

BUAN 6312 -Applied Econometrics and Time Series Analysis

Group 3 Project

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Research Project Topic

Examining the Impact of the Russia-Ukraine War on Key Economic Indicators in the US

Research Question

Do the COVID-19 pandemic and the Russia-Ukraine conflict have measurable impacts on key US economic indicators

Agenda

- 1 Title
- 2 Research Topic and Question
- 3 Motivation
- 4 Literature Review
- 5 Data Collection Strategy
- 6 Data Pre-Preprocessing
- 7 Exploratory Data Analysis (EDA)
- 8 Stationarity Analysis
- 9 Modeling Approach
- 10 Model Diagnostics
- 11 Results
- 12 Conclusion and Future Work

Research Motivation

Importance of Understanding Geopolitical Shock Effects



Geopolitical Shock Analysis

The ongoing conflict introduces volatility in energy prices, which can ripple through various economic sectors.



Contextual Economic Disruptions

To evaluate the resilience of the U.S. economy during periods of global uncertainty, helping to identify areas of vulnerability and strength in its economic framework.



Need for Data-Driven Insights

Informed policy decisions necessitate empirical evidence that highlights vulnerabilities within the economy in response to external shocks.

Numbers DO NOT LIE!!

Research Motivation

- **Research Question:** Our study poses an inquiry into the econometric evidence surrounding the influence of the COVID-19 pandemic and the Russia-Ukraine conflict on critical economic parameters in the US.
- **Methodology:** Utilizing Vector Autoregression with Exogenous Variables (VARX) modeling, we aim to systematically evaluate the impacts of these unprecedented events on key economic indicators such as inflation, unemployment rates, and crude oil prices.
- **Significance:** This research addresses a crucial question in economic policy-making, by understanding how geopolitical conflicts and pandemics shape macroeconomic dynamics, thereby informing the strategies that policymakers may adopt.

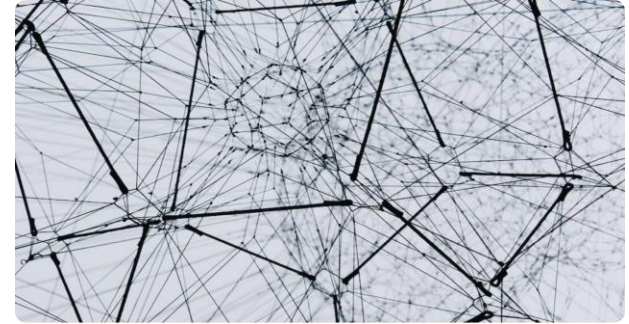


Literature Review

Assessing Economic Resilience to Global Shocks

The COVID-19 pandemic and Russia-Ukraine conflict disrupted global supply chains, energy markets, and trade dynamics. These events revealed the vulnerabilities of interconnected economies, particularly in areas like inflation, energy prices, and financial market volatility. Research by the International Monetary Fund (2022) highlights how such crises created inflationary pressures in developed economies, including the United States.

Source: International Monetary Fund. (2022). World Economic Outlook: War Sets Back the Global Recovery. <https://www.imf.org/>



Financial Market Volatility as an Indicator of Crisis -

Global crises often lead to heightened financial market volatility. The Federal Reserve (2023) reported significant market fluctuations due to both the COVID-19 pandemic and geopolitical tensions. This study aims to capture the extent of these changes and their implications for economic stability.

Source: Federal Reserve. (2023). Financial Stability Report. <https://www.federalreserve.gov/>

Data Collection and Consolidation



Source

Our dataset was collected through reputed publicly available and trusted sources.



Data Timeline

For Our Analysis, we have considered data from **January'2013** to **August'2024** at a **Monthly** Frequency.



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Specifications

With **140 observations** and **17 variables**, our dataset offers a snapshot view for analysis, encompassing various economic dynamics.



Economic Variables - Data Dictionary

| Variable Name | Economic Variable | Variable Description |
|---------------------------------------|-------------------------------|--|
| Date | | The date of each observation |
| Average_Hourly_Earning | Labor Market Indicator | Tracks changes in wages paid per hour to U.S. workers |
| Trade_Volume_Pct_Change_Index_Value | Trade Activity Indicator | Measures the percentage change in trade volume index value |
| US_Crude_Oil_Prices_Dollar_Per_Barrel | Energy Market Indicator | Reflects the price of crude oil in the U.S. economy |
| Federal_Rates_Monthly | Monetary Policy Indicator | Represents interest rate decisions by the Federal Reserve |
| CPI_Value_Inflation | Inflation Indicator | Measures changes in the prices of consumer goods and services |
| Nominal_Broad_US_Dollar_Index | Exchange Rate Indicator | Tracks the value of the U.S. dollar against a basket of foreign currencies |
| producer_price_index_all_commodities | Producer Cost Indicator | Measures average changes in prices received by domestic producers |
| Adjusted_Closing_Price | Financial Market Indicator | Reflects stock/index performance adjusted for splits and dividends |
| US_Export_to_Russia | Trade Indicator | Shows the value of U.S. goods and services exported to Russia |
| US_Unemployment_Rate | Labor Market Indicator | Represents the percentage of the labor force that is unemployed |
| US_Consumer_Sentiment | Consumer Confidence Indicator | Measures consumers' confidence in the economic outlook |
| US_Gasoline_Dollars_Per_Barrel | Energy Market Indicator | Indicates the price of gasoline per barrel in the U.S. |
| Price | Generic Price Indicator | USD to Rubble Price Change |
| US_Mean_Monthly_Market_Volatility | Financial Market Indicator | Tracks average monthly fluctuations in U.S. financial markets |
| Russia_Ukraine_Date_Flag | Geopolitical Event Indicator | Binary flag for the Russia-Ukraine conflict (1 = conflict, 0 = no conflict) |
| Covid_Flag | Pandemic Event Indicator | Binary flag for the COVID-19 pandemic (1 = pandemic period, 0 = no pandemic) |

