Prediction and Forecasting of Copper Prices using ARIMA models

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Abstract: Forecasting, being useful in risk management, requires a suitable model, chosen from several available techniques. The study is hence directed at finding a suitable forecasting model. A suitable model is one which is applicable to the product and data available. Selection of a suitable model requires determining efficiency of different models in predicting future outcomes and selecting the model which best suits the job of prediction.

The objectives of the study are as follows:

- To develop a suitable forecasting ARIMA models for Copper Prices
- To study the forecasting ability of univariate ARIMA models
- To suggest an optimal model ,Best forecast models selected.

Interactive chart of historical daily COMEX copper prices back to 1971. The price shown is in U.S. Dollars per pound. The current price of copper as of April 16, 2021 is **$4.17** per pound.

Keywords: copper (CU) , ACF, PACF,ARIMA,Forecast

I. INTRODUCTION

Archaeological evidence suggests that copper was one of the first metals used by humans as early as 10,000 years ago. In western Asia, humans used copper to make coins and ornaments. Copper when alloyed with tin produces bronze, and this discovery led humans from the Stone Age into the Bronze Age around 2500 B.C.

Copper is just as important today. Copper is the best non-precious metal conductor of electricity. It is used in power cables, generators, motors and transformers. Copper is also used extensively in the manufacture of electronics and electrical components. In homes and buildings, copper has decorative as well as practical uses in pipes and wiring. Other uses include industrial machinery, vehicles and coins.

The largest copper deposits can be found in Chile, Australia, Peru, Mexico and the United States. Together, these five countries sit on roughly 65% of the world's copper deposits. To date, roughly 700 million metric tons of copper have been mined in the world. An estimated 2.1 billion tons of identified deposits remain in the ground, while undiscovered deposits are estimated at 3.5 billion tons.

The price of copper is largely influenced by the health of the global economy. This is due to its widespread applications in all sectors of the economy, such as power generation and transmission, construction, factory equipment and electronics. Sometimes referred to as Doctor Copper, the base metal is seen as a reliable leading indicator. A rising market price suggests strong economic health, while a decline suggests the opposite.

- Humans have used copper for more than 10,000 years. Earliest applications included coins and ornaments.
- Today, copper is used in power generation and transmission, construction, factory equipment and electronics.
- Widespread usage means copper prices respond to expectations for the global economy.
- Chile, Australia, Peru, Mexico and the U.S. have the largest copper deposits.

Since 2004 the price of copper on the global market increased drastically, its consumption was mainly concentrated in developed industrial countries. The economic situation of developed countries has a greater impact on copper prices, addition of Asian nation's increased urbanization and industrialization

The economic situation of developed countries has a greater impact on copper prices, addition of Asian nation's increased urbanization and industrialization. Forecasts remain progressive as Asia advance with urbanization and industrialization plans.

II. Predictor of Copper Prices using ARIMA models:

ARIMA modelling:

In general, an ARIMA model is characterized by the notation ARIMA (p,d,q) where, p, d and q denote orders of auto-regression integration (differencing) and moving average respectively. Time series is a linear function of past actual values and random shocks. For instance, given a time series process $\{Y_i\}$, a first order auto-regressive process is denoted by ARIMA (1,0,0) or simply AR(1) and is given by

$$Y_i = \mu + \varphi_1 Y_{i-1} + \varepsilon_t \qquad (1)$$

and a first order moving average process is denoted by ARIMA (0,0,1) or simply MA(1) and is given by

$$Y_i = \mu - \theta_1 \varepsilon_{i-1} + \varepsilon_t \qquad (2)$$

Alternatively, the model ultimately derived, may be a mixture of these processes and of higher orders as well. Thus a stationary ARMA (p, q) process is defined by the equation

$$Y_i = \varphi_1 Y_{i-1} + \varphi 2 Y_{i-2} + \ldots + \varphi_p Y_{i-p} - \theta_1 \varepsilon_{i-1} - \theta_2 \varepsilon_{i-2} + \ldots - \theta_q \varepsilon_{i-q} + \varepsilon_q \qquad (3)$$

where ε_i' s are independently and normally distributed with zero mean and variance σ^2

