \qquad Eq. (2)$$

The stochastic meta-frontier for farms in both groups (user and non-users of trade credit) is expressed by (O'Donnell et al., 2008):

$$y_i = f(x_i, \beta^*)e^{(v^*{}_i-u^*{}_i)} \equiv e^{x_i\beta^*+v_i{}^*-u_i{}^*}, \qquad I = 1, 2, \dots \dots, N \qquad Eq. (3)$$

where, $N = \sum_{j=1}^{R} \quad N_j$ is the total number of observed farms in all R groups (here two groups) and the assumptions for the rest of the variable are analogous to those for the Eq. (1).

Since, the differences in efficiency between the groups depend on differences in how efficiently the production process is managed and in the production technology in use. Therefore, the technology difference between the group can be represented by ratio of group technical efficiency to meta-technical efficiency score as given below:

$$TGR_i = \frac{e^{x_i\beta}}{e^{x_i\beta^*}} \qquad Eq. (4)$$

where, TGR_i technology gap ratio of farm i indicating that technology gap for the farm in the given group relative to the technology available in the whole industry.

Propensity score matching estimator (PSM)

The propensity score matching (PSM) estimator used to approximate and quantify sources and size of the drain and gain of trade credit to farms' while probit regression is used for estimating factors influencing the probability of trade credit financing.

Farmers using trade credit are characteristically different from those who are not using trade credit and are not random. Further, responses based on direct interview in non-experimental settings are likely to suffer from selection bias. Therefore, following recent empirical literatures on agricultural economics (i.e., Mitra et al., 2021; Briggeman et al., 2009; Joo et al., 2014; Abadie et al., 2004; Abadie & Imbens, 2011; Dehejia & Wahba, 2002) the PSM is used comparing sources and size of drain and gain of TC controlling for selection bias.

The PSM allows examining the effects of treatment given to a group in the presence of a corresponding control group (Mitra et al., 2021; Khanal & Omobitan, 2020). The Ordinary Least Square (OLS) based estimate provides biased and inconsistent results if there is presence of selection bias. This study needs to account for selection bias since the survey respondents are divided into trade credit users and non-users, which are not random and are characteristically different (Khan, 2012; Moli et al., 2021). Thus, bias may originate from differences in both observable and unobservable characteristics between two groups (Ravallion, 2001).

PSM estimators are based on balancing the distribution of observed attributes of trade credit users and non-users; and computing differences after matching based on observed attributes. PSM can efficiently estimate the effects of treatment variables because similar groups are formed conditional on their basic characteristics; and thus, the factor causing difference between groups is only the treatment variable.

PSM is applied in three steps: the first step is that propensity score is estimated using a probit model with the binary treatment variable (trade credit use status of farmers) to measure farmers tendency to use trade credit. The propensity score varies between 0 and 1; the larger the score, the farmer is more likely to use trade credit. The second step the untreated units are matched with the control unit based on the estimated propensity score using an appropriate matching algorithm such as “nearest neighbor”, “exact”, “full” or “optimal” each of which has limitations and benefits over others. In the third step, impacts of the treatment on outcome variables are calculated with the matched sample (usually as mean differences) and the standard errors. The most perceived benefit of following these steps is that it minimizes the selection bias that might be present in the observed data sets.

The probit model

The probit model identifying factors influencing probability of financing through trade credit in multiple regression framework can be presented in generic form as:

$$y = \int (x_1, x_2, x_{3,} x_4 \dots \dots \dots \dots \dots \dots \dots x_n) \qquad Eq. (4)$$

where the dependent variable y is the binary response to trade credit recorded as ‘1’ if farmer avails trade credit otherwise ‘0’ and $x_1, x_2, x_{3,} x_4 \dots \dots \dots \dots \dots \dots \dots x_n$ represents a set of independent variables influencing the farmers’ decision to use or accessibility to trade credit. Because of the nature of dependent variables, a nonlinear model is appropriate for estimating the relationship. The most common methods are probit and logit because of its ability to transform the regression model to provide fitted values and estimated probabilities between ‘0’ and ‘1’. The both methods are relatively same, the main difference between the two are in the nature of their distribution. Logit takes a logistic distribution while probit takes normal distribution and thus the choice of the model depends on the distribution assumption. This study chose the probit method assuming that the error term is normally distributed, these methods are frequently used in agricultural economic studies (Khanal & Omobitan, 2020). The marginal effect indicates the effect a unit change in each independent variable used in the study has on the outcome variable (y) i.e., trade credit decision of farmers. The marginal effect is given by:

