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Forecast of The Price of Milk Paid to Producers in the departments of Magdalena, Córdoba and La Guajira: An Empirical Study Based on the Box-Jenkins Methodology

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Abstract

Due to the changing nature of the prices of agricultural products, such as dairy products, the Colombian dairy sector is an industry that experiences constant fluctuations of a seasonal and often cyclical nature, which makes it crucial for the actors involved in this productive activity. know how these prices behave in the present and soon, to determine actions that impact on improving productivity and therefore competitiveness. Therefore, the objective of the research is to predict the total price per liter of milk paid to producers in the departments of Magdalena, Córdoba and La Guajira in the Colombian Caribbean, through the Box-Jenkins methodology, with the aim of take the respective measures, based on true and updated information. The data used in this study were obtained from the portal of the Milk Price Monitoring Unit (USP) system belonging to the Ministry of Agriculture and Rural Development (MADR) from January 2008 to January 2023. The empirical results revealed that the models SARIMA, SARIMA and ARIMA (0,1,0) were chosen as the most appropriate to offer coherent results of the value of future predictions of the price per liter of milk paid to producers, suppliers of milk to the food sector in general, such as the production of coastal cheese. The results indicate that prices in these three departments present an increasing trend in the months of 2023.

Keywords: *Forecast, Prices, Milk, Fluctuations, Box-Jenkins Methodology*

INTRODUCTION

The dairy sector in Colombia represents a vital source of income, however, the volatility of dairy product prices and fluctuations in supply and demand generate uncertainty for the actors involved in the industry. The World Bank report (2023) and Causado-Rodriguez, E; Galindo-Montero, A & Peñaloza-Fernández, A. (2023c)., show the difficulty that is the general economic panorama of Colombia, according to the inflation reached at the end of 2022, which was of the order of 13.1% , continuing even until mid-2023, due to various factors, such as strong domestic demand, the inertia of inflation, income indexation, crop losses due to the heavy rains and the depreciation of the Colombian peso, among other aspects of the Colombian economy; which in turn would be impacting the dynamic economy of the dairy sector and its difficulty in adapting to these changes.

This high inflation rate has affected food in Colombia, reaching its highest point since 1999, which has led many households to rethink their dairy consumption habits, as a response to uncertainty and the need to adjust their budgets (Asoleche, 2022 y DANE, 2022).

Given this situation, the COVID-19 pandemic had a significant impact on the production, marketing and prices of milk in Colombia. The implementation of social distancing measures and border closures affected the supply chain, leading to a decrease in the supply of raw milk in some regions of the country. In addition, the interruption in the supply of inputs and the reduction in dairy processing capacity also contributed to the increase in the prices of milk and its derivatives (Fedegan, 2020. Maturana, 2021 y Causado-Rodriguez, E; Fonseca-Tovar, J & Galindo-Montero, A. (2023a)).

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In this sense, the dairy chain in the Colombian Caribbean region has been affected by the situation of price increases at the national level and by local factors specific to the region, which has directly impacted milk producers, and they turn to the production of coastal cheese. Furthermore, the decline in milk production in the region has been exacerbated by the dry season and the lack of adequate infrastructure and technology to guarantee the supply of water and feed to animals, which has resulted in a reduction in supply. raw milk (Causado-Rodriguez, E; Romero-Borja, I & Galindo-Montero, A. 2023b).

Therefore, the selection of the departments of Magdalena, Córdoba and La Guajira for the analysis of the milk price trend was based on several factors, including their recognition as important milk producers and artisanal cheesemakers in the Caribbean region. Colombian and its long tradition in the production of coastal cheese. For the analysis of the milk price trend in the departments of Magdalena, Córdoba and La Guajira, the Box-Jenkins methodology will be used, which allows modeling and predicting time series. This methodology has been widely used in studies on milk prices in different countries and has proven to be effective in identifying patterns and trends in the data (Zhang, L., Huang, C., Malskær, A. H., Jespersen, L., Arneborg, N., & Johansen, P. G. 2020, y Mishra, P. (2020).

Specifically, this study focused on analyzing the trend of milk prices paid to producers in these three departments (Magdalena, Córdoba and La Guajira) due to the importance of this milk supply link in the supply chain. supply of Costeño cheese in these areas and its economic relevance, and it is expected that the results of this study will be very useful in providing accurate and useful information so that producers and other actors involved in the dairy chain can predict the behavior future of prices and take the necessary measures in advance to reduce the risk in productive performance.