for t = 1,2,...n. Note here that the values of p and q, in practice lie between 0 and 3. The degree of differencing of main variable Y_i .
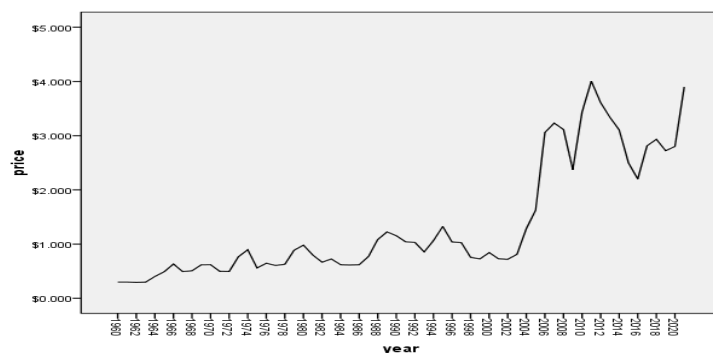
III.   Analysis
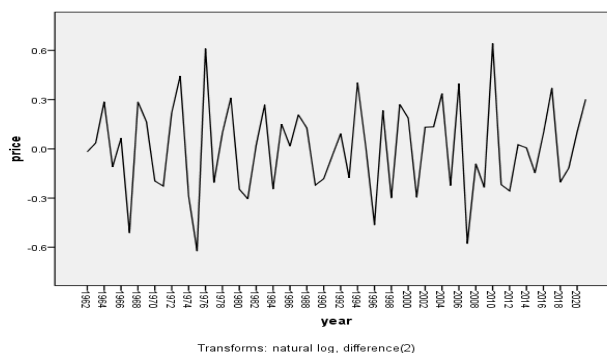
Time series Plot:

Figure 1

Sequence Plot:

Transforms: natural log, difference(2)

Figure:1.1

Table:1

| Lag	Autocorrelation	Std. Error	Partial Autocorrelation	Std. Error
1	-.326	.126	-.326	.129
2	-.199	.125	-.341	.129
3	-.037	.124	-.297	.129
4	.129	.123	-.113	.129
5	-.090	.122	-.202	.129
6	.017	.120	-.129	.129
7	.143	.119	.083	.129
8	-.148	.118	-.087	.129
9	-.022	.117	-.050	.129
10	.003	.116	-.099	.129
11	.100	.115	-.015	.129
12	-.030	.114	.017	.129
13	-.118	.112	-.153	.129
14	-.013	.111	-.205	.129
15	.081	.110	-.138	.129
16	.039	.109	-.102	.129
17	-.040	.108	-.091	.129
18	.084	.106	.041	.129
19	.009	.105	.135	.129
20	-.179	.104	-.036	.129
21	.113	.102	.084	.129
22	-.035	.101	-.112	.129
23	.103	.100	.041	.129
24	-.046	.098	.069	.129

correlogram Plot:
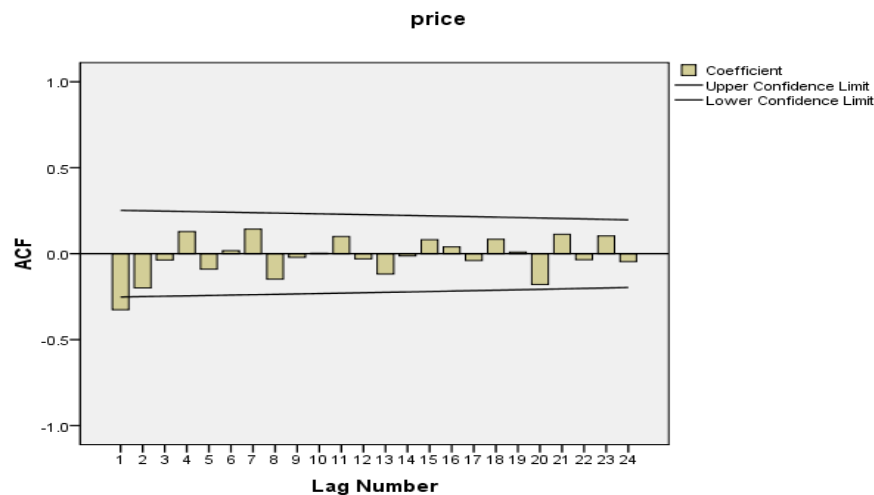
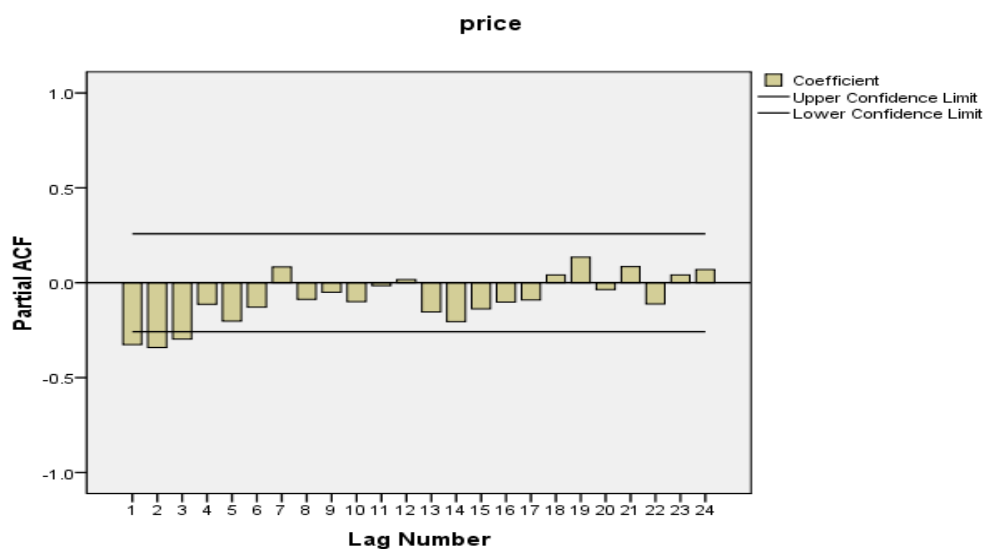Figure:1.2

