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Determination of consumer milk price in the informal dairy market in Bangladesh: A district level analysis of vertical system linkage

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Abstract

The objective of this study was to identify the determinants of consumer milk prices and test the hypothesis that input prices, e.g., rice straw and wheat bran, as well as the farmgate milk price exert an influence on the consumer milk price. A unique panel dataset from July 2018 to June 2021 was obtained from the Integrated Dairy Research Network (IDRN) Bangladesh Monthly Dairy Sector database and was analysed using the Generalized Methods of Moments (GMM) methodology. The data collection and validation were done with a national panel of experts jointly with the data collection and processing team. The study found: a) vertical linkage with input and output price is highly affecting the consumers milk price which was due to the substantial variation across the regions and time; b) The dynamic panel analysis of GMM revealed mixed relationship between input prices (rice straw and wheat bran), farm gate milk prices, and the consumer milk price; c) The farmgate milk price determines the increase in consumer milk prices, and it is possible to predict the consumer milk price based on the time-price-system interaction variability of the farmgate milk price; d) Using COVID-19 as a proxy for real time impact, the study found a stark impact of COVID-19 on the input price and output prices and triggering a decrease in consumer milk prices by 3.96 BDT kg^{-1} milk (0.05 USD kg^{-1}). The findings of this study are expected to be beneficial to the decisions making process of dairy farmers, milk processors, feed industry, consumers, and policy makers.

Keywords: Milk production, feed price, IDRN networking, regional price dynamics

1 Introduction

In Bangladesh, similar to other Asian countries (India, Pakistan, Nepal and China), the consumption of milk and milk-based products has been increasing steadily, driven by population and income growth (IFCN, 2021). Considering the dynamic development of consumption, milk production, processing and marketing activities have undergone a substantial transformation, toward enterprise-driven dairy industry (Uddin *et al.*, 2020). Milk production in Bangladesh is 11.96 million tons in 2020[1] (DLS, 2020) and is characterised by smallholder dairy production carried out on about 1.52 million farms, with an average cow number of 2.7 (IDRN, 2021). The national average milk availability per capita and day in 2021 was at 178 ml (translating to 64.85 kg per capita per year), which is still below the recommended intake of 250 ml per capita per day (DLS, 2019). The lower consumption vis-à-vis availability might be linked with higher consumer price and higher farm gate milk price. The seasonal fluctuation of milk production is thought to be another driver for high consumer milk price. Finally, the higher feed price (41 % higher than global feed price) lead to higher feed costs and consequently, the cost of milk production. Considering this, it is of high interest to see whether any feed ingredient price could have direct impact on consumer milk price.

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[1] According to IDRN, the total milk production is 8.75 million ton in 2020, which is about 3 million tons lower than national statistics. However, there is still controversy on total milk production which is under consideration for improving methodology to estimate the total milk production which is close to the reality.

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The milk produced by the farmers is marketed by both formal and informal marketing chains. The formal sector where milk is delivered to processors accounts for only 2.4 % in Bangladesh, where at global level the milk delivered to the processors accounts for 68 % (IFCN, 2021, Uddin *et al*., 2022). There are 13 major processors who collect milk from the dairy farmers and process into further dairy products. The major three processor (Milkvita, PRAN dairy Ltd., BRAC dairy and Food Ltd.) process 1.1 % of the total milk production in the country in 2021. The remaining ten processors process 0.6 %. The Top 3 processors have 64 % share of the formal milk marketing in Bangladesh.

Dairy farming is an integral part of the agricultural system where the vertical linkage of the farmers and consumers is a major component within the dairy value chain. This entails that a system dynamic approach offers new insights to sustainable agricultural systems (Walters *et al*., 2016) and it remains valid for dairy as the input and output relation matrix is a key for milk price and production systems.

However, the cost of milk production is highly linked with profitability and sustainability of dairy farmers (Hemme *et al*., 2014; Uddin *et al*., 2017). Along the supply chain of milk production to consumption, milk price is one of the major factors for dairy sector competitiveness (Roland *et al*., 2016) and increase in profit (Blackmore *et al*., 2020) because of its huge influence on the future development of the sector. Creating updated knowledge on the current situation and trends back to the past on milk production and prices are of utmost importance in making reliable forecasts of the future growth and dynamics of the dairy sector development. In order to predict the future, the past and the present have to be carefully analysed since the future is the further development of the present (Roland *et al*., 2016).

The higher production cost is translated to the higher milk price. The question remains how the CMP is affected and what steps shall the dairy farms consider to reduce the cost of milk production. With the current cost structure of dairy farms in Bangladesh, feed cost is on average 39 % higher than global feed costs (IDRN, 2022), which has repercussions on retail milk prices. As the most important cost element is feed prices and the highest determinant of dairy income is from milk sales, the milk production sector needs effective milk price policies in order to attain viable profit levels for future investments and further business development. The feed cost reduction would be seen as a promising way to reduce the cost of milk production (Hemme *et al*., 2014; Uddin *et al*., 2020). In Bangladesh, among the feed components commonly used in rations, rice straw is the major basal roughage, which is used by 92 % of the farmers year-round (Uddin *et al*., 2020), followed by the wheat bran (82 %). Both rice straw and wheat bran prices are thus the major determinants of input costs, hence it is highly important to see how these prices affect milk prices at the farm gate and at the consumer levels.

To the best of our knowledge, a system model specification that incorporates these variables has not been applied yet for Bangladesh dairy farming. In order to model the temporal and spatial price dynamics, panel data are needed which are scarce in almost all of developing countries, Bangladesh being no exception. The Integrated Dairy Research Network (IDRN) has provided us with the opportunity to collect data on a monthly basis on the different key parameters of the dairy sector. Hence, the objective of this study is to identify relationship between milk sale prices and feed prices in formal and informal market conditions.

