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Food safety and market choice of dairy producers in Bangladesh

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Abstract

Dairy production is an important income generating activity for smallholders in Bangladesh. However, milk production in Bangladesh is known to be of poor average quality and high losses due to limited and heterogeneous milk hygiene and food safety practices on farms and during milk collection. Dairy farmers in three agro-ecological zones of Bangladesh were surveyed in order to analyze their choice of dairy markets in relation to their food safety practices. After controlling for farm and household characteristics, physical infrastructure, type of delivery relationships and nominal milk prices received, we find that a particular group of farmers tends to maintain relatively high levels of food safety practices while receiving above average milk prices. Surprisingly, these farmers tend to choose local or traditional markets due to the absence of formal incentives for high food safety practices in cooperatives or among private dairy processors. Instead, informal institutions likely enable dairy farmers with above average food safety standards to negotiate higher prices in the local village surroundings. Regarding the transformation of Bangladesh's dairy sector towards more productivity, this finding highlights the importance to implement formal testing procedures and establish price related incentives that will reward above average food safety and milk hygiene.

JEL Codes: Q12, Q13, Q18.

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Keywords: Smallholders, dairy, food safety, milk hygiene, adverse selection, informal institutions, missing markets.

JEL Codes: Q12, Q13; Q18.

1. Introduction

The dairy industry in Bangladesh plays a significant role in reducing poverty by ensuring a steady flow of income from urban to rural areas (WHO, 2014; DLS, 2018; Adesogan, et. al., 2020). In Bangladesh, the dairy business accounts for about 20% of direct employment and 45% of indirect employment (DLS, 2018). This allows farming households to secure food and employment for family-own labor resources. Importantly, dairy farming provides a livelihood in particular for the poorest people, with rural poor households often deriving a large portion of their cash income from milk production and traditional milk processing (WHO, 2014; DLS, 2018; Adesogan, et. al., 2020).

In fact, Bangladesh's dairy sector is characterized by a large proportion of small-scale operations with only a few crossbred animals[1]. Dairy farmers are often landless and poor, and sometimes work under contracts for large private milk processing companies (World Bank, 2008; Shamsuddin, 2011; DLS, 2018; Adesogan, et. al., 2020). Due to their limited resources, the majority of small landholders in Bangladesh also engage in dairy farming as a subsistence activity.

However, over the past decade, there has been a significant increase in milk production in Bangladesh, along with a steady growth in the cattle population[2]. Despite being a densely populated country, Bangladesh's share of milk production is relatively small on a global scale and within the South Asian

[1] There are 8.385 million cattle holding households in Bangladesh. Among them, 7.2, 1.08 and 0.067 million cattle holding households are small, medium and large farms, respectively (BBS, 2020). About 81% of dairy cows are local breeds and only 19% are more productive non-local or cross breed cows in Bangladesh (BBS, 2020).

[2] There was an estimated growth from 23.3 to 24.7 million heads of cattle with 5.1 to 13.1 million metric tons of milk production between 2013 to 2022 in Bangladesh (DLS, 2022).

region (FAOSTAT, 2020). Milk, a healthy and nutritious food, is particularly beneficial for vulnerable groups such as children, pregnant women, and the elderly (WHO, 2014; Adesogan, et. al., 2020). In Bangladesh, the current demand for milk is 15.668 million metric tons (DLS, 2022). Milk availability varies across different socio-demographic factors such as regions, rural and urban areas, age groups, gender and income classes[3]. The average per capita milk consumption in Bangladesh is 193.38 ml/day/person, which is below the global average of 270 ml/day/person (Hemme and Otte, 2010). This highlights the significant differences in per capita consumption between Bangladesh and the world. It's worth noting that the WHO recommends a minimum milk consumption of 250 ml/day/person (Upadhyay, 2017; DLS, 2022).

In Bangladesh, the dairy market is predominantly traditional, accounting for 80% of the market share, while commercial markets procure only 20% of the milk from dairy producers (UNIDO, 2009; Islam, et. al., 2019). Selling milk to the commercial supply chain significantly improves the efficiency and effectiveness of dairy farms by increasing milk production and mitigating associated market-related risks (Barrett, et. al., 2012; Chen, et. al., 2015; Mutura et al., 2016). Therefore, choosing a producer-friendly dairy market can significantly enhance the livelihoods of resource-poor dairy producers and play a crucial role in equitable milk distribution throughout Bangladesh.

However, liquid milk, being highly perishable, poses also a risk to consumers unless it is cooled right after collection, especially in a warm country like Bangladesh[4]. Therefore, food safety practices are vital as they can further boost milk production, milk yield, reduction of post-collection losses and the profitability of dairy farms (Kumar, et. al., 2011, 2017, 2020).

It is therefore essential to pay considerable attention to food safety at the production stage, where the risk of milk contamination at the dairy farm is high (Desissa, et. al., 2013; Gossner, et. al., 2009; Kouamé-Sina, et. al., 2012; Montgomery, et. al., 2020). Milk buyers often complain about unhygienic milk production and reject spoiled milk, leading to waste if bacteria grow before the milk is sold to the nearest dairy market after quick collection from the dairy farm (Kumar, et. al., 2017, 2020; NDDB, 2014).

Also, dairy producers typically try to know and compare milk prices in advance and select their dairy market accordingly. However, a rise in milk prices does not always encourage dairy producers to adopt stricter sanitary practices, because relevant and effective raw milk testing facilities are not necessarily in place.

This study investigated the existing milk selling channels and dairy market structures in rural Bangladesh. The main focus was to identify the factors influencing a dairy producer's market choice and how this choice is related to food safety practices at the corresponding dairy farm. We considered both traditional and commercial dairy markets based on a survey conducted in dairy market-oriented villages in three distinct agro-ecological zones of the country.

