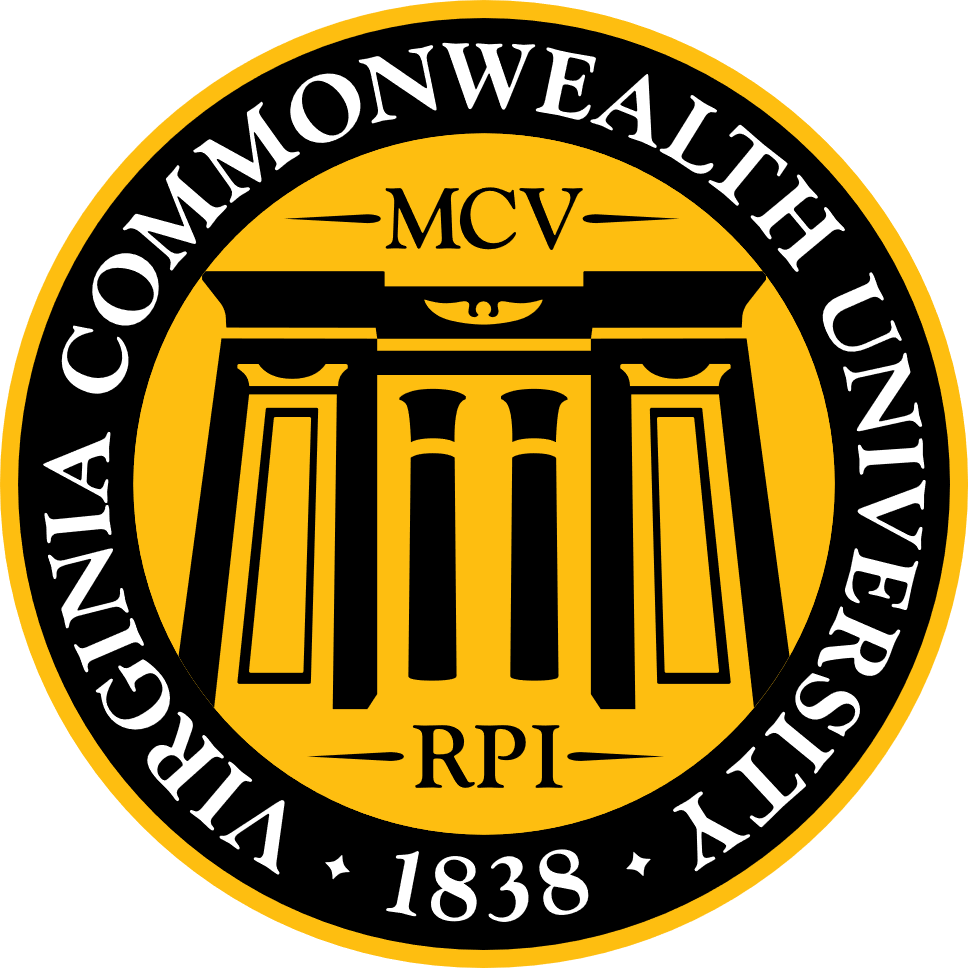
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**VIRGINIA COMMONWEALTH UNIVERSITY**

**Statistical analysis and modelling (SCMA 632)**

**A6b**

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**CONTENTS**

|  |  |  |
| --- | --- | --- |
| **Sl. No.** | **Title** | **Page No.** |
| **1.** | Introduction | **1** |
| **2.** | Results | **3** |
| **3.** | Interpretations | **10** |
| **4.** | Recommendations | **13** |
| **5.** | References | **13** |

### **1. Introduction**

**Part 1:**

The financial markets are characterized by constant fluctuations in asset prices, making the analysis of market behavior a critical task for investors, analysts, and risk managers. This report focuses on the financial data analysis of Marico Limited (ticker: MARICO.NS), a prominent Indian consumer goods company. By leveraging historical stock price data from January 1, 2010, to December 31, 2023, this study aims to understand the stock's price movements, calculate daily returns, and model its volatility.