2 Materials and methods

The imbalance in input and output price and driving factors that affect the informal milk market price, it is of high interest to see how the input price, particularly the rice straw (most typically used as a source of roughage in the ration) and wheat bran (the most typically used as a source of concentrate in the ration) price, influence the consumers milk price through the change in farm gate milk price. This study has envisaged to investigate this hypothesis using a combination of i) the System-Generalized Methods of Moments (GMM) approach, and ii) Integrated Dairy Research Network (IDRN) approach. The main goal of the GMM application in our study is to combine the observed economic data with the information on population moment conditions to produce the estimates of the unknown parameters of this economic model. At the same pace, the IDRN network approach focuses on the real time and panel database which has the capacity to explain the real time impact at those moments what GMM indents to specific. Thus, application of both methods seems to be plausible for our case which are further explained in the subsequent sections of the methodology.

2.1 System-Generalized Methods of Moments (GMM) for empirical model specification and estimation

The GMM as stated in the equation (1) represents the specification for the system GMM model which we apply to the data. The subscript i refers to district i of the total 9 observed districts. The subscript t refers to the value of the variable observed at timepoint t out of the total 36 observed timepoints. Cons_{it} is the consumer price. $\text{L.Cons}_{it\text{-}1}$ is the value of consumer price of district i lagged by one time period, $t\text{-}1$. Farmgate_{it} is the farmgate price. Analogously,

Ricestraw$_{it}$ and Wheatbran$_{it}$ are their respective values for district i and time t. COVID-19$_{it}$ takes the value of 1 if the timepoint is after March 2020 (t=21) and 0, if before or during March 2020, for district i. In equation (2), ε_{it} is the error term for district i at timepoint t. The error term comprises of two components as indicated in the equation, wherein, α_i refers to the district fixed effect for accounting for heterogeneity across districts and u$_{it}$ is the idiosyncratic part of the error term. The lagged value of the consumer price as well as the farmgate price have been specified as endogenous variables. Rice straw price and wheat bran prices have been specified as strictly exogenous in the model system.

$$\begin{aligned} \text{Consumer}_{it} &= \beta_0 + \beta_1 L.Consumer_{it-1} \\ &+ \beta_2 Farmgate_{it} + \beta_3 Ricestraw_{it} + \beta_4 Wheatbran_{it} \\ &+ \beta_5 COVID19_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

$$\varepsilon_{it} = \alpha_i + u_{it} \quad i = 1, 2, \ldots, 9 \quad t = 1, 2, \ldots, 36 \quad (2)$$

To incorporate the empirical specifications (from equation 1 and 2), one of the common approaches to accounting for unobserved fixed effects of the panel variable (district, in our case) is to apply Ordinary Least Squares (OLS) after first differencing the dependent variable as well as the explanatory variables in the model specification. However, if we have reason to consider the lagged value(s) of the dependent variable as regressor(s) as well, first differencing will lead to endogeneity. This is because the differenced error term is correlated with lagged value of the dependent variable which is one of the components of the variable formed by differencing of the lagged value of the dependent variable as a regressor. The difference-Generalized Method of Moments (GMM) proposed by Arellano & Bond (1991) entails Instrumental Variable (IV) estimation for solving this problem of endogeneity, wherein, the lagged values of the dependent variable are used as instruments. These lagged values of the dependent variable are already a part of the concerned variable obtained from first differencing of the lagged value of the dependent variable as a regressor. Thus, they qualify as relevant instruments. Their use as instruments assumes that the past values of the dependent variable are not correlated with the error terms of the future values of the dependent variable.

Difference-GMM was further enhanced through Arellano & Bover (1995) and Blundell & Bond (1998) for higher efficiency in estimation with the introduction of System-GMM. In System-GMM, we have the difference equation as well as the level equation and endogeneity in the level equation arising due to the correlation of the lagged dependent variable and the unobserved fixed effect of the district is tackled with the use of past differences of the dependent variables as instruments. Again, variables obtained from the past differences of the dependent variable qualify as instruments as they purge the unobserved fixed effects. The motivation for the usage of System-GMM method is in the description of the informal milk market of Bangladesh. According to knowledge from the field, there is no certain price policy in Bangladesh for setting both consumer and farmgate milk price. The price is, hence, determined by the real time demand and supply situation. Some of the triggering factors that affect the consumers demand vis-à-vis consumer price are the religious festival (both Muslim and Hindu), fasting days and other social programs. The supply of milk, on the other hand, is affected by seasonality in the main milk producing areas of Bangladesh, feeding of balanced ration and other system related management, and access to the input and output market. The endogeneity implies that apart from the farmgate price determining the consumer price, the consumer price also determines the farmgate price, which is a key researchable issue to explore by applying the empirical model considering the input and output price.

Farmgate milk price is on the other hand affected by the market channel, e.g., formal marketing and informal marketing. In the formal marketing channel, farmgate milk price is set by the fat percentage. The related other quality parameters are less important. In the formal market, the milk price is mainly set by its volume and some exogeneous physical properties which is cognitive to the consumers. The regional variation in farmgate milk price in the informal sector is quite distinct and hence identification of the district level milk price analysis might provide the insight on the role of the overall farmgate milk price. Production system and its impact on the dairy sector are closely associated with system specific input and output market (Uddin *et al.*, 2010). The management and efficiency of the system specific model of meta-frontier which combines various dairy production systems in pooled model and also able to determine individual production system performance were applied to the dairy sector and found that a production system embedded model represents the true endowment of the production performance and increasing productivity (Uddin *et al.*, 2014). In relation to costs and profits, the system specific model again provides the better output than non-systematic model.

