Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X 2022 / v.24 / n.4 / 001-006

http://dx.doi.org/10.1590/1806-9061-2021-1618

Original Article

# Analyzing the Factors Affecting the Price of Broiler Chicken in Turkey Using the Boosting Regression Method

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**Keywords**

Chicken meat, price, boosting regression, Turkey.



Submitted: 23/December/2021
Approved: 03/August/2022

## ABSTRACT

Investigating the factors that affect broiler chicken prices in Turkey is vital for understanding market formation. The parameters and factors likely to influence the price of broiler chicken were analyzed for the period between 2010–2020 in Turkey. The study adopted the boosting regression model to predict the correlation between broiler chicken consumer price and variable factors like broiler feed, corn, soybean meal, wheat prices, the dollar exchange rate, producer price index (PPI), and agricultural PPI. The accuracy of the estimation of the regression model created according to the results of the analysis was calculated as 86%. The producer price index variable caused the highest relative impact (25.63%) on broiler chicken meat prices. The highest positive correlation was obtained between the producer price index and the agricultural PPI (r = 0.984). Thus, it was determined that chicken prices were affected by feed raw material prices and the general economic conditions in Turkey. In addition to improving the prevailing economic conditions, an effective price control mechanism is required to prevent excessive price fluctuations in the sector. Simultaneously, it is essential to create policies to reduce input costs.

## INTRODUCTION

Broiler chicken farming provides significant benefits to the economies of the participating countries. This livestock sub-production sector is one of the areas with substantial development in Turkey in recent years. In 2019, 2,138,451 tons of chicken meat were produced in 12,725 coops in Turkey (MAFT, 2021).

The price formation in broiler chicken farming is directly impacted by the feed prices used during the production process. Additionally, feed prices are affected by the feed raw materials used in broiler rations. Soybean meal and corn are the leading raw materials (BESD-BIR, 2014). In Turkey, 25–35% of corn and 90% of soybean are imported, since production does not meet the consumption demand (Eşidir & Pirim, 2013).

Due to the high cost of broiler feed and the import of most feed raw materials in Turkey, broiler chicken production costs have increased considerably. Therefore, Turkey is at a disadvantage against competitive countries regarding production prices (USDA, 2016). As the Turkish Lira (TL) depreciates against the US Dollar and declines to a lower level, purchasing power is reduced; thus, making the import of feed raw materials difficult and causing an increase in the production costs. On the other hand, since the rise in costs reduces profitability, it prevents the efficient use of domestic resources (Benalywa *et al.*, 2019).

Since broiler chicken production costs are not expected to reduce in the short term in Turkey, increases in the input prices are reflected in the final product price. The prices of broiler feed and chicken meat are co-integrated in the short term, and these prices follow each other (Arıkan *et al.*, 2019).

Changes in the production costs are transferred to retail prices symmetrically (Barahona *et al.*, 2014). The inputs affect the wholesale and retail prices of chicken meat in the short and long term (Erdem *et al.*, 2011). The most crucial factor in determining chicken meat supply is feed prices (Rezitis & Stavropoulos, 2010). Price fluctuations in these inputs influence the regulation of the chicken meat market (Khiyavi *et al.*, 2012).

Considering the factors affecting chicken meat prices in econometric studies has revealed the need for a holistic evaluation of these effects. The change in animal product prices is an essential economic risk factor affecting the production level. Therefore, investigating the factors affecting chicken meat prices in Turkey is essential for balancing the market. The objective of this study was to reveal the correlations and effects of the factors impacting the price of chicken meat in Turkey from 2010 to 2020 using the Boosting regression method.

## MATERIALS AND METHODS

In the study, the Boosting regression method was used to determine the correlation and impact of variables like broiler feed price, corn, soybean meal, wheat (TFIA, 2021), the dollar exchange rate (CBRT, 2021), PPI, and agricultural PPI (TSIb, 2021) on broiler chicken consumer price between 2010 and 2020 (TSIa, 2021). In the analysis, the JASP (Version 0.14.1.0) software was used for the structural determination of the relations between the variables and the visualization processes (JASP Team, 2020).