Data Pre-Processing



Cleaning Process

- We trimmed the data down and considered monthly data from Jan'2013 to Aug'2024
- Converted Daily Data to Monthly Data
- Null Value Check
- **Covid**: 20th Jan'20 – 11th May'23
- **War**: February'2022
- Consolidated Dataset



Ensuring Stationarity

- Augmented Dickey Fuller Test (**ADF Test**)
- Kwiatkowski-Phillips-Schmidt-Shin test (**KPSS Test**)
- 1st and 2nd Differencing to make the series Stationary

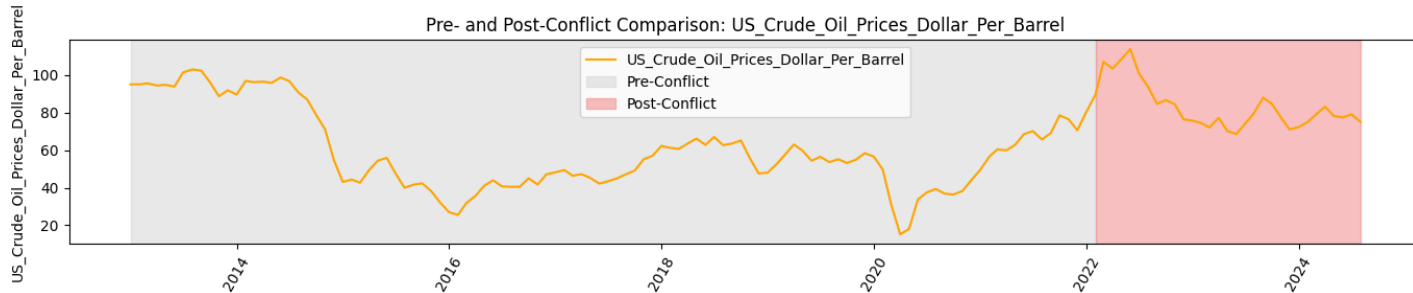


Tools Used

- Python
 - Pandas
 - Matplotlib
 - Seaborn
 - Statsmodel
 - Pickle

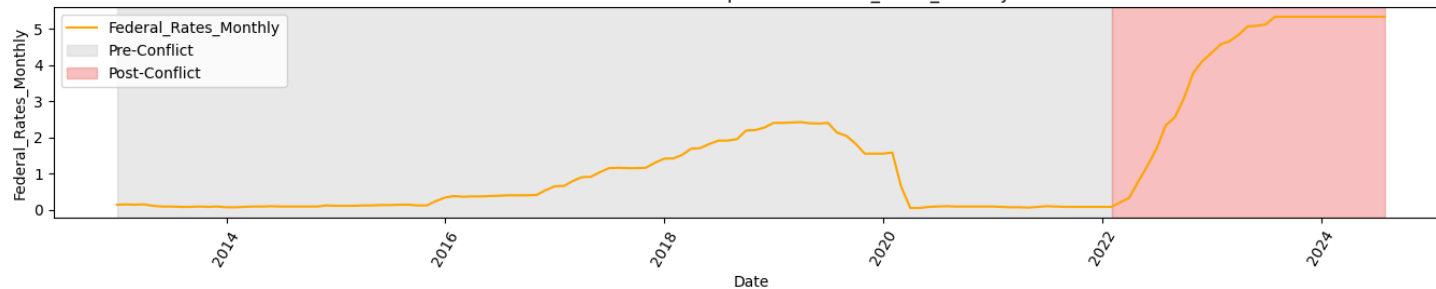
Exploratory Data Analysis : Important Highlights

