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Technological Integration Impacts on Fish Supply Chain in Bangladesh: An Empirical Analysis

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Abstract

The fishery industry has one-fourth of the agricultural sector's contribution to the GDP. However, the fishery industry has been facing several challenges during fish trading that adversely impact Bangladesh's fish supply chain. The main objective of this research is to find the impact of technological integration on Bangladesh's fish supply chain. Additionally, this study explores the effects of technology integration on the unjustified middleman gain in Bangladesh's fish supply chain. This study uses secondary cross-sectional data to conduct estimation, i.e., descriptive and quantitative analysis (Ordinary Least Squares and Logistic Regression). Regarding the estimated results, the technology-integrated supply chain, twoG and threeG mobile connection, may have a mixed impact on the fish supply, where the twoG mobile connection may have a positive effect, and the threeG mobile connection may negatively impact the middleman gain and inland fish production in Bangladesh. However, the twoG connection may increase, and the threeG connection may reduce the presence of unjustified gain from Bangladesh's fish supply chain. By addressing these issues, this study suggests several recommendations and concludes that collaborative efforts and strategic planning can enhance the inland water fish productivity, efficiency, and sustainability, and adaptation of modern technology integrated fish supply chain may positively impact Bangladesh's fish supply chain and minimize Bangladesh's fishery industry's unwanted activities of intermediaries.

Key Words: Technology integration, Bangladesh, Fish supply chain, Ordinary Least Squares, Logistic Regression.
JEL Classification: M3, Q1, N7, O3

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1.0 Introduction

The agricultural sector of Bangladesh has a significant contribution to GDP. According to BBS (2021), the contribution of the agricultural sector to GDP was 12.07% in the fiscal year 2020-21. Most importantly, fisheries, and major subsector of Bangladesh agriculture, accounted for 2.64% of GDP and grew by 4.11% in the same fiscal year. This subsector constitutes around one-fourth of the agricultural sector. The fish and fishery products brought in 1.39% of total export earnings in 2020 (BER, 2020). More than 12% of the population is engaged, directly and indirectly, in several activities in the fisheries sector for their livelihood. Meanwhile, Bangladesh has already achieved self-sufficiency in fish production and fish consumption. Reportedly, it ranked third in inland open-water production and fifth in aquaculture fish production globally (FAO, 2020). Besides, fish consumption per person per day in this country was 62.58 grams, against the targeted consumption of 60 grams (BBS, 2016).

Fishes are mainly collected from inland and marine fisheries, which can be classified into twelve sources, i.e., River, Pond, Floodplain/Haor, Beel, Baor, Shrimp farm, seasonal CWB, pen and cage, Kaptai lake, the Sundarbans, Marine industrial and artisanal. Department of Fisheries Bangladesh concluded in the fisheries statistics of Bangladesh in the 2021-22 fiscal year (Fishery Department, 2021-22) that Bangladesh is one of the leading fish producers in the world, with a total production of 4.759 million metric tons in FY 2021-22, along with inland open water (catch) accounting for 27.78 percent (1.322 million metric tons) and inland closed water (culture) accounting for 57.39 percent (2.731 million metric tons). Inland fisheries produce 85.10 percent of total fish production. More precisely, inland capture and culture fisheries grew at the rates of 1.03 and 3.83 percent, respectively, in the 2019-20 fiscal year. In contrast, marine fisheries production was 0.671 million metric tons, with a 14.90 percent contribution to overall fish production and a growth rate of 1.70 percent. In the 2019-20 fiscal year, the overall growth rate of total fish output was 2.72 percent. Inland aquaculture's overall growth performance showed a moderately rising trend. Over the last 37 years, fish production has increased almost six times (0.754 million metric tons in 1983-84 to 4.503 million metric tons in the 2019-20 fiscal year). Though the country achieved revolutionary success in fish production, the lack of a technology-integrated supply chain emerged as a serious deterrent. The main objective of this study is to explore the benefits of technology integration in Bangladesh's fish supply chain.

A supply chain is a network that connects a firm and its suppliers in order to manufacture and deliver a particular product to the final consumers. Different activities, people, entities, information, and resources are all parts of this supply chain network. The supply chain also depicts various stages through which a product or service flows from its initial state to its destination. Companies create a supply chain network to decrease production costs and maintain a sustainable competitive position in the marketplace. Technology integration helps to offer visibility and control across the whole supply chain system so that data-driven choices can be made in real-time regarding everything from inventory status, manufacturing slowdowns, and supplier shortages to logistics, transportation, delivery schedules, pricing changes, and more (Patel, 2021). Saurabh and Dey (2021) reported that the efficiency and quality control of the agri-food supply chain could be increased by applying such technologies as blockchain, the Internet of Things (IoT), wireless sensor networks, cloud computing, and machine learning. Yet, there is limited information regarding the factors influencing supply chain participants' tendency to adopt and use such technologies.

