Dynamic Models to Determine External Factors and their Impact on the Shrimp Price Forecast

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Abstract
Ecuador has a historic dependence on the export of its raw materials to generate income. This makes its economy extremely vulnerable to external imbalances. During 2021, the export of products such as bananas and shrimp fell to 17%, which can be explained by the changes in consumption habits brought about by the pandemic. This research aims to take an in-depth look at price forecasts for shrimp farming. For this purpose, an ARIMA econometric analysis was used. We considered 66 monthly price and export observations collected from the beginning of 2017 to the middle of 2022 in order to forecast 24 prices for the second semester of 2022, 2023, until June of 2024, with the idea being to use this to make better public policy decisions at the shrimp's sector.

Keywords
Time Series, Exports, Forecast, ARIMA, Supply and Demand, Shrimp Price, C10

1. Introduction

In general, the prices of raw materials are characterized by long periods of stability, punctuated by brief but intense price spikes [1]. These spikes are a cause for concern, primarily because they can have a large economic impact on poverty levels in developing countries [2]. They include a discussion of a wide range of contributing, such as shocks that are exogenous to supply and demand, below-trend stock levels, speculative behavior, and trade policy shock responses. Johnson emphasizes policy responses in his analysis of the 1973-74 price increase, as do most available evaluations of the 2006-08 shock [3, 4, 5]. Several authors, such as Hochman et al., [6], suggest that export restrictions (and perhaps import subsidies as well) played an important role, just as intensified export subsidies and triggered import restrictions played an important role in 1986-8, when international commodity prices collapsed [6].

Due to the region's ecosystem and climate, Ecuador has a comparative advantage in shrimp cultivation and production. Rural areas in provinces such as Manabí and El Oro are also advantageous, as they have large tracts of land at affordable prices [7]. This has led many of the country's business sectors to take an interest in shrimp farming. Shrimp aquaculture is therefore one of the most dynamic components of the agricultural sector. This sector plays

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an important role in the country's economic growth and creates thousands of jobs. This is supported by several reports, such as a recent study that states:

"Shrimp exports from Ecuador in 2000 present a growth trend; that is, the production of exported pounds has shown a year-on-year increase; however, the average price per pound has declined, meaning that the income in dollars is not what was anticipated" [8].

2. Problem Statement

This investigation seeks to establish the relationship between price and the number of pounds of shrimp exported and to carry out an analysis using ARIMA econometric models to predict prices for the second semester of 2022, 2023, and the first semester of 2024. This exploration is therefore longitudinal in nature because the observed data have been studied over a certain period [9].

3. Objectives

Understanding the external factors that have affected the changes in shrimp prices. Predicting shrimp prices for 24 months from July 2022, using ARIMA and structuring a price prediction model for 2022, 2023, and 2024.

4. Theoretical Basis

This investigation has the following structure: theoretical basis, description of the shrimp sector, historical figures, econometric analysis (time series forecasting), and conclusions.

This document presents a process for building a predictive model of stock prices using the ARIMA model. Shrimp prices obtained from the Ecuadorian Chamber of Commerce are used with a predictive model to calculate price projections. The results obtained revealed that the ARIMA model has great potential for short-term forecasting and can compete favorably with existing techniques for shrimp price forecasting. Prediction is important in economics and has stimulated researchers' interest over the years in developing better predictive models [10].

Considering the uncertainty of price fluctuations, one way to reasonably plan decision-making is to generate reliable forecasts of this variable's future behavior [11]. Recent years have seen an explosion of interest in forecasting time series behavior in different areas. Forecasting is one of the main goals of time series mining. Time series forecasting has been proven effective for appropriate decision-making in several domains. In system reliability analyses, few would argue about the need for and importance of forecasting: decision makers are interested in estimating future occurrences of system failures for resource planning, inventory management, realistic policy development, process improvements, and logistical support. Virtually all systems are repairable, and their reliability varies with time.

By considering this change a time series process, the system's "growth" or "deterioration" can be estimated. However, predicting reliability from available data is often quite subjective due to the lack of adequate models, and several difficult-to-validate assumptions must be made in the modeling process.

Traditionally, the Duane model has been widely adopted for data analysis and this is very useful to check the general trend and reliability [12]. When adjusting the data, equal weights are assumed in the model, and sometimes improvements are made by removing early data as outliers to obtain a better fit. However, some might consider this inappropriate in a reliability analysis because valuable information could be lost. It is likewise more reasonable to assume that the highest weights should be associated with the current data that has the highest repair effort since they are considered more significant than the previous data. Autoregressive Integrated Moving Average (ARIMA) models, pioneered by Box-Jenkins, present a suitable modeling alternative. By iteratively fitting the weights in this time series model, autocorrelation between the failure data can be explored and better estimates can be obtained. In this article, we examine the application of time series modeling in shrimp export analysis. ARIMA models are often called atheoretical models because they do not derive from any economic theory [13].