Our study aims to provide recommendations on how to make the dairy market more efficient in procuring raw milk of higher average quality from dairy farmers in Bangladesh.

The paper is organized as follow: section 2 presents our conceptual framework in which we establish the suspected causal linkages between market choice and specific farm household characteristics including the number of food safety practices that they follow. Section 3 describes our data collection procedure and the econometric estimation strategy based on which we test the hypotheses that were

[3] Also, in Bangladesh, the average supply of protein of animal origin is 12.00 gm/capita/day, child malnutrition is 30.20% and prevalence of undernourishment was 11.40% in 2021 (ADB, 2022 & FAOSTAT, 2022).
[4] Maximum temperature is >=30^{o}C for 8-9 months (World Bank Group, 2020).

derived in the conceptual framework. Section 4 presents descriptive and econometric estimation results that are briefly discussed in section 5, while section 6 concludes.

2. Conceptual Framework and Model

2.1 Dairy markets, price formation and food safety in Bangladesh

The dairy sector in Bangladesh has been experiencing consistent growth in its overall market volume. This expansion is driven by several factors, including an increase in the demand for dairy products (World Bank, 2008; Shamsuddin, 2011) due to rising incomes and rapid urbanization (Sharma and Gulati, 2003), a growing middle-class population, the proliferation of modern retail markets like supermarkets that require high-quality and safe food items (Reardon and Timmer 2014), and government initiatives aimed at improving the population's nutritional status (Sharma and Gulati, 2003; Islam and Hoque, 2013; Montgomery, et. al., 2020).

Dairy production regions in Bangladesh are diverse in terms of i) annual milk production, ii) the number of dairy producers, and iii) the structure of cattle holdings. Moreover, not all geographic locations have access to both traditional and commercial dairy markets. In our analysis of the dairy value chain in Bangladesh, we identified two primary types of dairy markets: formal or commercial markets including dairy cooperatives and private dairy processors on the one hand and informal or traditional markets including local collectors and processors on the other hand (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019).

We use the following definitions to identify these markets:

M_1 - Local Market: This refers to markets where farmers sell milk directly to local consumers, or local collectors visit each farm to collect milk. They pay a fixed price for the milk, without considering its fat content. These collectors later sell the milk to local processors at a higher price to cover their labor and travel costs. Producers also have the option to sell their milk directly to local processors. In this study, local collectors and local processors are collectively referred to as the "local market", which is also known as the traditional or informal dairy market (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019, Morgan 2009, p.72).

M_2 - Cooperative Processors: This involves the formation of small groups of dairy producers through registration with a cooperative. One member of each group collects milk from the other members and sells it to a cooperative collection center. Each group member is paid a price based on the fat percentage of their milk (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019). The cooperative also offers dairy-related services to its group members, such as veterinary care, artificial insemination, and training on feed and farm management (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019).

M_3 - Private Dairy Processors: In this system, dairy producers travel to a private milk collection center to sell their milk. The price they receive is based on a chart that considers the fat percentage of the milk (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019). However, these private processors do not offer any dairy-related services to their suppliers. This private market, also known as the commercial market, involves the industrial use of milk in large-scale processing plants. This includes milk collection, transportation, reception, processing with various equipment lines, packaging, distribution networks and sales e.g. to urban consumers over longer geographical distances (Morgan 2009, p.72).

We refer to M2 and M3 as the commercial market due to its similarities of processing and marketing systems, and due to its larger scales of operation and distribution.

In any region, it can be assumed that producers prefer to sell their milk on the market where they can achieve the highest milk price net of transport- and other transaction cost. However, these factors may vary strongly across regions. We therefore formulate the first hypothesis:

Hypothesis 1: Factors that affect the dairy market choice of producers in Bangladesh differ across households, market types and agro-climatic regions.

Dairy processors and products in Bangladesh have a low safety record (Montgomery, et. al., 2020, Islam and Hoque, 2013). This has led to the safety of dairy products becoming a top priority for the Bangladeshi government (Islam and Hoque, 2013). The enhancement of productivity, quality, and safety of raw milk faces challenges such as the need for quality feeds, mastitis control, improved farm hygiene, better milk transportation, and more efficient cooling systems (Kumar, et. al., 2017). Consequently, there are numerous factors, starting from the dairy farm (Kumar, et. al., 2017; Montgomery, et. al., 2020) to the collection process (Montgomery, et. al., 2020), that influence the quality and safety of milk.

The milk collection process has distinct features in various dairy markets in rural villages (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019) that are sometimes missing in other locations. This is due to the influence of various heterogenous factors (Figure 1) that drive producer decisions on market selection.