Pre- and Post-Conflict Comparison: US_Crude_Oil_Prices_Dollar_Per_Barrel



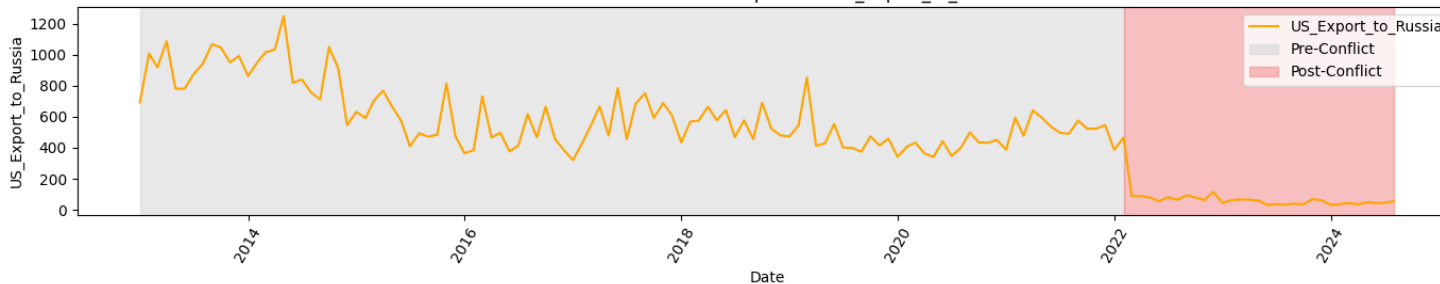
Significant fluctuations are visible post-2022, which aligns with the onset of the Russia-Ukraine conflict

Pre- and Post-Conflict Comparison: Federal_Rates_Monthly



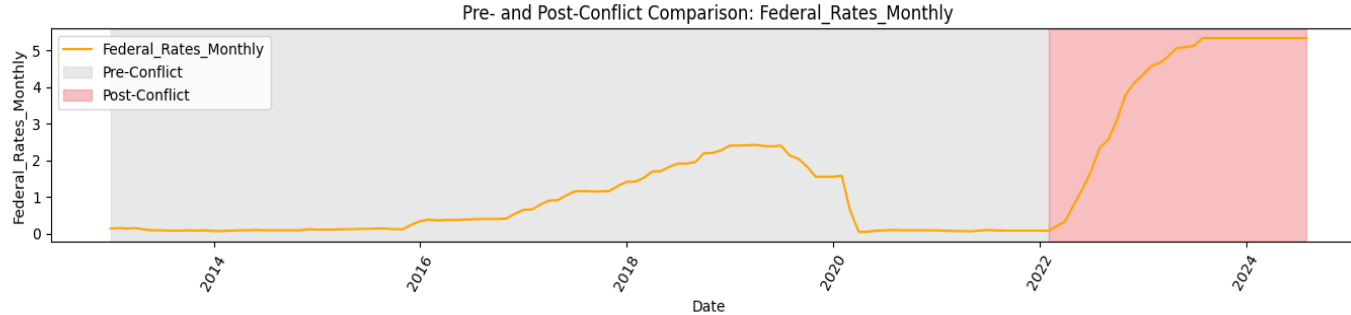
A sharp increase in federal rates post-2022 is evident, likely in response to inflationary pressures exacerbated by the conflict.

Pre- and Post-Conflict Comparison: US_Export_to_Russia

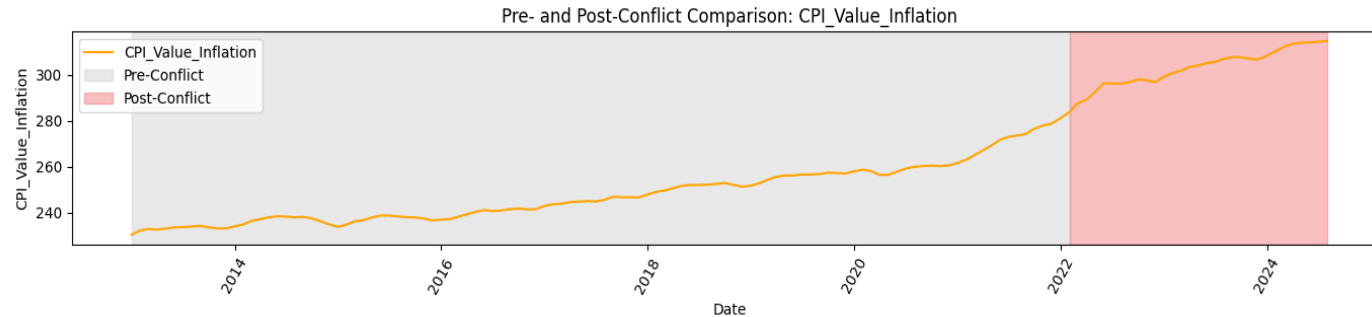


Exports to Russia sharply decline to near zero post-2022, illustrating the impact of sanctions and strained trade relations following the conflict.