The processes followed when constructing an ARIMA model for predictive purposes are as follows: identification, estimation, verification, and forecast. Here, we seek to identify the stochastic process generating the data, estimate the parameters that characterize the said process, and verify that the hypotheses are fulfilled. If these assumptions are not borne out, the verification phase serves as feedback for a new identification phase. When the starting conditions are satisfied, the model can be used for forecasting [14].

The autoregressive integrated moving average (ARIMA) model is a time series model that is used for short-term forecasting through equations in relation to the autoregressive [15]. Also, the ARIMA model performs well on price decline curves and performs even better when the price series is affected by frequent changes in manual trading.

4.1. Description of the Shrimp Sector

Shrimp production has been one of the most important aquatic product exports in Ecuador [16], second only to tuna, and it is very important on the international market. On the one hand, the world market demand for shrimp products is growing. The export of shrimp from Ecuador has been driven by several factors, such as the characteristics of product export in foreign trade. Given the use of comparative and competitive advantages, in order to expand our export of shrimp products, we must take advantage of our comparative advantages and then translate them into a competitive advantage. One characteristic of this type of market is that it is difficult to project prices, meaning that shrimp producer associations do not have useful tools for making price decisions. Figure 1 presents the growth in Ecuadorian shrimp exports.

The Ecuadorian population has undergone considerable population growth [17] and it is estimated that 15% of shrimp production is consumed locally. However, the Ecuadorian shrimp industry is highly dependent on the world market. That is, 85% of the remaining production is exported to be sold in foreign markets in the form of fresh, refrigerated, and frozen shrimp, and seasoned shrimp and shrimp products in their various forms [18]. Hence, the price of shrimp in Ecuador depends largely on economic conditions in the world market, such as economic growth in trading countries, non-tariff barriers, market demand and supply, and world shrimp prices.

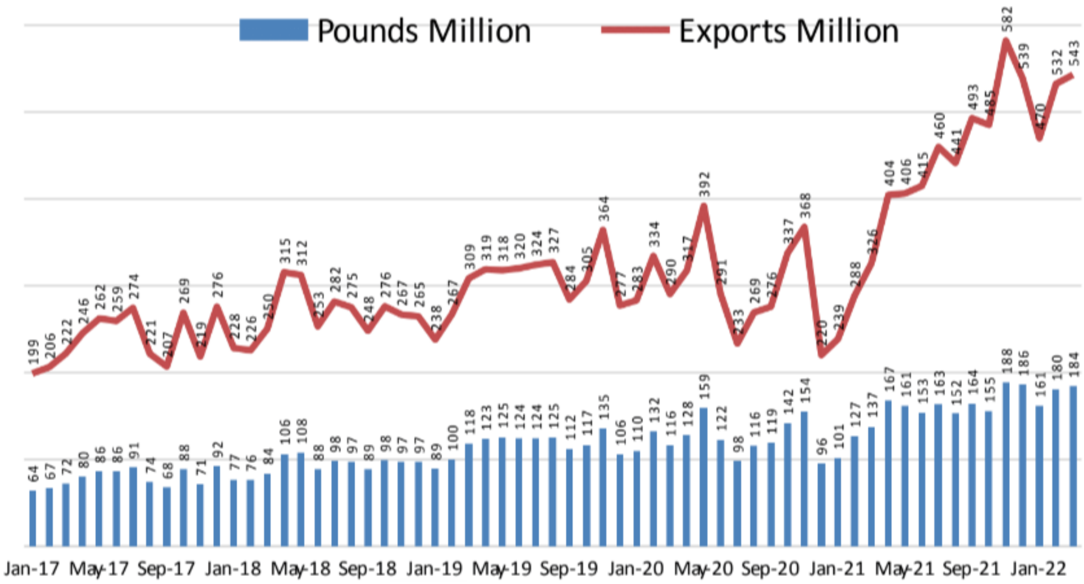

Figure 1: Ecuadorian Shrimp exports.

4.2. Factors that Affect Prices

Post-harvest shrimp prices are assumed to be determined by retail demand for the commodity. As such, ensuring minimum prices at the end-user level results in more stable revenues for producers. Since promotional sales are a common practice in retail chains, it may be useful to know what factors help products maintain a minimum price, including by special offers. Economic factors that also affect shrimp prices include climate change, shrimp diseases, demand, and supply in the country, to name a few. In a dynamic and volatile panorama for competition, we must consider various factors that influence competitiveness [19].

The objective of this study is thus to analyze the factors influencing shrimp industry prices in order to forecast industry prices in a technical and accurate fashion, i.e., the prices charged by farmers in Ecuador. Said information will be beneficial for shrimp farming, entrepreneurs, factory processed shrimp products, as well as private commercial sectors that export shrimp products to the world market. It can be used decision making, production management and strategic planning in business to maximize efficiency. Figure 2 presents the evolution of the prawn's annual average price 1997 – 2021.

