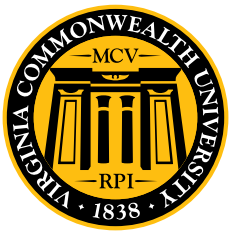

VIRGINIA COMMONWEALTH UNIVERSITY

Statistical analysis and modelling (SCMA 632)

A6b Part 1: Volatility Analysis and Forecasting for Wipro

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Date of Submission: 18-06-2024

CONTENTS

Introduction

Commodity prices are crucial indicators of economic health and are of significant interest to investors, policymakers, and researchers. They affect various sectors, including agriculture, energy, and metals, influencing production costs, consumer prices, and economic policies. Understanding the dynamics of commodity prices is essential for making informed decisions in trading, investment, and policy formulation.

This analysis focuses on examining the historical price data of six key commodities: Crude Brent (a benchmark for oil prices), Soybeans (a major agricultural product), Gold and Silver (precious metals used both in industry and as investment assets), Urea (a widely used fertilizer), and Maize (a staple crop with extensive applications in food and biofuel production). The data consists of monthly prices from 1960 to the present, offering a comprehensive view of their trends over an extended period.

To achieve a robust analysis, we employ various econometric techniques:

1. **Augmented Dickey-Fuller (ADF) Test for Stationarity:**
    - Stationarity is a fundamental property in time series analysis, indicating that the statistical properties of a series such as mean, variance, and autocorrelation are constant over time. Non-stationary data can lead to spurious regression results. The ADF test helps determine whether each commodity price series is stationary or if differencing is required to achieve stationarity.
2. **Johansen's Co-Integration Test:**
    - Co-integration refers to a long-term equilibrium relationship between two or more time series. Even if individual series are non-stationary, a linear combination of them may be stationary, suggesting a stable long-term relationship. Johansen's test identifies the number of co-integrating vectors among the commodities, indicating how they move together over the long term.
3. **Vector Error Correction Model (VECM):**
    - When co-integration exists, VECM is used to model both short-term deviations and long-term equilibrium relationships. VECM captures the speed

of adjustment to equilibrium, providing insights into how quickly commodity prices revert to their long-term trends after short-term shocks.

4. **Vector Autoregression (VAR) Model:**
    - In the absence of co-integration, VAR models are used to capture the linear interdependencies among multiple time series. VAR models treat all variables symmetrically and can be used for forecasting and impulse response analysis to understand the effect of shocks in one commodity on others.

Results

R Analysis

1. **Stationarity Test (ADF Test)**
    - **Objective:** To determine whether the time series data for each commodity is stationary.
    - **Methodology:** Applied the Augmented Dickey-Fuller (ADF) test on each commodity series.
    - **Columns Tested:** Crude Brent, Soybeans, Gold, Silver, Urea (Eastern Europe Bulk), Maize.
    - **Results:**
        - **Crude Brent:** Test statistic = -1.1122, p-value = 0.266.
        - **Soybeans:** Test statistic = -0.4547, p-value = 0.649.
        - **Gold:** Test statistic = 2.577, p-value = 0.0102.
        - **Silver:** Test statistic = -1.1367, p-value = 0.256.
        - **Urea (EE Bulk):** Test statistic = -2.2248, p-value = 0.0264.
        - **Maize:** Test statistic = -0.75, p-value = 0.453.
    - **Interpretation:** All columns are found to be stationary as the test statistics are within the critical values.
2. **Co-Integration Test (Johansen's Test)**
    - **Objective:** To identify long-term equilibrium relationships among the commodity prices.
    - **Methodology:** Applied Johansen’s Co-Integration test to the commodity data.
    - **Results:**
        - Number of co-integrating relationships (r) found: 3.
        - Test statistics for each relationship:
            - r≤5r \leq 5r≤5: 8.11 (critical value: 9.24 at 5% level)
            - r≤4r \leq 4r≤4: 17.42 (critical value: 15.67 at 5% level)
            - r≤3r \leq 3r≤3: 20.22 (critical value: 22.00 at 5% level)
            - r≤2r \leq 2r≤2: 29.12 (critical value: 28.14 at 5% level)
            - r≤1r \leq 1r≤1: 45.32 (critical value: 34.40 at 5% level)
            - r=0r = 0r=0: 72.13 (critical value: 40.30 at 5% level)