Exploratory Data Analysis : Important Highlights

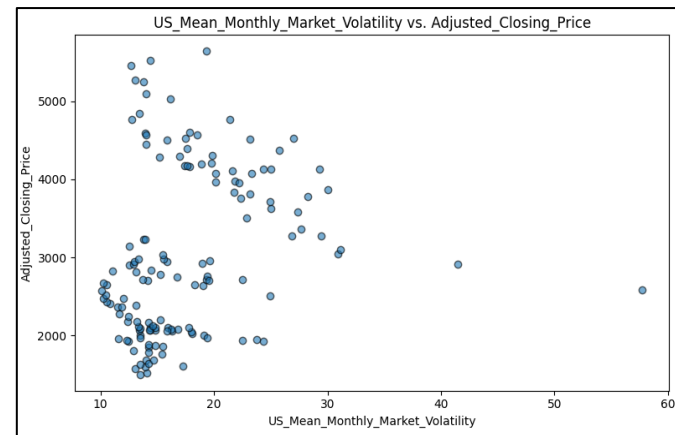
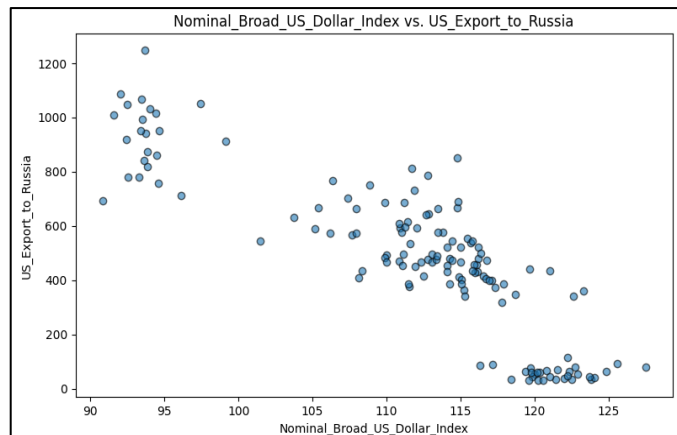
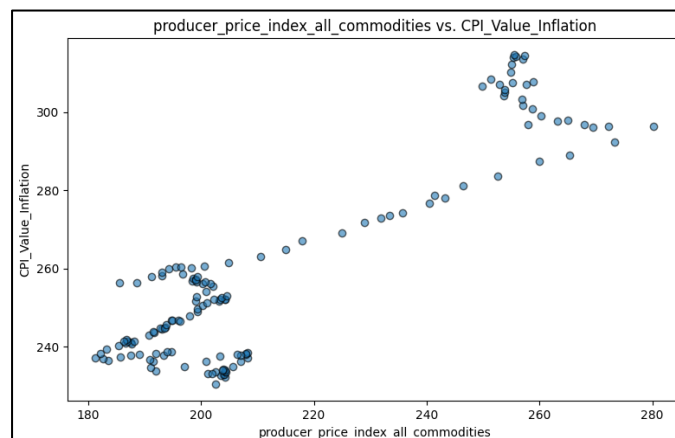
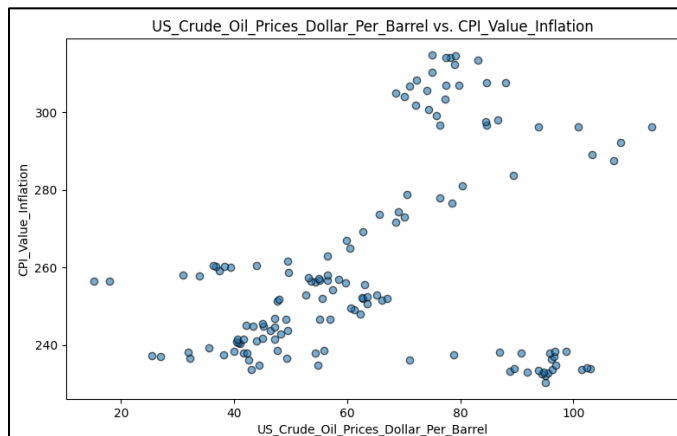


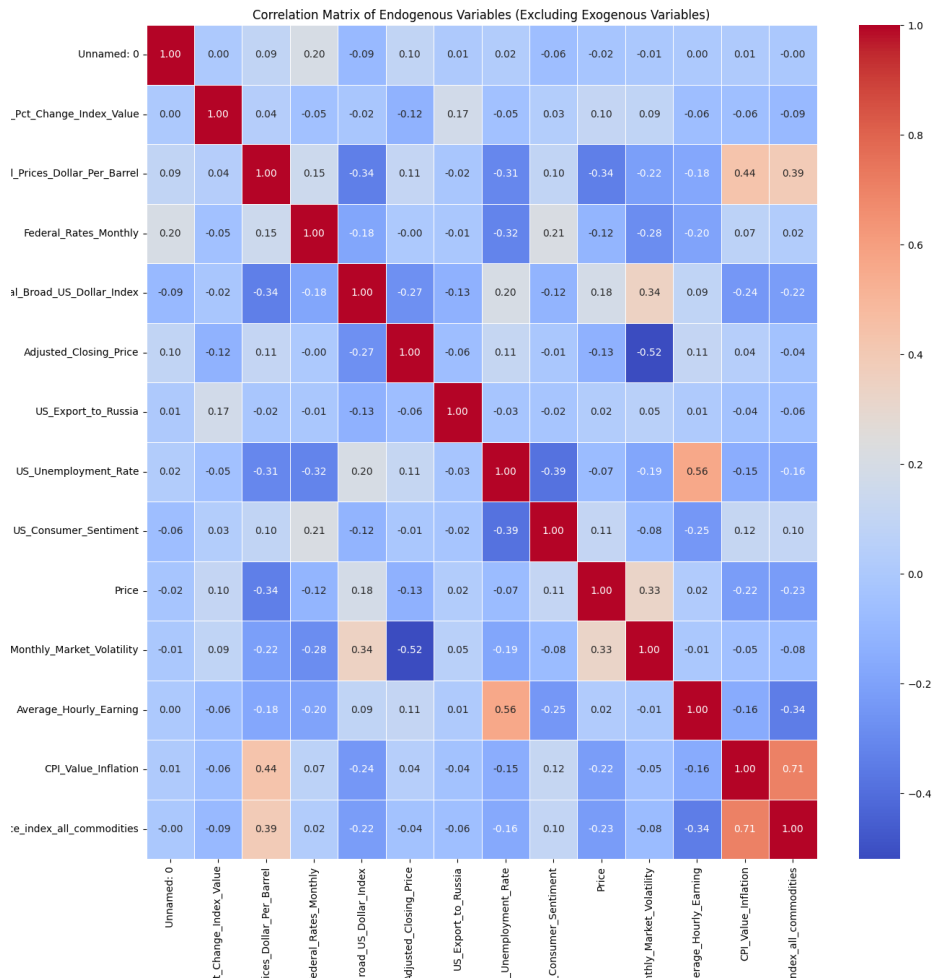
A sharp increase in federal rates post-2022 is evident, likely in response to inflationary pressures exacerbated by the conflict.



