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Analyzing Commodity Market Volatility and Price Forecasting: A GARCH and ARIMA Model Approach

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Abstract

Commodity trade is a cornerstone of world financial markets, providing investment opportunities, risk management, and price discovery. As commodities are inherently volatile, understanding their price fluctuations and forecasting future trends is essential. This study examines the performance and volatility of four widely traded commodities in the United States - Gold, Silver, Wheat, and Crude Oil using the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to measure volatility and the Autoregressive Integrated Moving Average (ARIMA) model to predict future price trends. The GARCH model effectively captures volatility clustering, a key characteristic of financial time series data, while ARIMA analyzes historical patterns for price prediction. Using a decade's worth of daily historical price data from secondary sources, this research provides a robust dataset for in-depth analysis. Additionally, this study highlights the need for advanced predictive models that enhance accuracy during market fluctuations. By analyzing GARCH and ARIMA applications in commodity trading, this research contributes to financial modeling and risk management literature, encouraging further exploration of alternative forecasting methods.

Keywords: *Alternative Investments, Gold, Silver, Wheat, Crude Oil, Price Volatility, Commodity Trading, Price Forecasting, Commodity Markets, Forecasting Models, ARIMA, GARCH*

1. Introduction

Commodity trading has a long history, dating back to ancient civilizations. Egyptians traded commodities like grain and precious metals. The Silk Road, a network of commercial routes connecting Asia, the Middle East, Europe, and Africa, was very significant in history. (Ojha & Shukla, 2023). A commodities market is a physical or virtual marketplace where raw or primary products are traded. These products are typically natural resources or agricultural products that are largely uniform in quality across producers. Commodity exchanges are where commodities and derivatives are bought and exchanged.

A commodities exchange is a regulated marketplace where contracts for raw materials like agricultural products, metals, and energy, are bought and sold. The two major commodity exchanges in the United States are the Chicago Mercantile Exchange (CME) and the New York Mercantile Exchange (NYMEX). Market participants in the commodities market participate in transactions involving either physical commodities (spot) or derivatives contracts that are derivative of a physical commodity. The method of using this market will depend on the purpose of the trader. For instance, a trader can enter into a purchase or sale of a physical commodity, hedge segments of their investment portfolio, speculate about changes in commodity prices, or take advantage of price differences among markets.

Commodity futures markets give protection to processors and merchants from the risks that are involved in price volatility. A trader's risk exposure is determined by negative price movements caused by changes in supply or demand, which may affect the overall value of their commitments. The higher the value of their inventory, the greater the risk. The futures market allows traders to offset the per-unit inventory risk associated with their cash market positions where physical delivery of the commodity is mandatory. A trader is considered a hedger if his or her cash market positions are offset by offsetting positions in the futures market.

Volatility dynamics are crucial in developing strategies for hedging, derivative trading, and portfolio optimization. Understanding the variables behind price variations is beneficial for both producers and consumers when making investment decisions. (Schwartz, 1997)

The dominance of few countries in both the production and consumption of commodities can impact markets worldwide significantly. Even if partners in trade encounter the same economic shocks, still, the dominance of the market can shape things overall. Returns on commodity futures are influenced by changes in expectations of interest rates, convenience yield, and risk premiums. Such expectations are adjusted based on fresh information about upcoming conditions. Key variables to consider are economic measures like inflation and trends in the business cycle, along with expected supply and demand for commodities, which include consumer economic health and producer hedging difficulties. This is important to consider when assessing the impact of rising demand from developing countries on commodity prices. (Watugala, 2015)

2. Literature Review

2.1 Commodity

A commodity is an item that possesses market value. It can be created, purchased, firm, and ingested. Commodities essentially originate from the primary sector of an economy. (Shree Bhagwat, Angad Singh Maravi, 2015)

While the body of academic work on commodity markets is vast, a significant portion has centered on production and storage choices, as well as the role of commodities in global trade. The perspective of commodities from an investor's viewpoint has emerged more recently, apart from precious metals that have historically been seen as a means of preserving wealth. Investors have multiple avenues for gaining exposure to commodities, including physical markets (gold, timberland), equity markets (stocks of commodity producers or consumers), and derivatives (futures, forwards, swaps, options). In this review, our primary focus will be on the derivatives markets, specifically the commodity futures markets. The futures markets lay the groundwork for investments in commodity indices, mutual funds, exchange-traded notes and funds, and swaps. (Tang)