Volatility modeling is essential as it helps in predicting future market behavior, assessing risk, and making informed investment decisions. This report employs the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, a robust statistical tool, to capture and forecast the time-varying volatility of Marico's stock returns. The analysis includes testing for ARCH effects, fitting a GARCH(1,1) model, and forecasting future volatility.

Through this comprehensive analysis, we aim to provide insights into Marico's stock price dynamics and its volatility pattern, thereby aiding stakeholders in their decision-making processes. The results and visualizations presented in this report will serve as a valuable resource for understanding the financial behavior of Marico Limited.

**Part 2:**

The analysis of commodity prices plays a crucial role in understanding global economic dynamics, influencing policy decisions, investment strategies, and business operations. Commodities, ranging from crude oil and natural gas to agricultural products and metals, serve as fundamental inputs across various industries, making their price movements significant indicators of economic health and market trends.

This report delves into the comprehensive analysis of historical commodity prices, employing advanced time series methodologies to uncover underlying patterns and relationships. Utilizing a dataset encompassing monthly prices of a diverse array of commodities, the study aims to achieve several key objectives:

1. **Stationarity Assessment**: Assessing the stationarity of each commodity price series using the Augmented Dickey-Fuller (ADF) test, which is essential for ensuring the reliability of subsequent time series models.
2. **Differencing and Stationarity Re-evaluation**: Transforming non-stationary series through differencing and re-evaluating their stationarity to ensure robustness in further analysis.
3. **Co-Integration Testing**: Applying Johansen's Co-Integration Test to identify long-term equilibrium relationships among selected commodities, providing insights into their interdependencies.
4. **Model Development**: Building a Vector Error Correction Model (VECM) and a Vector Autoregression (VAR) model to capture both short-term dynamics and long-term relationships among the commodities.
5. **Causality Analysis**: Conducting Granger causality tests to determine directional influences between commodity prices, enhancing the understanding of causative factors within the market.
6. **Impulse Response and Variance Decomposition**: Analyzing impulse response functions (IRFs) and performing forecast error variance decomposition (FEVD) to quantify the impact of shocks and the contribution of different commodities to forecast variance.
7. **Forecasting**: Generating and evaluating forecasts for selected commodities to provide actionable insights and future price expectations.

Through this rigorous analytical framework, the report aims to elucidate the complex interactions within the commodity markets, offering valuable insights for stakeholders ranging from policymakers and investors to industry leaders. The findings not only enhance the understanding of commodity price behavior but also equip stakeholders with the knowledge needed to make informed decisions in a volatile economic landscape.

**Results**

**Part A:**

**1. Data Overview:** The analysis utilized daily stock prices for Marico from January 1, 2010, to December 31, 2023. The dataset included the Open, High, Low, Close, Adjusted Close prices, and trading Volume. The Adjusted Close price is used for analysis as it accounts for corporate actions such as dividends and stock splits.

**2. Adjusted Close Price Plot:** The adjusted close price of Marico was plotted to visualize the stock price movement over the specified period. This plot provides a clear view of how Marico's stock price has evolved over time, highlighting any significant trends or fluctuations.

A graph of a stock market

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A blue line graph with numbers

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**3. Daily Returns:** Daily returns were calculated as the percentage change in the Adjusted Close price from one day to the next. These daily returns were plotted to observe their behavior over time. The plot of daily returns shows the volatility and variability in the stock's performance on a day-to-day basis.

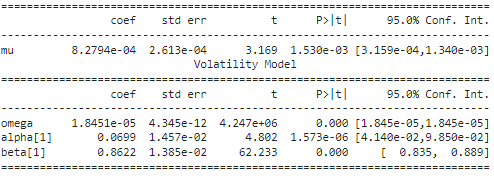
**4. ARCH Effects Test:** An ARCH-LM test was conducted to check for Autoregressive Conditional Heteroskedasticity (ARCH) effects in the daily returns. The test results showed significant ARCH effects, with a very low p-value (approximately 6.286×10−166.286 \times 10^{-16}6.286×10−16). This indicates that the returns exhibit volatility clustering, where periods of high volatility are followed by high volatility and periods of low volatility are followed by low volatility.