4.3. External Shocks

As a consequence of the pandemic, the national fishing industry contracted by 30% [20]. This unforeseen circumstance has created major challenges for this sector. Let's consider an exogenous shock induced by the climate (or the financial market) in the global market of basic foodstuffs that causes an increase in their international price. Suppose that, in response, exporting countries impose or increase an export tax or tighten export restrictions (or reduce any export subsidy), and importing countries reduce their tariffs or other import restrictions (or

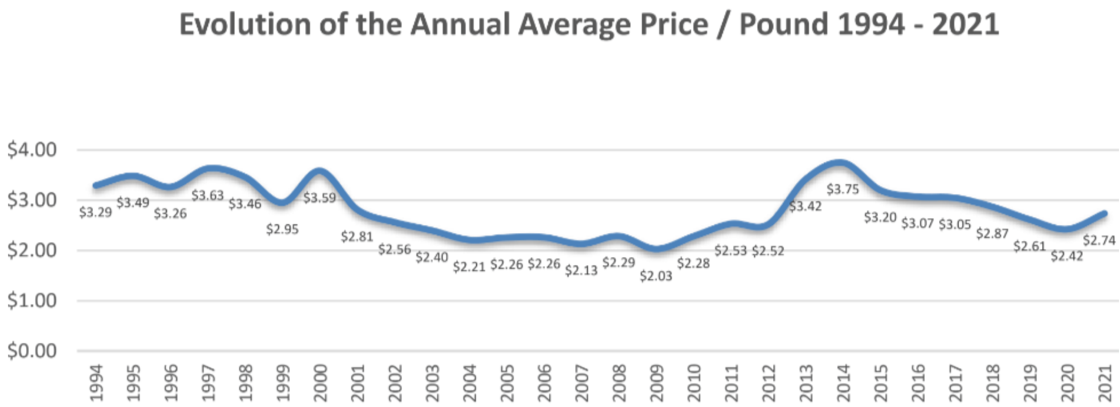

Figure 2: Evolution of the prawn's annual average price.

introduce or increase an import subsidy) to reduce their domestic price increase. If both sets of countries try to reduce the impact of the shock on domestic prices to the same extent, we can infer that their attempts will be collectively useless. Isolation creates a classic collective action problem similar to when a crowd stands up in a stadium to get a better view: no one has a better view standing up, but those who remain seated have a worse view. Unfortunately, this collective action is not only completely ineffective, it creates an international public "bad" by amplifying the volatility in the world price of the product and, as a result, the volatility of income transfers associated with changes in the terms of trade.

The government sector and related stakeholders can also use these empirical findings as a guide for strategic planning to improve and promote the Ecuadorian shrimp industry throughout the supply chain system.

At the start of 2019, China accounted for a total of 57% of Ecuadorian shrimp exports. However, in both May and November of 2020 the export level had drastically reduced, dropping by 41% according to figures presented by the National Chamber of Aquaculture (2020). This can be explained by issues related to Covid-19, which was first detected in the city of Wuhan, in China, and spread rapidly throughout the country and on to the rest of the world [8].

The prices can be visualized in the Figure 3. They were subsequently transformed into time series in order to process them and apply the ARIMA model.

5. Methodology

We will use a time series analysis and an ARIMA model to determine future prices. Time series analysis is a specific way of analyzing a sequence of data points collected over a time interval. In time series analysis, analysts record data points at constant intervals over a set period, rather than simply recording data points intermittently or randomly. The simplest time series forecasting methods make use of data on the variable to be forecast. As such, the intention is not to establish factors that condition variable behavior. This will provide us with graphic information.

Table 1
Evolution of the Price of Shrimp per pound.