2.2 Commodity Trading

It is difficult to open a newspaper without reading about another multi-billion-dollar deal by a previously unheard-of commodity trader. Today's leading commodity traders excel at "optionality". " These traders thrive as they can offer producers higher payments than end users can, while selling commodities to end consumers at lower prices than producers can manage. Traders achieve this by skillfully overseeing a variety of options concerning the timing, location, quality, lot size, and logistics of sourcing or transporting their valuable goods. They take advantage of the options that exist within their collection of purchase and supply agreements. This is a capability that producers and end users frequently cannot or do not wish to utilize. (Frankl)

Commodities today are seen as an alternative asset class that many institutional investors, such as pension funds, hedge funds, and insurance companies, include in their portfolios. Empirical research identifying the diversification contribution of commodities, coupled with the poor performance of stocks and bonds during the early 2000s, has caused institutional index investors and hedge funds to become major participants in commodity markets. Concurrently, commodity prices have witnessed a significant surge, culminating in the days leading up to the global financial crisis unfolding in 2008. (Junttila et al., 2018)

2.3 Commodity vs Other Financial Products

The speed of product innovation by futures exchanges in recent years has been exceptionally remarkable. Just two decades prior, futures markets were restricted to agricultural goods and metals. In agriculture, it was widely believed that only storable goods could be suitable for futures trading. Considering the speed and variety of contemporary innovation, one could conclude that the early creation and adjustment of futures markets occurred equally quickly. (Peck, 1985)

This research uses an equally weighted index of monthly commodities futures returns from July 1959 to December 2004 to analyze the asset class's simple features. Fully collateralized commodities' futures have traditionally provided the same return and Sharpe ratio historically as equity. Commodity futures have the same risk premium as equities, but their returns

are inversely associated with both equity and bond returns. Commodity futures have a negative correlation with other asset classes, which can be attributed to varying business cycles. Commodity futures show a favorable correlation with inflation, both unexpected and predicted inflation. (Gary Gorton, 2006)
The research explored commodity segmentation as an asset allocation approach and discovered an increasing trend. Institutional investors have a big impact on commodities purchasing indexes. Commodity market prices have been influenced by a new trend which began to shape the price behaviour of commodity markets. (Stoll & Whaley, 2011)

2.5 Commodity Trading - Gold

The worldwide gold market has garnered significant interest lately, with the price of gold being comparatively elevated compared to its historical pattern. To reduce risk and uncertainty from gold price variations, mining companies should rely on forecasting future price trends to make decisions regarding hedging, future investments, and evaluations. (Shafiee & Topal, 2010)

The pricing and production patterns of gold are distinct from those of most other mineral resources. During the 2008 financial crisis, the price of gold rose by 6%, whereas numerous essential mineral prices declined, and other stocks fell by about 40%. The distinct and varied factors influencing gold demand and supply do not strongly correlate with fluctuations in other financial assets. The oil price and inflation rate are two main macroeconomic variables that influence the gold market. (Shafiee & Topal, 2010)

Over the course of history, gold has been considered an important financial asset, mainly due to its role as an inflation and US dollar fluctuation hedge. Previously, gold was the bedrock of the monetary system for a significant period, with currencies being pegged to gold at fixed rates. While the majority of physical consumption of gold is associated with jewelry, financialization of commodity markets has led to a significant surge in the use of gold-related exchange-traded products. Currently, investment demand for gold makes up the second-largest category of total demand for precious metal. (Junttila et al., 2018)

2.6 Commodity Trading - Silver

Silver, much like gold, has captivated human interest globally for centuries. Its intrinsic aesthetic appeal and relative scarcity have led to its appreciation of millennia as a symbol of wealth and a means of preserving legacy. Additionally, the metal's durability and rarity have rendered it ideal for financial applications, including trade and wealth accumulation. Historically, the price movements of silver have shown an 80% correlation with those of gold. This indicates that when investors exhibit a favorable outlook on gold, a similar sense of optimism typically extends to silver. Additionally, both gold and silver, when valued in US Dollars, demonstrate a positive correlation with the trade-weighted exchange rate of the USD. (Matiushin & Hundal, 2019)

2.7 Commodity Trading - Wheat

Wheat has long been a staple crop in Western countries. Today, it is the third most cultivated cereal in the world after rice and corn and the second most used cereal for human consumption after rice. (FAO, 2018)

Studies suggest that future markets function best with a multiplier of approximately thirty, although this can vary depending on the commodity and market conditions. However, the proper functioning of the future market is hindered when the government regulates or intervenes in the domestic market, as exemplified by the case of wheat. Furthermore, it was argued that the ban on future wheat trading should be maintained because the significant role of government controls on the spot market for wheat rendered the future market for wheat ineffective. (Jha & Mohapatra, 2003)

