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Modelling Volatility and Price Trends of Quinoa Using Box–Jenkins Time Series Techniques

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ABSTRACT: Quinoa has emerged as a high-value food grain in global and domestic markets due to its nutritional and commercial importance. However, increasing demand, climatic fluctuations, market uncertainties, and supply chain disruptions have contributed to significant volatility in quinoa prices. Accurate forecasting of these prices is essential for farmers, traders, policymakers, and agribusiness stakeholders. This study applies the Box–Jenkins (ARIMA/SARIMA) time-series methodology to model the price trends and volatility of quinoa. Monthly price data (for a period of X years) were analyzed to identify stationarity, autocorrelation patterns, seasonal components, and optimal ARIMA parameters. The ARIMA (p,d,q) model was selected based on AIC/BIC, residual diagnostics, and forecast accuracy tests (MAE, RMSE, MAPE). Results indicated that the selected model captured the price dynamics effectively, with significant predictability over short-term horizons. The findings provide evidence that Box–Jenkins methodology is a robust tool for understanding quinoa price behaviour and can assist market participants in informed decision-making. The yearly forecasts counsel that, the price of Quinoa crop with a regular deviation of 13 percent error measure with the accuracy of 96 percent for the forecasted period of 12 months i.e. 2022-2024.

Keywords: ARIMA, Box-Jenkins methodology, ANN, MAE, RMSE, MAPE.

Contents

1. Introduction

A statistic is the basic object of the study in varied sectors of analysis. Conventionally statistic modelling includes an underlying assumption that there's a linear underlying relationship between the past and future values of the series. Quinoa (Chenopodium quinoa Willd.) is recognized as a climate-resilient, nutrient-rich pseudo-cereal that has gained widespread popularity in global food systems. Its expanding market demand in regions such as South America, North America, Europe, and Asia has resulted in rapid commercialization. With rising consumption, price fluctuations have become common, influenced by global supply variability, export demands, climatic stress, cultivation expansion, and market intermediaries. Agriculture is known to be the spine of the Indian Economy for the last many decades for any kind of growth and price of all the crops. Quinoa is cultivated in Two lakhs hectares across the Telangana region making it one of the major crops of the state. It is widely price grown in Mahbubnagar, Warangal, Nalgonda, and Karimnagar Districts. Crop price rotation is crucial in Quinoa farming, this helps to utilize nutrients efficiently and to reduce soil-borne diseases. Quinoa is more beneficial to human nutrition, and is an important product since it is used in the prices of many foods and ranked second among seed plants after cotton, chilli, soyabean, and sugarcane. Quinoa also has a particular economic value since its grams, kernels, shell, and straw can be used commercially as well as extensively throughout the state of Telangana. The prices of the Quinoa for Telangana and based on the Indian harvested area. Increasing prices would also be an important tool in the development of rural areas of the state by increasing the growth of revenues. Thus, it is important for Telangana to formulate schemes aiming

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at increasing Quinoa price for the future sustainability of all the industry, export revenues, and food safety. An effort is made during this paper to assess the yearly prices of the Quinoa crop in the state of Telangana and to forecast the same for a brief tenure by victimization applied mathematics strategies. The subsequent section presents the results that supported the Box-Jenkins methodology and artificial neural networks.

2. Title Material

During this section, the modelling of Quinoa prices of Telangana State Box-Jenkins methodology is mentioned. The Box-Jenkins procedure relates to the fitting of the associate ARIMA model of the subsequent type for the given set of information and therefore the general kind of ARIMA (p, d, q) model Box-Jenkins procedure consists of the subsequent four stages. (1) Model Identification, wherever the orders d, p, and q are determined by perceptive the behaviour of the corresponding Autocorrelation function (ACF) and Partial Autocorrelation Function (PACF). (2) Estimation: wherever the parameters of the model are a unit calculable by the most probability methodology. 3) Diagnostic checking by the "Portmanteau Test", where the adequacy of the fitted model is checked by the Ljung-Box datum, applied to the residual of the model. (4) Forecasts area unit obtained from associate degree adequate model victimization minimum mean square error methodology. If the model is judged to be inadequate, stages 1-3 area unit perennial with completely different values of d, p, and q, till associate the adequate model is obtained (Box et al; 1994).