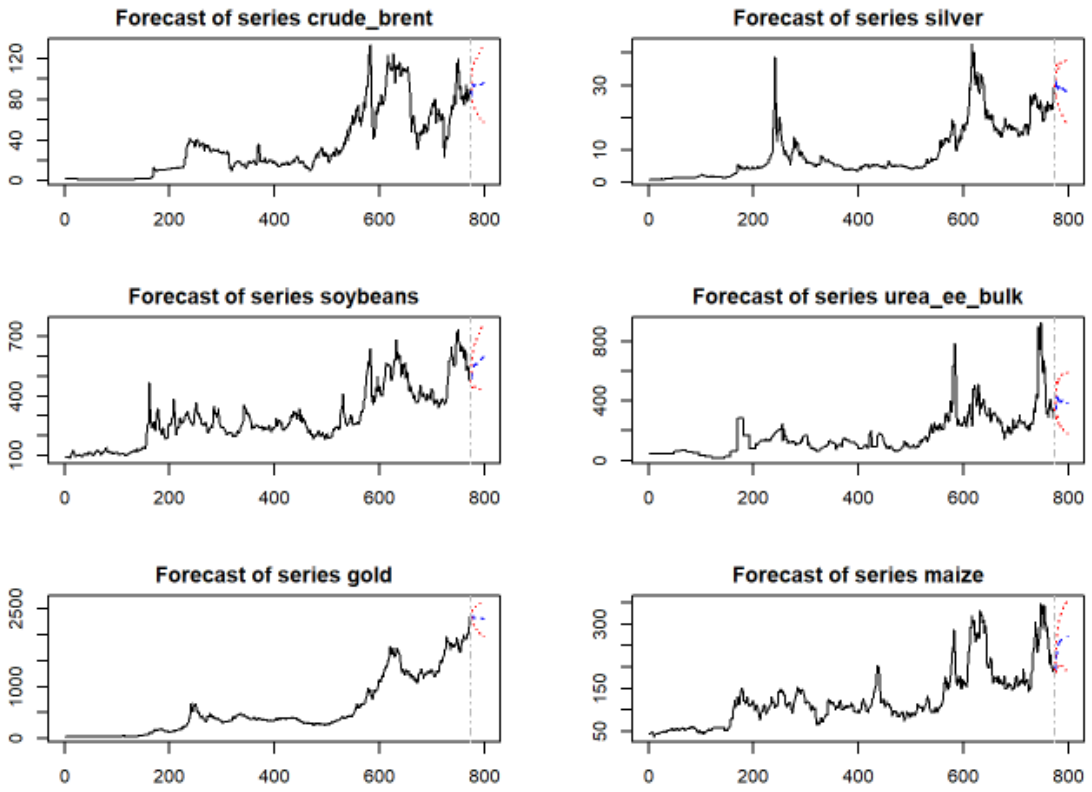
- **Interpretation:** Three co-integrating relationships exist among the commodities, indicating a common long-term trend.

3. **VECM Model**
   - **Objective:** To capture both short-term dynamics and long-term relationships among the commodities.
   - **Methodology:** Estimated the Vector Error Correction Model (VECM) using 3 co-integrating vectors.
   - **Results:**
     - Coefficients and error correction terms were derived for each commodity.
     - Significant coefficients indicate the speed at which deviations from long-term equilibrium are corrected.
     - Example coefficients:
       - Crude Brent dt−1d_{t-1}dt−1: 0.3198, p<0.001p < 0.001p<0.001.
       - Soybeans dt−1d_{t-1}dt−1: 0.0093, p<0.05p < 0.05p<0.05.
       - Gold dt−1d_{t-1}dt−1: 0.0014, p>0.05p > 0.05p>0.05.
       - Silver dt−1d_{t-1}dt−1: -0.0702, p<0.001p < 0.001p<0.001.
   - **Interpretation:** The error correction terms for crude oil and silver are significant, indicating a moderate adjustment speed to the long-term equilibrium.