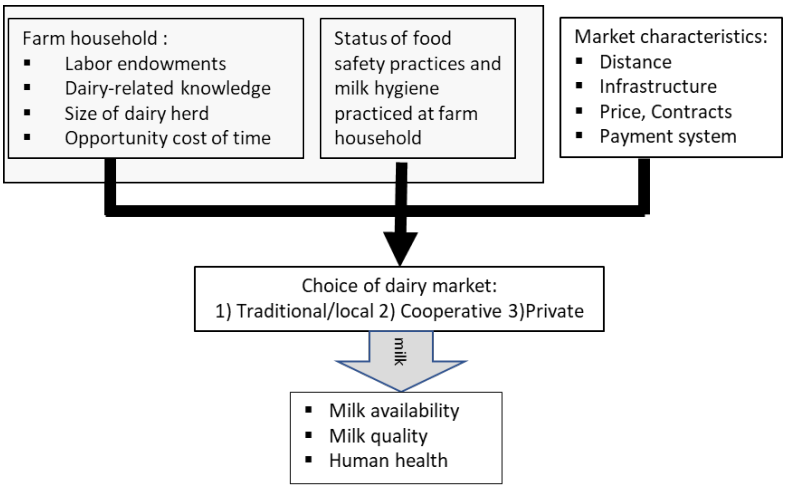

Figure 1: Conceptual framework

Dairy processors often blame producers for the unhygienic production of milk (NDDB, 2014). However, due to the costs involved (Kumar, et. al., 2017) and certain market characteristics, producers struggle to fully adhere to all food safety standards, e.g. inadequate farm management can lead to biological infections such as mastitis disease (Montgomery, et. al., 2020). Furthermore, poor cleaning practices can result in milk contamination through chemical transmission (Montgomery, et. al., 2020). It's important to note that the safety of milk is crucial for sales, as in the commercial market milk is tested for safety before sale (UNIDO, 2009; HIB, 2013; Islam, et. al., 2019), yet higher than minimum quality is not necessarily rewarded.

We therefore formulate the second hypothesis:

Hypothesis 2: Food safety practices are a characteristic of the farm household that influence the choice of the dairy market.

We test these hypotheses within the following general modelling framework:

$$M_{k,i} = f(X_i, T_{i,k}, M_{i,k}, S_i)$$

This framework explains the probability that farmer *i* chooses market M_k from *k=3* markets subject to four vectors of explanatory variables:

X: A vector of characteristics that describe the household, the persons who operate the dairy production and the size of the dairy farm.

T: A vector of location-specific characteristics that describe the structure of transport- and transaction cost between the respective dairy farm and the corresponding market.

M: A vector of control variables that describe conditions in the respective market, such as price paid to farmers, delivery conditions, type of contract between buyer and seller, etc.

S: A vector of variables that describe milk safety and hygienic practices that the farm may follow to some extent, or not at all.

We included the three market types M_1, M_2, M_3 defined above in our analysis.

2.2 Econometric estimation approach

We applied a Multinomial Logistic Regression (MNL) model to examine the statistical relationship between producers' choice of dairy markets in the three regions of Bangladesh and the four vectors of explanatory variables including food safety practices, farm characteristics and socio-economic control variables. Multinomial logistic regression is a classification method that can handle more than two discrete outcomes (Greene, 2003). It estimates the effects of explanatory variables in terms of log odds ratios when choosing one dairy market over a reference market category.

In our case, the reference category for each region is the local market (M_1). The model predicts the probabilities of choosing commercial markets (M_2 cooperative or M_3 private dairy markets) over the local market, based on the interpretation of their respective explanatory variables. The model satisfies the assumption of the Independence of Irrelevant Alternatives (IIA), as confirmed by the Hausman-McFadden test (1984). The specification of the MNL model used for testing market selection was as follows:

$$ln\left(\frac{P(M=Cooperative\ or\ Private\ market)}{P(M=Local\ market)}\right) = \beta_{0k} + \beta_{1k}X + \beta_{2k}T + \beta_{3k}M + \beta_{4k}S + \varepsilon \quad (1)$$

On the left-hand side of the equation, the endogenous variable is the log odds ratio of choosing the cooperative dairy market or the private dairy market, respectively, versus the local dairy market as the reference. On the right-hand side of the equation, β_{0k} is the constant term and ε is the error term. β_{1k} to β_{4k} are the coefficients estimated for the explanatory variables that explain dairy market selection according to our conceptual framework. These variables are listed in the table 3 together with summary statistics. For estimations, the Stata command for MNL models has been used without further modifications.

3. Data

3.1. Study area:

Traditional dairy markets are more or less spread throughout Bangladesh. However, the milk collection centres of cooperative and private dairy markets are primarily located in the three major milk producing divisions of Bangladesh. These divisions are Rangpur, Rajshahi, and Khulna, which produce 23.88%, 18.12%, and 14.18% of the national milk output, respectively (BBS, 2020). We conducted our survey in five districts of these divisions: Rangpur, Khulna, Shatkhira, Sirajgonj, and Pabna. These districts were categorized based on their geographical locations in Bangladesh. The survey area and

sample size are presented in Table 1. Regarding the agro-climatic differences, the survey regions can broadly be described as dry, coastal and river regions. These agro-climatic zones follow official definitions in the National Adaptation Plan of Bangladesh (2022).

Table 1: Survey location and market wise sample size

Division	*District*	*Geographic category*	*Sample size (N)*	*Cooperative market (N)*	*Private market (N)*	*Local collector (N)*	*Local processor (N)*
Rangpur	Rangpur	Dry zone	146	23	79	41	3
Khulna	Khulna	Coastal zone	122	29	39	35	19
	Shatkhira						
Rajshahi	Sirajgonj Pabna	River zone	230	112	49	33	36

Source: Author's own survey (2023).

Subsequently, districts, upazilas, and villages were selected from these three divisions based on the presence of a high number of dairy producers and the presence of both commercial and traditional market clusters. The location of these dairy market clusters allowed us to identify their respective milk suppliers, which were our survey targets.