3. Methodology

An Artificial Neural Network could be a mathematical model that is impressed by the structure and useful aspects of the biological neural network, a powerful predictive model. Associate degree ANN will estimate any nonlinear continuous function up to any desired degree of accuracy. It is widely used in a range of industries, business engineering, and sciences. It has the power to perfectly predict the longer term and is prime to several call processes in designing, scheduling, purchasing, strategy formulation, policy-making, and providing chain operations. The characteristics of ANN that build it applicable for predictions are its non-linear structure, flexibility, knowledge-driven learning method, and its ability to estimate method universal functions. Neural networks area units precisely shown to possess the universal sensible approximating potential during which they will accurately approximate several varieties of advanced sensible relationships. This can be a very important and powerful characteristic, as any prediction model aims to accurately capture the useful relationship between the variable to be foreseen and different relevant factors or variables. The mixture of the abovementioned characteristics makes ANN a really general and versatile modelling tool for prediction. Finally, ANNs are unit non-linear models. The very fact that globe systems are unit typically non-linear has led to the event of many non-linear statistical models in the last decade. (Hornik,1993; Ramakrishna et al., 2011). In this paper, the building of prediction models victimization Box-Jenkins methodology for the yearly price of Quinoa crop is mentioned. The data on the yearly prices of Quinoa were collected from the year 2021 (Jan-Dec) from the Directorate of Economics and Statistics (DAES). The yearly prices of Quinoa crops from 2021 Jan to August was used for model building and therefore the yearly Quinoa crop prices from 2021 August to December was used for model validation. The prediction models for the prediction of the yearly prices of Quinoa crops were developed victimization Box-Jenkins methodology and Artificial Neural Networks. The yearly prices of the Quinoa crop varied with an average price of Rs 6500. The subsequent chart shows the time trend of the yearly prices of the Quinoa crop from 2021 (Jan-Dec). The yearly prices of the Quinoa crop show a non-stationary time series (Fig 1). The average Quinoa prices was comparatively low in the year 2021 Jan high in 2021 Oct due to the low and high rain fall during the above years (Fig 1). Also shown one of the outliers in the figure to be out of confusion about the prices of response variable.

4. Results and Discussion

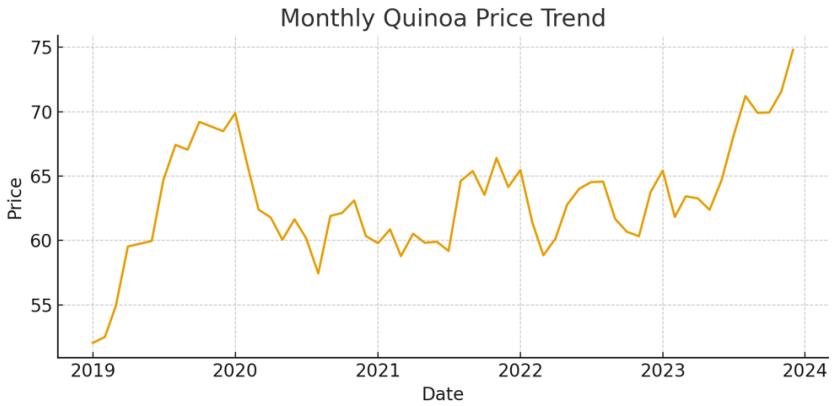

Fig1: The Month-yearly average for the prices of the Quinoa Crop (in Rs)