THEORETICAL FRAMEWORK

The Box-Jenkins methodology was developed by British statisticians George Box and Gwilym Jenkins in the 1970s as a technique for time series analysis and prediction. This technique is based on the idea that any time series can be decomposed into three main components: trend, seasonality and random or error components. The objective of the methodology is to identify and model these components effectively to make accurate forecasts of the time series in question (Brockwell &Davis 2002; Anand, 2013; Gutierrez y Burbano, 2015).

In milk price studies, this methodology has been widely used, as can be seen in the study carried out by (Kinnucan & Forker 1985) where they compare preliminary milk price predictions with predictions generated by time series models of Box-Jenkins, concluding that the Box-Jenkins models produced more accurate and useful predictions for decision making compared to the preliminary pricing models. In addition, they highlighted the importance of using time series techniques in predicting milk prices and decision making in the dairy industry.

(Özkan & Toktaş 2012), analyze milk production in Turkey using two time series forecasting techniques. The results showed that both methods are effective in forecasting milk production in the country, but that the Box-Jenkins methodology performed better in terms of accuracy and accuracy compared to exponential smoothing method.

In the case of India, milk production has increased enormously in the country and has become an important driver of economic growth, which is why (FAO, 2020; Mishra et al 2020) focuses on the analysis of time series data. of five major milk producing states in India for the year 2017-2018 and uses an autoregressive integrated moving average (ARIMA) model to make milk production projections for the year 2024-2025, assisting in the formulation of national agricultural policies and proper product planning for the dairy sector in India.

In summary, the studies reviewed suggest that the Box-Jenkins methodology is a useful tool in time series analysis and price prediction in the dairy industry (Causado-Rodriguez, E; Galindo-Montero, A & Peñaloza-Fernández, A. (2023c)). It was found that this methodology has been widely used to model milk production and price in different countries, such as the United States, Turkey, India and Colombia, among others. Consequently, it is expected that the application of the Box-Jenkins methodology in the analysis of price per liter of milk paid to producers in the departments of Magdalena, Córdoba and La Guajira will allow obtaining accurate predictions and contribute to the design of production strategies and more efficient marketing.

METHODOLOGY

Data

The data of the study are the monthly prices per liter of milk paid to the producer in the departments of Magdalena, Córdoba and La Guajira during the period from January 2008 to January 2023. The data were selected from the portal of the Milk Price Monitoring Unit system. The milk (USP) belongs to the Ministry of Agriculture and Rural Development (MADR).

Box-Jenkins Methodology

Time series consist of periodic observations over time and the accuracy of the predictions depends on the stability of past values. Given the type of data available, it was decided to choose a general time series model known as SARIMA (p, d, q) × (P, D, Q) $_s$ (with trend and seasonal component of period *s*) which is explicitly written as follows:

$$\phi(B)\Phi(B^s)(1-B)^d(1-B^s)^D X_t = \theta(B)\Theta(B^s)u_t,$$

Where:

$$\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \dots - \phi_p B^p, \qquad \phi_p \neq 0$$

Is the autoregressive operator of order *p*

$$\Phi(B^s) = 1 - \Phi_1 B^s - \Phi_2 B^{2s} - \dots - \Phi_P B^{Ps}, \qquad \Phi_P \neq 0$$

Is the seasonal autoregressive operator of order *P*,

$$\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \dots + \theta_q B^q, \qquad \theta_q \neq 0$$

Is the order moving average operator q, and

$$\Theta(B^s) = 1 + \Theta_1 B^s + \Theta_2 B^{2s} + \Theta_Q B^{Qs}, \qquad \Theta_Q \neq 0$$

Is the order seasonal moving average operator *Q*.

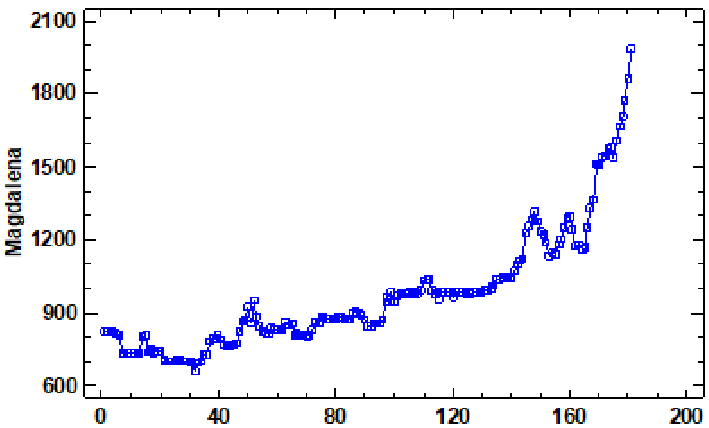
RESULTS

With the purpose of determining the forecast on the prices per liter of milk paid to the producers of Magdalena, Córdoba and La Guajira, a time series analysis of the corresponding records is carried out from January 2008 to February 2023.