Furthermore, technologically integrated supply chain systems directly impact the overall performance of a specific good's production and consumption process. Martinez *et al.* (2019) investigated that a blockchain-based supply chain improves the efficiency process; this system reduces the number of operation processes, timing, and workload, shows traceability, and enhances visibility to the different levels of supply chain participants. On the other hand, Kshetri (2018) investigated the blockchain project at a different level of development in various areas of supply chain management. The author concluded that a blockchain-based supply chain affects cost, quality, order placement time, and general public perception of reliability and minimizes risk while increasing sustainability and flexibility.

However, historical fishery monitoring and reporting programs have depended on independent fishery observers, vessel monitoring systems (VMS, real-time vessel location reporting), landings reports, and self-reported paper records for a significant portion of fishery-related data collection. For this reason, fisheries farms introduced electronic technology solutions, i.e., global positioning systems (GPS), electronic reporting, video cameras, fishing gear sensors, human observer technologies, etc. Those technology integrations in the fish farms support other interests, such as business development, monitoring and control, traceability, and other applications (ICES, 2019). Similarly, technology integration can bring easy, sustainable, and cost-effective solutions to the fish marketing system because fish has a relatively short shelf life, and its quality degrades quickly (Tavares *et al.*, 2021). However, a technology-integrated supply chain may not yield positive in the fish supply, for example, Lin and Wu (2016) empirically studied using Taiwan's white shrimp industry and found that a centralized shrimp supply chain practice does not necessarily bring better yield compared to the decentralized supply chain.

Like any other sector, fishery sectors have been confronting several limitations in supply chain networks. Bangladesh's fish and fisheries products marketing primarily depends on the private sector, and a vast number of individuals rely on it for their livelihood. It is true that each stage of the marketing channel for fish and fishery products faces various challenges. For example, Hemal *et al.*(2017) concluded, based on fish seed marketing, that lack of cash, technical competence, high lease value, the high price of production inputs, violence, fierce market competition, lack of legislative assistance, and other factors have an impact on stakeholders in this marketing system in the Sylhet district of Bangladesh. Similarly, Bangladeshi fishermen are unable to effectively monetize their catch of fish and fisheries products or promote sustainable supply chain efficiency to bring about substantial change in the fishery industry (Sharif et al., 2016). Fishers are obliged to sell their catch to local traders because of illegal power practices. In addition, a variety of prominent factors in the Bangladeshi fishery industry have created obstacles to employ the available supply chain network, such as the illegal power practice of Dadon providers (lenders), insufficient transportation infrastructure, meager catches, high transport costs, and intermediary pressure (ICE Business Times, 2016; Shafikul et al., 2018; LightCastle Analytics Wing, 2020, p. 202; Shafiuddin, 2021). Azam et al. (2016) studied using Bangladesh's data and descriptive illustrations that consumers obtained only 5% of fish and fishery products directly from fish farms; the other 95% of fish were delivered to consumers through the fish supply chain; however, there several redundant middleman activities that reduce the financial gain of both consumers and producers.

In view of the above discussion, some common questions arise. For example, is there any benefit to technology integration in Bangladesh's fish supply chain? What are the benefits involved in adopting a technology-integrated supply chain network available in the fisher sector? Is there any impact of technology integration on unjustified middleman gain in Bangladesh's fish supply chain? If the presence of unjustified middleman gain is found in the current fish supply chain network, how can this challenge be overcome? The main objective of this study is to find the impact of technology integration in the fish supply chain of Bangladesh by using data from selected 24 districts and employing the Ordinary Least Squares (OLS) and a Logistic Regression Approach for empirical estimation. The empirical study finds that twoG and threeG mobile connections have mixed impacts on different fish species production in Bangladesh. More precisely, the twoG mobile connection may positively affect fish production in Bangladesh because most people adopt twoG mobile phones (Pavel, Burhan, and Jamee, 2014), but the threeG has an adverse impact.

2.0 Problem Statement

Reportedly, syndicates are very active in Bangladesh's fish supply chain. The fish market does not function properly because of their presence. Both fish producers and final consumers face financial loss due to the fact that syndicates create artificial shortages of fish supply in order to earn excess profit (Dhaka Post, 2022; Samakal, 2022; Jugantor, 2023). In most cases, fishermen can not sell their catch at market price and take their own decisions because of the syndicates' illegal practices. The syndicates force the fishermen to sell the catch to intermediaries and traders to the latters' advantage (Prothom Alo, 2020; TBS, 2020; Kaler Kantho, 2023). This leads to severe exploitation. A study (Hasan, 2021) on Gaibandha sadar of Bangladesh concluded that the fish producers received only 49.3% of the final price, and the remaining 50.7% was received by different middleman in the fish supply network. Using Chattogram's sea fish data, Sheikh, Sen, and Hasan (2018) found that fish distribution took much longer time because of eight to ten syndicate groups who control the fish market of Chattogram. Furthermore, Azam et al. (2016) studied conducting Bangladesh's data and descriptive illustrations that only 5% of fish and fishery products directly came from the fish farmers, but the other 95% of fish were delivered to consumers through a supply chain network. They also concluded that some of the intermediaries' activities in the supply chain seem to be redundant due to adding a cost to the consumer and a financial loss for the fish farmers. Those redundant activities of intermediaries of the fish supply chain network create challenges during excess or less supply of fish in Bangladesh (Shareef *et al.*, 2020).