The Model ensemble method uses multiple models to provide the best estimation performance. The boosting method tool improves the classification or estimation accuracy and reduces the bias of the basic method. The Boosting method is used alongside Random Forest, K Nearest Neighbors, and Regularized Linear methods but gives more conservative results. This method is advantageous since it does not use any assumptions and avoids autocorrelation and multicollinearity problems (Hechenbichler & Schliep, 2004; James *et al.*, 2013).

The boosting method was introduced by Freud and Schapire in 1997 (Freund & Schapire, 1997). The process uses many explanatory variables to achieve a lower estimation error and error rate. It is a technique where errors from previous models are resolved in new models. This step is accompanied by a resampling of the data to improve classification or estimation accuracy. In the boosting method, the estimator of the regression model is trained on different sub-samples of the training set. First, the procedure is established and trained with N-dimensional samples drawn from the original dataset. With this process, the samples with more errors are determined. The concept of excess in error is used for samples with the largest difference between the predictive values and the observed values for regression machine models. The sample with the highest error is defined to the training set so that the probability of being sampled in the second machine model is higher. Thus, the observation values in step 'n' are dependent on the results obtained in step 'n-1'. The estimations are combined by using the weighted median. The predictors with high reliability in their predictive values are weighted to be more significant. The model is obtained because of weighting. The evaluation is performed with the obtained model performance metrics (Duffy *et al.*, 2002; James *et al.*, 2013; Alpaydın, 2020).

### Performance Metrics

#### *1) Mean Absolute Percentage Error (MAPE)*

This error metric expresses the error between the predicted values and the actual values as a percentage. It measures the accuracy of the prediction in regression models and expresses this accuracy as a percentage. For estimations in the regression models, this is the percentage value for the average ratio of the absolute value of the model errors to the absolute value of the observation data. The formula is defined as follows:

$$MAPE = \frac{100}{n}\sum_{i=1}^{n}\left|\frac{y_i - y_i^{'}}{y_i}\right|$$

#### *2) Root Mean Square Deviation (RMSD)*

This metric finds the distance between the predicted values of the predictor variable and its true values. Root Mean Square Deviation is the standard deviation of the difference between actual values and predicted values. The formula is defined as follows:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_i^{'}\right)^2}$$

(Chai & Draxler, 2014).

### 3) Mean Absolute Error (MAE)

Mean Absolute Error expresses the difference between two continuous variables. It is the sum of the absolute values of the difference between the estimated values and the actual values. The formula is defined as follows:

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|y_i - y_i^{'}\right|$$

(Chai & Draxler, 2014).

### 4) Mean Square Error (MSE)

It measures the performance of the predictor variable and always has a positive value. It is the sum of the square of the difference between the estimated values and the actual values. The formula is defined as follows:

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - y_i^{'}\right)^2$$

### 5) Coefficient of Determination (R2)

This metric measures the extent of the variation in the dependent variable of the model. It represents the square of the correlation coefficient. The formula is defined as follows:

$$R^2 = \frac{\sum_{i=1}^{n}\left(y_i^{'}\right)^2}{\sum_{i=1}^{n} y_i^2}$$

## RESULTS

A dataset consisting of 131 units was used in the study. The values for the most productive model created with the dataset are presented in Table 1.

**Table 1 –** The Most Productive Model Values.

| Method | Tree | Accuracy MSE | Test MSE |
|---|---|---|---|
| Boosting Regression | 35 | 0.608 | 0.878 |

A random sample of 15% (19) of the dataset was selected with the Hold-out method to test the algorithm. A sample of 20% (23) from the remaining 112 units was used for validation. The remaining data units (89) were used for training.

The success values calculated for the regression algorithm are presented in Table 2.