Given the possible simultaneity in consumer price and farmgate price determination, we treat the farmgate price as an endogenous regressor. We also use the rice straw price and wheat bran price as exogenous explanatory variables. Further, we add a dummy variable accounting for timepoints occurring after the onset of COVID-19 in Bangladesh.

Given that we use System-GMM, we assume a dynamic data generating process, wherein, the consumer milk price at

time t depends on prices of earlier timepoints. We also assume heterogeneity across districts in realization of the consumer price. Farmgate price is an endogenous regressor and the remnant error term after subtracting district fixed effects is heteroscedastic and serially correlated. The Fig. 2 shows the development of consumer milk prices by district. Fig. 1

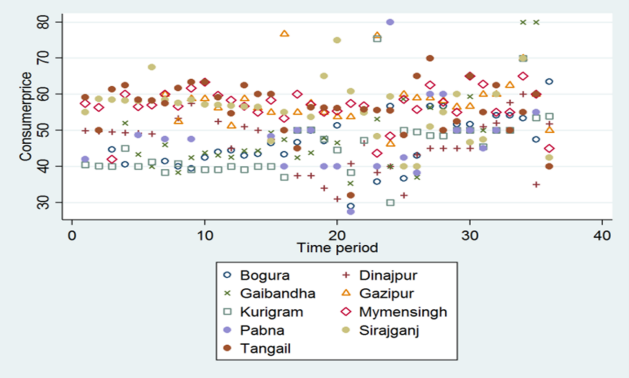

Fig. 1: *The time trajectory of consumer price in BDT per kg of milk by district. Source: Figure produced from own data. The time period refers to the 36 timepoints related to each month in the database.*

motivates the use of district fixed effects (which is accounted for in System-GMM) which indicates heterogeneity in the realisation of consumer price across districts. Each district exhibits a distinct trajectory of consumer price originating from a distinct base level from time period 1, and maintains the approximate level across the 36 time periods.

2.2 *Integrated Dairy Research Network (IDRN): Data summary and analysis*

The data used for this study were taken from the Integrated Dairy Research Network (IDRN) dairy sector database where the data are collected from the individual dairy farmers, processors and consumers on monthly basis. The data on 10 key variables were collected using the standard questionnaire where the study locations, farmers name, contact address and variables are formatted as standard and structured Excel Management Tool (EMT) for longer term use. In Bangladesh, there are 64 districts (region) where there exists substantial regional variation in terms of feeds and feeding system, technical efficiency, cost of milk production and resource endowment (Uddin *et al*, 2011, Uddin *et al*., 2014). Within IDRN regular data collection process, each month the data were collected from 30-40 districts. In our study, we used the IDRN database from July 2018 to June 2021 from nine districts. The selection of the districts was based on the number of data month. Out of the 64 districts, the IDRN database contains 43 districts but each of these districts has a different data period time (from 4 to 36 data-months). In our study, we selected nine districts based on two criteria: firstly, where the data period covers minimum 24 months (two years) and maximum 36 months (three years). Secondly, the data on two major input prices, i.e., rice straw and wheat bran; and major output prices, i.e., farmgate and consumer milk price, were considered.

The key input price and output price, the feed price (equivalent to compound feed price) is estimated using the weighted average of 35 % wheat bran, 20 % mustard oil cake, 20 % rice polish, 15 % corn and 10 % soybean meal (IDRN, 2022). The price of rice straw and wheat bran is increasing much faster than the milk price, while the rice straw price is increased by 53 % and wheat bran price by 25 % in 2021 compared with 2018 (IDRN, 2022). On the other side of the market functions, a high variation was found between the farmgate milk price and consumer milk price, with special reference to informal milk market[2]. The average farmgate milk price increased by 44 % while the consumer milk price by 35 % from 2018 to 2021.

Table 1: *Unique features of the data collection methodology of the IDRN compared with traditional approach.*

Area	*Traditional approach*	*Network approach*
Data collection	Data collected by enumerator and sporadic way	A trained database team from this field for collecting data from different districts. Students, field level experts, organisational support.
Data Validation	No panel expert	Three stage data validation through an expert panel (farmers, local expert, national expert).
Data interpretation	No specific model is used	Data interpretation is done by using an international model and locally developed model. Workshop at regional, national and international level.
Results		Regional data compared with global
Use of results	Report, scientific article, popular article, policy decision	Report, scientific article, popular article. Decision making tools for farmers, dairy business and policy makers. Kept data in structured database.

The collected data were processed through IDRN Data Validation Tool (DVT) in three different magnitudes: i)

[2]Informal milk market is defined as the milk market where there is no structure for selling and buying of milk. Both buyers and sellers are free of making any contract with anyone.

Comparing the time series (month to month comparison), ii) Comparing the database team member's comparison with panel of experts following IFCN panel approach (Hemme, 2000; Uddin *et al*., 2020; IFCN 2021) and iii) comparing the regional variation with national statistics data. The data collection in the framework of IDRN is unique to develop and build the accounting matrix that is comparable at local, regional, national and international level than traditional system. The unique feature of the IDRN data collection process is depicted in Table 1.

Since there is no existing data as such and also the dairy farming systems are highly complex, the IDRN data collection process provides high-quality data as it followed the IFCN data collection process (Sultana *et al*., 2014a; 2014b).