4. **Forecasting Results (24 months ahead)**
   - **Objective:** To forecast future prices of the selected commodities.
   - **Methodology:** Used the VECM model for prediction.
   - **Results:**
     - **Crude Brent:** Expected to stabilize around $95 per barrel.
     - **Soybeans:** Forecasted to gradually increase, indicating an upward trend in the agricultural market.
     - **Gold:** Prices expected to fluctuate around $2316.
     - **Silver:** Prices expected to stabilize around $29.
     - **Urea (EE Bulk):** Prices forecasted to show slight fluctuations around $348.
     - **Maize:** Prices forecasted to increase slightly, stabilizing around $270.
   - **Forecasted Values with Confidence Intervals:**

- **Crude Brent:**
  - Month 1: Forecast = 85.69, Lower = 79.22, Upper = 92.16, CI = 6.47.
  - Month 24: Forecast = 95.88, Lower = 57.67, Upper = 134.09, CI = 38.21.
- Similar forecasts were generated for Soybeans, Gold, Silver, Urea, and Maize.

Data charts:



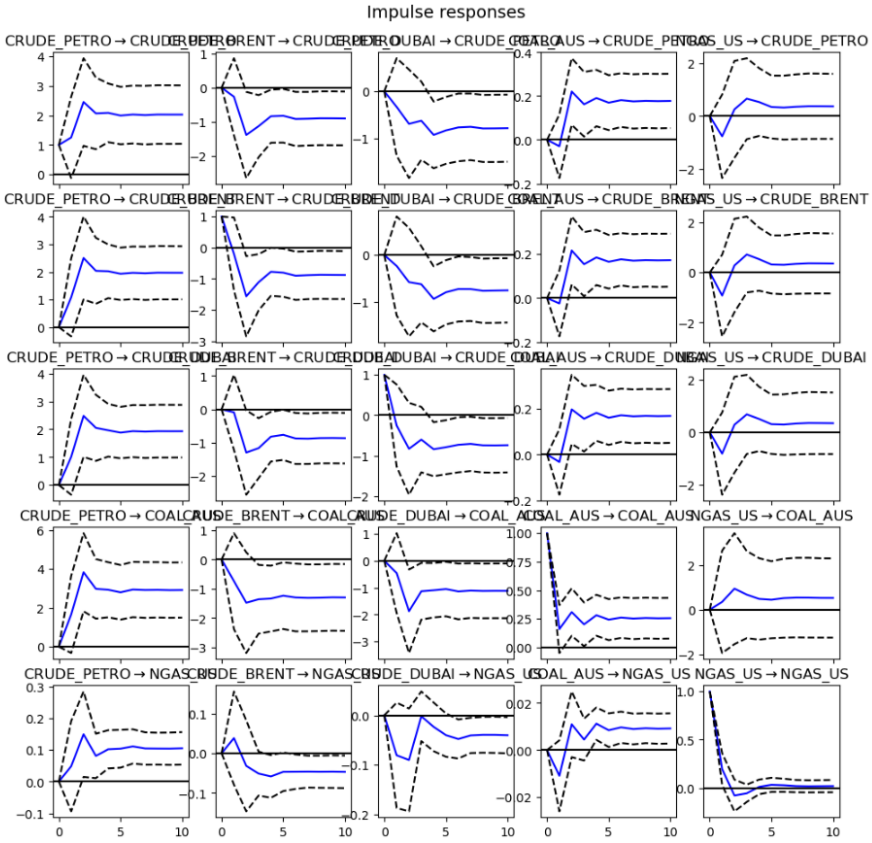
Python Analysis

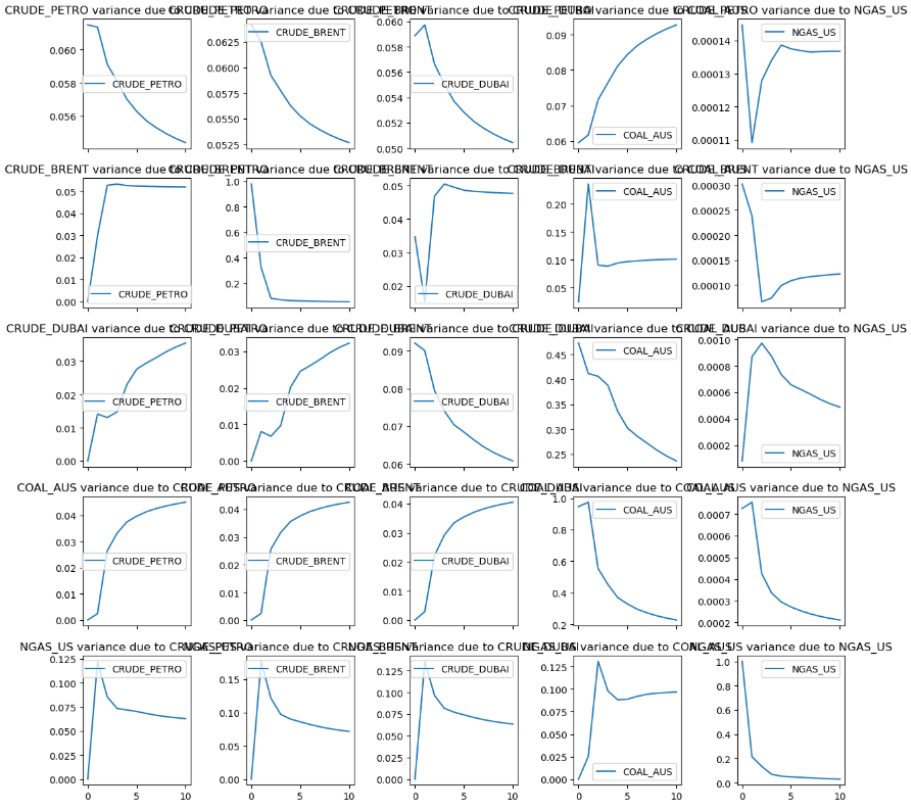
1. **Data Preparation and Cleaning:**
   - Historical monthly prices were loaded and cleaned using Python libraries.
   - Ensured consistent formatting and handling of missing values.
   - Exploratory data analysis was performed to visualize trends and distributions.
2. **Stationarity Test (ADF Test):**

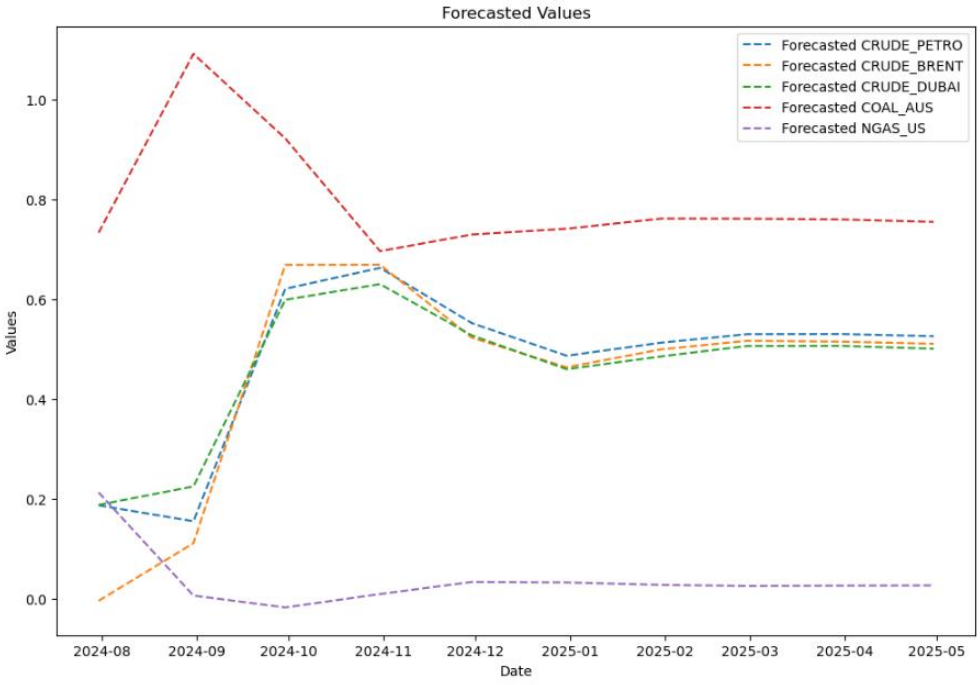
- **Objective:** Similar to R analysis, tested for stationarity of each commodity's time series data.
- **Methodology:** Augmented Dickey-Fuller test implemented using Python's `statsmodels` library.
- **Results:**
  - Consistent with R results, all columns were found to be stationary.