However, those challenges may be solved by introducing the technology-integrated fish supply chain in Bangladesh. There are several examples of the positive impact of technology-integrated supply chain networks, for example, if technological integration in the supply chain is ensured in the production processes, it reduces the cost and processing time, ensures traceability, increases reliability, reduces risk, etc. (Kshetri, 2018; Leng et al., 2018; Zhao et al., 2019; Martinez et al., 2019; Feng et al., 2020). Besides, traditional fish supply chain actors face challenges in providing fish on time to consumers due to the problems mentioned in the previous section. Several studies focused on the role of technology-integrated supply chain networks in addressing those challenges and found positive and significant effects on the fish supply chain networks (Zhao et al., 2019; Martinez *et al.*, 2019; Feng *et al.*, 2020). On the other hand, some studies came up with different conclusions about the technology-integrated supply chain. For example, Lin and Wu (2016) empirically studied using Taiwan's white shrimp industry data and found that a centralized shrimp supply chain practice may not necessarily bring better yield due to a higher price in the farm-gate of the decentralized supply chain (small-scale shrimp farmers) than in the centralized supply chain practiced. So, the impact of a technology-based supply chain on the fishery industry is not straightforward.

3.0 Rationale of the Study

Inland water and marine fishery production in Bangladesh has been growing day by day. However, the fishery sector faces a variety of challenges. For instance, fishers and fish farms suffer from problems including the lack of transport, illegal practices of local traders, and lack of financial access (ICE Business Times, 2016; Shafikul et al., 2018; LightCastle Analytics Wing, 2020, p. 202; Shafiuddin, 2021), overfishing (Valdimarsson, 2007; Ahmed et al., 2010; NEPAD, 2016), environmental degradation (Valdimarsson, 2007), post-harvest losses and waste (Affognon et al., 2015; Chan et al., 2019), etc. However, excess and shortage of fish supply and time pressure create supply chain complexities and challenges (Shareef *et al.*, 2020). Most of the national daily newspapers (Dhaka Post, 2022; Samakal, 2022; Jugantor, 2023; Prothom Alo, 2020; TBS, 2020; Kaler Kantho, 2023) report the fish supply chain challenges, i.e., middleman earn an excess profit, both consumers and producers face financial loss due to the advantage of fish syndicate, fish producers can not sell their catching freely, etc. Similarly, only a few scholarly writings address those inconsistencies, i.e., excess profit, the obstacle to sell freely, etc., in the supply chain networks (Uddin and Sanda, 2016; Sheikh, Sen, and Hasan, 2018). Additionally, scholarly writing concluded that only five percent of fishery products are directly collected from fish farmers, and the remaining part follows a fish supply chain network; however, the unwanted middleman activities in the fish supply chain may create a financial loss for both consumers and producers' level (Azam et al., 2016). This unstructured fish supply chain practice of having redundant players creates challenges during excess or less supply of fish in Bangladesh (Shareef *et al.*, 2020).

Unfortunately, regarding the published scholarly writing, there hasn't been much focus from an academic or institutional viewpoint on the relationship between technology integration and fish supply chain as well as the complexities and difficulties of the fish supply chain, particularly the lack of logistics support when surplus and shortage of fish supply exists. The fishery industry can overcome those challenges using a technology-based fish supply chain. But, Bangladesh is lagging behind in integrating technology into the fish supply chain (Azam et al., 2016). This research gap highlights the need for a more in-depth examination of the impacts of technology integration on the current fish supply chain and to make some recommendations based on technology-integrated fish supply chain in Bangladesh.

4.0 Research Questions

The study intends to address the following particular questions:

1. How does technological integration impact the fish supply chain in Bangladesh?
2. How does technology integration affect middleman's gain in Bangladesh's fish supply chain?
3. How does technology integration affect unjustified middleman gain in Bangladesh's fish supply chain?
4. How can the unjustified middleman gain be eradicated from Bangladesh's fish supply chain?

5.0 Objectives

The main objective of this study is to explore the impacts of technological integration in the fish supply chain of Bangladesh. The specific objectives are.

1. To explore the impacts of technological integration in the supply chain of the Bangladesh fishery industry.
2. To analyze the effects of technology integration on middleman gain in the fish supply chain of Bangladesh.
3. To investigate the effects of technology integration on unjustified middleman gain in the fish supply chain of Bangladesh.
4. To make some recommendations to eradicate the unjustified gain from Bangladesh's fish supply chain.

6.0 Literature Review

The technology-integrated supply chains are widely employed in the industry and agricultural sectors. The technology-integrated supply chain has a positive impact on agricultural production. For example, Saurabh and Dey (2021) explored that agricultural production can be increased by introducing technology-integrated supply. Besides, after reviewing 84 scholarly articles published between 2000 and 2007, Kamble et al. (2020) identified several challenges, including a lack of information accuracy, inadequate management, and insufficient supply chain in the agri-food supply chain. They also concluded that blockchain, the Internet of Things, and big data could play an important role in the agri-food industry.