3 Results

3.1 Dairy production and market system specification

The statistics of key variables that are used in this study to characterise the dairy market and production system is depicted in the Table 2. The mean consumer milk price is 51.21 BDT kg^{-1} (0.5 USD kg^{-1}) while the mean farmgate milk price is 43.67 BDT kg^{-1} (0.51 USD kg^{-1}). The input price, such rice straw price (Ricestraw) price is 10.64 BDT kg^{-1} (0.13 USD kg^{-1}) with a wide variation which implies for strong improvement possibility to narrow down the price. At the same pace the price for the wheat bran also varied substantially. This analysis also includes the effect

Table 2: *Descriptive statistics of variables used in the analysis.*

Variables	*Mean (in BDT)*	*Min.*	*Max.*
Consumer price	51.21 (9.11)	27.5	80
L.Consumerprice	51.22 (9.15)	27.5	80
Farmgate price	43.67 (8.80)	22.5	70
Ricestraw price	10.64 (4.36)	3.3	30
Wheatbran price	34.28 (2.52)	28.7	40.7
COVID-19 dummy	0.41 (0.49)	0	1

Note: Currency conversion: 1 USD = 84.8 BDT (source: Bangladesh Bank: https://www.bb.org.bd/en/index.php/econdata/exchangerate), Date: 30 June 2021; Standard deviation in brackets.

of COVID-19 as dummy variables so that we can confirm whether our database has the impact of COVID-19 on the dairy sector in Bangladesh or not. Finally, those variables were modelled into the GMM for identifying the determinants. However, before being modelled with those variables, it was interesting to understand the farming system, input and output price differences and their interactions within the regions.

3.2 Region and time specific dairy production systems

3.2.1 Herd structure and milk production

The detailed herd structure in different regions is given in the Fig. 2. Milk productivity in the dairy farms is determined by the productivity of the cows and its herd structure (% of lactating cows in the herd). The average dairy cows (lactating and dry cows) in the study regions (9 districts) are 48.5 %, 52.6 %, 47.7 %, 52.0 %, 56.8 %, 50.1 %, 51.4 %, 46.7 % and 47.8 % in Gazipur, Tagnail, Mymensingh, Bogura, Pabna, Sirajganj, Dinajpur, Gaibandha and Kurigram, respectively with an average of 50.4 %. The highest milk producing districts in the country are Sirajganj (1st in the country) (50.1 %) and Pabna (2nd in the country) have the highest number of dairy cows (56.8 %). All those districts have a higher proportion of dairy cows (dry + lactating) higher than the national average of 38 % dairy cows. This implies that our selected regions are promising for milk production within the country and hence the milk production and milk price are important determinants for particular production systems. The milk production is depicted in Fig.

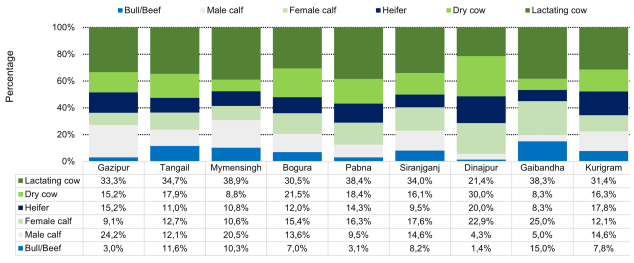

Fig. 2: *Herd structure in the selected regions.*

3. The average milk production in the study region is 4.6 litres per cow and day. The resulting average milk production per farm is 10.6 litres per day. The highest milk production is seen in the Pabna region with an average of 6.3 litres per cow and day, and the second highest in Sirajganj district at about 6.2 litres per cow and day (Sirajganj is considered as the dominating region for milk production in Bangladesh though some regions are catching up rapidly in milk production). On the other hand, the lowest milk production is in

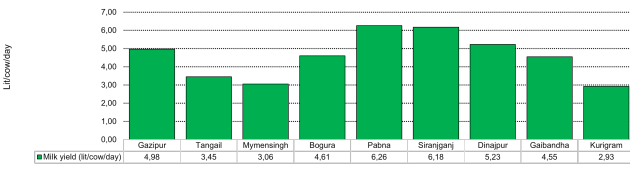

Fig. 3: *Milk yield in the selected regions.*

Kurigram district about 2.93 lit/cow/day. The milk sale is the major source of the return for a dairy farm (Hemme *et al*., 2014), and also the feed use efficiency, greenhouse gas

emission and water use efficiency are linked with milk production per cow per day (Sultana *et al*., 2014 and Uddin *et al*., 2022). The sustainability of the dairy farm, increasing the resilience capacity of the dairy farms and to combat the loss from the COVID-19 is highly linked with milk yield and strategies to use the feed ration (Uddin *et al*., 2020).

3.2.2 *Farm gate and consumer milk price: Regional and time variation*

Two key stakeholders of the dairy value chain, farmers and consumers are the key determinants for the dairy sector growth. Hence, the milk price which is an external to the dairy farm, is the major source of revenue and profitability of the dairy farms (Hemme *et al*., 2014). The farm gate milk price and consumer milk price, its variation in different regions and time horizon is depicted in Fig. 4a and 4b.

The consumer milk price is the liquid unpasteurised milk price which a consumer has to pay per kg of liquid milk. The price of milk varies from urban to rural areas which is also reflected in the Fig. 4a and 4b. The highest milk price is presented in the Gazipur district about 58.12 BDT kg^{-1} (0.67 USD kg^{-1}) which is an urban area and next to Dhaka the capital city of Bangladesh. The lowest milk price is seen in the Kurigram District about 45.63 BDT kg^{-1} (0.54 USD kg^{-1}) and the average milk price in the study region is 51.21 BDT kg^{-1} (0.64 USD kg^{-1}).