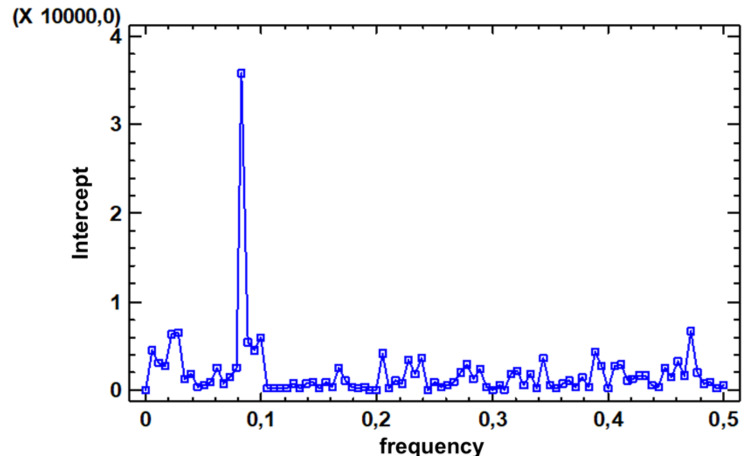
Magdalena

Graph **a**) shows the behavior of the data observed from January 2008 to February 2023. An increasing trend is evident, and a seasonal component is not visible at first glance. **b**) However, the periodogram of the differentiated data shows a pronounced peak corresponding to a 12-month period. Having eliminated the trend and the seasonal component, graph **c**) suggests that the variance is not constant. After a power transformation with exponent λ=0.5 the result is shown in graph **d)**.