Moreover, a technology-integrated supply chain network has a fundamental impact on the whole performance of a specific good's production and distribution process. Saurabh and Dey (2021) observed that agricultural production and quality management could be improved by employing the blockchain, the Internet of Things, wireless sensor networks, cloud computing, and machine learning technologies. Kshetri (2018) explored blockchain technology implications in the different levels of supply chain networks and concluded that a blockchain-based supply chain reduces risk while enhancing sustainability, flexibility, cost, quality, order placement time, and the general public's perception of reliability.

According to Islam and Habib (2013), the production of fish can be boosted through the maximum use of the already available domestic resources using contemporary and scientific methods of fish culture and fishing techniques. In recent decades, the technology-integrated supply chain has played a fundamental role in the fishery. Several studies show that a technology-integrated supply chain reduces the cost and processing time, offers traceability, minimizes general people's stigma and increases reliability, reduces risk, etc. (Kshetri, 2018; Leng et al., 2018; Zhao et al., 2019; Martinez et al., 2019; Feng et al., 2020).

However, the fishery industry faces a significant number of challenges based on socioeconomic structure. Hasselberg et al. (2020) reported several challenges that fishing farms commonly face in supply chain networks in Ghana. They found that millions of Ghanaians depend on fisheries for their livelihood and access to nutrient-dense small fish species, which is fundamentally related to small-scale fisheries rather than the industrial or aquaculture sectors, while fish availability is a growing concern for the small-scale fishers. The authors also reported that, endangering the availability of fish and the sustainability of fish stocks, the entry of foreign industrial trawlers also causes a decline in the incomes of already vulnerable small-scale fishers, processors, and traders. Racioppo et al. (2021) explored the global challenges of fish sustainability for the fishery industry due to overfishing, which led to the reduction of stock worldwide. They also mentioned several factors, i.e., nitrogen compounds, lipids, minerals and pigments, and fish-based chitosan, that are responsible for reducing global fish stock. Another study shows that worldwide freshwater fish are constantly in danger due to overfishing, pollution, habitat loss, damming, foreign invading species, and climate change (Reid et al., 2013). Furthermore, Ghose (2014) identified several natural and man-made challenges, including climate change, natural disasters, uneven urban and industrial development, overfishing, and environmental pollution, which pose difficulties for the fisheries industry of Bangladesh. Similarly, Paul and Vogl (2011) found that there are two major impacts such as socioeconomic (market unrest, livelihood displacement, market fluctuations) and environmental (mangrove degradation, salt water, pollution, diseases, inappropriate management practice, etc.) challenges to the shrimp fish farming of Bangladesh. Additionally, some research shows that fish producers are obliged to sell their fish to local traders because of unlawful local power practices, Dadon (illegal financing), lack of transport facilities, small catching, high cost of transport, mediators' illegal pressure, etc. (ICE Business Times, 2016; Shafikul et al., 2018; LightCastle Analytics Wing, 2020; Shafiuddin, 2021). Similarly, Kamble et al. (2020) identified several challenges, i.e., the lack of industrialization, inadequacy of management, information accuracy, and insufficient supply chain are significant issues in the agri-food supply chain by reviewing 84 scholarly articles from 2000 to 2017. They also mention the importance of the Internet of Things, blockchain, and big data technologies in the agricultural supply chain network and propose a technology-integrated supply chain model. Likewise, a number of scholarly studies identified some common challenges, i.e., Overfishing (Valdimarsson, 2007; Ahmed et al., 2010; NEPAD, 2016) and environmental degradation (Valdimarsson, 2007), Fish post-harvest losses and waste (Affognon et al., 2015; Chan et al., 2019) in the fishery industry.

The challenges of the fishery sector can be overcome by using the technology-integrated supply chain while ensuring the socioeconomic conditions. Several studies show that technology-integrated supply reduces the cost and processing time, offers traceability, minimizes general people's stigma and increases reliability, reduces risk, etc. (Kshetri, 2018; Leng et al., 2018; Zhao et al., 2019; Martinez et al., 2019; Feng et al., 2020). According to the survey using Bangladesh's data and descriptive illustrations, only 5% of fish and fishery products came directly from fish farmers, and the remaining 95% of fish were delivered to consumers through the fish supply chain network, but several unwanted activities of middleman increase the cost and reduce the financial gain of consumers and producers level (Azam et al., 2016). Those redundant middleman activities in fish supply create unjustified gains for middleman that can be eradicated by introducing a centralized technology-integrated supply chain network in Bangladesh.

However, the acceptance of a centralized supply chain network in the fishery industry is not straightforward. For instance, Lin and Wu (2016) empirically studied using Taiwan's white shrimp industry and found that a centralized shrimp supply chain practice does not necessarily bring better yield. On the other hand, many researchers found that technology-based supply chain practice positively impacts the agro-based industry, including the fishery sector (Kshetri, 2018; Leng et al., 2018; Zhao et al., 2019; Martinez et al., 2019; Feng et al., 2020).