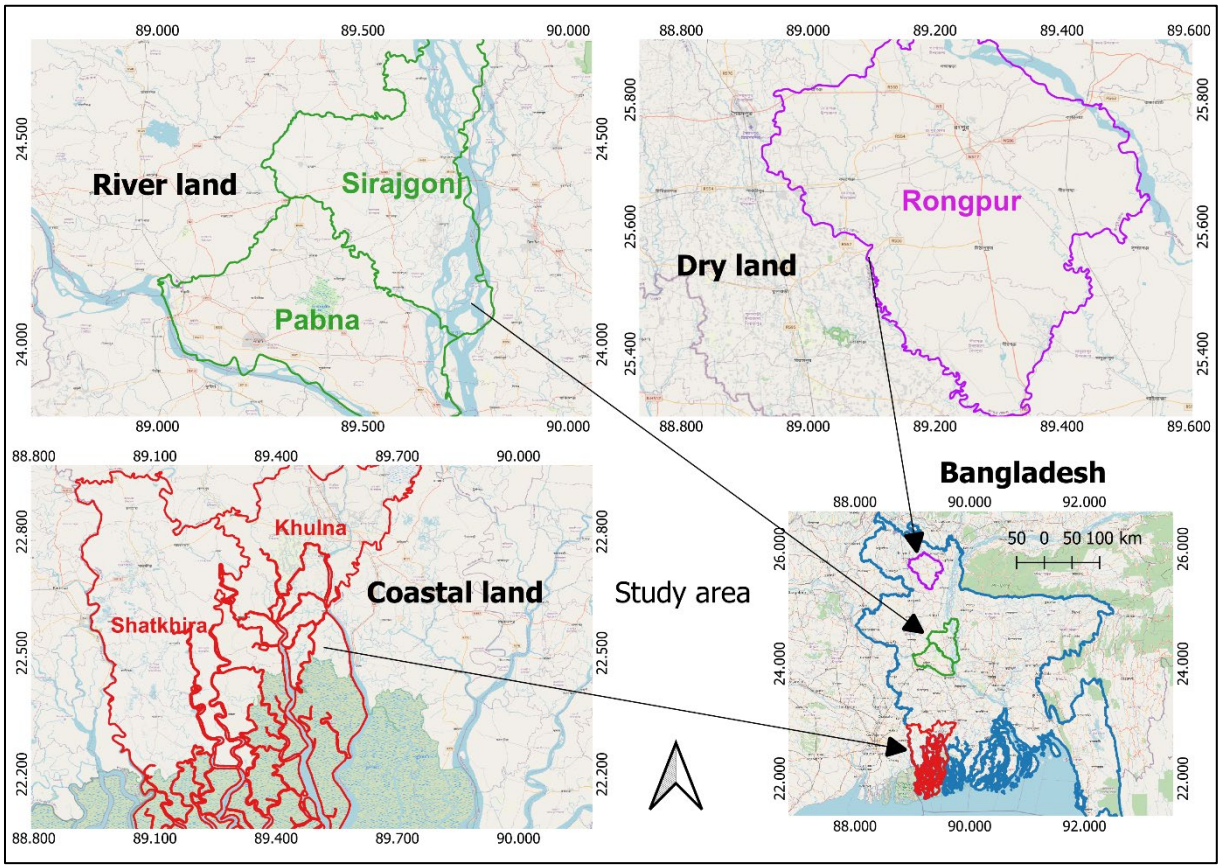

Figure 2: Survey area and land category in Bangladesh.

Figure 2 provides a map that identifies the three agro-ecological survey regions where the sample was collected.

3.2. Survey design

Data were collected in the dry, coastal, and river regions from March to June in 2023. We interviewed a total of 498 dairy producers using a structured questionnaire. The producers were chosen based on their affirmative response to the question, "Do you sell milk to the market?". Villages were selected based on the presence of dairy farmers, and upazilas were chosen based on the availability of dairy markets. We used multistage cluster sampling to identify market-oriented dairy producers. The Department of Livestock Service (DLS), a government body, was asked to assist in tracing the locations of these producers. There is only one government-operated cooperative dairy processor, BMPCUL (Milk Vita cooperative), established in 1973, and more than 13 commercial or private processors (Raha, 2007). During our survey, we identified Akij Dairy, Arong/Brac Dairy, and Pran Dairy as active private dairy processors with a high market share in 2023. We found that the milk collection centers of the MilkVita cooperative and of the private processors were mostly located in the same region. We also discovered anonymous local collectors and local processor markets in the respective locations of the dairy producers.

3.3. Measuring food safety practices

Particular attention was paid to survey indicators of food safety practices in the three regions. To assess the adoption status of food safety at the farm level, we identified 73 measures that are potentially being practiced by farmers and can be related to milk safety (Table 2). A complete list of related survey questions can be found in the Appendix. These 73 practices were grouped under six categories following Kumar et al. (2011, 2017,2018, 2020) who developed a list of common food safety issues. Also, these practices were adopted in consultation with scientists working on milk safety issues in Bangladesh including the study of Yang, et. al., (2019). These measures were mostly related to the control of chemical and microbiological hazards along with primary hygiene practices at farm. Furthermore, for comparative assessments of food safety practices of dairy producers who sell milk to one or more of the three different markets, we developed an index of adoption of food safety practices (FSI). This index was based on principal component analysis (PCA) of the 73 different measures of food safety. This method also solves the problem of potentially high correlations between the explanatory variables (Hair et al., 1998) which may distort further regression analysis (e.g. due to "Multicollinearity").

Table 2: Categories and scores of food safety practices of dairy producers in the sample

Grouping food safety practices	Group wise no. of food safety practices (total =73)	Label and code of food safety practices	PCA FSI score range
A. Hygiene practice in milking	20	Always =1 Sometimes=0.5 and Never=0	-1.356 to 1.555
B. Milk storage hygiene practice	18		
C. Cow raising environment practice	12		
D. Dairy cow health practice=8	8		
E. Farm information record practice	11		
F. General hygiene practice	4		

Note: FSI=food safety index; PCA=principal component analysis.

Source: Author's own survey (2023).