$$Marginal\ effects_{probit} = \frac{\partial y}{\partial x_j} = \beta_j \emptyset(x'\beta) \qquad Eq. (5)$$

where β_j is the coefficient on variable x_j from probit regression and $\emptyset(,)$ denotes the standard normal density.

3. Econometric model for analyzing effects of price and non-price factors on fish price:

Since the market price of fish is influenced by a variety of factors, a clear relationship has been established between market fundamental characteristics connected to pricing as well as macroeconomic variables. Therefore, the empirical model for this study can be shown as follows:

$$\mathrm{FP_t} = \phi \mathrm{X_t} + \delta \mathrm{I_t} + \varepsilon_\mathrm{t} \quad (1)$$

where FP_{it} is the market price of carp fish, X_{it} stands for the price factors, I_{it} defines the macroeconomic non-price determinants, and ε_{it} denotes the error term. We converted all variables into natural log form to eliminate multiple units of parameters and normalization (Hossain et al., 2022c,d). To put it another way, transforming data into logarithms makes coefficients as elasticities easier to interpret (Dahir and Mahi, 2021). A log-linear model can be used to represent the expanded version of Eq. (1):

$$\mathrm{lnFP_t} = \alpha_0 + \alpha_1 \mathrm{lnCP_t} + \alpha_2 \mathrm{lnSP_t} + \alpha_3 \mathrm{lnMP_t} + \alpha_4 \mathrm{lnFWRP_t} + \alpha_5 \mathrm{lnFCP_t} + \alpha_6 \mathrm{lnGDP_t} + \alpha_7 \mathrm{lnINF}_t + \alpha_8 \mathrm{lnPRD}_t + \varepsilon_\mathrm{t} \quad (2)$$

where lnFP is the natural logarithm of the market price of major carp. lnCP, lnSP, lnMP, lnFWR denote the log conversion of corn price, soybean price, mustard rice, and fisheries wage rate, respectively, while combinedly these four determinants represent the price factors i.e., $\mathrm{X_{it}}$ of Eq. (1). In addition, lnFC, lnGDP, lnINF, and lnPRD signify the log conversion of annual per capita fish consumption, GDP per capita, inflation rate, and total annual production of major carps, respectively which represents the non-price part i.e., $\mathrm{I_{it}}$ of Eq. (1). The coefficient of CP is expected to positive ($\alpha_1 = \frac{\vartheta lnFP_t}{\vartheta lnCP_t} > 0$). Similarly, the coefficients of SP, MP, and FWR should be greater than zero ($\alpha_2 = \frac{\vartheta lnFP_t}{\vartheta lnSP_t} > 0;\ \alpha_3 = \frac{\vartheta lnFP_t}{\vartheta lnMP_t} > 0;\ \alpha_4 = \frac{\vartheta lnFP_t}{\vartheta lnFWR_t} > 0$); implying that these variables have a positive effect on fish price. If corn, soybean and mustard prices, and fisheries wage rates rise, fish farmers will have to pay more for operating the production process, resulting in increased production costs. As a result, producers would expect a higher fish price. The elasticity of FC should be greater than zero ($\alpha_5 =$

$\frac{\vartheta lnFP_t}{\vartheta lnFC_t} > 0$) because as fish consumption rises, so does demand, which in turn raises the price of fish. The coefficient of GDP is projected to be greater than zero ($\alpha_6 = \frac{\vartheta lnFP_t}{\vartheta lnGDP_t} > 0$), if per capita income grows, so does purchasing power, which leads to an increase in the market price of fish. The parameter of INF is expected to have a positive sign ($\alpha_7 = \frac{\vartheta lnFP_t}{\vartheta lnINF_t} > 0$), as a consequence of the devaluation of money, customers will have to pay more for a given quantity of fish if inflation grows; hence, fish prices will rise. The parameter of PRD is expected to be negative ($\alpha_8 = \frac{\vartheta lnFP_t}{\vartheta lnPRD_t} < 0$), if production is considerably expanded, the market will become overcrowded, lowering the price of fish. It's completely in accordance with economics' supply-demand paradigm.