**Table 2 –** Regression Algorithm Success Value.

| Regression Algorithm | MSE | RMSE | MAE | MAPE | $R^2$ |
|---|---|---|---|---|---|
| Boosting Regression | 0.878 | 0.937 | 0.651 | %7.5 | 0.86 |

The estimation accuracy calculated on the broiler feed, dollar exchange rate, PPI, agricultural PPI, corn, soybean meal, and wheat variables for the consumer price of chicken meat was 7.5%. Additionally, the degree of accuracy for the estimation of the average chicken meat consumer price of broiler feed, dollar exchange rate, PPI, agricultural PPI, corn, soy meal, and wheat variables was 86%. Therefore, the model using Boosting regression displayed a high rate of explanation.

The relative influence of the model estimators established with the boosting regression is presented in Table 3.

**Table 3 –** The Relative Influence of Estimators.

| | Relative Influence (%) |
|---|---|
| Producer Price Index | 25.63 |
| Wheat | 23.30 |
| Corn | 19.75 |
| Dollar Exchange Rate | 10.91 |
| Broiler Feed Price | 8.53 |
| Soybean | 6.63 |

The Producer Price Index was identified as the variable with the highest relative influence (25.63%), followed by the wheat at 23.30%. The variable with the lowest relative influence was soybean at 6.63%.

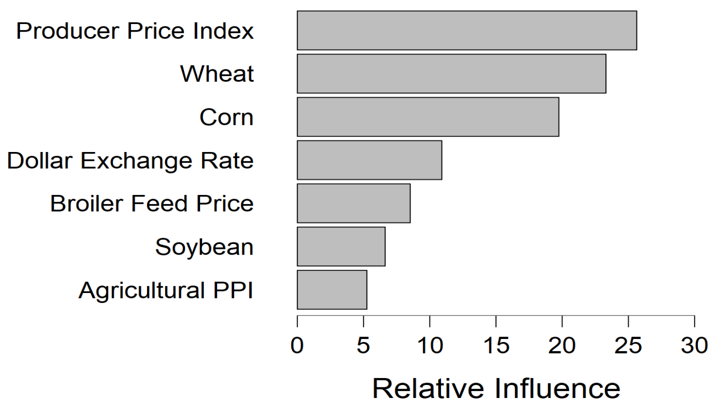


**Figure 1** – Relative Influence Graph.

Figure 1 expresses the relative influence shown in Table 3 in a graphical form. The variable with the strongest relative influence was the Producer Price Index at 25.63%.

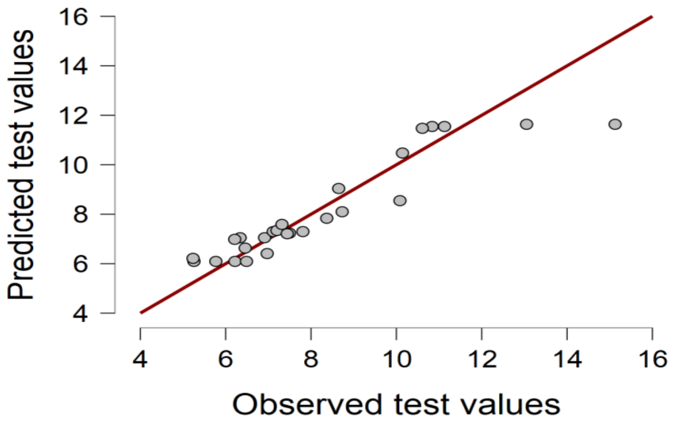


**Figure 2** – Performance Graph According to Real and Observed Values.

Figure 2 provides the predicted performance graph of the model. If the gray dots in the graph lie on the red line, the error between the actual observation values and the estimated observation values is low. If they are far from the red line, the error is high. Since most of the gray dots in the model gathered on the red line, the model exhibited high performance.