The continuous rise in CPI post-2020 (COVID-19) and a further surge post-2022 indicates inflationary trends influenced by the pandemic and geopolitical tensions,

Exploratory Data Analysis : Important Highlights





Correlation Analysis of Data (Post Making the Time Series Stationary)

After making the data stationary, correlation analysis helps identify the relationships between variables by removing trends and seasonality. This ensures that the analysis focuses on the true underlying dynamics rather than spurious correlations caused by non-stationary data.

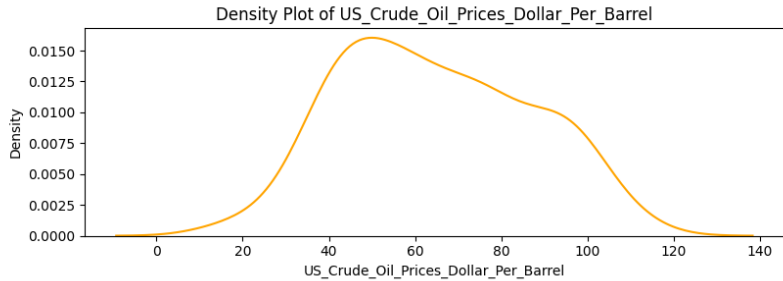
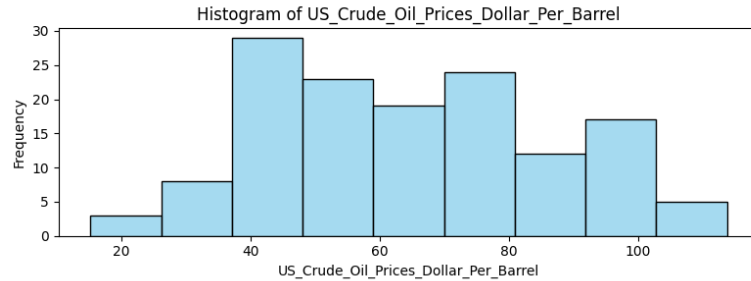
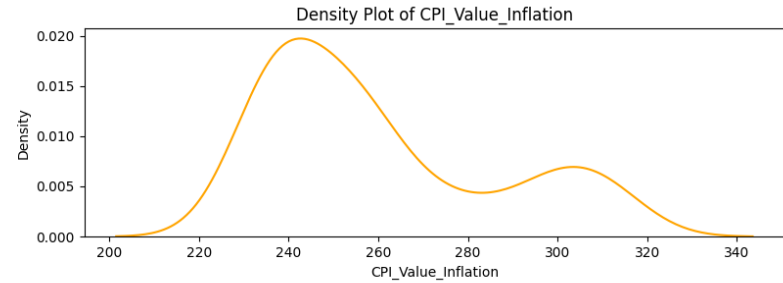
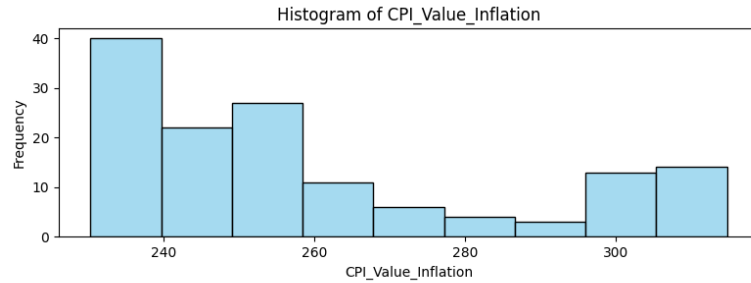
Strongest Positive Correlation - Producer Price Index (PPI) and CPI Value Inflation (0.71)

Strongest Negative Correlation - Adjusted Closing Price and Market Volatility (-0.52)