Monthly Evolution of the pounds and price Shrimps 2017 (January) – 2022 (May)							
MONTHLY HISTORICAL SUMMARY (2014 - 2022)							
Month	**Punds**	**Price (USD)**	**Price (Average)**	**Month**	**Punds**	**Price (USD)**	**Price (Average)**
ene-17	64,303,584	$199,045,946	$3.10	oct-19	116,745,652	$305,288,553	$2.61
feb-17	66,620,606	$206,099,394	$3.09	nov-19	135,273,597	$364,320,933	$2.69
mar-17	71,869,640	$222,036,344	$3.09	dic-19	105,986,034	$277,308,729	$2.62
abr-17	79,851,780	$245,601,182	$3.08	ene-20	109,712,762	$283,056,725	$2.58
may-17	85,869,921	$262,213,940	$3.05	feb-20	131,998,915	$334,212,222	$2.53
jun-17	86,082,995	$259,491,253	$3.01	mar-20	115,811,924	$290,384,082	$2.51
jul-17	91,361,157	$274,293,481	$3.00	abr-20	127,751,797	$317,430,911	$2.48
ago-17	73,629,117	$221,409,742	$3.01	may-20	159,145,827	$392,124,656	$2.46
sep-17	67,692,637	$207,106,338	$3.06	jun-20	122,263,463	$291,154,723	$2.38
oct-17	88,432,893	$268,999,147	$3.04	jul-20	98,311,746	$233,305,331	$2.37
nov-17	70,957,849	$218,612,937	$3.08	ago-20	115,666,912	$269,090,674	$2.33
dic-17	91,911,350	$275,721,729	$3.00	sep-20	118,950,401	$275,908,691	$2.32
ene-18	76,740,046	$228,251,420	$2.97	oct-20	141,703,470	$337,330,001	$2.38
feb-18	76,478,433	$225,804,062	$2.95	nov-20	154,257,289	$367,520,431	$2.38
mar-18	83,568,002	$250,423,742	$3.00	dic-20	95,557,708	$220,352,183	$2.31
abr-18	106,117,594	$315,475,765	$2.97	ene-21	101,421,858	$238,565,407	$2.35
may-18	107,592,012	$312,424,063	$2.90	feb-21	126,636,641	$288,295,658	$2.28
jun-18	88,303,488	$253,377,264	$2.87	mar-21	137,398,429	$325,992,265	$2.37
jul-18	97,947,911	$281,940,230	$2.88	abr-21	167,273,101	$404,490,955	$2.42
ago-18	97,434,163	$275,218,913	$2.82	may-21	161,190,067	$406,308,292	$2.52
sep-18	88,599,933	$247,966,604	$2.80	jun-21	153,299,074	$414,774,774	$2.71
oct-18	98,449,999	$276,231,793	$2.81	jul-21	162,826,458	$459,572,274	$2.82
nov-18	96,842,610	$266,763,496	$2.75	ago-21	152,297,115	$441,272,957	$2.90
dic-18	97,149,564	$264,838,171	$2.73	sep-21	164,254,725	$493,016,057	$3.00
ene-19	89,192,404	$237,806,527	$2.67	oct-21	155,185,007	$485,194,548	$3.13
feb-19	99,644,130	$267,058,138	$2.68	nov-21	188,165,830	$582,151,974	$3.09
mar-19	117,737,601	$308,545,725	$2.62	dic-21	185,686,546	$539,190,089	$2.90
abr-19	122,841,387	$319,096,198	$2.60	ene-22	161,094,284	$470,006,159	$2.92
may-19	125,293,328	$318,003,985	$2.54	feb-22	180,446,924	$532,430,796	$2.95
jun-19	123,967,355	$320,166,091	$2.58	mar-22	184,043,936	$542,803,778	$2.95
jul-19	123,831,883	$324,050,948	$2.62	abr-22	182,579,815	$538,747,730	$2.95
ago-19	124,943,552	$326,912,722	$2.62	may-22	208,671,837	$610,058,453	$2.92
sep-19	112,033,456	$284,125,532	$2.54				

Figure 4 shows the historical data from 2017 until June 2022. Figure 5 presents the application of a correlogram (also called an Automatic Correlation Function [ACF] or Autocorrelation Graph). This is visual form of showing serial correlation in data that changes over time (i.e., time series data). Serial correlation (also called autocorrelation) is where an error at one point in time travels to a later point in time. The ACF plot clearly shows the number of lags for moving average. In this case it was one and the PACF of the auto covariance reflects only an autoregressive vector.

5.1. ARIMA Model

ARIMA models provide us with an approach to time series forecasting. The exponential smoothing method and the ARIMA models are the two most commonly used approaches for

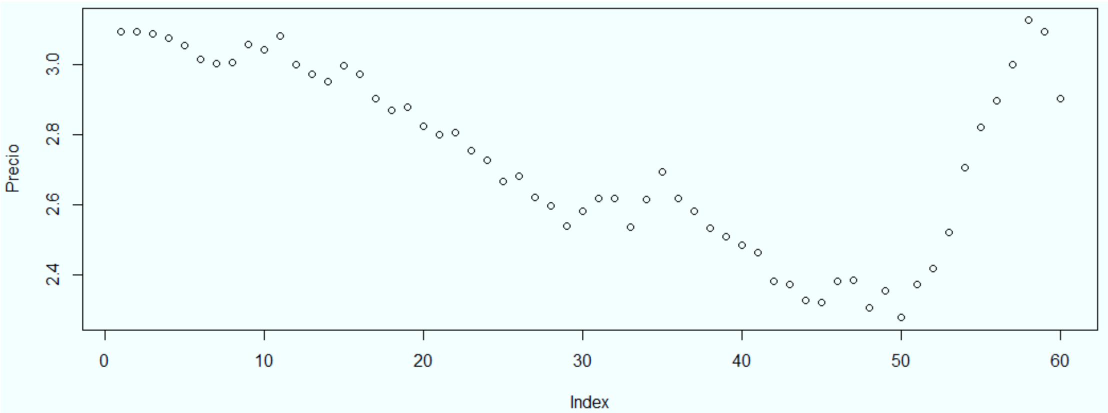

Figure 3: Prices of Ecuadorian Shrimp.