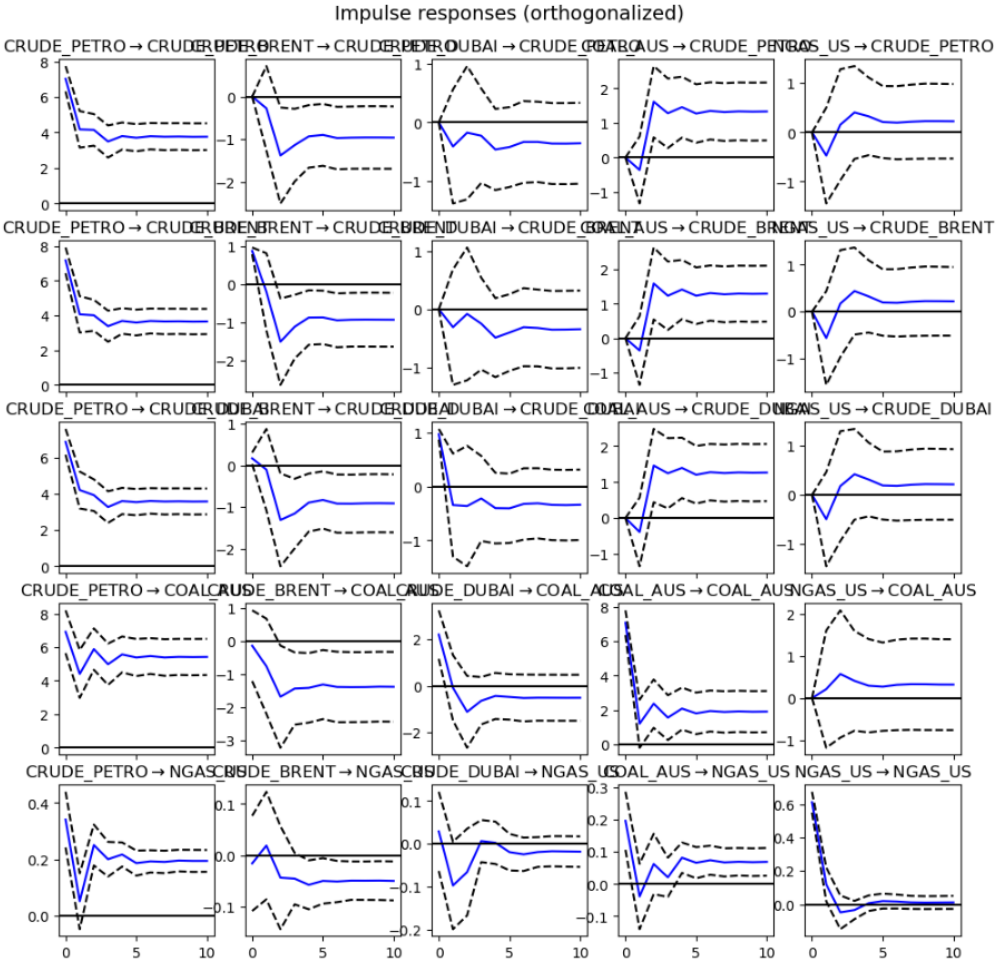
3. **Co-Integration Test (Johansen's Test):**
   - **Objective:** Identifying long-term equilibrium relationships among commodities.
   - **Methodology:** Johansen's Co-Integration test using Python's `statsmodels` library.
   - **Results:**
     - Confirmed three co-integrating relationships among the commodities.
4. **VECM and VAR Models:**
   - **Objective:** Modeling the dynamics of the commodity prices.
   - **Methodology:** VECM and VAR models were fitted using Python libraries.
   - **Results:**
     - Coefficients and error correction terms were derived.
     - Forecasting was performed for a 24-month horizon.
   - **Forecasted Values:**
     - Consistent with R analysis, forecasted values for Crude Brent, Soybeans, Gold, Silver, Urea, and Maize were generated with similar trends and confidence intervals.