Variance Inflation Factor (VIF):

| | Variable | VIF |
|----|---------------------------------------|----------|
| 0 | const | 1.232401 |
| 1 | Trade_Volume_Pct_Change_Index_Value | 1.087875 |
| 2 | US_Crude_Oil_Prices_Dollar_Per_Barrel | 3.101137 |
| 3 | Federal_Rates_Monthly | 1.382016 |
| 4 | Nominal_Broad_US_Dollar_Index | 1.458683 |
| 5 | Adjusted_Closing_Price | 1.546184 |
| 6 | US_Export_to_Russia | 1.072789 |
| 7 | US_Unemployment_Rate | 2.385836 |
| 8 | US_Consumer_Sentiment | 1.311815 |
| 9 | US_Gasoline_Dollars_Per_Barrel | 2.782467 |
| 10 | Price | 1.334567 |
| 11 | US_Mean_Monthly_Market_Volatility | 2.162934 |
| 12 | Average_Hourly_Earning | 1.758266 |
| 13 | CPI_Value_Inflation | 2.399105 |
| 14 | producer_price_index_all_commodities | 2.484177 |

Exploratory Data Analysis : Important Highlights



CPI Value Inflation- Inflation is a critical economic indicator directly affected by global events like the COVID-19 pandemic and the Russia-Ukraine conflict. This plot provides an insight into the distribution of inflation over the observed timeline, reflecting the economic pressures during crises.

US Crude Oil Prices (Dollar per Barrel) - Crude oil prices are highly sensitive to geopolitical events, especially the Russia-Ukraine conflict, which disrupted global energy supply. This plot highlights how crude oil prices behaved during this period, offering an understanding of the broader economic implications.

Stationarity Analysis : Meeting the VARX Requirements

ADF Test
KPSS Test



First Differencing
Second Differencing



ADF Test
KPSS Test

Stationary Variables (p-value < 0.05)

1. Trade_Volume_Pct_Change_Index_Value
2. US_Unemployment_Rate
3. US_Mean_Monthly_Market_Volatility

Non-Stationary Variables (p-value \geq 0.05)

1. Average_Hourly_Earning
2. US_Crude_Oil_Prices_Dollar_Per_Barrel
3. Federal_Rates_Monthly
4. CPI_Value_Inflation
5. Nominal_Broad_US_Dollar_Index
6. producer_price_index_all_commodities
7. Adjusted_Closing_Price
8. US_Export_to_Russia
9. US_Consumer_Sentiment
10. US_Gasoline_Dollars_Per_Barrel
11. Price

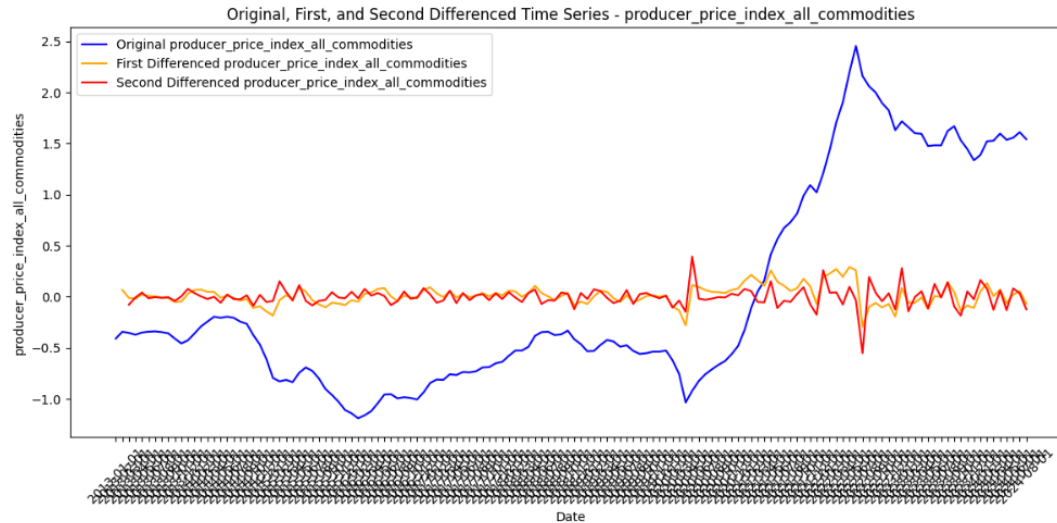
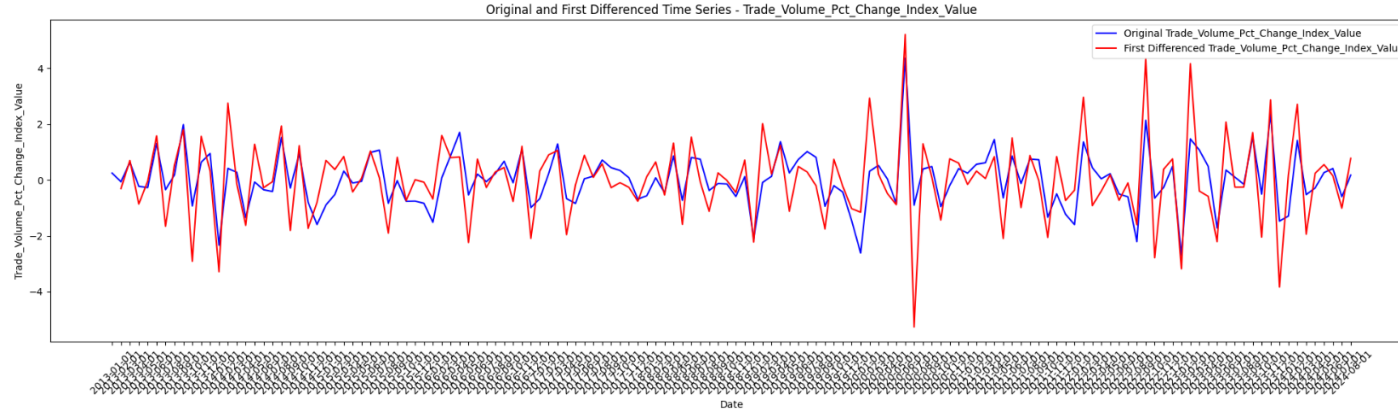
Variables that become Stationary After 1st Differencing:

- Average_Hourly_Earning
- Federal_Rates_Monthly
- CPI_Value_Inflation
- Nominal_Broad_US_Dollar_Index
- producer_price_index_all_commodities

Variables that become Stationary After 2nd Differencing:

- Average_Hourly_Earning',
- 'CPI_Value_Inflation',
- 'producer_price_index_all_commodities'

Stationarity Analysis : Meeting the VARX Requirements



VARX Modelling : Why this Model??

A VARX (Vector Autoregression with Exogenous Variables) model is a statistical tool used to **analyze the relationships between multiple interdependent variables over time, while also considering the effects of external factors or events**. It helps us understand how variables influence each other dynamically and how external events, like the COVID-19 pandemic or the Russia-Ukraine conflict, impact the system. This makes it ideal for studying complex economic systems.

- Captures the dynamic interdependencies between multiple economic indicators, offering a comprehensive view of their relationships.
- Incorporates exogenous shocks like the COVID-19 pandemic and the Russia-Ukraine conflict, directly assessing their impacts.
- Effectively models lagged relationships, addressing the delayed effects often seen in economic variables.
- Provides robust and interpretable insights compared to machine learning models, aligning with econometric best practices.
- Overcomes the limitations of univariate models like ARIMA, which cannot handle multiple interdependent variables or external events.

- **Regression vs. VARX:** Regression models assume a unidirectional relationship (independent vs. dependent variables), while VARX captures bidirectional influences and feedback among multiple variables over time.
- **ARIMA vs. VARX:** ARIMA focuses on univariate forecasting and does not handle multiple interrelated time series, whereas VARX models are specifically designed for multivariate systems.
- **Exogenous Variables:** VARX integrates external events (like the Russia-Ukraine conflict and COVID-19) into the analysis, which traditional time series models like ARIMA cannot do effectively.

Stationarity Analysis : Meeting the VARX Requirements

General Hypothesis:

H₀: The Russia-Ukraine war (as captured by the exogenous variable `Russia_Ukraine_Date_Flag`) has no significant impact on key U.S. economic indicators.

H₁: The Russia-Ukraine war has a significant impact on key U.S. economic indicators.

Covid Flag (Exogeneous Control)

H₀: The COVID-19 pandemic has no additional impact on U.S. economic indicators, independent of the Russia-Ukraine war.

H₁: The COVID-19 pandemic has a significant additional impact on U.S. economic indicators, independent of the Russia-Ukraine war.

Understanding the VARX Model Outputs

The **VARX model** outputs a regression-like summary for each variable because it models a system of equations where each variable is treated as a dependent variable in its own equation.

Market Volatility Variable

Results for equation US_Mean_Monthly_Market_Volatility

| | coef | std err | z | P> z | [0.025 | 0.975] |
|--|---------|---------|----------|-------|--------|--------|
| ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| intercept | 0.0308 | 0.039 | 0.791 | 0.429 | -0.046 | 0.107 |
| L1.Trade_Volume_Pct_Change_Index_Value | 0.0636 | 0.057 | 1.116 | 0.264 | -0.048 | 0.175 |
| L1.US_Crude_Oil_Prices_Dollar_Per_Barrel | -0.3657 | 0.014 | -26.942 | 0.000 | -0.392 | -0.339 |
| L1.Federal_Rates_Monthly | 0.1709 | 0.003 | 53.638 | 0.000 | 0.165 | 0.177 |
| L1.Nominal_Broad_US_Dollar_Index | 0.0395 | 0.012 | 3.340 | 0.001 | 0.016 | 0.063 |
| L1.Adjusted_Closing_Price | -1.3805 | 0.007 | -208.939 | 0.000 | -1.393 | -1.368 |
| L1.US_Export_to_Russia | -0.2294 | 0.023 | -10.101 | 0.000 | -0.274 | -0.185 |
| L1.US_Unemployment_Rate | -0.3466 | 0.018 | -19.645 | 0.000 | -0.381 | -0.312 |
| L1.US_Consumer_Sentiment | 0.3510 | 0.019 | 18.030 | 0.000 | 0.313 | 0.389 |
| L1.Price | 0.0029 | 0.014 | 0.208 | 0.835 | -0.024 | 0.030 |
| L1.US_Mean_Monthly_Market_Volatility | -0.3233 | 0.011 | -29.873 | 0.000 | -0.344 | -0.302 |
| L1.Average_Hourly_Earning | 1.2908 | 0.001 | 1147.908 | 0.000 | 1.289 | 1.293 |
| L1.CPI_Value_Inflation | 2.0178 | 0.002 | 812.814 | 0.000 | 2.013 | 2.023 |
| L1.producer_price_index_all_commodities | -0.3944 | 0.005 | -72.493 | 0.000 | -0.405 | -0.384 |
| beta.Russia_Ukraine_Date_Flag | -0.0754 | 0.023 | -3.340 | 0.001 | -0.120 | -0.031 |
| beta.Covid_Flag | 0.0575 | 0.010 | 5.764 | 0.000 | 0.038 | 0.077 |