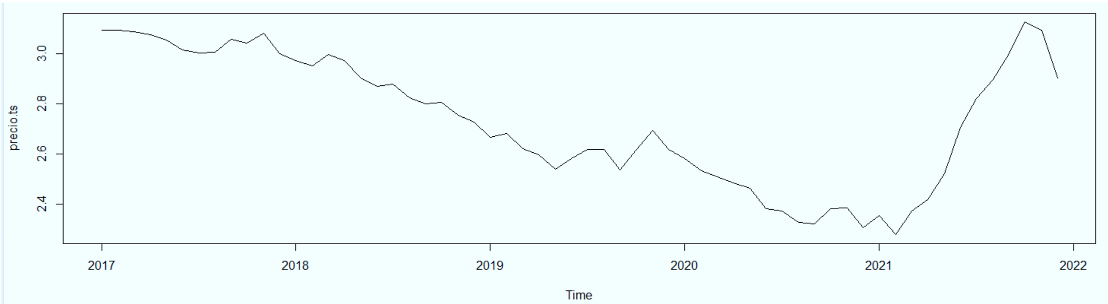

Figure 4: Ecuadorian Shrimp Prices in Time Series.

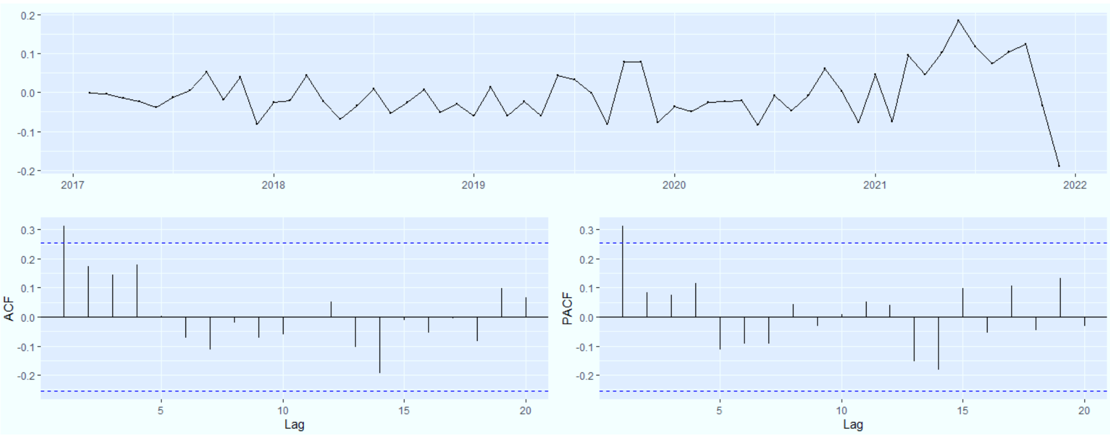

Figure 5: Time Series Visualization.

time series forecasting, and they provide complementary approaches to the problem. While exponential smoothing models are based on a description of the trend and seasonality of the data, ARIMA models aim to describe the data autocorrelations. For our case study, Figure 6 uses