This study used the novel dynamic ARDL estimator to investigate the predictors' short and long-run elastic effects on the dependent variables; however, the series had to have a particular integration order before the estimation of the final empirical model. As a result, the ADF and PP unit root tests were used to investigate the series' integration order as a first step. Second, the ARDL bounds technique was used to see if the series were cointegrated. According to Pesaran et al. (2001), the bound test model was developed as follows:

$$\begin{aligned}\Delta(\mathrm{lnFP})_t = {} & \varphi_0 + \varphi_1 \mathrm{lnFP}_{t-1} + \varphi_2 \mathrm{lnCP}_{t-1} + \varphi_3 \mathrm{lnSP}_{t-1} + \varphi_4 \mathrm{lnMP}_{t-1} + \varphi_5 \mathrm{lnFWR}_{t-1} \\ & + \varphi_6 \mathrm{lnFC}_{t-1} + \varphi_7 \mathrm{lnGDP}_{t-1} + \varphi_8 \mathrm{lnINF}_{t-1} + \varphi_9 \mathrm{lnPRD}_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta \mathrm{lnFP}_{t-i} \\ & + \sum_{i=1}^{p} \beta_2 \Delta \mathrm{lnCP}_{t-i} + \sum_{i=1}^{p} \beta_3 \Delta \mathrm{lnSP}_{t-i} + \sum_{i=1}^{p} \beta_4 \Delta \mathrm{lnMP}_{t-i} + \sum_{i=1}^{p} \beta_5 \Delta \mathrm{lnFWR}_{t-i} \\ & + \sum_{i=1}^{p} \beta_6 \Delta \mathrm{lnFC}_{t-i} + \sum_{i=1}^{p} \beta_7 \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{p} \beta_8 \Delta \mathrm{lnINF}_{t-i} + \sum_{i=1}^{p} \beta_9 \Delta \mathrm{lnPRD}_{t-i} \\ & + u_t \qquad (3)\end{aligned}$$

where u_t highlights the error term, p indicates the lag length, t-i represents the optimal lags selected, and Δ indicates the change operator. Moreover, φ's and β's is long- and short-run parameters, respectively which need to be explored. The null (H_0) and alternative (H_1) hypotheses in the bound test are written as follows:

H_0: No cointegration

H_1: cointegration

If the upper I(1) is smaller than the F value obtained, the variables are cointegrated. If, on the other hand, the I(0) value takes precedence over the F value, the series do not have cointegration. Finally, the judgment becomes inconclusive if the computed F value falls between the I(0) and I(1) (Islam et al., 2021; Agboola et al., 2022).

After establishing cointegration, this research adopted dynamic ARDL simulations to demonstrate our model's short and long-run estimations. Jordan and Philips (2018) developed the DARDL estimator to solve the shortcomings of the traditional ARDL approach. The findings of the ARDL model are particularly challenging to comprehend and interpret since they frequently involve numerous or differential lags (Musah, 2022). Furthermore, if the convergence speed to the long-run relationship is sluggish and the time dimension is insufficient, sampling uncertainty may be significant (Chudik et al., 2016). After discovering these flaws, Jordan and Philips (2018) developed the DARDL technique to remedy the problem. Aside from assessing long and short-run relationships between variables, the DARDL may also draw graphs of positive and negative counterfactual alterations in independent variables and their effect on the dependent variables (Jordan and Philips, 2018). This is a critical feature that the traditional ARDL approach lacks. The DARDL technique can be used if the variable has an I(1), I(0), or both integration orders (Jordan and Philips, 2018). This study used 5000 simulations to produce the outcome. Following the Jordan and Philips (2018), and Sarkodie (2019), the empirical model of the study with the error correction term (ECT) can be expressed as follows:

$$\Delta(\ln FP)_t = \lambda_0 + \theta_0 \ln FP_{t-1} + \beta_1 \Delta \ln CP_t + \theta_1 \ln CP_{t-1} + \beta_2 \Delta \ln SP_t + \theta_2 \ln SP_{t-1} + \beta_3 \Delta \ln MP_t +$$

$$\theta_3 \ln MP_{t-1} + \beta_4 \Delta \ln FWR_t + \theta_4 \ln FWR_{t-1} + \beta_5 \Delta \ln FC_t + \theta_5 \ln FC_{t-1} +$$

$$\beta_6 \Delta \ln GDP_t + \theta_6 \ln GDP_{t-1} + \beta_7 \Delta \ln INF_t + \theta_7 \ln INF_{t-1} + \beta_8 \Delta \ln PRD_t +$$

$$\theta_8 \ln PRD_{t-1} + \xi ECT_{t-1} + u_t \qquad (4)$$

where the error correction term, ECT, should be negative and statistically significant. Several diagnostic tests were carried out to verify the model's accuracy.

4. Econometric models for estimating shrimp competitiveness

To determine the competitiveness of shrimp export, the Revealed Symmetry Comparative Advantage (RSCA) index (Laursen, 2015) was used. The RSCA index is so far the most effective tool for determining export competitiveness (Laursen, 2015). In recent research, it has been frequently used (Islam et al., 2021a; Munir and Sultan, 2019; Naseer, 2019). The equational form of RCA index can be stated as follows:

$$RCA_{ab} = \frac{\frac{X_{ab}}{X_{at}}}{\frac{X_{db}}{X_{dt}}} \qquad (1)$$

where RCA_{ab} stands for revealed comparative of country “a” for a product “b” and “X_{ab}” denotes total exports of country “a” for product “b”. Subscript “at” denotes exports of all products of country “a”. Subscript “db” represents the world export of product “b”, and subscript “dt” refers to the total export of all products across the world.

And the equational form of RSCA can be shown as follows:

$$RSCA = \frac{RCA-1}{RCA+1} \qquad (2)$$

The RSCA index has a value ranging from -1 to 1. RSCA>0 indicates that a country has a comparative advantage in that particular product that it exports. In contrast, RSCA<0 suggests the opposite.

Determination of factors influencing the export competitiveness

Following our investigation of shrimp export competitiveness, we proceeded on exploring the effect of potential factors on the shrimp export competitiveness of Bangladesh using time series data. Before diving into time series data analysis, we need to confirm the stationarity check of data series. This study employed Augmented Dickey–Fuller (ADF) (1979), Phillips–Perron (PP) (1988), Kwiatkowskie - Phillipse – Schmidte – Shin (KPSS) (1992) test for investigating the stationarity property of data series.

Upon checking the unit root outcome, cointegration testing must be performed before applying the dynamic ARDL simulations method. To confirm the presence of long association among the variables included in the model, we conducted *F*-bounds test. The following ARDL bounds test equation is formulated to investigate the long-run and short-run relationship among the studied variables:

$$\Delta(\mathrm{lnEXS})_t = \alpha_0 + \alpha_1 \mathrm{lnEXS}_{t-1} + \alpha_2 \mathrm{lnGDP}_{t-1} + \alpha_3 \mathrm{lnKOFEG}_{t-1} + \alpha_4 \mathrm{lnEPS}_{t-1} + \alpha_5 \mathrm{lnIQ}_{t-1} + \alpha_6 \mathrm{lnTO}_{t-1} + \alpha_7 \mathrm{lnTA}_{t-1} + \alpha_8 \mathrm{lnTF}_{t-1} + \sum_{i=1}^{p} \beta_1 \Delta \mathrm{lnEXS}_{t-i} + \sum_{i=1}^{p} \beta_2 \Delta \mathrm{lnGDP}_{t-i} + \sum_{i=1}^{p} \beta_3 \Delta \mathrm{lnKOEFG}_{t-i} + \sum_{i=1}^{p} \beta_4 \Delta \mathrm{lnEPS}_{t-i} + \sum_{i=1}^{p} \beta_5 \Delta \mathrm{lnIQ}_{t-i} + \sum_{i=1}^{p} \beta_6 \Delta \mathrm{lnTO}_{t-i} + \sum_{i=1}^{p} \beta_7 \Delta \mathrm{lnTA}_{t-i} + \sum_{i=1}^{p} \beta_8 \Delta \mathrm{lnTF}_{t-i} + u_t \quad (3)$$