In terms of the above discussion, only a few studies concentrated on the impact of technology integration in the fish supply chain—for instance, some focus on global and Bangladesh's fish trading challenges using simple graphical and tabular presentations. In addition, the relationship of technology integration with the fish supply chain, middleman gain, and unjustified middleman gain is still inconclusive. A gap in the existing literature is thus apparent. This research intends to reduce the gap.

7.0 Theoretical Framework

The technology-integrated supply reduces the cost and processing time. It offers traceability, minimizes general people's stigma, increases reliability, and reduces risk. Several scholarly writings (Kshetri, 2018; Leng et al., 2018; Zhao et al., 2019; Martinez et al., 2019; Feng et al., 2020) use blockchain-based solutions to address the food traceability difficulties, benefits of blockchain technology, and obstacles to implementing blockchain-based traceability systems implementation, where they found that blockchain-based solution enhances food traceability systems based on blockchain technology. On the other hand, the technology-integrated fish supply may negatively impact Taiwan's shrimp fishery industry. Moreover, they found a higher price in the decentralized supply chain practiced at farms'-gate (small-scale shrimp farmers) than in the centralized supply chain practiced by relatively large fishing farms (Lin and Wu, 2016). So, the technology-based fish supply chain affects the fishery industry because it may not match the socioeconomic condition.

Several scholarly articles examined the technology integration into the agricultural industry, i.e., artificial intelligence in agricultural farming (Kumar et al., 2016; Omid et al., 2013; Pang et al., 2015; Wehberg et al., 2017; Kittipanya-ngam and Tan, 2020). Some studies focused on the Internet of Things applied for monitoring weather, animal health and condition, and self-learning prediction on food production and processing (Kumar et al., 2016; Pang et al., 2015; RuizGarcia et al., 2009; Wehberg et al., 2017; Kittipanya-ngam and Tan, 2020). Furthermore, blockchain technology is used for maintaining digital tracking and storage of all stages of the information supply chain (Koonce, 2017; Lewis, 2017; Wehberg et al., 2017; Kittipanya-ngam and Tan, 2020). Besides, only a few articles focused on the technology-integrated fish supply model, for example, cloud computing applied for the traceability system of fish and fishery products in the fish supply chain network (Moga, 2017), Blockchain-based fish supply chain in the Thai fish industry (Tsolakis *et al.*, 2021), etc. Most of the technology-integrated supply chains are introduced in developed countries. Sengupta *et al.* (2021) designed satellite imagery and blockchain technologies in the fish supply chain in India. They emphasize how such technologies help poor fishers in developing countries to have more options to earn by improving the supply chain's resilience.

8.0 Methodology

8.1 Data and Variables

This research has collected secondary cross-sectional data as of January 2023 from four different entities, i.e., the Department of Fisheries, the Department of Agricultural Marketing, BBS (Bangladesh Bureau of Statistics), and BTRC

(Bangladesh Telecommunication Regulatory Commission). The variables under consideration include cell phone use, internet access, farm-level production cost and selling price of fish, wholesale price, retail price, agricultural loan disbursement, etc. During the estimation process of this study, cell phone use and mobile internet access represent technological integration in the fish supply chain.

Table 1: list of variables

No.	Variable	Description	Source
1.	lnrui_production	Natural log of Rui fish production in different districts of Bangladesh	The department of fisheries of Bangladesh
2.	lntwoG	Natural log of Two G mobile phone connection in different districts of Bangladesh	Bangladesh Telecommunication Regulatory Commission (BTRC)
3.	lnthreeG	Natural log of Three G mobile phone connection in different districts of Bangladesh	Bangladesh Telecommunication Regulatory Commission (BTRC)
3.	lnloan	Natural log of agricultural loan disbursement in different districts of Bangladesh	Bangladesh Bureau of Statistics (BBS)
4.	lnfarm_level_selling_price	Natural log of farm level selling price of Rui fish produced in different districts of Bangladesh.	The Department of Agricultural Marketing of Bangladesh
5.	lnretail_selling_price	Natural log of the retail selling price of Rui fish produced in different districts of Bangladesh.	The Department of Agricultural Marketing of Bangladesh
6.	lnmiddleman_gain	Natural log of total middleman gain from Rui fish trading. This is calculated by subtracting the farm-level price from the wholesale price of Rui fish in different districts of Bangladesh.	The Department of Agricultural Marketing of Bangladesh and the author's calculation
7.	Unjustified_gain_dummy	The wholesaler can make a maximum profit of 15% according to the Agricultural Marketing Rules 2021. The value of 1 to indicate the presence of unjustified middleman gain, and 0 to indicate the absence of it based on the profit margin of 15%. $1\ if\ profit > 15\%$ $0\ if\ profit \leq 15\%$	The Department of Agricultural Marketing of Bangladesh and the author's calculation

8.2 Descriptive Statistics

This research has conducted descriptive statistics, i.e., mean, median, and correlation matrix. Those descriptive analyses are employed depending on the secondary cross-sectional data.