4. Results

4.1. Descriptive results

Table 3 presents descriptive statistics (means and standard deviations) for the explanatory variables that were included in the MLR model. Within each climate zone, the sample means from the

cooperative and private markets, respectively, have been tested against the hypothesis of equality of their mean with the mean value of the local market in that climate zone. This was done in order to analyze if the dairy farms in the sample would differ according to market choice. Table 3 reveals that there are in some instances statistically significant differences between farmer or farm level characteristics. For instance, in the coastal region significantly more farmers in the cooperative have received training on milk production than farmers in the two other market types. However, this pattern cannot be confirmed for the other two agro-ecological zones: neither in the river zone nor in the dry land exhibit farmers in the cooperatives on average a higher level of received training on milk production. Instead, in the dry region, farmers that sell to private dairy processors have received significantly more training. Also, in this region the dairy farmers in the cooperative and private market, respectively have stated less often that dairy farming would be their main agricultural occupation compared to farmers who sell to the local market. In the two other zones, this pattern cannot be confirmed either.

However, both in the coastal and in the river region it turns out that the largest farms tend to sell to private dairy processors or to the cooperative. In the dry region there is a tendency that larger farms tend to sell to the local market, even though the difference is statistically not significant.

Regarding market and transportation characteristics, it turns out that private dairy processors pay the highest prices to producers in all three climatic regions, and this difference is statistically significant. Surprisingly, cooperatives exhibit the lowest average milk prices both in the river region and the dry region, and in the latter region this difference is even statistically significant. Only in the coastal market are the lowest average milk prices reported for local sales of raw milk.

As expected, mandatory milk supply is a statistically significant feature of cooperatives in all three regions, and this also holds for private dairy processors. Interestingly, for these market types farmers in the sample have also reported transport access via concrete roads in all three climatic zones.

Even though it's not in all instances statistically significant, the descriptive statistics show also an average tendency that in both commercial market types (cooperative and private), farmers have to pay the travel costs themselves.

The number of food safety practices that farmers in the sample have reported to follow also differs strongly between market types and across the three climatic regions: while the food safety practices appear to be rather similar across market types in the coastal region, cooperative farmers in the river region report substantially less food safety practices than in the local market, while farmers who sell to private processors in this region report a higher number of food safety practices. This picture is reversed in the dry region: cooperative producers report on average the highest number of food safety practices, followed by farmers who sell to private processors. In this region, farmers in the local market report on average the lowest number of food safety practices, and this is also the lowest average number of food safety practices from all observed three markets across all regions.

Table 3: Mean and standard deviation for the selected variables across three ecological zones

Category	Climate zone:	Coastal			River			Dry		
k	Market:	Local	Cooperative	Private	Local	Cooperative	Private	Local	Cooperative	Private
X	Dairy experience (year)	14.963 (9.934)	16.069 (12.03)	12.897 (8.632)	22.522 (14.103)	21.946 (10.418)	15.673*** (11.05)	20.5 (13.016)	16.696 (10.675)	17.671 (11.676)
X	Household head (dummy, 1= dairy farmer)	0.648 (0.482)	0.655 (0.484)	0.769 (0.427)	0.739 (0.442)	0.866** (0.342)	0.796 (0.407)	0.75 (0.438)	0.652 (0.487)	0.797 (0.404)
X	Training on milk production (dummy, 1=yes)	0.259 (0.442)	0.483** (0.509)	0.282 (0.456)	0.101 (0.304)	0.17 (0.377)	0.184 (0.391)	0.045 (0.211)	0.087 (0.288)	0.165* (0.373)
X	Joining association (dummy, 1=yes)	0.241 (0.432)	0.207 (0.412)	0.359 (0.486)	0.159 (0.369)	0.313** (0.466)	0.163 (0.373)	0.136 (0.347)	0.13 (0.344)	0.076 (0.267)
X	Household size (no.)	5.185 (1.705)	5 (2)	5.026 (1.885)	5.478 (1.72)	5.571 (1.887)	4.796** (1.369)	5.045 (2.134)	4.565 (1.409)	4.772 (1.739)
X	Male person(no.)	2.444 (1.058)	2.621 (1.049)	2.641 (1.063)	2.667 (1.233)	2.929 (1.278)	2.714 (1.021)	2.5 (1.131)	2.565 (0.992)	2.405 (1.138)
X	Main agricultural occupation (dummy, 1=dairy)	0.815 (0.392)	0.931 (0.258)	0.846 (0.366)	0.928 (0.261)	0.982* (0.133)	0.939 (0.242)	0.727 (0.451)	0.304*** (0.47)	0.519** (0.503)
X	Herd size (no.)	7.389 (6.908)	8.621 (9.132)	12.641** (13.204)	8.058 (6.347)	10.304** (6.819)	10.837** (8.432)	6.75 (22.164)	3.174 (1.922)	4.051 (2.895)
T	Distance of selling place (km.)	6.18 (11.799)	8.466 (10.121)	1.74** (4.815)	1.537 (4.876)	3.908*** (3.695)	0.726 (0.987)	0.261 (1.232)	2.548* (7.55)	1.233*** (0.825)
T	Travel mode (dummy, 1=walk)	0.611 (0.492)	0.241*** (0.435)	0.359** (0.486)	0.362 (0.484)	0.438 (0.498)	0.429 (0.5)	0.932 (0.255)	0.348*** (0.487)	0.316*** (0.468)
T	Type of road (dummy, 1=concrete)	0.259 (0.442)	0.724 *** (0.455)	0.436* (0.502)	0.652 (0.48)	0.795** (0.406)	0.857** (0.354)	0.295 (0.462)	0.652*** (0.487)	0.684*** (0.468)
T	Travel cost paid (dummy, 1=by farmer)	0.315 (0.469)	0.552** (0.506)	0.538** (0.505)	0.667 (0.475)	0.75 (0.435)	0.694 (0.466)	0.273 (0.451)	0.391 (0.499)	0.544 (0.501)
T	Distance of nearby food market (km.)	1.487 (1.912)	2.328 (3.288)	1.165 (1.475)	1.633 (1.698)	2.156 (2.36)	2.166 (1.772)	1.595 (1.472)	2.046 (1.663)	1.548 (0.997)
M	Milk supply contract (dummy, 1=yes)	0.481 (0.504)	0.793*** (0.412)	0.744*** (0.442)	0.623 (0.488)	0.643 (0.481)	0.735 (0.446)	0.523 (0.505)	0.783** (0.422)	0.772*** (0.422)