$p > 0.05$ - Insignificant

$P \leq 0.05$ - Significant

$$\begin{aligned} \text{US_Mean_Monthly_Market_Volatility}_t = & 0.0308 \\ & + 0.0636 \cdot \text{Trade_Volume_Pct_Change_Index_Value}_{t-1} \\ & - 0.3657 \cdot \text{US_Crude_Oil_Prices_Dollar_Per_Barrel}_{t-1} \\ & + 0.1709 \cdot \text{Federal_Rates_Monthly}_{t-1} \\ & + 0.0395 \cdot \text{Nominal_Broad_US_Dollar_Index}_{t-1} \\ & - 1.3805 \cdot \text{Adjusted_Closing_Price}_{t-1} \\ & - 0.2294 \cdot \text{US_Export_to_Russia}_{t-1} \\ & - 0.3466 \cdot \text{US_Unemployment_Rate}_{t-1} \\ & + 0.3510 \cdot \text{US_Consumer_Sentiment}_{t-1} \\ & + 0.0029 \cdot \text{Price}_{t-1} \\ & - 0.3233 \cdot \text{US_Mean_Monthly_Market_Volatility}_{t-1} \\ & + 1.2908 \cdot \text{Average_Hourly_Earning}_{t-1} \\ & + 2.0178 \cdot \text{CPI_Value_Inflation}_{t-1} \\ & - 0.3944 \cdot \text{producer_price_index_all_commodities}_{t-1} \\ & - 0.0754 \cdot \text{Russia_Ukraine_Date_Flag} \\ & + 0.0575 \cdot \text{Covid_Flag} \\ & + \epsilon_t \end{aligned}$$

VARX Model Results

| Variable | Affected by COVID | Affected by War | Affected by Both | Unaffected |
|---|-------------------|-----------------|------------------|------------|
| Trade Volume % Change Index Value | ✓ | ✗ | ✗ | ✗ |
| US Crude Oil Prices (Dollar per Barrel) | ✗ | ✗ | ✗ | ✓ |
| Federal Rates Monthly | ✗ | ✗ | ✗ | ✓ |
| Nominal Broad US Dollar Index | ✗ | ✗ | ✗ | ✓ |
| Adjusted Closing Price | ✗ | ✗ | ✗ | ✓ |
| US Export to Russia | ✗ | ✗ | ✗ | ✓ |
| US Unemployment Rate | ✗ | ✓ | ✗ | ✗ |
| US Consumer Sentiment | ✓ | ✗ | ✗ | ✗ |
| Price | ✗ | ✗ | ✗ | ✓ |
| US Mean Monthly Market Volatility | ✓ | ✓ | ✓ | ✗ |
| Average Hourly Earnings | ✗ | ✗ | ✗ | ✓ |
| CPI Value Inflation | ✗ | ✗ | ✗ | ✓ |
| Producer Price Index (All Commodities) | ✗ | ✗ | ✗ | ✓ |

VARX Model Results with Real World Happenings

| Variable | Correctly Matches Real-World Dynamics? | Notes |
|----------------------------|--|---|
| US Exports to Russia | No | Misses war's direct impact due to sanctions. |
| CPI (Inflation) | No | Misses sharp shocks from COVID and war. |
| Average Hourly Earnings | No | Misses COVID- and war-driven wage dynamics. |
| Trade Volume | Partially | Misses war's effect, but captures autocorrelation and volatility links. |
| US Crude Oil Prices | Partially | Captures persistence and inflation link but misses COVID and war impacts. |
| Federal Rates | Partially | Correct for CPI linkage, but misses external shock impacts. |
| US Unemployment Rate | Partially | Captures war effect but not COVID-driven unemployment surge. |
| Consumer Sentiment | Partially | Captures CPI and market links, but underestimates war impact. |
| PPI | Partially | Links to CPI and rates are accurate, but war impacts are missing. |
| Nominal Broad Dollar Index | Yes | Captures persistence and inflation links accurately. |
| Adjusted Market Prices | Yes | Matches real-world rate and inflation linkages. |
| Market Volatility | Yes | Matches persistence and CPI effects. |

Thank You