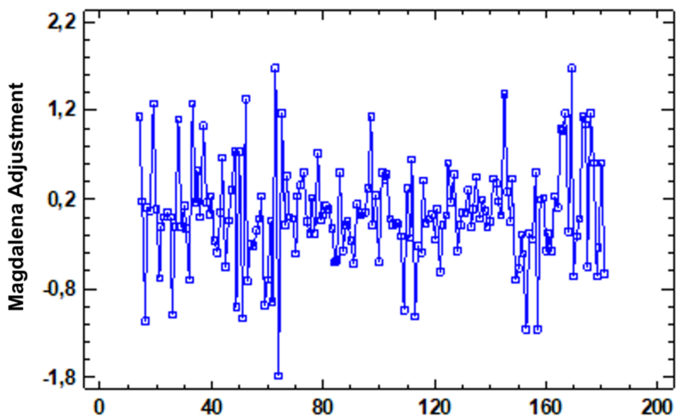
a) behavior of the observed data



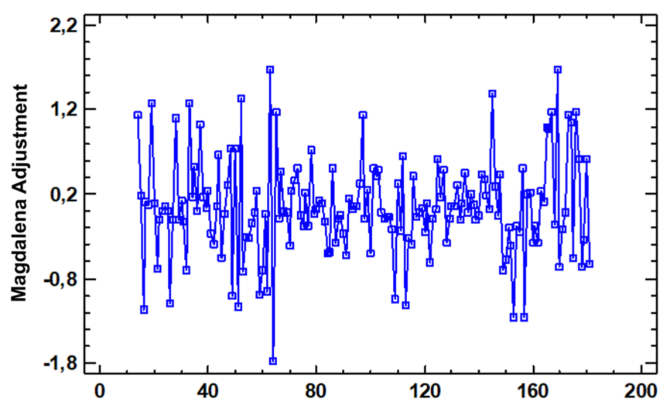
b) Periodogram



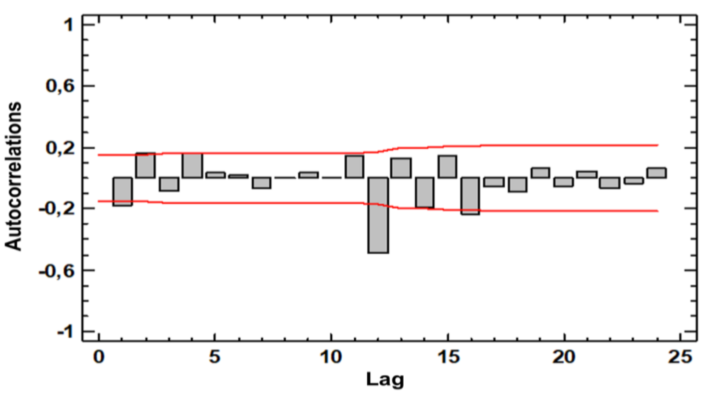
c) Transformation



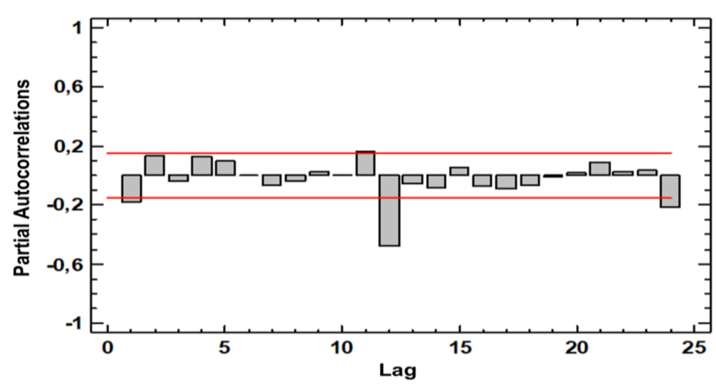
d) Power transformation



e) Correlogram



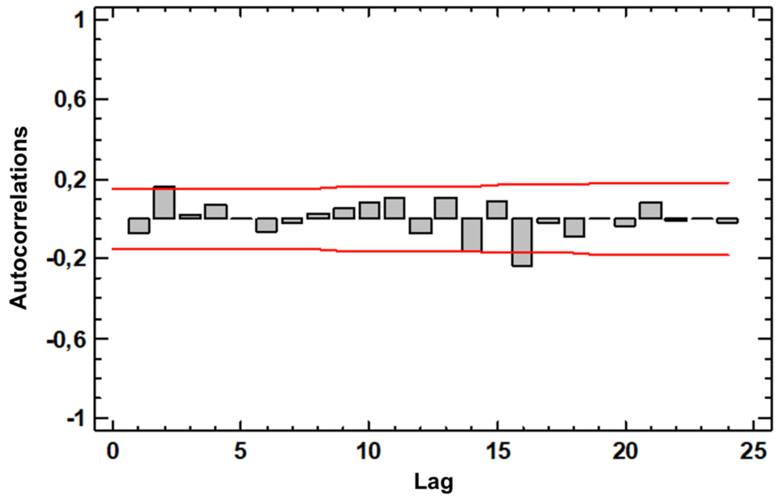
f) Correlogram partial



We then proceed, based on correlogram **e**) and partial correlogram **f**), to fit the following model (the t statistic of each estimated parameter is shown in parentheses):

$$(1-B)(1-B^{12})X_t^{1/2} = \underset{(3.25)}{1.57} + (1 - \underset{(40.48)}{0.89}\, B^{12})u_t$$

g) Autocorrelations Residuals $ARIMA\ (0,1,0) \times (0,1,1)_{12}$



The model parameters are significant. However, the correlogram of the residuals does not strictly correspond to white noise since ϱ_{16} is different from zero. The joint significance test is done

$$Q = \sum_{k=1}^{m} \rho_k^2 \sim X_m^2$$

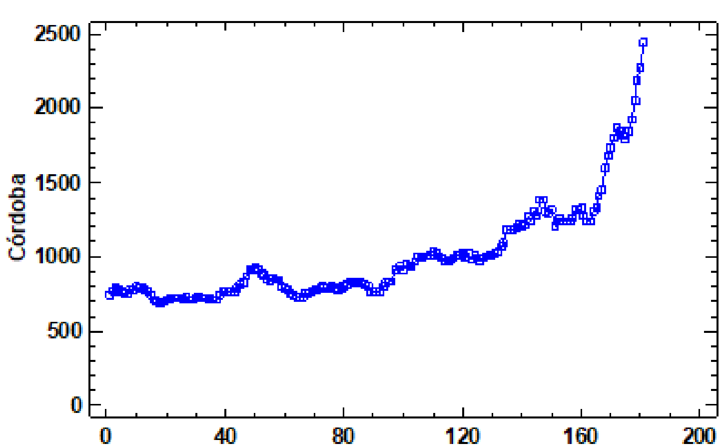
$$H_0 : \rho_1 = \rho_{24} = 0$$
$$H_1 :\sim H_0$$

The observed value $Q = 33{,}6$ is less than the critical Chi-square value at 95% (χ^2 =36.4). H_0 is not rejected and in conclusion the model is considered acceptable.