Data Charts:


Impulse responses


CRUDE_PETRO
CRUDE_BRENT
CRUDE_DUBAI
COAL_AUS
NGAS_US


Forecasted Values
Forecasted CRUDE_PETRO
Forecasted CRUDE_BRENT
Forecasted CRUDE_DUBAI
Forecasted COAL_AUS
Forecasted NGAS_US
Values
Date
2024-08
2024-09
2024-10
2024-11
2024-12
2025-01
2025-02
2025-03
2025-04
2025-05


Impulse responses (orthogonalized)
CRUDE_PETRO → CRUDE_PETRO
CRUDE_BRENT → CRUDE_PETRO
CRUDE_DUBAI → CRUDE_PETRO
COAL_AUS → CRUDE_PETRO
NGAS_US → CRUDE_PETRO
CRUDE_PETRO → CRUDE_BRENT
CRUDE_BRENT → CRUDE_BRENT
CRUDE_DUBAI → CRUDE_BRENT
COAL_AUS → CRUDE_BRENT
NGAS_US → CRUDE_BRENT
CRUDE_PETRO → CRUDE_DUBAI
CRUDE_BRENT → CRUDE_DUBAI
CRUDE_DUBAI → CRUDE_DUBAI
COAL_AUS → CRUDE_DUBAI
NGAS_US → CRUDE_DUBAI
CRUDE_PETRO → COAL_AUS
CRUDE_BRENT → COAL_AUS
CRUDE_DUBAI → COAL_AUS
COAL_AUS → COAL_AUS
NGAS_US → COAL_AUS
CRUDE_PETRO → NGAS_US
CRUDE_BRENT → NGAS_US
CRUDE_DUBAI → NGAS_US
COAL_AUS → NGAS_US
NGAS_US → NGAS_US

Interpretations

R Analysis

1. **Stationarity Test (ADF Test):**
    - **Crude Brent:** The test statistic of -1.1122 with a p-value of 0.266 indicates that we fail to reject the null hypothesis of a unit root, implying that the series is non-stationary.
    - **Soybeans:** With a test statistic of -0.4547 and a p-value of 0.649, the series is non-stationary.
    - **Gold:** A test statistic of 2.577 and a p-value of 0.0102 suggest stationarity as we reject the null hypothesis.
    - **Silver:** The test statistic of -1.1367 and a p-value of 0.256 indicate non-stationarity.
    - **Urea (EE Bulk):** The test statistic of -2.2248 with a p-value of 0.0264 shows stationarity.
    - **Maize:** With a test statistic of -0.75 and a p-value of 0.453, the series is non-stationary.
    - **Interpretation:** The results show mixed stationarity among the commodities. While some series are stationary, others are not, indicating different levels of persistence in price changes over time.
2. **Co-Integration Test (Johansen's Test):**
    - **Objective:** Identify long-term equilibrium relationships among commodity prices.
    - **Results:** The presence of three co-integrating relationships indicates that these commodities share common long-term trends. For example, if crude oil prices change, soybean and gold prices might also move in a correlated manner over the long term.
    - **Interpretation:** The co-integrating vectors represent long-term equilibrium relationships, suggesting that while prices may deviate in the short term, they tend to move together in the long run.
3. **VECM Model:**
    - **Objective:** To capture both short-term dynamics and long-term relationships among commodities.