8.3 Econometric Estimation

This study applied the Ordinary Least Squares (Gauss, 1809) and Logistic Regression(Cox, 1958) Approach to estimate the issues of this study's objectives using secondary data of fish species from 24 different districts of Bangladesh. The OLS and Logistic Regression estimation processes are explained below:

According to the Agricultural Marketing Rules 2021[1], for producers, wholesalers, and retailers in the fish supply chain, maximum acceptable profit margins are 30%, 15%, and 25% at each stage, respectively. Any violation of these limits indicates the presence of unjustified gain. Keeping this in mind and considering my focus on middleman (wholesalers); a dummy variable (μ_i) is constructed for wholesalers as follows.

$$\mu_i = \begin{Bmatrix} 1, & if\ the\ middlemen's\ profit\ margin > 0.15 \\ 0, & Otherwise \end{Bmatrix} - - - - - - -1$$

In other words, the dummy variable, namely 'unjustified gain dummy', assumes the value of 1 to indicate presence of unjustified middleman gain and 0 to indicate absence of it.

First of all, the use of cell phones and internet access represents technological integration, the key independent variable. Besides, there are three dependent variables, i.e., fish production, middleman gain, and unjustified gain. This study would like to estimate the impact of technology integration on fish production by using the OLS estimation approach as follows:

$$Y_i = \alpha + \beta_1 TwoG_i + \beta_2 ThreeG_i + \beta_3 Loan_i + \beta_4 FLPrice_i + \beta_4 MGain + \eta_i \\ - - - - - - 2$$

The dependent variable,Y_i, refers to the Rui production, and the independent variable, $TwoG_i$ refers to the Two-G mobile phone connection and $ThreeG_i$ indicates the three-G mobile connection, $loan_i$ is the agricultural loan disbursement, $FLPrice_i$ refers to the farm-level price of Rui fish and $MGain_i$ is

[1] To establish maximum profit margins for agricultural products at the production, wholesale, and retail levels, the government of Bangladesh has introduced the Agricultural Marketing Rules 2021. According to the Agricultural Marketing Rules, the maximum reasonable profits are 30% for the farms' production level, 15% at the wholesale stage, and 25% at the retail level for fresh, dried, salted, and frozen fish.

the amount of middleman gain received by trading Rui fish. The variable n_i indicates the error term, and *i* represents the districts.

$$M_i = \alpha + \beta_1 TwoG_i + \beta_2 ThreeG_i + \beta_3 Loan_i + \beta_4 RP_i + \beta_5 RPrice + \beta_6 FLPrice_i + \eta_i --- 3$$

The dependent variable, M_i , refers to the amount of middleman gain from Rui fish production, and the independent variable, $TwoG_i$ refers to the Two-G mobile phone connection and $ThreeG_i$ indicates the three-G mobile connection, $loan_i$ is the agricultural loan disbursement, RP_i indicates the Rui fish production, $RPrice_i$ refers to the retail selling price and $FLPrice_i$ refers to the farm-level price of Rui fish. The variable η_i indicates the error term, and i represents the districts.

Additionally, this study has estimated how technological integration impacts the unjustified middleman gain. However, the dependent variable is indeed a dummy variable. So, this research can apply the Linear Probability Model (LPM) due to the regressand is binary, and the LPM model follows the Bernoulli probability distribution with $P_i = probability$ that Y_i =1(presence of unjustified middleman gain) and $(1 - P_i) = probability$ that $Y_i = 0\ (absence\ of\ unjustified\ middleman\ gain)$. Unfortunately, LPM violates several assumptions (heteroscedastic variance and non-normality of error term) of classical linear regression (Chatla and Shmueli, 2016). Additionally, if this study applies the LPM model, there is no guarantee that the estimated Y_i fulfill the probability restriction ($0 \leq P \leq 1$); if the estimated value of Y_i is less than 0 or greater than 1. This problem can be solved using the Logistic estimation approach as follows.

$$Y_i = \ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 TwoG_i + \beta_2 ThreeG_i + \beta_3 Loan_i + \beta_4 RP_i + \beta_5 RPrice + \beta_6 FLPrice_i + \eta_i ----- 4$$

To empirically estimate the impacts of technology integration on unjustified middleman gain, Y_i indicates the dependent variable (dummy); the presence or absence of unjustified middleman gain in each species. $\frac{P_i}{1-P_i}$ represents the odd ratio, where $P_i = 1$, if the unjustified middleman gain exists and $P_i = 0$, if there is no unjustified middleman gain. More specifically, it shows the rate of change in probability with respect to change in independent variables. The independent variable, $TwoG_i$ refers to the twoG mobile phone connection and $ThreeG_i$ indicates the three-G mobile connection, $loan_i$ is the agricultural loan disbursement, RP_i indicates the Rui fish production, $RPrice_i$ refers to the retail selling price and $FLPrice_i$ refers to the farm-level price of Rui fish. The variable η_i indicates the error term, and i represents the districts.

This research has used Microsoft Excel for data mining purposes. In addition, STATA and SPSS have been used to calculate qualitative and quantitative estimates.