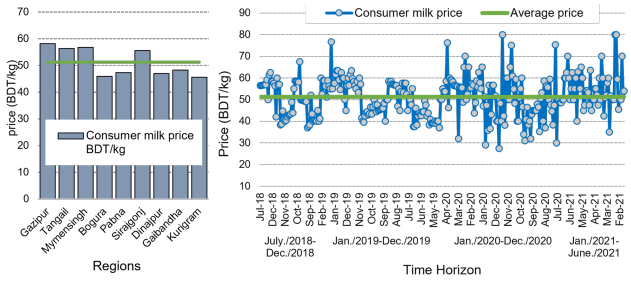

Fig. 4: *Consumer milk price: mean per region (4a) and time horizon (4b).*

The farmgate milk price according to region and time horizon was shown in Fig. 5a and 5b, respectively. The farmgate milk price has also effects on consumer milk price. When the farmgate milk price is higher the consumer milk price goes up. Over time, the consumer price has increased by about 12 % from 2018 to 2021.

The farmgate milk price is the liquid unpasteurised milk price which a farmer get by selling the milk to neighbour, local market, Goala i.e. in the informal channel. This study is focused in the informal channel milk price since most of the milk is traded informally. The farmgate milk price amid regions and time period are given in the Fig. 5a and 5b. The

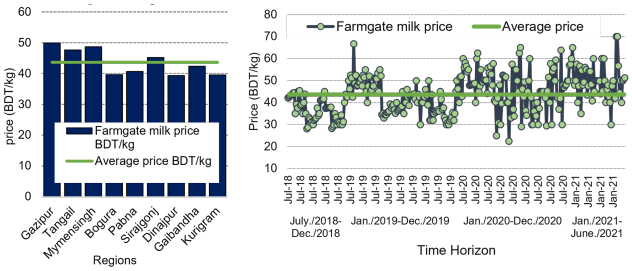

Fig. 5: *Farmgate milk price: mean per region (5a) and time horizon (5b).*

highest milk price is presented in the Gazipur district about 49.95 BDT kg^{-1} (0.59 USD kg^{-1}) and the lowest price is given in Kurigram about 39.53 BDT kg^{-1} (0.47 USD kg^{-1}). This is because the consumer price and farmgate milk price are positively corelated. The average milk price in the study region is 43.68 BDT/kg (0.52 USD/kg). On the contrary, the farmgate milk price is 37.3 % higher than 2018 to 2021. This might be due the effect of COVID-19 with an increase in demand when a lockdown had been imposed and schools were closed. Since the outbreak of COVID-19, the government has taken special focus to support the farmers by declaring the agriculture as an emergency in the country and also in the consumer level, the intention to drink milk has increased since milk boost the immune and nutritional system to fight against COVID-19.

3.2.3 *Regional and time variation in input price: Rice straw price*

Rice straw is the mostly used feed in animal production in Bangladesh. The average price of rice straw varies amid regions and also in different time period are depicted in the Fig. 6a and Fig. 6b.

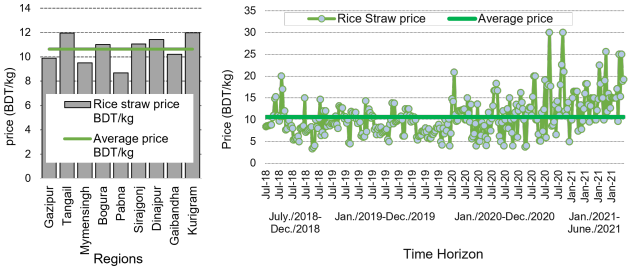

Fig. 6: *Rice straw price: mean per region (6a) and time horizon (6b).*

The highest price of rice straw is seen in Kurigram district about 11.99 BDT kg^{-1} (0.14 USD kg^{-1}) and lowest price is seen in the Pabna district about 8.69 BDT kg^{-1} (0.12 USD kg^{-1}). The average rice straw price is 10.64 BDT kg^{-1} (0.13 USD kg^{-1}). There is a sharp shift of rice straw price in

study period about 61.1 % (from July-2018 to June-2021). The average rice straw price in 2018 was 9.04 BDT kg^{-1} (0.11 USD kg^{-1}) and in 2021 the average rice straw price is 14.57 BDT kg^{-1} (0.17 USD kg^{-1}).

3.2.4 *Regional and time variation in input price: Wheat Bran price*

The wheat bran is the main concentrate source for dairy cattle production in Bangladesh. The wheat bran price according to region and time horizon is depicted in Fig. 7a and Fig. 7b.

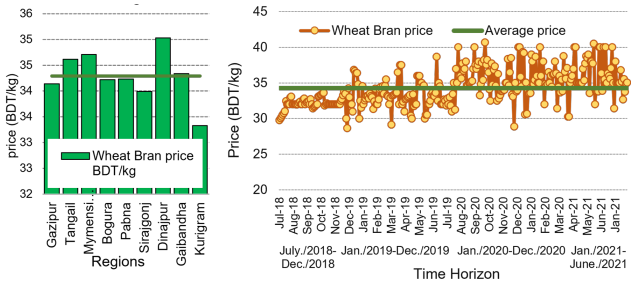

Fig. 7: *Wheat bran price: mean per region (7a) and time horizon (7b).*

The average price of wheat bran is 34.29 BDT kg^{-1} (0.40 USD kg^{-1}) whereas the highest price is seen in Dinajpur district about 35.03 BDT kg^{-1} (0.41 USD kg^{-1}) and lowest in Kurigram district about 33.33 BDT kg^{-1} (0.39 USD kg^{-1}). The percentage shift from 2018 to 2021 is about 12.9 % in absolute value is 32.07 BDT kg^{-1} (0.38 USD kg^{-1}) in 2018 and 36.21 BDT kg^{-1} (0.43 USD kg^{-1}) in 2021.

3.3 *Econometric estimation of the determination of the milk price: Model estimation*

The price of wheat bran, rice straw, farmgate and consumer milk price were evaluated through application of the dynamic panel approach. The estimated coefficients are depicted in Table 3, based on a System GMM estimation. In model (1), we employ the lagged consumer price and farmgate price as regressors. In model (2), we add the input prices, namely, rice straw price and wheat bran price. In model (3), we add the dummy variable for estimating the differential effect of COVID-19 after its first incidence as compared to the time period before the onset of COVID-19.