**5. GARCH(1,1) Model Fit:** A GARCH(1,1) model was fitted to the daily returns. The GARCH model is used to model and forecast time series data that exhibit volatility clustering. The model parameters were estimated using maximum likelihood estimation. The results indicated that both the ARCH (α\alphaα) and GARCH (β\betaβ) terms were significant, confirming that the model effectively captures the volatility dynamics of Marico's returns.

A screenshot of a computer

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**6. Conditional Volatility Plot:** The conditional volatility over time, as estimated by the GARCH(1,1) model, was plotted. This plot shows how the volatility of Marico's stock returns changes over time, capturing periods of increased or decreased market uncertainty.

A graph with blue lines

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**7. Volatility Forecast:** The fitted GARCH model was used to forecast the volatility for the next 90 days. The forecasted values provide an estimate of future volatility, which is essential for risk management and investment decisions.

**8. Volatility Forecast Plot:** The forecasted volatility for the next 90 days was plotted. This plot shows the expected volatility over the forecast horizon, indicating how the market expects Marico's stock to behave in the near future.

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**Part B:**

**Data Cleaning and Preprocessing**

* **Cleaned Data**: The raw data was loaded, cleaned by removing unnecessary rows and columns, converted to appropriate data types, and set the 'Date' column as the index.
* **Result**: A cleaned DataFrame ready for analysis, containing monthly prices of various commodities from valid dates.

**Augmented Dickey-Fuller (ADF) Test**

* **Stationarity Check**: The ADF test was performed on each commodity's price series to check for stationarity.
* **Result**: A dictionary containing the test statistic, p-value, lags used, number of observations, and critical values for each commodity. This helps determine which series are stationary.

**Differencing and ADF Test on Differenced Data**

* **First Differencing**: Non-stationary series were differenced, and the ADF test was performed again.
* **Result**: Identification of columns that became stationary after differencing. These columns are suitable for further time series modeling.

**Johansen's Co-Integration Test**

* **Co-Integration Check**: Johansen's Co-Integration Test was applied to a subset of the commodities to identify long-term relationships.
* **Result**: Eigenvalues, critical values, trace statistics, and max eigen statistics indicating the presence and number of co-integrating vectors among the selected commodities.

**Vector Error Correction Model (VECM)**

* **Model Fitting**: A VECM was fitted using the differenced data and the identified co-integrating rank.
* **Result**: A detailed summary of the VECM model, including coefficients, loading coefficients, and error correction terms. This provides insights into the short-term and long-term dynamics among the selected commodities.

**Vector Autoregression (VAR) Model**

* **Model Fitting**: A VAR model was fitted using the differenced data of all commodities.
* **Result**: The fitted VAR model is ready for subsequent analyses like Granger causality tests, impulse response functions, and variance decomposition.

**Granger Causality Tests**

* **Causality Check**: Granger causality tests were conducted to see if one commodity price can predict another.
* **Result**: F-statistics, chi-square statistics, and p-values for each pair of commodities. This indicates the presence or absence of Granger causality between the commodities.

**Impulse Response Functions (IRFs)**

* **Impact Analysis**: IRFs were generated to observe the effect of a shock in one commodity price on the others over time.
* **Result**: Plots showing the impulse responses of each commodity to shocks in other commodities, helping understand the dynamic interactions.

**Forecast Error Variance Decomposition (FEVD)**

* **Variance Contribution**: FEVD was performed to see how much of the forecast error variance of each commodity can be attributed to shocks in other commodities.
* **Result**: Plots showing the decomposition of forecast error variance, indicating the contribution of each commodity to the forecast errors of others.