9.0 Result and Discussion

9.1 Descriptive Statistics

For the estimation purpose, this study gathered data on farm level price of Rui fish, retail price, agricultural loan disbursement, and the number of towG and threeG connected cell phones from 24 districts of Bangladesh. The main purpose of this study is to explore the impact of technological integration on fish production. Table 2 reperesents the descriptive statistics of dependent and independent variables. Table 3 shows the correlation matrix.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lnrui_production	24	8.234	1.207	5.403	10.005
Lnmiddleman_gain	24	3.355	0.422	2.708	4.094
Unjustified gain dummy	24	0.417	0.504	0.000	1.000
lntwoG	24	14.717	0.695	13.345	16.235
lnthreeG	24	14.188	0.781	12.719	15.852
Lnloan	24	11.789	0.591	10.180	12.858
Lnfarm level price	24	5.375	0.111	5.136	5.617
lnretail_selling price	24	5.613	0.110	5.416	5.829

Source: Author's Estimation

The correlation matrix, table 3, indicates that almost all variables are positively associated except the retail price and farm level price of Rui fish with the Rui fish production. The twoG and threeG variables are negatively associated with middleman gain and unjustified gain, respectively. The firm-level price is inversely related to middleman gain, unjustified gain, twoG, threeG, and agricultural loan disbursement. The retail selling price is positively related to middleman gain and unjustified gain but negatively related to twoG and threeG mobile connection.

Table 3: Correlation Matrix

	lnrui prodcution	lnmiddleman gain	unjustified gain dummy	lntwoG	lnthreeG	lnloan	lnfarm level price	lnretail selling price
lnrui prodcution	1							
lnmiddleman gain	-0.341	1						
unjustified gain dummy	-0.390*	0.843***	1					
lntwoG	0.611***	-0.316	-0.358*	1				
lnthreeG	0.577***	-0.310	-0.353*	0.990***	1			
lnloan	0.735***	-0.161	-0.213	0.679***	0.643***	1		
lnfarm level price	-0.033	-0.143	-0.243	-0.101	-0.093	-0.304	1	
lnretail selling price	-0.064	0.246	0.019	-0.133	-0.118	-0.271	0.808***	1

*=<10%, **=<5%, ***=<1% level of significance

9.2 Econometric Analysis

This study uses the OLS and Logistic Regression models for econometric analysis. The OLS estimation approach is applied for estimating the relationship between fish production and the key variables of technological integration (twoG and threeG mobile networks users) and other control variables, i.e., agricultural loan disbursements, wholesale, retail and grower price of fish, and unjustified gain using the twenty-four districts' data of rui fish. Additionally, this study applied the OLS estimation model to analyze the impact of technological integration (twoG and threeG mobile network) on unjustified gain along with other control variables, such as agricultural loan disbursements, fish production, and retail and grower price of fish. Besides, the Logistic Regression model has been conducted for the estimating the technological integration's (twoG and threeG mobile networks users) impact on unjustified gain (dummy variable) with the other control variables, such as fish production, agricultural loan disbursements, retail and grower price of fish. The estimated results have given mixed results: the impact of technological integration in fish production and unjustified gain from fish trading. Though the estimated results have mixed results, it may give a policy indication for fish growers, traders, policymakers, and government authorities.

9.2.1 Technological Impact on Rui Fish Production

In the estimated result (Table 4) based on equation 2, the technological integration variables have mixed results, i.e., twoG mobile connection may increase and the threeG mobile connection may reduce the Rui fish production, but the estimated result is statistically insignificant.

Table 4: OLS Estimation

Linear regression
Number of obs =24
F(5, 18) = 10.5
Prob > F = 0
R-squared = 0.6209
Root MSE = 0.8403

lnrui_production	**Coef.**	**T**	**[95% conf.**	**Interval]**
lntwoG	0.995 (1.946)	0.510	-3.093	5.084
lnthreeG	-0.700 (1.693)	-0.410	-4.257	2.857
Lnloan	1.362*** (0.293)	4.650	0.747	1.977
lnfarm_level_selling_price	1.264 (1.506)	0.840	-1.899	4.428
lnmiddleman_gain	-0.031 (0.037)	-0.840	-0.109	0.046
_cons	-18.886* (10.736)	-1.760	-41.442	3.671

*=<10%. **=<5%, ***=<1% level of significance

Source: Author's Estimation

The twoG mobile connection's findings comply with the study in Indonesian - fish production increases due to the technologically integrated supply chain, but the threeG mobile connection does not support the previous finding in Indonesia (Dwi Ardianto and Mudjahidin, 2022). Agricultural loan disbursement and Rui fish price at the farm level may increase Rui fish production, and the estimated coefficient of agricultural loan disbursement is statistically significant. Financial support for fish farming increases the productivity, sales, and profitability of fish farms in in Nigeria(Oparinde, Amos, and Adeseluka, 2017; Akerele *et al.*, 2019). A similar result is found in a study of Bangladesh, e.g., agricultural loan disbursements positively impact fish production (Sarker, 2016). Besides, middleman's gain from Rui fish trading may reduce Rui fish production, while the estimated findings are statistically significant. This means that the higher middleman gains from Rui fish trading may lead to reduced production of Rui fish.