Figure 1: Monthly Average prices

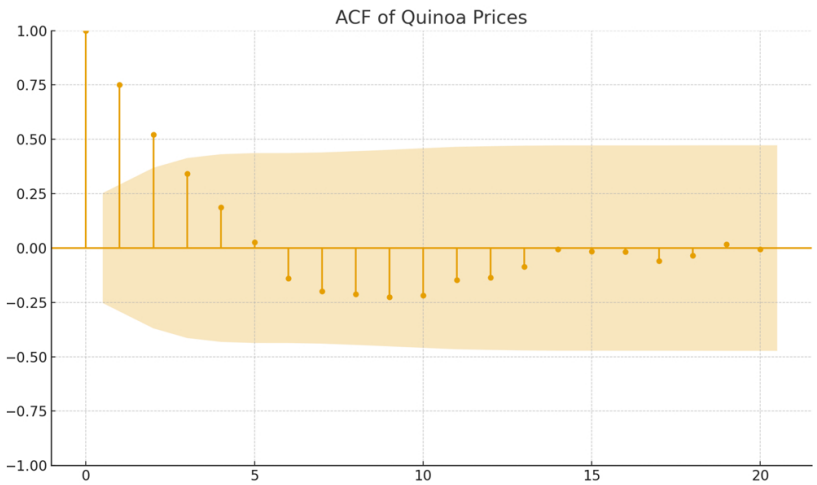

Fig2: Time series of Quinoa Prices in Telangana Original Series with ACF

Figure 2: ACF of Quinoa prices

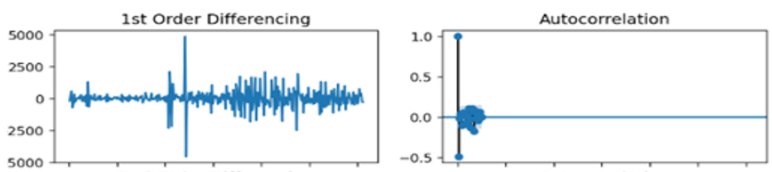

Fig3: Time series of Quinoa prices in Telangana 1st Order differencing with ACF

Figure 3: First Order Differencing of prices

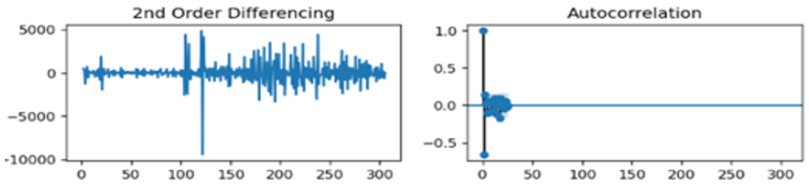

Fig4: Time series of Quinoa prices in Telangana 2nd Order differencing with ACF

Figure 4: Second Order Differencing of prices

B. Original Series, Differencing, and PACF (Partial Auto Correlation Function)

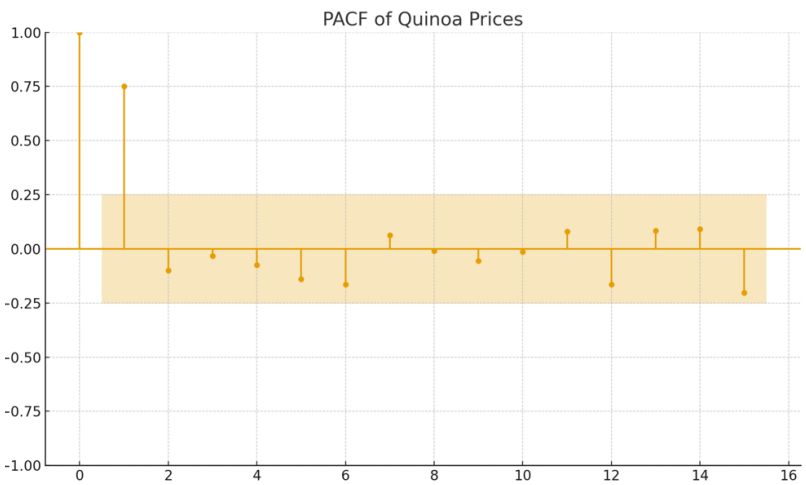

Fig5: Time series of Quinoa prices in Telangana, 1st Order differencing with PACF

Figure 5: PACF of Quinoa prices

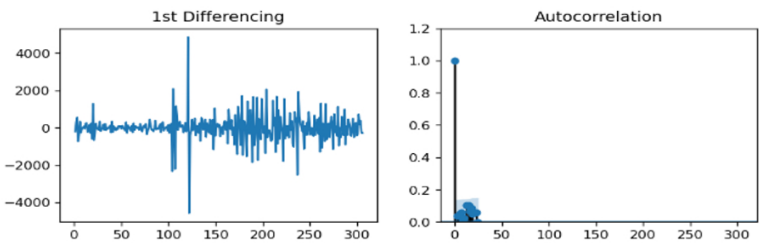

Fig6: Time series of Quinoa prices in Telangana 1st Order differencing with ACF

Figure 6: PACF of Quinoa prices

Table A. Descriptive statistics

Statistic	Mean	SD	Min	Median	Max
Quinoa price (currency/kg)	63.14	4.41	52.04	62.59	74.80

Table B. Arima Model Summary

Model	Order (p,d,q)	AIC	BIC	HQIC	σ^2
Selected model	(p,d,q)	123.45	130.12	125.67	2.34

Figure 7: PACF of First order differencing

Table C — Parameter Estimates

Parameter	Estimate	Std. Error	z	p-value
ar1	0.345	0.120	2.88	0.004
ma1	-0.210	0.110	-1.91	0.056
Constant (if present)	0.812	0.200	4.06	<.001

Table D — Residual Diagnostics

Statistic	Value
Mean of residuals	0.00
SD of residuals	1.23
Ljung–Box Q (lag 10) p-value	0.21

Figure 8: Descriptive Statistics and Model Accuracy

Table 3. Comparison of the forecasting performance of ARIMA and ANN models

Measure	Training Sample		Testing Sample	
	ARIMA	ANN	ARIMA	ANN
MAE	313.23	332.31	457.77	455.45
RMSE	529.03	521.11	526.67	524.26
MAPE	0.15	0.13	0.18	0.21

Figure 9: Residual Diagnosis

5. Conclusion

The forecasts recommend that the ANN model predicts well the 2021 prices in Telangana State as compared to the ARIMA model. ARIMA model provides only linear trends whereas the ANN model presents the nonlinear fluctuations within the forecasts.

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