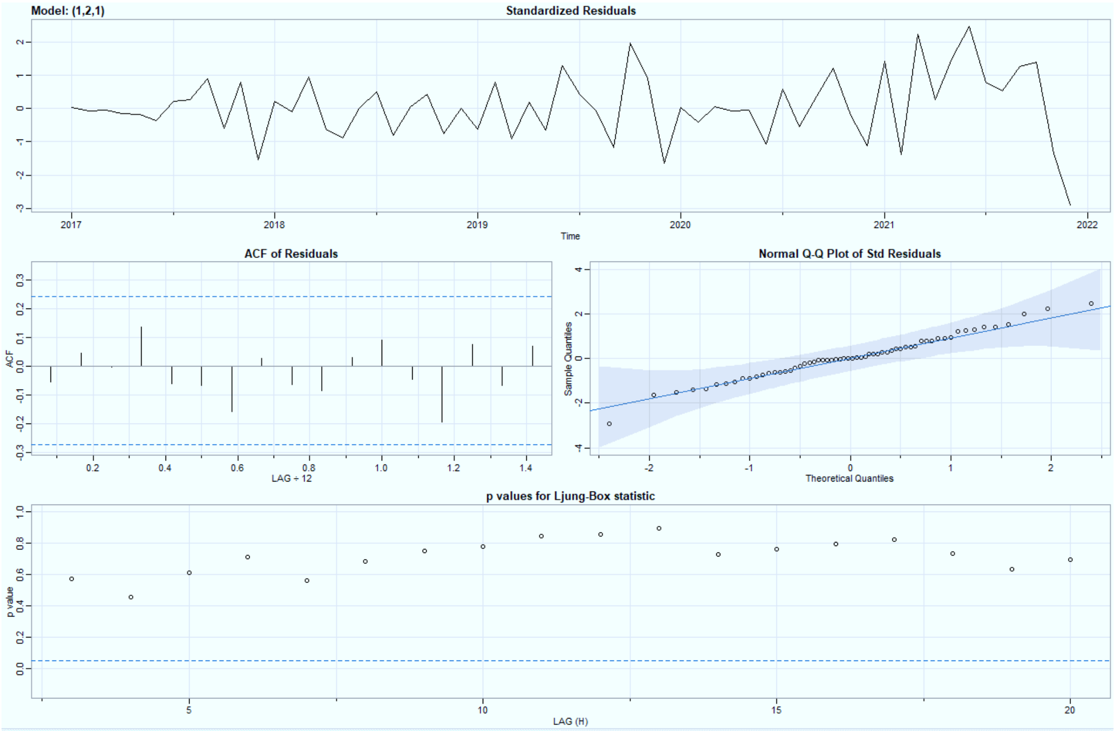

Figure 6: Simulation and Prediction with Seasonal ARIMA Models.

the SARIMA command in Package R.

5.2. Prediction for 2022 and 2023 (ARIMA)

In this study we analyze 65 monthly observations of the price of shrimp to ensure reliability and consistency collected from January 1, 2017, to May 2022. According to the Box-Jenkins models, the data must have at least 50 observations to obtain better predictions.

In the case of our model, we considered 65 monthly observations. Having a large data set ensures a representative sample size and allows the analysis to filter out noisy data.

It also ensures that any trend or pattern detected is not an outlier and can explain seasonal variation. In addition, time series data can be used for forecasting, i.e., predicting future data based on historical data. For the first model, the projected forecast for one year is shown in Figure 7.

The forecast suggests a relative stabilization of prices for the whole of year 2023. This represents a good opportunity for the industry: stable prices would allow producers to technify their production processes to increase profit margins.

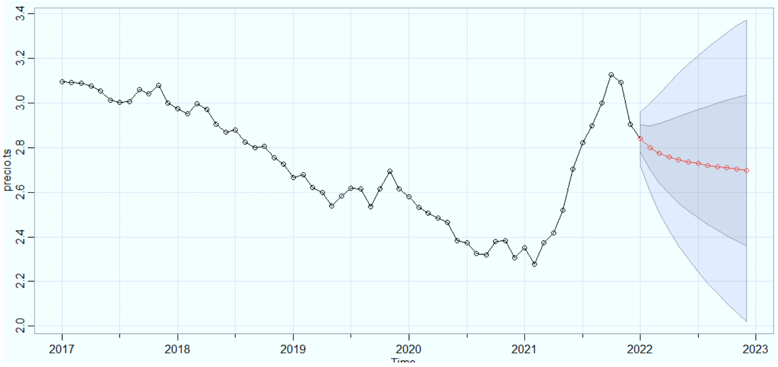

Figure 7: Forecast M1.

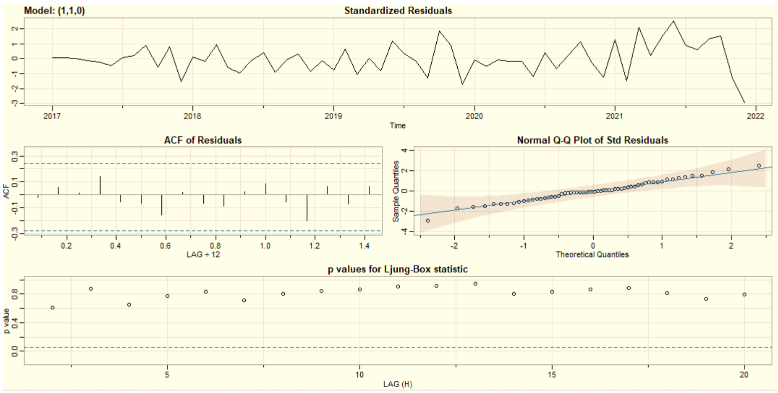

Figure 8: Simulation and Prediction with Seasonal ARIMA Models M2.

5.3. ARIMA Model Suggested by the R Console

5.4. Akaike Criterion

The Akaike information criterion (AIC) is a mathematical method for evaluating how well a model fits the data from which it was generated. In statistics, AIC is used to compare different possible models and determine which one best fits the data. In the case of our study, it was determined that the first model best represents the data being analyzed.

5.5. ARIMA Model by STATA: Dickey-Fuller Test for Seasonality

The Dickey-Fuller statistical test allows us to determine if the shrimp price time series is stationary. In this case, the price of shrimp is not non-stationary. The P-value is greater than 0.05 of significance with the Dickey-Fuller test, meaning that we apply the first differential. We thereby obtain a P-value within the significance ranges (0.002).