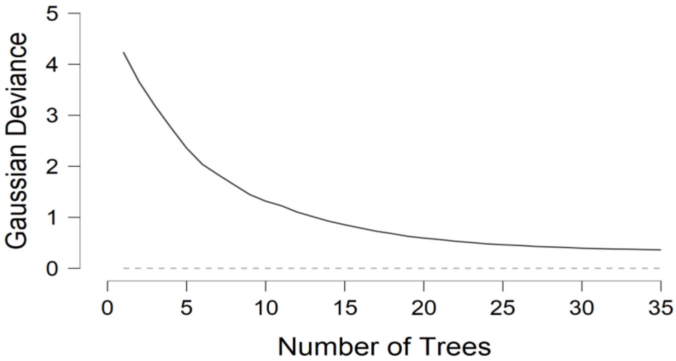


**Figure 3** – Deviation Graph.

The graph in Figure 3 shows the estimation error plotted against the number of trees in the model. As the number of trees in the model increases, the prediction error decreases.

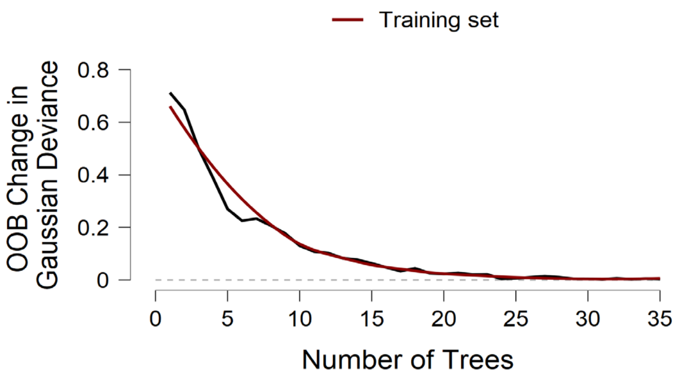


**Figure 4** – Out-of-bag Improvement Plot.

The graph in Figure 4 shows the accuracy of the test and training set. It plots the number of trees versus improvement in the out-of-bag classification accuracy of the model. The graph shows the number of trees when it catches the minimum bias on training and testing as it goes down to zero. A tree number of 17-19 hits the optimum point between the test set and the training set, with an average difference of zero. Out-of-Bag Improvement refers to the point where the most efficient tree is found at the optimum point where the bias of the test and training set is captured.

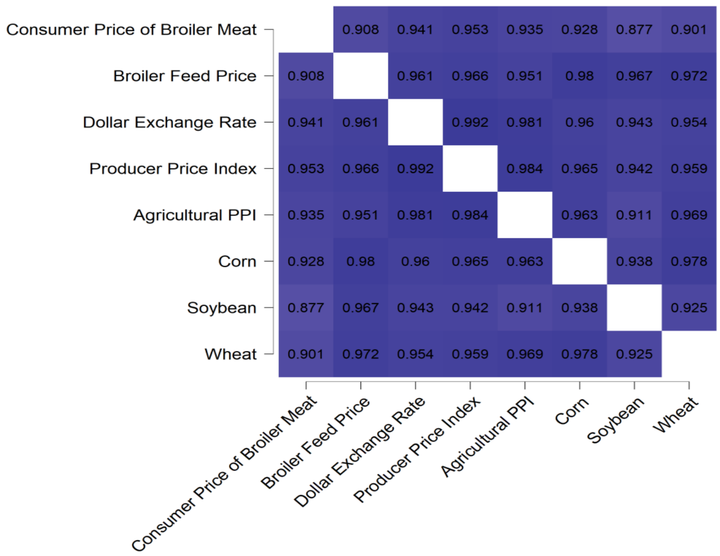


**Figure 5** – The Relationship between Variables.

According to Figure 5, the highest positive relation was observed between the Producer Price Index and the Agricultural PPI (r = 0.984). The second highest positive relation was recorded between Agricultural PPI and Dolar Exchange Rate (r = 0.981).

This study evaluated the broiler chicken consumer price and its correlation with the broiler feed, corn, soybean meal, wheat, the dollar exchange rate, PPI, and agricultural PPI using the boosting regression method.