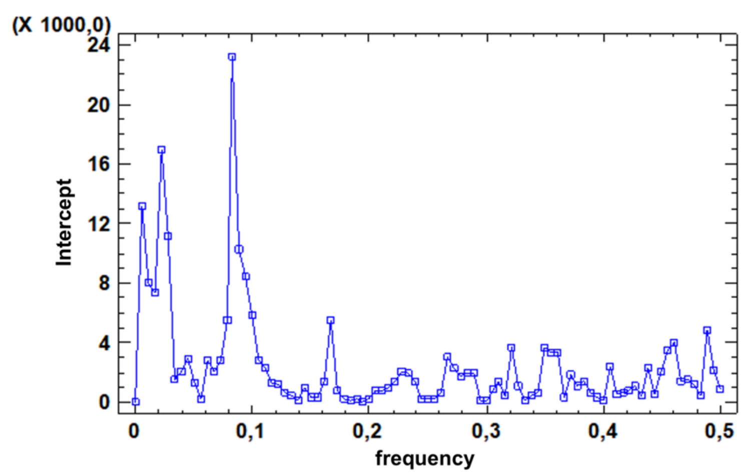
Córdoba

In graph **h)** the data show an increasing trend, and a seasonal component is not visible at first glance. However, the periodogram of the differentiated data, graph **i)** shows a pronounced peak corresponding to a 12-month period. Having eliminated the trend and the seasonal component, graph **j)** suggests that the variance is not constant. After a power transformation with exponent λ=0,5 the result is shown in the graph **j)**.