M	Mandatory milk supply (dummy, 1=yes)	0.093 (0.293)	0.31** (0.471)	0.436*** (0.502)	0.246 (0.434)	0.143* (0.351)	0.306 (0.466)	0.205 (0.408)	0.565*** (0.507)	0.544*** (0.501)
M	Milk price (BDT./litre)	45.889 (0.828)	46.310 (1.148)	50.128*** (0.813)	46.545 (0.886)	45.478 (1.067)	49.481*** (0.565)	49.232 (0.451)	47.75** (0.423)	51.061** (0.827)
S	Food safety practice (no.)	24.722 (8.313)	27.276 (13.117)	23.897 (8.672)	16.928 (11.525)	11.732*** (7.11)	20.531* (10.458)	11.227 (2.495)	20.087*** (11.966)	17.241*** (8.89)
S	Food safety index (FSI)	0.759 (0.133)	0.601 (0.195)	0.361** (0.140)	-0.529 (0.110)	-0.027** (0.241)	0.099*** (0.111)	0.015 (0.099)	-0.412*** (0.076)	-0.227 (0.160)
	n	54	29	39	69	112	49	44	23	79
	N	122			230			146		

Note: BDT is the currency, Bangladeshi Taka. Each market in a particular region is tested (e.g. t-Test) against the respective local market. ***P < 0.01, **P < 0.05, *P < 0.1. Source: Author's own survey (2023).

4.2 Results from MNL estimations

Estimation results for the MNL model that was specified in equation 1 are reported in Table 4. The table shows three separate MNL estimations for each of the three agro-climatic zones, respectively. Next, within each estimation, the local market serves as the omitted base category and the two other columns contain estimated coefficients that indicate the estimated effect of an explanatory variable on the probability that a farmer has chosen this particular market. Due to the relatively large number of estimated coefficients, we discuss only statistically significance at commonly used levels and the sign of the estimated coefficients; for brevity we do not report marginal effects that are available upon request.

Category X:

Experienced dairy producers sell to local markets. Interestingly, having more male members in the family encourages producers to choose cooperative and private (=commercial) markets. Also, producers who are heads of their families prefer to sell milk to local markets in dry regions and to private markets in coastal regions. In river regions, dairy farming as a main occupation seems to influence producers to sell milk to cooperatives and private (=commercial) markets, yet not in dry and coastal regions where milk is primarily sold to local markets.

Dairy producers with more family members sell their milk on the local market in all regions. Family members are likely to be busy with other tasks, such as education, crop and fish production, farm work, and off-farm activities. Therefore, household management requires more time, and dairy producers prefer to sell milk at the farm door to the local milk collector.

Dairy producers with larger dairy herds sell their milk exclusively to the private market in river and coastal regions. Training on dairy farming influences the selection of cooperative and private markets, while membership in village associations encourages sales to the cooperative market in river regions and to private markets in coastal regions. This is because, in river regions, cooperative milk collectors are very close to dairy farms, so producers do not need to travel far nor pay substantial transportation costs. Thus, membership in village associations plays an active role in selecting either one or the other commercial market.

Category T:

In all three regions, market access by concrete road has a statistically significant and positive effect on choosing cooperative or private dairy processors. In contrast, walking as the primary transportation mode reduces the probability of choosing a respective market significantly in all three regions.

In dry regions, producers prefer local dairy markets primarily if the nearest food market is relatively far away. However, in coastal and river regions, it can be observed that producers may choose cooperatives or private processors more likely even if the nearby food market is relatively far away.

Category M:

Interestingly, the partial effect of reported milk prices received by farmers is not in all markets positively and in a statistically significant way related to market choice. At first sight, this seems counterintuitive because markets that pay a higher price should be expected to attract a farmer more likely. However, from our conceptual framework it becomes clear that opportunity cost within the household as well as transport and transaction cost differ strongly across households. Therefore, it is plausible that not the nominal market price received would be relevant for the market choice but

instead the implicit shadow value that the received market price has net of the household specific opportunity cost.

Given the household specific labor endowments, skills and other income generating activities, also the structure of delivery contracts may be an important component of such opportunity cost: Dairy producers who have supply contracts with cooperatives or private markets tend to choose these markets in all regions, especially in river regions. These contracts, usually in written form, ensure that producers are committed to supplying and selling milk to the private or cooperative market daily during the dairy cow's lactation period. This commitment encourages dairy producers in all regions to choose the private- or cooperative market.

In coastal and dry regions, dairy producers select cooperative and private markets where milk supply is mandatory. Such mandatory supply regulations reduce risk for buyers and farmers and ensure a more stable supply of raw milk. However, we found the opposite results in the river region, where mandatory milk supply drives producers to sell milk in the local market.

The private market has expanded its milk collection centres mostly in the last 20 years (Raha, 2009). In the absence of the private market, milk producers traditionally sold their milk to the local market, either to local collectors or processors. Thus, long experience, selling habits, and beliefs do not make dairy producers switch to a new market, especially to the private market, and instead they still tend to prefer the traditional local market.