where EXS is the index value of export competitiveness (RSCA), GDP denotes gross domestic product as a proxy for economic growth, KOFEG is the economic globalization, EPS is the export price of Bangladeshi shrimp, IQ is the index value of institutional quality, TO is the trade openness, TA is the number of trade agreements, and TF is the trade freedom. Besides, Δ denotes the first difference operator, t-i represents the optimal lags chosen using the Akaike information criterion (AIC), u_t represents the error term, and p represents the lag length. Furthermore, α's and β's are long-run and short-run estimates, respectively.

The null hypothesis for the ARDL *F*-bounds test (H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = 0$) implies that no variables cointegrate. Whereas, the existence of cointegration specified by the alternative hypothesis (H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq 0$). On the basis of estimated value of the *F*-statistic, we may reject or accept the null hypothesis. Furthermore, we compare the *F*-statistic value to the critical value. If the *F*-statistic value surpasses the critical values at the 1%, 5%, and 10% levels of significance, the long-run association can be ascertained. If the lower bound value is greater than the estimated *F*-statistics, it suggests that there is no long-run relationship among the variables. And, if the estimated *F*-statistics stands in between the higher and lower bounds, the decision is inconclusive (Islam et al., 2021b; Khan et al., 2019).

To estimate the long-run and short-run coefficients, this study employed the dynamic ARDL simulations approach developed by Jordan and Philips (2018). This model is established to untangle the constraints of the existing ARDL model for investigating the long-run and short-run relationship among studied variables. Aside from that, the dynamic simulated ARDL approach can estimate, simulate, and generate graphs to project counterfactual alterations in one predictor variables and its impact on the dependent variable, while holding the other regressors unchanged (Hossain et al., 2022a,b; Agboola et al., 2022). To execute the dynamic ARDL simulations approach, the series employed in the model should be integrated at I(1) and have cointegration among them (Sarkodie et al., 2019), and the study's variables conformed to the pre-requisite. This study used 5000 simulations in the framework of the dynamic ARDL error correction term technique for the parameters vector of a multivariate normal distribution. The equational form of the dynamic ARDL model along with the error correction term is represented as:

$$\Delta(\mathrm{lnEXS})_t = \lambda_0 + \theta_0 \mathrm{lnEXS}_{t-1} + \beta_1 \Delta\mathrm{lnGDP}_t + \theta_1 \mathrm{lnGDP}_{t-1} + \beta_2 \Delta\mathrm{lnKOFEG}_t + \theta_2 \mathrm{lnKOFEG}_{t-1} + \beta_3 \Delta\mathrm{lnEPS}_t + \theta_3 \mathrm{lnEPS}_{t-1} + \beta_4 \Delta\mathrm{lnIQ}_t + \theta_4 \mathrm{lnIQ}_{t-1} + \beta_5 \Delta\mathrm{lnTO}_t + \theta_5 \mathrm{lnTO}_{t-1} + \beta_6 \Delta\mathrm{lnTA}_t + \theta_6 \mathrm{lnTA}_{t-1} + \beta_7 \Delta\mathrm{lnTF}_t + \theta_7 \mathrm{lnTF}_{t-1} + \xi \mathrm{ECT}_{t-1} + u_t \quad (4)$$

Photographs

Enumerators training and data collection

Stakeholders Training

Final Policy Workshop