In all the three model specifications, the coefficient of the lagged value of the consumer price is high in magnitude as well as significant. It is reduced slightly as we introduce more variables across the models but is remained high and significant. This explains the evolution of consumer price as depending on its previous time period's value. This means the consumer price can be predicted from its value in the previous time period. If the consumer price in the previous time period increased, the consumer price will increase in the current time period. If the consumer price in the previous time decreased, the consumer price will decrease in the current time period.

Table 3: *Estimates from System GMM applied to consumer milk price**.

	Consumer price		
Variable	*1*	*2*	*3*
L. Consumer price	0.16***	0.15***	0.14***
	(0.02)	(0.02)	(0.02)
Farmgate price	0.77***	0.84***	0.89***
	(0.03)	(0.03)	(0.03)
Rice straw price		-0.14**	0.03
		(0.05)	(0.06)
Wheat bran price		-0.47***	-0.15
		(0.10)	(0.11)
COVID-19 dummy			-3.96***
			(0.68)
Constant	8.81***	23.55***	11.08***
	(1.57)	(3.53)	(4.03)
Observations	315	315	315
No. of instruments	304	306	306

* We conducted model diagnostics by observing Arellano-Bond test statistics for autocorrelation, namely, AR (1) and AR (2) tests. The test result were as desired, i.e. we can reject the null hypothesis of AR (1) test and cannot reject the null hypothesis of AR(2) test. We also find that the result of the Difference-in-Sargan test supports validity of instruments used in the estimation. Standard errors in parentheses. ** $p < 0.05$, *** $p < 0.01$.

The farmgate price reports a very high and positive effect (0.778) on the consumer price and the effect increases as more variables are included in the model. In model (2), the effect of rice straw price is negative and significant. Also, the effect of wheat bran price is negative, significant, and high in magnitude. According to Model 2, if rice straw price increases, the consumer price decreases. If rice straw price decreases, the consumer price increases. Similarly, if wheat bran price increases, the consumer price decreases. If wheat bran price decreases, the consumer price increases.

Model (3), with the inclusion of the dummy variable for the time period before and after the onset of COVID-19 changes the result of the System-GMM drastically. The coefficient estimates which capture the effect of rice straw price and wheat bran price on the consumer price are no longer significant in model (3).

In model (3), the estimate of the dummy variable (−3.96) is high and significant. This estimate implies that the influence of COVID-19 on the consumer price was high and negative. The consumer price was, on an average, lower by 3.96 BDT kg^{-1} (0.05 USD kg^{-1}) after the onset of COVID-19 in Bangladesh, as compared to the time period before the onset of COVID-19.

The IDRN special issue on Economic Analysis of Bangladesh Dairy Sector published on April 1, 2020, showed that during the onset of the COVID-19 infection in Bangladesh (first wave) that feed price increases by 3.7 % which cause decrease in farm gate milk price and consumer milk price (IDRN 2020). Out of 40 districts analysed, consumer milk price decreased in 37 districts with a range of decrease from 5 to 44 %. Since the unexpected results on input price (rice straw and wheat bran) to the output price (consumer milk price), a correlation analysis was performed among the farmgate price and consumer price with rice straw and wheat bran. The results revealed a strong correlation between consumer price and farmgate milk price (+81.47 %). The Consumer milk price with rice straw and wheat bran showed poor correlation (r = 18.84 %, between rice straw and consumer milk price; r = 17.15 %, between wheat bran and consumer milk price) which is true from the empirical analysis (showed in Table 3). The same was also observed among the rice straw and wheat bran with farmgate milk price (r = 27.85 %, between rice straw and farmgate milk price; r = 29.33 %, between wheat bran and farmgate milk price). Additionally, it is also found that the substitutable relationship among the various input might be helpful in reducing the pressure on production costs (Suh & Moss, 2021) which is also applicable for our findings as the wheat bran price development is non-stationary and rice straw is stationary. Therefore, it is also interesting to undertake which type of concentrate might be replaced with wheat bran.

Rice straw and wheat bran as inputs, are locally produced, and their prices are highly likely to get affected during the season of harvest. Similarly, the consumer milk price is likely to get during the months of religious festivals. In order to study the effects of these events, Model (3) from Table 3 was modified to include dummy variables for the months of harvest months as well as their interaction with rice straw and wheat bran prices. In addition, we added the lagged input prices of rice straw and wheat bran to the model. Table 4 presents the GMM estimates of this specification.

The results for the effect of lagged consumer price, farmgate price, rice straw price, wheat bran price, and COVID-19 dummy are similar to those obtained in Model (3) of Table 3. The effect of harvest dummy and its interaction with wheat bran price is significant. The effect of the dummy variable for festivals is positive and high in magnitude.

Table 4: *One step GMM accounting for months of festivals and harvest**.

Variable	*Est.*	*Std. err.*	*z*	*P* > *z*
Consumer price				
L1.	0.16	0.03	5.55	0.00
Farmgate price	0.89	0.03	26.46	0.00
Ricestraw price				
-.	0.01	0.08	0.15	0.88
L1.	-0.02	0.07	-0.26	0.80
Wheatbran price				
-.	-0.14	0.13	-1.10	0.27
L1.	-0.24	0.13	-1.82	0.07
COVID19_dummy	-3.53	0.75	-4.70	0.00
Harvest dummy	-17.80	8.81	-2.02	0.04
Festival dummy	0.47	0.57	0.82	0.41
RS*Harvest	0.11	0.13	0.83	0.41
WB*Harvest	0.53	0.26	2.05	0.04
_cons	18.30	5.01	3.65	0.00

* We conducted model diagnostics by observing Arellano-Bond test statistics for autocorrelation, namely, AR (1) and AR (2) tests. The test result were as desired, i.e. we can reject the null hypothesis of AR (1) test and cannot reject the null hypothesis of AR(2) test. We also find that the result of the Difference-in-Sargan test supports validity of instruments used in the estimation. The number of observations and instruments remain the same as in Model (3) of Table 3. Est.: Estimate; Std. Err.: Standard errror; RS: Ricestraw price; WB: Wheatbran price. Ricestraw price-. and L1. are the actual price and the lagged value of ricestraw price. Wheatbran price-. and L1. are the actual price and the lagged value of wheatbran price.