The results indicated that the variables of broiler feed, dollar exchange rate, PPI, agricultural PPI, corn, soybean meal, and wheat prices predicted the average chicken meat consumer price at a high degree of accuracy of 86% between 2010 and 2020 (Table 2).

## DISCUSSION

In intensive poultry production systems, feed costs account for up to 70% of the total costs (Donohue & Cunningham, 2009). One of the feed raw materials, soybean meal, is used as the protein source with high biological value, and corn and wheat are used as vegetable energy sources. However, since the domestic soybean production demand cannot be met, the supply deficit is compensated by importing (Güler, 2013; Taşçı, 2018). In 2020, 27.5% of the meal that was imported as raw material for feed was soybean meal, and 71% of the vegetable energy source was corn (TFIA, 2021).

Domestic market prices of feed raw materials interact with the global market at the dollar exchange rate. Changes in the dollar exchange rate mainly increase the interaction of the local domestic market prices with the world prices. Studies have shown that Turkey's wheat and sunflower seed prices interact with the world reference prices (Conforti, 2004). Moreover, there is an interaction between world prices and the domestic market prices for wheat. This interaction increases during crisis/drought periods, and with the devaluation of the TL, the domestic prices have reached levels closer to the world prices (Kıymaz, 2015). On the other hand, the increase in import prices reduces the comparative advantage in broiler chicken production (Benalywa, 2019).

Changes in the dollar exchange rate are significant to understand the effect of world prices on feed raw materials. In our study, the dollar exchange rate variable exhibited the highest relative impact on the price of broiler chicken (Table 3). In 2011, the cost of imported corn increased by $83/ton compared to the previous year and was $357/ton; this resulted in a 35% increase in the domestic market prices in Turkey in the same year. In the following period, with the world prices falling below the $175/ton (2016), a parallel development was observed in Turkey, and the price decreased below the $250/ton level (Numanoğlu *et al.*, 2016).

The highest positive relation was observed between the Agricultural PPI and Producer Price Index (Figure 5). A long-term positive effect between the uncertainty of agriculture and food prices and inflation has been recorded in Turkey (Erdal *et al.*, 2008). Further, the increasing agricultural price inflation has a statistically significant effect on inflation of food prices and total CPI (Çıplak & Yücel, 2004).

The changes occurring in the prices of feed raw materials impact the prices of other feed raw materials used in broiler feed production. For example, there is a one-way transfer of volatility from the corn and barley market, the most commonly used raw materials in poultry feeds in Turkey, to the wheat market (Çınar, 2018). Additionally, an increase in the soybean (the leading imported input of feed raw materials) price by 10% resulted in a 3.84% rise in the cost of chicken meat (Çınar & Keskin, 2018).

According to the research results, the second highest positive relationship was observed between the dollar exchange rate and the agricultural PPI (Figure 5). A significant short and long term relationship has been reported between the input, retail, and wholesale prices (Erdem *et al.*, 2011). The prices of broiler feed and chicken meat in Turkey are co-integrated in the short term, and these prices follow each other. In this situation, a change in the feed prices impacts the cost of poultry meat two periods (two months) later in TL, and one period (one month) later in United States Dollar (Arıkan *et al.*,2019).

The poultry meat sector in Turkey is advanced in terms of technology and capacity. Yet, its dependence on foreign sources for raw materials negatively influences the development and sustainability of the sector. The constant dependency on foreign resources has left the poultry industry vulnerable to foreign currency movements and the problems encountered in supplying the ingredients necessary for production.

Since the domestic commodity market is strongly linked to the global commodity market, any price fluctuation in the global market is transferred directly to the domestic commodity market prices. A long time will be required to solve the transfer problem in the price fluctuations of developing countries. The lack of policies in the production industry can cause severe price fluctuations in these countries. Therefore, sector representatives and policymakers should actively use commodity exchanges and implement measures to prevent price volatility from the international market to we accept domestic markets. The other branches of production that provide inputs to the sector should also be simultaneously monitored.

## CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest in this study.

## ACKNOWLEDGMENT

There are no funding sources for this article.

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