Correlogram Plot:

Figure:1.3

Since the above correlogram indicates stationarity, maximum lag order 24, The asterisks below indicate the best (that is, minimized) values of the respective information criteria, MAPE = Mean Absolutely Percentage Error, RMSE = Root Mean Square Error and Normalised BIC = Normalized Bayesian Information criterion

Table:2

Performances of Different ARIMA (p,d,q) Models of Copper Prices								
ARIMA (p,d,q)	Stationary R-squared	R-squared	RMSE	MAPE	MaxAPE	MAE	MaxAE	Normalized BIC
0,3,0	6.668E-17	.557	.718	35.352	134.120	.474	2.414	-.594
0,3,1	.581	.815	.468	23.203	85.755	.311	1.795	-1.378
0,3,2	.591	.819	.467	22.650	87.897	.305	1.761	-1.316
1,3,0	.263	.674	.622	30.676	108.734	.423	2.241	-.813
1,3,1	.613	.829	.455	21.300	93.597	.292	1.634	-1.369
1,3,2	.594	.820	.470	22.781	90.766	.308	1.633	-1.235
2,3,0	.364	.719	.583	25.873	103.142	.361	2.534	-.873
2,3,1	**.660**	**.849**	**.430**	**19.885**	**81.220**	**.270**	**1.463**	**-1.412**
2,3,2	.613	.829	.463	21.189	93.658	.292	1.646	-1.196

The above analysis tells us to identify the model as ARIMA (2,3,1) because all criteria significant. OLS estimates, observations 1962-2019 (T = 61) R squared = 85% our prediction will be accurate.

Table:3

Model Statistics

Model	Number of Predictors	Model Fit statistics			Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	R-squared	Normalized BIC	Statistics	DF	Sig.	
Price-Model_1	0	.660	.849	-1.412	37.146	15	.001	0

Forecast

In this section, already defined models are used to forecast from 2021-2031.The forecasting accuracy assessment is performed at the end of this session, comparing forecast with the actual data.

Table:4

◆ Following table displays Copper Prices for next few years:

Year	Forecast	UCL	LCL
2021	$2.931	$2.074	$3.788
2022	$4.598	$3.741	$5.455
2023	$5.175	$3.519	$6.831
2024	$5.995	$3.535	$8.455
2025	$6.837	$3.409	$10.265
2026	$7.663	$3.134	$12.192
2027	$8.560	$2.844	$14.277
2028	$9.512	$2.512	$16.512
2029	$10.497	$2.115	$18.878
2030	$11.530	$1.680	$21.379
2031	$12.614	$1.212	$24.016

Goodness of fit

Table - 2 show goodness of fit statistics for the Copper Prices data. R-squared represents an estimate of the proportion of the total variation in the series that is explained by the model. Largest value (maximum value) indicates a more accurate prediction and it means that the model does an excellent job of explaining the observed variations in the series. Mean percentage error (MAPE) for the model is a measure of how much a dependent series varies from its model-predicted level. Root Mean Square Error (RMSE), i.e. the square root of mean square error is a measure of how much a dependent series varies from its model-level of prediction ,expressed in the same units as the dependent series. This measure is useful for imagining a worst-case scenario for the forecast model.

Findings

◆ Researcher has applied different types of prediction models for the data collected for Copper Prices.

◆ Finally, ARIMA (2,3,1) was found to be the best applicable model from which the predictions are made for 2021-2031.

◆ ARIMA was used for the reasons of its capabilities of making predictions using a time series data with various kinds of pattern and with autocorrelations between the successive values in the time series.

◆ The study was also tested statistically and validated the residuals (forecast errors)

◆ The fitted ARIMA time series and residuals are seem to be normally distributed with mean 0 and constant variance. Hence it can be concluded that the selected seasonal ARIMA (2,3,1) will provide an adequate model for interpreting and forecasting gold price in India.

◆ The ARIMA (2,3,1) model predicted indicates an increase in the Copper price for the years selected for the forecast study.

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