4 Discussion

4.1 Discussion of estimated results

The farmgate price is one of the most important determinants of the consumer price. The increased farmgate milk price is associated with increased consumer milk price in order to maintain the marketing margin. The marketing margin is measured as the difference between the consumer price and the farmgate price. The marketing margin plays significant role in ensuring the profitability, marketing efficiency and access to the output market by the dairy farmers, sustaining the dairy farms. This marketing margin is highly driven by the farmers milk selling options where the direct selling to the consumers provides the highest margin (Sarna *et al.*, 2020).

The consumer milk price in the informal market is not linked with input price perhaps due to the fact that both

farmgate and consumer milk price are not determined based on the production costs, but rather by various other non-economic factors (such as festivals, seasonal influence on demand and supply, and the import price for the skimmed milk powder (SMP). The other reason could be that during high input price, the demand for milk decreased and thus consumer price decreased. The milk price setting using the real time cost of milk production can be used as safeguard for the farmgate and consumer milk price. One can also explain that if most of the rice straw is from own farm production, then there might not be a big influence of its market price on production cost. This could be same with wheat bran.

The consumer price, rice straw and wheat bran prices were heavily affected after COVID-19 occurred in Bangladesh. Government policies, events in the input and output markets led to a shock in these prices (example, the import policy of wheat). This means that after the onset of COVID-19, consumer prices were decided by policies related to COVID-19. After COVID-19, rice straw and wheat bran prices no longer independently affected consumer price. Instead, they were affected themselves by COVID-19.

While the harvest season significantly reduces the consumer milk price, it substantiates the effect of wheat bran price on consumer milk price. This implies that during the harvest season an increase or decrease in wheat bran price will influence the consumer milk price more strongly than in the non-harvest season. Festival months lead to increase in the consumer milk price.

4.2 Summary from a systems perspective

The production system, milk yield and its linkage with various input and output prices provide an overall picture of the existing dairy sector and market drivers in terms of regional variation and time horizon. Modelling those into the existing study are highly relevant not only for Bangladesh but also for similar other dairy industry situation elsewhere in the world. The mixed results obtained refer to the determinants of the consumer milk price. The results revealed that consumer milk price can be predicted from the previous time of the farmgate milk price. Interesting to note that input price system (rice straw and wheat bran) has negative impact on the consumer milk price. The marketing system of these two feed ingredients is quite diverse. There are no formal and structured market mechanisms for the rice straw both for the quantity and price setting for the famers (Islam *et al*., 2020). The wheat bran market is regulated by the import of wheat and wheat bran as well as the local demand for the flour. The region, season and festivals determine the flour demand which directly affect the wheat bran price which are close to the proximity of the United Kingdom dairy farmer's farm gate milk price determinants (seasonality, herd size, milk yield and regional variation) (Wilson, 2011).

The results on market determinants of the consumer price in relation to rice straw and wheat bran revealed that the market is imbalanced (e.g, not follow the demand and supply situation) and there was no market controlling system The increase in wheat bran price cause immediate shifting to the use of the alternative feed ingredients which is relatively cheap. The system linkage among the input and output market does not have capacity for predicting the future price and making weekly or monthly outlook. To the lower segment of the dairy value chain, where the famers does not maintain any accounting matrix and database due to which famers are not able to set their price based on the real time cost of milk production. Currently there is no real time data on specific input and output price and consumption which could be overcome using the application of the IDRN approach. The regional variations could build a foundation for minimizing the gap between the higher and lower farmgate and consumer milk price. The matrix with higher farmgate milk price along with lower consumer price is the goal for the country as a whole but difficult to achieve as due to the mixed results of the input and output. The networking could leverage data generation process and making the real time update of the information that could support the stakeholders for taking their own decisions.

4.3 Policy implications

The regional findings from this study have policy implications at the global feed market due to the fact that Bangladesh is a net importing country for three feed ingredients such as Wheat bran (from wheat), Soybean meal (from Soybean) and Corn crushed (from Corn). The local feed ingredient price is highly influenced by the global feed price. The major exporting country for wheat is Russia, Ukraine, Australia, USA, India and Canada.

Given this, identification of the regional potential, variation in input and output price, consumer and farmgate milk price as well as the regional dairy potential (herd size and milk yield) are also important for developing the specific region for dairy. This kind of decision, controlling and monitoring the international market for the wheat bran and national market for the rice straw, milk price requires regular update on the real time data at comparable basis with scientific evidence. In this regard, the networking analysis on collective actions on dairy is a proven knowledge platform for generation, dissemination, and use of the real time knowledge by all stakeholders who participated in the network.

Linked with our study results particularly for the descriptive statistics on the rice straw, wheat bran, milk price, milk

production and herd structure provide the real production system perspectives with regional dominance one over others. This clearly implies that more regional dynamics are desirable for extrapolating the findings to other regions. The GMM results provided the interactions between production system and market mechanism for specific time. This further explains that any policy decisions that focus only single agenda would not be beneficial while it provides the ground for the argument for the holistic view and multi-stakeholder participation to find innovate solution in dairy system perspectives (Straete, 2007 and Sreeram and Gupta, 2018).