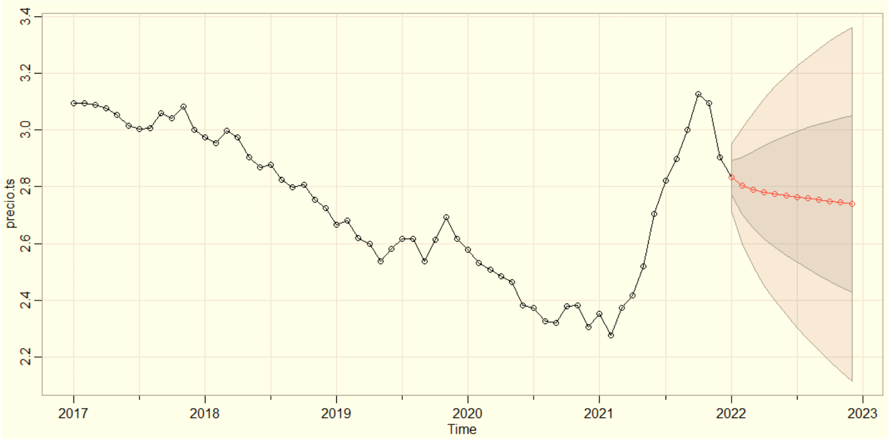

Figure 9: Forecast M2.

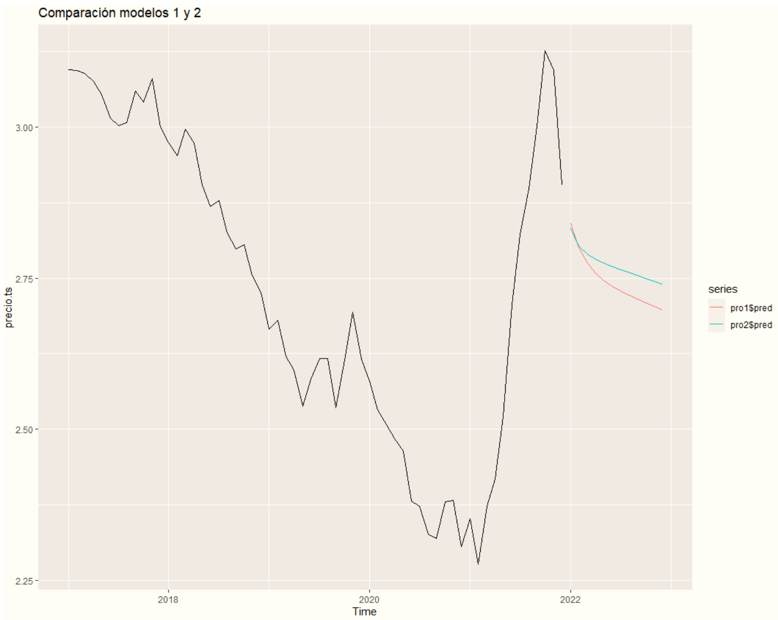

Figure 10: Comparison of Models.

5.6. Forecast Prices

Finally, we forecast the results of the prices from the ARIMA model. Table 2 presents the prices from June 2022 until May 2024.

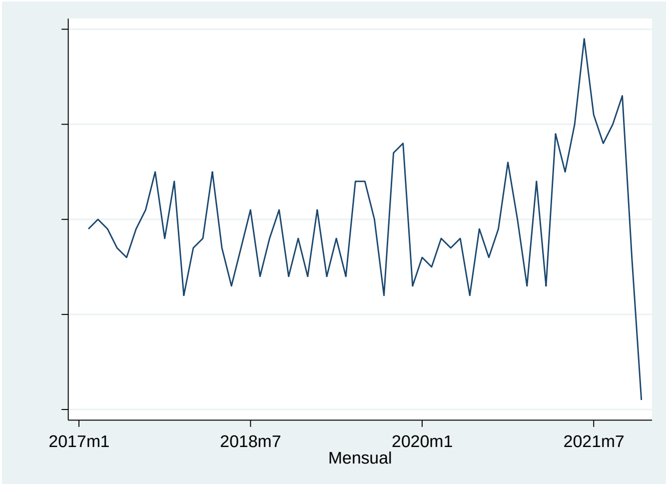

Figure 11: Seasonality in the First Differential of the Shrimp Price.