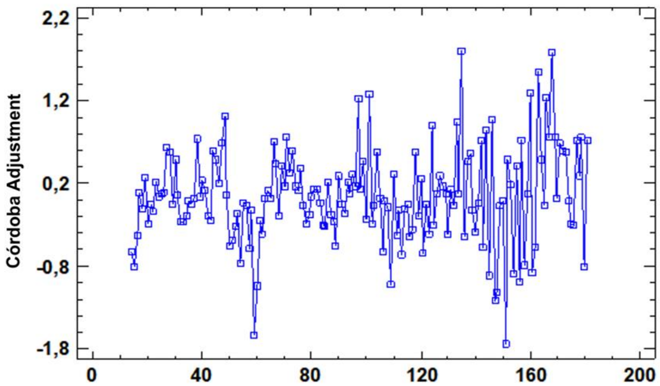
h) behavior of the observed data



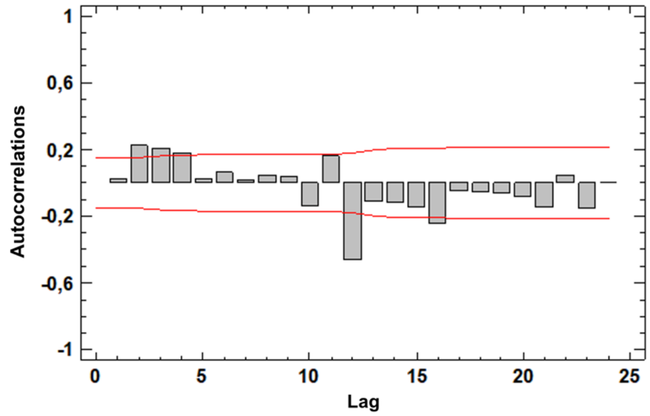
i) Periodogram



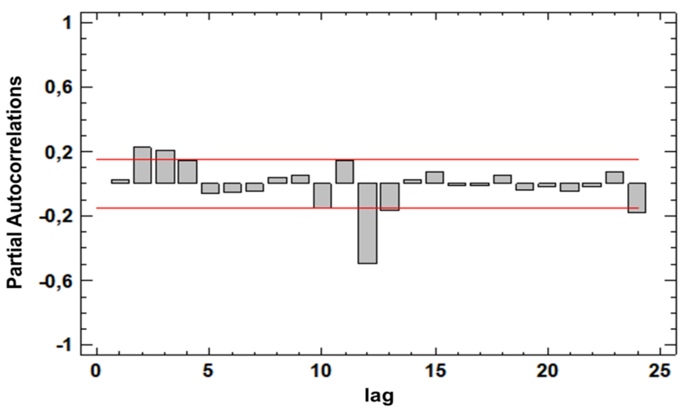
j) Transformation



k) Correlogram



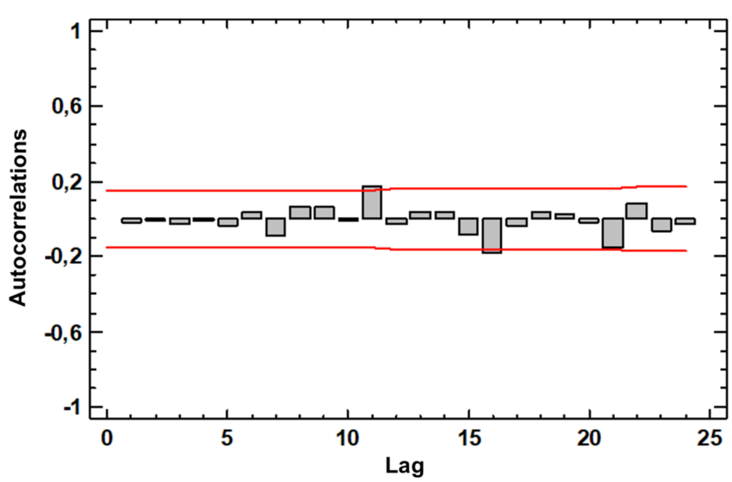
l) Correlogram Partial



The correlograms **k)** y **l)** clearly suggest a model MA (1) for the transformed data. The result is

$$(1-B)(1-B^{12})X_t^{1/2} = \underset{(2.17)}{2.001} + (1 + \underset{(-3.57)}{0.26}\, B^2 + \underset{(-4.35)}{0.32}\, B^3 + \underset{(-2.84)}{0.22}\, B^4)(1 - \underset{(33.9)}{0.87} B^{12})u_t$$

m) Autocorrelations Residuals $ARIMA\ (0,1,4) \times (0,1,1)_{12}$



The behavior of the waste is not white noise. The joint significance test, despite everything, confirms that the residuals can be considered as noise at 95%, that is, that at that level the model is acceptable (the statistic Q = is less than 36.4, the critical value of Chi-square with 24 degrees of freedom.

$$Q = \sum_{k=1}^{m} \rho_k^2 \sim X_m^2$$

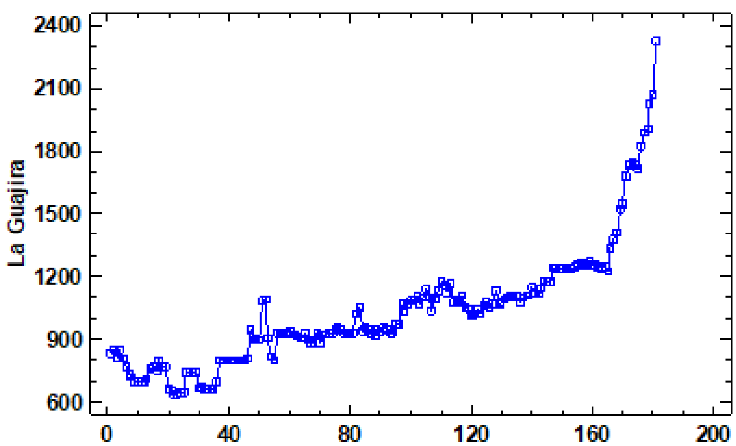
$$H_0 : \rho_1 = \rho_{24} = 0$$

$$H_1 :\sim H_0$$

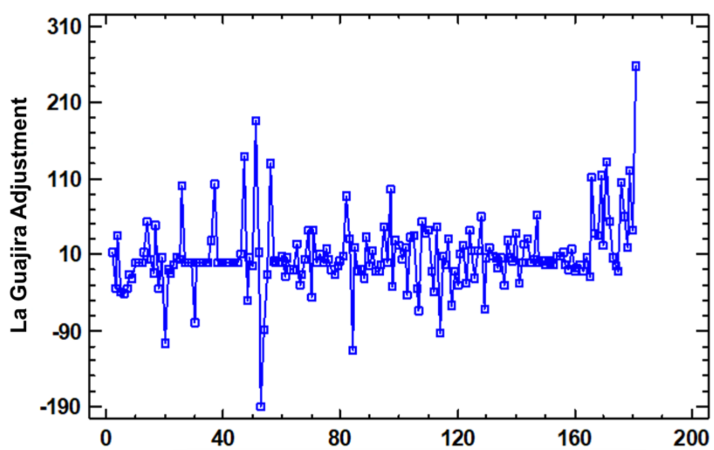
La Guajira

In figure **m)** the data show a behavior with an increasing trend and with signs of heteroskedasticity. In the transformation of figure **n)** the result of a non-seasonal difference and power transformation with parameter is presented λ=0,5.