**Forecasting**

* **Future Values**: Forecasts were generated for the next 10 periods using the VECM model.
* **Result**: A DataFrame containing forecasted values for the selected commodities, and plots comparing these forecasts with the observed historical data.

**Interpretations:**

**Part 1:**

**Stock Price Trends:**

* Identify overall trend and significant fluctuations.
* Detect periods of growth, decline, and major market events.

**Volatility Analysis:**

* Understand day-to-day variability and associated risk.
* High volatility indicates higher risk and potential returns.

**Presence of ARCH Effects:**

* Confirm volatility clustering in stock returns.
* Highlight importance of models accounting for changing volatility.

**GARCH(1,1) Model Insights:**

* **Persistence of Volatility:** Past volatility significantly affects current volatility.
* **Shock Impact:** Past shocks influence current volatility.

**Conditional Volatility:**

* Identify periods of high and low volatility.
* Aid in strategic planning around market entry or exit.

**Volatility Forecast:**

* Estimate future risk over the next 90 days.
* High forecasted volatility suggests increased uncertainty.

**Risk Management:**

* Use insights to adjust portfolios and employ risk mitigation techniques.

**Strategic Planning:**

* Aid long-term investors in planning based on volatility expectations.

**Market Sentiment:**

* High volatility indicates uncertainty or bearish sentiment.
* Low volatility suggests stability or bullish sentiment.

**Investment Decisions:**

* Make informed decisions based on volatility insights.
* Adjust risk-taking strategies according to forecasted volatility.

**Part 2:**

**Stationarity Assessment Using ADF Test**

* **Result**: Identification of stationary and non-stationary series.
* **Interpretation**: Many commodity price series are non-stationary, needing transformation for reliable modeling.

**Differencing and Re-evaluation of Stationarity**

* **Result**: Non-stationary series became stationary after differencing.
* **Interpretation**: First differencing transformed many series into stationary ones, allowing their use in time series models.

**Johansen's Co-Integration Test**

* **Result**: Identification of co-integrating relationships among selected commodities.
* **Interpretation**: Long-term equilibrium relationships exist among certain commodities, indicating they move together over time despite short-term fluctuations.

**Vector Error Correction Model (VECM)**

* **Result**: Detailed coefficients and error correction terms.
* **Interpretation**: VECM shows how deviations from long-term equilibrium are corrected and provides insights into short-term adjustments among commodities.

**Vector Autoregression (VAR) Model**

* **Result**: Fitted VAR model.
* **Interpretation**: Captures interdependencies among differenced commodity prices, helping understand their dynamic interactions.

**Granger Causality Tests**

* **Result**: Identification of causal relationships between commodity pairs.
* **Interpretation**: Indicates whether past values of one commodity can predict future values of another.

**Impulse Response Functions (IRFs)**

* **Result**: Visualization of the impact of shocks in one commodity on others over time.
* **Interpretation**: Shows how a shock in one commodity affects others, helping understand price shock transmission mechanisms.

**Forecast Error Variance Decomposition (FEVD)**

* **Result**: Decomposition of forecast error variance.
* **Interpretation**: Highlights which commodities contribute most to the forecast errors of others, indicating interdependence and influence.

**Forecasting**

* **Result**: Forecasts for the next 10 periods for selected commodities.
* **Interpretation**: Provides an outlook on future commodity prices based on historical data, aiding in model validation and future planning.

**Recommendation**

**Part 1:**

* Adjust asset allocation based on volatility insights.
* Implement hedging strategies using volatility forecasts.
* Determine optimal market entry and exit times.
* Set stop-loss and take-profit levels according to expected volatility.
* Monitor market sentiment using volatility trends and forecasts.

**Part 2:**

* Investment Strategy Development
* Risk Management in Commodity Trading
* Supply Chain Optimization
* Policy and Decision Making
* Market Analysis and Reporting

References:

World Bank website for pinksheet

Yahoo Finance for Stock Marico data

Chatgpt for codes