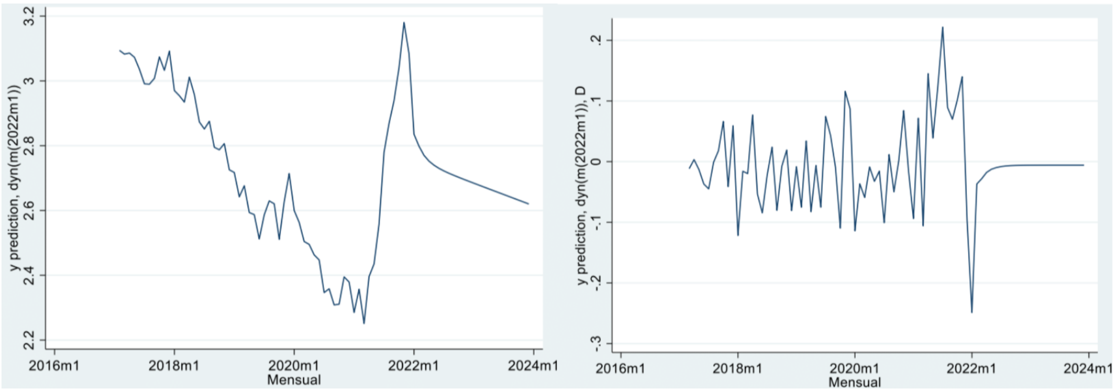

Figure 12: Comparison between the Forecasted Shrimp Price and the Forecasted First Stationary Differential.

6. Conclusions

Time series analysis allows producers to understand the underlying correlations of general trends or patterns over time. Using data visualizations, decision-makers for the shrimp industry can observe seasonal trends and deepen their understanding of why these trends occur. With modern analysis platforms, these visualizations can go far beyond line charts. If organizations analyze data at constant intervals, they can also use time series forecasts to predict the probability of future events: in this case, shrimp prices in international markets. Time series forecasting is part of predictive analytics. It can show likely changes in data, such as seasonality or cyclical behavior, which provides a better understanding of data variables and helps to better forecast to that companies can make decisions based on possible scenarios.

The main scientific contribution of the work is the use of forecasting tools and the use of computer statistical programs to have a better vision of future prices based on historical prices

Table 2
Forecast Prices.

Monthly	Price estimated
jun-22	2.905.281
jul-22	2.888.677
ago-22	2.874.238
sep-22	2.861.423
oct-22	2.850.015
nov-22	2.839.823
dic-22	2.830.701
ene-23	2.822.526
feb-23	2.815.197
mar-23	2.808.622
abr-23	2.802.724
may-23	2.797.431
jun-23	2.792.681
jul-23	2.788.419
ago-23	2.784.593
sep-23	2.781.160
oct-23	2.778.079
nov-23	2.775.314
dic-23	2.772.832
ene-24	2.770.605
feb-24	2.768.605
mar-24	2.766.811
abr-24	2.765.201
may-24	2.763.756

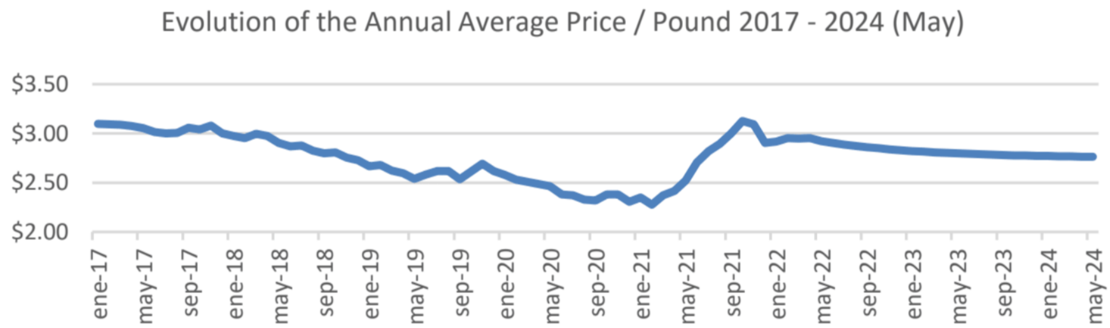

Figure 13: Price evolution from January 2017 to May 2014.

and how external shocks affect the evolution of prices.

Since 2020, after the first ravages caused by the pandemic, shrimp exports have trended upwards, meaning that year after year, the volume of pounds exported has increased. However, the average price per pound has tended to decline, resulting in a sector characterized by lower-than-projected income. In 2014, the price of shrimp reached its maximum price of $3.75. Since then, price has been gradually decreasing, which creates an immense challenge for decision-making in this sector.

Pricing is one of the most important processes in business management. Pricing not only determines a company's revenues and profits but is also a very powerful marketing tool with short-term effects. Price levels affect demand and the quantities of product to be sold at any given time. The forecast suggests a relative stabilization of prices for the whole of year 2023 and part of 2024. This represents a good opportunity for the industry: stable prices would allow producers to technify their production processes to increase profit margins. Proper pricing ensures stable demand for a product, improves company profits, and reduces financial risks. Finally, it is crucial to know the impact of the Russian-Ukrainian war on shrimp prices for future projections.

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