The estimated relationships between the prices at various levels of the dairy value chain suggest that market information systems with a focus on price information would be beneficial for both farmers and consumers. Till today there is no such mechanism exists although the recent approach under the framework of Livestock and Dairy Development Project (LDDP) under the Ministry of Fisheries and Livestock (MoFL) is focusing on the developing the Knowledge Initiative Platform. However, there are many challenges to take this forward because participation from all stakeholders is not easily incorporated into a single platform. In contrast, the dairy networking approach could be an alternative pathway towards supplying market information, as the network is quite successful in data generation, its use for the right stakeholder at comparable way worldwide (IFCN, 2022) which was also replicated to the case of Bangladesh using the similar principle termed as Integrated Dairy Research Network (IDRN).

The policy implications for combating the impact of the COVID-19 were also revealed in this study, which can be pointed as the benefit of the data generation in comparable and sustainable manner through the IDRN. The IDRN database contains the data before, during and after COVID-19 impact. The results clearly identified that consumer price was affected and decreased due to the fact that farm gate milk price was decreased in 37 districts (out of 64 districts). As a summary, the following policy implications could be stated which might be taken forward by addressing the upcoming dairy policy revisions:

1. Interventions on the input market (rice straw and wheat bran) need to be provided so that these two feed ingredients stay relatively stable across the region. Although it is difficult, but still the government might start the incentives policy during the time of high price. The rice straw in the typical ration has direct influence on milk production and environmental degradation and water footprint (Sultana *et al*., 2014) which ultimately cause additional burden for the dairy farmers by increasing the cost and thus, farmers are also diverting their willingness to get more farmgate milk price.

2. The policy should acknowledge that all stakeholders are profit-oriented which upon maximization might create imbalance between the farmgate and consumer milk price. A strategy to set for the maximum market margin could solve this.

3. The share of the farmers to the consumer price is decreasing (IFCN, 2022) which causes structural transformation from the household farms to commercial oriented farms. To sustain this, policy should consider the safeguard for the farmers' production cost.

4. As the farmgate milk price and previous time milk price can determined the consumer's milk price, the well documentation of the data in structured format is highly needed. The policy can encourage the academician or research to take such effort. In relation to this, IDRN, which has been working for updating the real time data as holistic view using scientific and evidence-based methodology could be taken as benchmarking network for bringing all stakeholders into knowledge pooling platform.

5. Scenarios analysis that are possible from time series and long-term database, are a way forward for predicting future development of the sector (Ehlers *et al*., 2022) which might be taken forward for more interaction among stakeholders of the dairy network for creating price scenario analysis to support the dairy farmers.

6. Input use level and price and their intensity (like rice straw and wheat bran) and output (milk production) determine the efficiency in resources use (Sultana *et al*., 2014). From our study where it is found that input price is highly volatile (from descriptive statistics) particularly increasing trend with milk price provides sufficient insight for the future research on balancing the input and output price.

Based on the results of this study, a few recommendations can be made for overcoming the regional variations and to develop the network further for its nationwide operation for real time data update.

a) In areas where the milk price is low, the drivers for the low milk price and cost of milk production need to be known so that this knowledge can be extrapolated to other regions. At the same pace, the consumer milk price can be stabilised even with the fluctuation of the

farmgate milk price to ensure the adequate consumption of the milk and thus ensuring the nutrition security.

b) The other side of the equation, the input price (rice straw and wheat bran) needs to be affordable which can be done by monitoring the prices and identify the drivers which thereafter could be addressed by appropriate interventions.

c) Attempt to increase local production of wheat could increase the local wheat bran but it should also need be competitive so that it can sustain in the market with the imported wheat bran.

d) As the market for the rice straw is quite under performance, and rice straw is by product of the rice (a staple grain for Bangladesh), the government should focus on the rice straw market formalization with ideal market tools.

4.4 Limitations and need for further research

Amide with substantial, new and innovative findings from this study, it should be confessed that this study is not out of limitations. One of the key limitations is that this study only took two feed ingredients while the typical dairy feed rations consider several other feed ingredients (Sultana *et al*., 2014). The use of grass was also not into considered. The feed costs and total cost of the milk production could be another determinant of the consumer milk price as there is evident that higher cost of milk production is ended up with higher consumer milk prices (Hemme *et al*., 2014). The IDRN full database on the input and output price was not possible to be used which otherwise could bring more robust results. Therefore, further research could be undertaken by including more regions, more factors and more data coverage.

5 Conclusion and recommendation

This study is a time being approach for generating the knowledge base by combining both networking approach and econometric approach. The results revealed that two major inputs, e.g., rice straw and wheat bran, has direct negative impact on the consumer milk price. The regional dynamics and time horizon also cause variation in input and output price. The GMM results (especially Model 3) clearly identified the impact of COVID-19 on the reduction of the consumer milk price which implies that the dairy networking database and its continuation is highly relevant for the dairy sector development for a country like Bangladesh where the real time database is scarce. This study results are vertically linked with production systems and informal dairy market. The district level analysis clearly revealed the regional differences within the system that are highly specialised within the production system. The linkage with production system characterization, input price and output price provide the regional superiority where the district of Sirajganj and Pabna shows the biggest potential for further improvement. The policy decisions on the price regulation on input and output market can use the findings of this study. The data set used from the IDRN was a unique as Bangladesh does not have such kind of database. This study recommends continuing the IDRN and its database for future research and also the policy maker might take the information to define the policy for balancing input and output price and setting consumer milk price policy in the informal market. It is highly expected that the application of the networking approach has stronger impact on sustainable data and research. This study results are also equally applicable to similar other countries globally.

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Conflict of interest

The authors declare that there is no conflict of interest.

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