m) behavior of the observed data

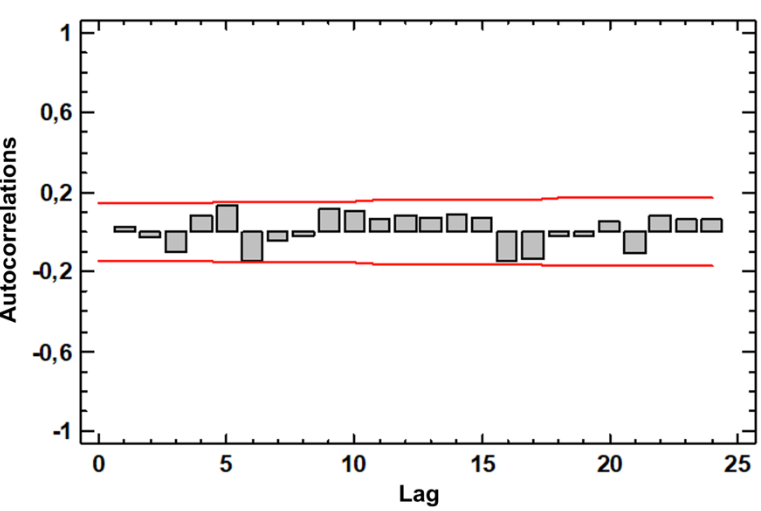


n) Data transformation

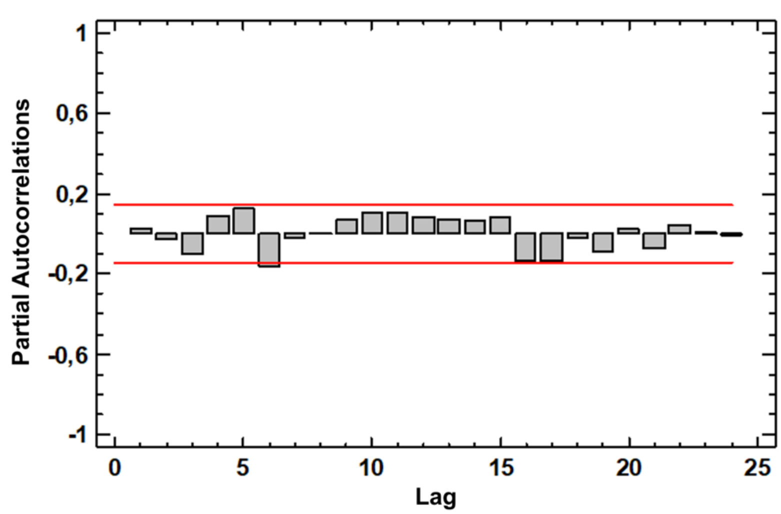


Correlograms **o)** and **p)**, since the correlations are within the confidence band, correspond to white noise.

o) Correlogram



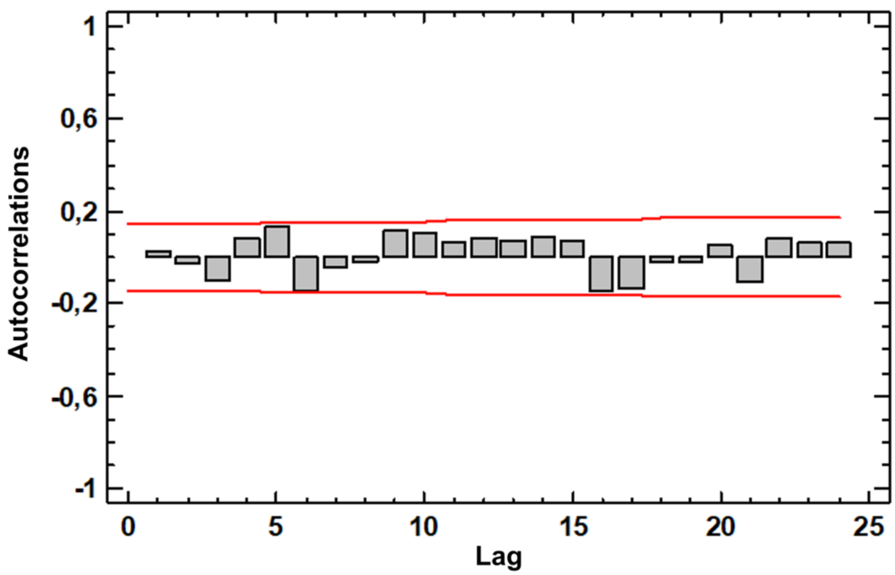
p) Correlogram Patcial



This is equivalent to saying that, after the transformation, the data is white noise or, at most, a constant added to white noise. After adjustment, a significant constant is obtained. In conclusion, the fitted model is