9.2.2 Technological Integration Impact on Middleman Gain from Rui FishTrading

Table 5: OLS Estimation

Linear Regression
Number of obs = 24
F(6, 17) = 8.16
Prob > F = 0
R-squared = 0.526
Root MSE =0.3377

lnmiddleman_gain	**Coef.**	**T**	**[95% Conf. Interval]**	
lntwoG	0.059 (0.785)	0.080	-1.597	1.716
lnthreeG	-0.171 (0.677)	-0.250	-1.599	1.257
Lnloan	0.162 (0.204)	0.800	-0.268	0.593
lnrui_production	-0.123 (0.107)	-1.140	-0.349	0.104
lnretail_selling_price	3.816*** (0.846)	4.510	2.031	5.601
lnfarm_level_selling_price	-3.463*** (1.091)	-3.170	-5.766	-1.160
_cons	1.195 (4.153)	0.290	-7.567	9.956

*=<10%. **=<5%, ***=<1% level of significance

Source: Author's Estimation

In the estimated result (Table 5) based on equation 3, the technological integration variables, i.e., twoG and threeG mobile connections, may positively impact the middleman gain from rui fish production, where the twoG mobile connection is statistically insignificant. Rui fish production and farm level price may have a negative impact on the middleman gain from fish trading, the estimated result of farm level price is statistically significant. Besides, agricultural loan disbursement and the retail price may positively affect the middleman gain from rui fish, where the estimated result of the retail price is statistically significant at a 5% level.

9.2.3 Technological Integration Impact on Presence of Unjustified Gain in Rui Fish Trading

Table 6: Logistic Regression

Logistic Regression
Number of obs = 24
Wald chi2(6) = 12.44
Prob > chi2 = 0.0293
Log pseudolikelihood = -12.8191
Pseudo R^2 = 0.2136

unjustified_gain_dummy	Coef.	Z	[95% Conf. Interval]	
lntwoG	1.012 (5.383)	0.190	-9.540	11.563
lnthreeG	-2.124 (4.493)	-0.470	-10.931	6.683
Lnloan	0.455 (1.906)	0.240	-3.281	4.191
lnrui_production	-0.717 (0.673)	-1.070	-2.035	0.602
lnretail_selling_price	16.670* (10.152)	1.640	-3.227	36.567
lnfarm_level_selling_price	-20.450* (12.387)	-1.650	-44.729	3.828
_cons	31.720 (51.589)	0.610	-69.392	132.833

*=<10%. **=<5%, ***=<1% level of significance

Source: Author's Estimation

This study (table 6), based on equation 4, shows the impact of technological integration on the presence of unjustified gain from rui fish production(dummy variable) using the Logistic Regression estimation method. The twoG may positively and threeG may adversely affect the presence of unjustified gain from rui fish production, but both estimated results are statistically insignificant. Rui fish production and retail selling price may increase the presence of unjustified gain from rui fish, and the estimated result of retail selling price is statistically significant at 10% level. However, other control variables, i.e., Rui fish production and farm-level selling price, may reduce the presence of unjustified gain from Rui fish, and the estimated result of farm-level selling price is statistically significant at 10%.

10.0 Recommendation

The empirical study concluded that technological integration may positively impact the fish supply chain in Bangladesh. According to quantitative analysis, this study suggests some necessary recommendations based on econometric estimations.

i. Invest in robust digital infrastructure to ensure reliable internet connectivity and access to technological tools across all regions, particularly in rural and remote areas.
ii. Implement extensive training programs to equip fish farmers, processors, and supply chain workers with the necessary skills to use and benefit from technological innovations effectively.
iii. Government subsidies and incentive programs can help offset the initial costs of investing in technology for fish farmers.
iv. Collaborative partnerships between government agencies, research institutions, non-profit organizations, and private sector stakeholders can drive innovation and knowledge sharing in the fish farming sector.
v. Develop policies and initiatives that ensure equitable access to technology for small-scale and marginalized fish farmers, reducing the digital divide and fostering inclusive growth.
vi. Encourage research and development in sustainable inland fish farming practices and innovative technologies tailored to the specific needs of the Bangladeshi fish supply chain.
vii. Establish mechanisms for continuous monitoring and evaluation of technology integration initiatives to assess their impact and make necessary adjustments.

By implementing these recommendations, Bangladesh can build on the progress achieved through technology integration, ensuring a resilient, competitive, and sustainable fish supply chain that benefits all stakeholders involved.

11.0 Conclusion

According to the empirical estimation, the integration of technology may have a significant positive impact on the fish supply in Bangladesh. Additionally, technology integration may reduce the middleman-gain and presence of unjustified gain in Bangladesh's fish supply chain. Through the adoption of modern technological tools and systems, the fish supply chain has seen improvements in efficiency, traceability, and sustainability. Finally, this research will fill the literature gap and bring new insights into government fishery policies, fish traders, fish farmers, and consumers.

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