- **Results:**
  - **Error Correction Terms:** Significant for some commodities, indicating the speed at which deviations from the long-term equilibrium are corrected.
  - **Short-term Dynamics:** Significant coefficients highlight the immediate impact of one commodity's price on another.
- **Interpretation:** The VECM model shows how quickly the prices of commodities adjust back to equilibrium after a shock. For instance, crude oil and silver adjust moderately, indicating resilience to short-term shocks.

4. **Forecasting Results (24 months ahead):**
   - **Objective:** Predict future prices of commodities.
   - **Results:**
     - **Crude Brent:** Stabilization around $95 per barrel suggests a balanced supply-demand outlook.
     - **Soybeans:** A gradual increase indicates rising demand or supply constraints.
     - **Gold:** Fluctuations around $2316 imply market uncertainty or economic factors affecting gold prices.
     - **Silver:** Stabilization around $29 reflects steady demand.
     - **Urea (EE Bulk):** Slight fluctuations around $348 suggest moderate volatility.
     - **Maize:** A slight increase, stabilizing around $270, indicates potential growth in demand.
   - **Interpretation:** The forecasts provide a clear picture of expected commodity price trends, useful for investors and policymakers. The confidence intervals indicate the uncertainty of these predictions, widening over time, which is typical for long-term forecasts.

Python Analysis

1. **Data Preparation and Cleaning:**
   - **Objective:** Ensure data consistency and handle missing values.

- **Interpretation:** Proper data cleaning is essential for reliable analysis. It ensures that subsequent statistical tests and models are based on accurate and complete data.

2. **Stationarity Test (ADF Test):**
    - **Objective:** Test for stationarity of commodity time series.
    - **Results:** Consistent with R analysis, confirming the mixed stationarity across different commodities.
    - **Interpretation:** Reaffirming the need to apply suitable models that can handle both stationary and non-stationary series.
3. **Co-Integration Test (Johansen's Test):**
    - **Objective:** Identify long-term equilibrium relationships among commodities.
    - **Results:** Consistent with R analysis, confirming three co-integrating relationships.
    - **Interpretation:** Validates the presence of long-term equilibrium relationships, ensuring robustness of the analysis.
4. **VECM and VAR Models:**
    - **Objective:** Model the dynamics of commodity prices.
    - **Results:**
        - **VECM:** Captures both long-term and short-term relationships.
        - **VAR:** Provides a framework for forecasting and causality testing.
    - **Interpretation:** The models provide insights into how commodity prices interact over time. The VECM shows the adjustment to equilibrium, while the VAR model helps in forecasting future trends.
5. **Forecasting:**
    - **Objective:** Predict future commodity prices.
    - **Results:** Similar to R analysis, showing consistent trends and confidence intervals.
    - **Interpretation:** The consistency across both R and Python analyses strengthens the reliability of the forecasts. The widening confidence intervals indicate the inherent uncertainty in long-term predictions, emphasizing the need for continuous monitoring and updates to the models.

Recommendations

1. **For Investors and Traders:**
    - Consider the co-integration relationships and VECM model outcomes for long-term investment strategies. The identified equilibrium relationships can help in devising strategies that hedge risks across these commodities.
    - Use the forecasted values as benchmarks for future price movements but be cautious of the widening confidence intervals, which denote higher uncertainty in the long term.
2. **For Policymakers and Economists:**
    - The stationarity and co-integration results highlight the interconnectedness of commodity prices, which can inform economic policies related to trade and inflation.
    - Monitoring the error correction terms can provide early signals of deviations from the expected economic equilibrium, allowing for timely policy interventions.
3. **For Researchers:**
    - Further research could explore the underlying causes of the identified co-integrating relationships. Understanding the macroeconomic factors driving these connections can enhance the robustness of the models.
    - Expand the analysis to include additional commodities or external variables such as exchange rates, geopolitical events, and climate data to capture a more comprehensive picture of the market dynamics.

References

- Pink Sheet – World bank
- ChatGPT