$$\nabla X_t^{1/2} = \underset{(2.005)}{6.79}$$

q) Autocorrelations Residuals $ARIMA$ (0,1,0)



Forecasts

For the months of 2023, the models predict prices to be paid to producers that maintain the increasing trend observed throughout the study period. These results are of great interest to producers and other stakeholders in the dairy industry, as they allow them to anticipate and plan their economic activities more effectively.

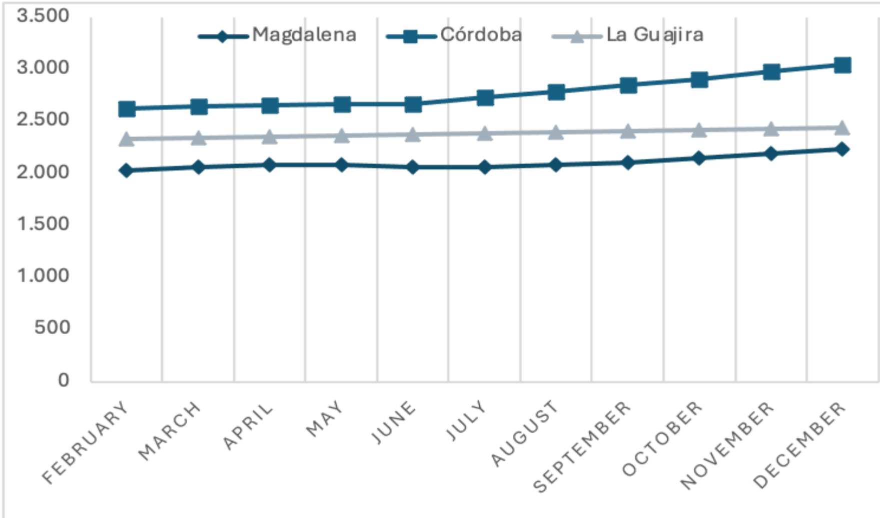


Table 1. Forecasts of prices per liter of milk paid to the producer (February – December 2023)

Months	Departments		
	Magdalena	Córdoba	La Guajira
February	2.025	2.620	2.336
March	2.059	2.650	2.347
April	2.078	2.660	2.357
May	2.078	2.662	2.368
June	2.067	2.671	2.378
July	2.065	2.729	2.388
August	2.083	2.783	2.399
September	2.110	2.850	2.409
October	2.148	2.903	2.420
November	2.191	2.977	2.431
December	2.235	3.050	2.441

CONCLUSIONS

This article presents an analysis of the behavior of the price per liter of milk paid to producers in the departments of Magdalena, Córdoba and La Guajira over a period of 15 years. The results obtained indicate that in the three departments an upward trend in milk prices is observed. For the analysis, the SARIMA models for Magdalena, SARIMA for Córdoba and ARIMA (0,1,0) for La Guajira were used. This study is relevant since it is the first time that a time series analysis has been carried out for the price of milk in these departments and can be a basis for future research in the area. Furthermore, the increase in prices in the dairy chain has effects on the industry and the local economy, as well as a social impact on producers and consumers. It is important to consider the impact of climate change on milk production and the dairy chain in general.

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CONTRIBUTION OF THE AUTHORS

Edwin Causado-Rodriguez worked on data analysis. in the research methodology, especially in the design and implementation of the Box-Jenkins methodology, in the analysis of time series and the validation of the precision of the models. Johana Fonseca Tovar and Maria Pedrozo Acosta worked on data collection and the development of econometric models, applying statistical analysis. The three authors contributed to the interpretation of the results obtained and analysis of the econometric models. The three authors contributed to the preparation and writing of the document.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in relation to the publication of this manuscript. Additionally, ethical aspects, including plagiarism, informed consent, data fabrication and/or falsehood, duplicate, and redundant publication were observed and verified by the authors.

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