Category S:

Dairy farmers who maintain a higher Food Safety Index (FSI) than the sample average are more likely to sell their milk to private and cooperative markets in dry areas, and to private markets in coastal regions. In contrast, a higher number of food safety practices according to FSI has no effect on commercial market choice in the river zone.

In order to analyze the potential interaction between market prices received and food safety practiced on the farm we have also added an interaction effect between these two variables to the model ("Price x FSI"). The interaction between FSI and milk price provides additional insights beyond the individual effects of these two variables: this variable identifies farms for which a particular high price received goes along with a particular high number of food safety practices followed.

Interestingly, this interaction term is significantly negative for the private market in both coastal and dry areas. This suggests that producers with a higher FSI who at the same time have received a relatively high milk price are less likely to sell their milk to the private and cooperative market, preferring local collectors or processors instead, even though the private market offers comparatively higher nominal prices (see Table 3). This unexpected result may be due to several reasons. Firstly, the private market tests only the fat content, and pays accordingly, without systematically assessing the producer's hygiene status at the farm. Secondly, there is no special price reward from the private market for milk from farms with a particular high FSI. This may encourage dairy producers to sell their milk to the local market. Additionally, the price difference between the private and local market is not significant and can be offset by the producer's travel costs to the private milk collection center.

On the other hand, local milk collectors, who visit the dairy farm daily if they have at least a verbal supply agreement with producers, have the opportunity to inspect the dairy farm's hygiene and the producer's food safety practices. Although they pay slightly lower prices than the private market, they offer services such as no travel costs, no travel time, and no travel required by dairy producers in all regions.

For the cooperative dairy market, the interaction term between price and FSI is positive in the coastal and river region, yet the effect is statistically not significant in any of the regions. This is because producers selling milk to the cooperative market are usually members of the milk cooperative society, which provides them with various incentives such as training on milk production, farm and feed management, and milk marketing. Yet, cooperative prices are typically pooled prices such that even farms with an above average FSI may not be able to receive a higher price since this might violate common cooperative practices. In other words: to the extent that cooperatives may have a systematic training approach towards milk hygiene and food safety, it follows from the standard philosophy of cooperatives that a collectively high FSI level is targeted for supplying farmers rather than incentivizing individual performance.

Table 4: Multinomial logit model for dairy market selection in three dairy production regions

Category	Climate zone:	Coastal		River		Dry	
k	Market:	Cooperative	Private	Cooperative	Private	Cooperative	Private
X	Dairy experience (year)	0.0275 (0.0362)	-0.128** (0.0541)	-0.0228 (0.0190)	-0.0727*** (0.0240)	-0.0298 (0.0457)	-0.0182 (0.0426)
X	Household head (dummy, 1= dairy farmer)	-0.327 (0.789)	3.407*** (1.235)	0.711 (0.557)	0.535 (0.617)	-4.573** (1.839)	-3.508** (1.768)
X	Training on milk production (dummy, 1=yes)	0.759 (0.743)	-2.091** (1.053)	1.225* (0.698)	1.217 (0.767)	1.400 (3.074)	2.238 (2.904)
X	Joining association (dummy, 1=yes)	0.0919 (0.846)	2.986*** (1.126)	1.585*** (0.527)	-1.072 (0.687)	-2.266 (1.821)	-3.349* (1.724)
X	Household size (no.)	-0.797** (0.339)	-0.452 (0.367)	-0.177 (0.189)	-0.809*** (0.250)	-0.435 (0.449)	-0.315 (0.408)
X	Male person(no.)	1.257** (0.617)	0.462 (0.616)	0.401 (0.267)	0.943*** (0.321)	1.101 (0.747)	0.433 (0.690)
X	Main agricultural occupation (dummy, 1=dairy)	-0.0320 (1.335)	-2.261 (1.632)	1.991** (0.944)	0.350 (0.969)	-4.778*** (1.352)	-3.693*** (1.240)
X	Herd size (no.)	0.0277 (0.0461)	0.116* (0.0596)	0.0464 (0.0370)	0.120*** (0.0420)	-0.111 (0.183)	-0.0108 (0.0464)
T	Distance of selling place (km.)	-0.0725* (0.0392)	-0.246*** (0.0718)	0.443*** (0.0912)	-0.456** (0.228)	-0.111 (0.130)	-0.306* (0.183)
T	Travel mode (dummy, 1=walk)	-1.881** (0.954)	-2.826** (1.162)	1.597*** (0.526)	-0.630 (0.652)	-7.116*** (2.185)	-6.586*** (2.093)
T	Type of road (dummy, 1=concrete)	2.472*** (0.814)	-1.165 (1.061)	1.277** (0.554)	1.709** (0.712)	3.178** (1.595)	2.803* (1.487)
T	Travel cost paid (dummy, 1=by farmer)	1.431* (0.837)	2.224** (1.019)	0.563 (0.556)	0.0968 (0.666)	0.398 (1.264)	1.623 (1.050)

T	Distance of nearby food market (km.)	0.321* (0.165)	-0.309 (0.268)	0.0468 (0.111)	0.325** (0.150)	-0.207 (0.486)	-0.423 (0.456)
M	Milk supply contract (dummy, 1=yes)	0.226 (0.868)	1.948 (1.248)	0.0123 (0.486)	0.983* (0.577)	7.663*** (2.806)	6.998*** (2.609)
M	Mandatory supply (dummy, 1=yes)	1.589 (1.027)	3.401*** (1.154)	-0.0460 (0.539)	-0.587 (0.586)	0.587 (1.914)	0.910 (1.769)
M	Milk price (Tk./litre)	-0.152* (0.0867)	0.276*** (0.105)	-0.0742 (0.0519)	0.0545 (0.0585)	-0.332** (0.159)	-0.174 (0.149)
S	Food safety index (FSI)	-2.817 (3.180)	13.52** (5.253)	-5.043 (3.100)	-2.601 (3.040)	30.15*** (9.991)	32.17*** (9.692)
S	Price x FSI	0.0569 (0.0704)	-0.325*** (0.118)	0.0779 (0.0614)	0.0431 (0.0593)	-0.607*** (0.203)	-0.642*** (0.196)
	Constant	4.917 (4.081)	-10.90** (4.993)	-2.467 (2.857)	-3.840 (3.282)	21.10** (8.734)	14.68* (8.370)
	N	121		229		146	
	LR $chi^2(36)$	135.87		172.03		167.28	
	Prob > chi^2	***		***		***	
	Pseudo R^2	0.5253		0.3603		0.5817	

Note: Standard errors in parentheses. Local market is the reference category. ***P < 0.01, **P < 0.05, *P < 0.1. Source: Author's own survey (2023).

5. Discussion

Food safety practices at dairy farms can influence their market selection. Studies by Jiang and Batt (2016) and Yang et al. (2019) in China found that higher price premiums encouraged producers to adopt improved food safety measures at dairy farms. However, Aggelogiannopoulos et al. (2007) and Giacomarra et al. (2016) found that increasing the selling price had a lesser effect on FSI, possibly due to asymmetric information about hygiene at the dairy farm.

If producers are offered a higher price and are involved in the price negotiation process for higher FSI (as suggested by Jiang and Batt 2016 & Yang et al., 2019), this could increase milk production and profitability at the dairy farm (Kumar et al., 2011, 2017, 2020). It could also stimulate the growth of the private and cooperative dairy market.

However, in rural Bangladesh, food safety at farm is not factored into the milk collection structure of private and cooperative dairy markets, and these markets lack information about farms that prioritize food safety as part of the milk production process. As a result, dairy producers with a high Food Safety Index (FSI) are not incentivized to sell their milk to private and cooperative markets, as these markets do not evaluate hygiene farm separately; also, there are no price incentives for hygienic milk production. This information asymmetry prevents private or cooperative milk collectors from identifying milk from high FSI dairy farms, making the private market less appealing to those dairy producers who individually prioritize high food safety standards- a potential adverse selection problem.

To address this, processors in Bangladesh should identify farms that maintain high food safety standards and encourage them to sell their milk by offering a price premium. This approach could promote better food safety practices at dairy farms and contribute to the long-term expansion and sustainability of milk production and supply in both cooperative and private markets.

6. Conclusions

We have surveyed dairy farmers' market choice in three agro-ecological zones of Bangladesh. For this, we have distinguished between cooperative markets, private dairy processors and the traditional or local markets for dairy products. In particular, we were interested to understand how the number and intensity of food safety and milk hygiene practices that a farm household reported to follow may explain the choice of any of the three markets. For this, it has been decided to analyze market choice in the three agro-ecological zones separately, because this allowed us to better control for regional heterogeneity.

At first glance, our findings confirm some expected and widely established results: cooperative and private dairy processors represent in Bangladesh, as in many other developing countries, a more commercial value chain that offers on average higher nominal prices to farmers. However, quite often physical infrastructure in terms of paved roads seems to be a decisive factor regarding farmers having access to these markets. Thus, it seems obvious that farmers would choose these commercial markets and prefer them over the traditional or local market if favorable physical infrastructure was present.

However, in all regression results we found the nominal raw milk price to be of only limited explanatory power, if any. Instead, after controlling for household specific opportunity cost and further transaction cost related aspects of the milk delivery relationships in each market, we found that it is likely the household specific shadow value of raw milk sales that may determine market choice.

Even more interestingly, we found that a particular subgroup of farmers seems to follow relatively high food safety standards while receiving high reported nominal prices. According to our regression

results, this subgroup of farmers tends to favor the local or informal market over commercial (cooperative or private) processors even after controlling for physical market access through the type of infrastructure, distance and delivery relationships.

Our interpretation of this finding is as follows: due to the absence of formal testing procedures and on-farm monitoring of food safety practices even in the commercial markets, the farmers who voluntarily follow such practices ambitiously are deterred from these markets due to missing price incentives.

Informal institutions in the local market however may function in this respect as surprisingly effective food safety control and reward mechanisms: in local, village-based markets, customers may know the approximate level of food safety standards maintained by a certain farm from personal experience and this may give such farms the opportunity to negotiate an above average milk price.

From a scientific perspective, this finding highlights the importance and effectiveness of informal institutions for rewarding food safety practices even in the absence of formal control measures. This however will only work to the extent that producers and consumers at the local level share the same understanding of milk hygiene and food safety, highlighting the importance of knowledge provision and dissemination even in the absence of formal commercial market structures.

To a certain extent, this finding may also add to our understanding why local or informal dairy market structures in least developed countries tend to be so persistent. In the long run however, this may indicate also an adverse selection problem and a potential lock-in effect especially for famers with high food safety standards. These effects may bear potentially severe implications for structural change: as long as dairy farmers with an above average commitment to milk hygiene and food safety practices experience their highest price reward in local markets, options for farm growth will be rather restricted to small production volumes that can be marketed in the very near surroundings of a farm.

Further productivity increases through investment in larger, more efficient and more commercial farm structures in Bangladesh will according to our results therefore also critically depend on the ability of actors in the related value chains to establish credible monitoring and reward systems for milk hygiene and food safety practices.

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Appendix:

The list of all 73 food safety practices that were part of the survey is available upon request.