2.8 Commodity Trading - Crude Oil

Crude oil stands as a crucial commodity in international markets, with its pricing significantly influencing macroeconomic factors like inflation, exchange rates, and economic growth. The primary benchmarks for crude oil pricing include the WTI Cushing Crude Oil Spot Price, which is traded on the New York Mercantile Exchange (NYMEX), and the North Sea Brent, available on the Intercontinental Exchange (ICE). The essential spot price of crude oil is determined by the balance between demand and supply. It acts as the most sought-after fossil fuel globally, representing 38 percent of total fossil fuel consumption in 2010. In 2011, OECD nations accounted for the largest portion of global crude oil consumption, with a share of 51.1 percent, while the United States, Japan, and China emerged as the top three consumers of crude oil worldwide. On the supply side, OPEC member countries dominate the market, providing 72.5 percent of the global crude oil supply. (Junttila et al., 2018)

3. Research Objectives

This study aims to examine the commodities trading market in the US, with a specific focus on the Metals, Agricultural, and Energy sectors. To provide a detailed analysis, this paper will primarily concentrate on four key commodities: Gold and Silver from the Metals sector, Wheat from the Agricultural sector, and Crude Oil from the Energy sector.

1. To analyse the performance and volatility of the four widely traded commodities on the Commodities Stock Exchange using the GARCH model.
2. To forecast future price movements of these four major commodities using the ARIMA Model.

4. Research Methodology

This research adopts a quantitative approach to analyze the volatility of four selected commodities, Gold, Silver, Crude Oil, and Wheat. Two key models are employed: the GARCH (1,1) model for volatility assessment and the ARIMA model for price forecasting. The GARCH model captures volatility clustering and interdependencies among these commodities over a 10-year period, providing deeper insights into market fluctuations. Meanwhile, the ARIMA model analyzes historical price patterns to generate reliable forecasts, aiding in the prediction of future price trends.

The study relies on secondary data sourced from 'investing.com', comprising 10 years of daily historical price data for the selected commodities, all actively traded on the United States of America's Stock Exchange. The analysis was conducted using Excel to implement the GARCH (1,1) model for volatility estimation, while 'Orange' software was utilized to apply the ARIMA model for forecasting commodity prices over the next 30 days.

5. Results, Analysis, and Interpretation

5.1: Performance and volatility using GARCH model

The basic GARCH (1,1) model equation is given as:

$$\sigma_t^2 = \omega + \alpha \cdot \epsilon^2_{t-1} + \beta \cdot \sigma^2_{t-1}$$

where σ_t^2 represents the conditional variance at time t, measuring the volatility of returns. The parameter ω is the long-run average variance, ensuring that variance remains positive.

The term $\alpha \cdot \epsilon^2_{t-1}$ captures the impact of past squared returns or shocks on current volatility, with ϵ^2_{t-1} representing the squared residual from the previous period. The coefficient alpha (α) determines how strongly new information influences volatility.

The term $\beta \cdot \sigma^2_{t-1}$ accounts for the persistence of past volatility, where σ^2_{t-1} is the conditional variance from the previous period. The coefficient β reflects how long past volatility persists in the system.

The sum of α + β determines the persistence of volatility; if close to one, volatility is highly persistent, and if greater than one, the model may indicate a non-stationary process.

'α' Denotes the coefficient attached to the lagged squared error (or previous volatility shock) when predicting the current conditional variance. The higher the alpha value the higher the weights for recent squared errors in the current volatility.

'β' Denotes the weight attributed to the lagged conditional variance (or past volatility) when predicting the current conditional variance. A higher beta means that the past volatility has a larger impact and greater persistence on current volatility.

'ω' Represents the unconditional long-run variance of the process. It's an average variance of the series for a long period, assuming the GARCH model has converged to its stationary state.

5.1.1 Metals – Gold**:**

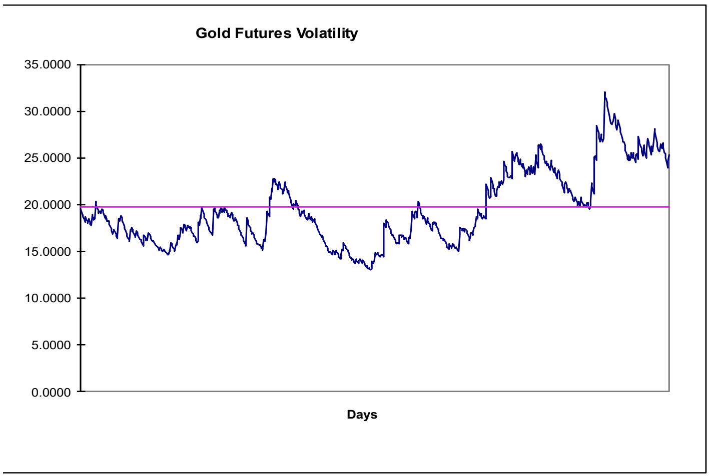

Figure 5.1.1: Volatility Chart – Gold

The volatility dynamics of gold futures were modeled using a GARCH (1,1) framework, given by the equation:

$$\sigma_t^{\,2} = \omega + \alpha \cdot \epsilon^2_{t-} \, \sigma_t^{\,2} = \omega + \alpha \cdot \epsilon^2_{t-1} + \beta \cdot \sigma^2_{t-1}$$

where the estimated parameters are ω = 3.7691, α = 0.0370, and β = 0.9546. The low value of α indicates that gold futures exhibit limited sensitivity to immediate market shocks, while the high β value reflects strong volatility persistence, implying that periods of high volatility tend to persist over time. The sum α+β = 0.99166 is close to but less than one, confirming that although volatility is highly persistent, it remains mean reverting in the long run.

The unconditional variance, calculated as:

$$\frac{\omega}{1-(\alpha+\beta)}$$

is 391.22, suggesting a relatively high long-term average volatility level. These results are consistent with the commonly observed volatility clustering in gold markets, where volatility tends to evolve gradually and remain elevated following shocks.

5.1.2 Metals – Silver**:**

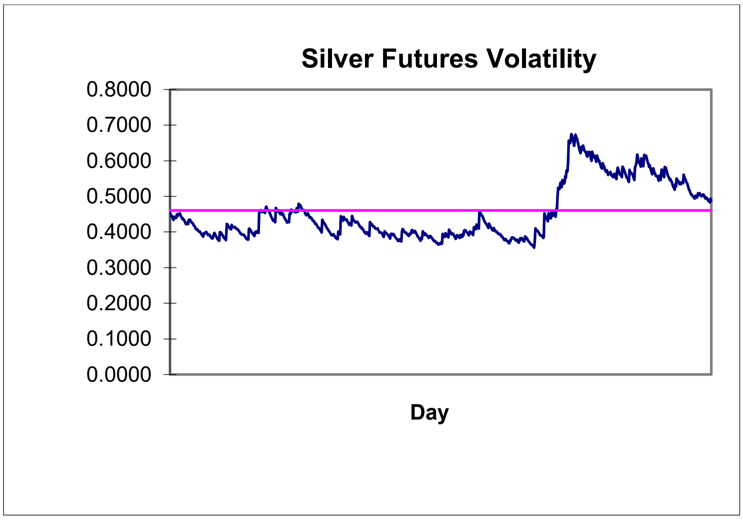

Figure 5.1.2: Volatility Graph – Silver

The volatility of silver futures was analyzed using a GARCH (1,1) model, given by the equation:

$$\sigma_t^2 = \omega + \alpha \cdot \epsilon^2_{t-1} + \beta \cdot \sigma^2_{t-1}$$

where ω = 0.00193673, α = 0.02268382, and β = 0.96843677. The low α value suggests that silver prices exhibit minimal immediate reaction to new market shocks, while the high β indicates strong persistence in volatility, meaning once volatility rises, it tends to remain elevated for an extended period. The sum α+β = 0.9911 confirms that volatility is highly persistent but still mean-reverting in the long run.

The unconditional variance, computed as:

$$\frac{\omega}{1-(\alpha+\beta)}$$

is approximately 0.2122, reflecting the long-run average volatility level. These findings highlight that silver, like gold, experiences significant volatility clustering, with gradual adjustments to shocks and sustained periods of elevated market uncertainty.

5.1.3 Agricultural – Wheat:

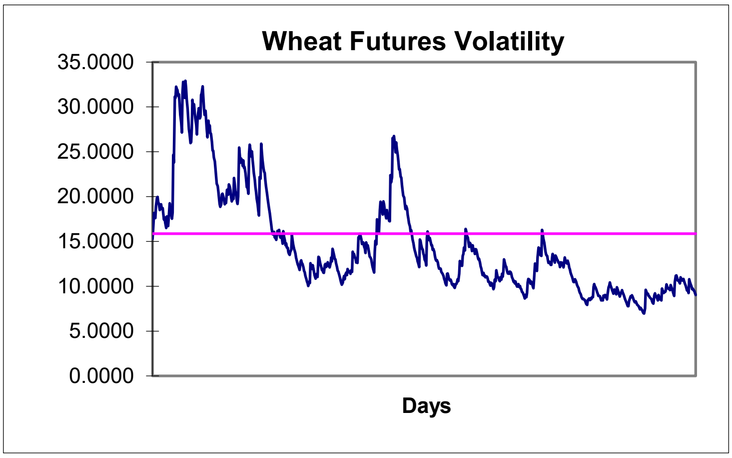

Figure 5.1.3: Volatility Graph – Wheat

The volatility of wheat futures was modeled using a GARCH (1,1) specification, given by the equation:

$$\sigma_t^2 = \omega + \alpha \cdot \epsilon^2_{t-1} + \beta \cdot \sigma^2_{t-1}$$

where the estimated parameters are ω = 1.6409, α = 0.0695 β = 0.9229. The relatively low α value indicates that wheat prices are moderately sensitive to new market shocks, while the high β value suggests strong persistence of volatility over time. The sum α+β = 0.9924 points to a highly persistent but still mean-reverting volatility process.

The unconditional variance, calculated as:

$$\frac{\omega}{1-(\alpha+\beta)}$$

is approximately 251.73, indicating a high long-run volatility level for wheat futures. This supports the presence of volatility clustering in the wheat market, where shocks have prolonged effects on price variability.

5.1.4 Energy – Crude Oil**:**

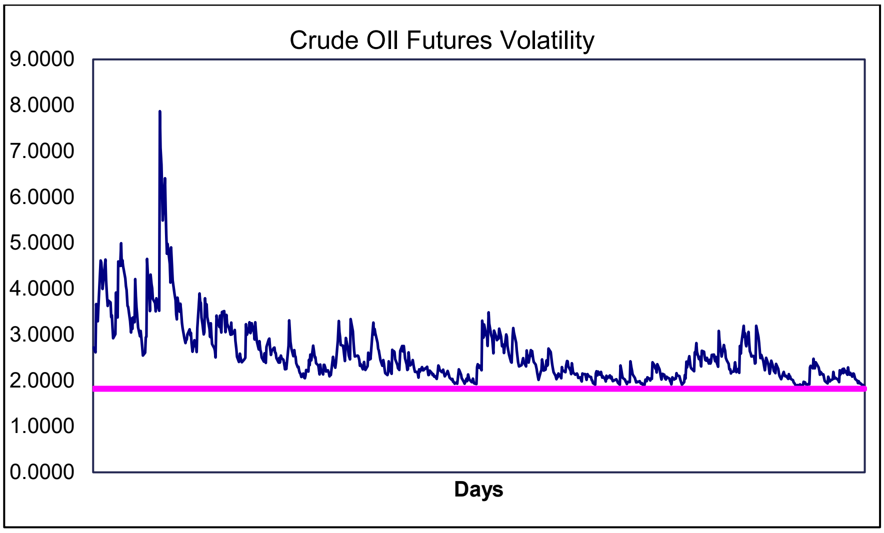

Figure 5.1.4: Volatility Graph - Crude Oil

The volatility of crude oil futures was estimated using a GARCH(1,1) model, represented by the equation

$$\sigma_t^2 = \omega + \alpha \cdot \epsilon^2_{t-1} + \beta \cdot \sigma^2_{t-1}$$

with parameters ω=0.6436, α=0.2675, and β=0.7874. The relatively high α value indicates a strong immediate response to market shocks, meaning crude oil prices are highly sensitive to sudden changes. The β coefficient, while still high, is lower than in other commodities like gold or silver, suggesting that volatility in crude oil is persistent but less so in comparison. The sum α+β=1.0549 slightly exceeds 1, which may indicate an explosive or non-stationary volatility process unless corrected, though rounding or estimation error could play a role.

The unconditional variance, computed as

$$\frac{\omega}{1-(\alpha+\beta)}$$

is approximately 3.32, reflecting the average long-term volatility. Overall, crude oil futures demonstrate both sharp reactions to shocks and moderately persistent volatility, consistent with the highly reactive nature of global oil markets.

5.2: Forecasting of future prices of the four commodities using ARIMA

5.2.1 Metals – Gold**:**

The ARIMA (2,0,3) model used for forecasting the price of gold futures for April 2025 shows a reasonable degree of predictive accuracy, especially in the initial portion of the month. Out-of-sample performance gave an RMSE of 42.2, MAE of 25.9, and MAPE of 1.1%, with R^2 being 0.888, implying that the model accounts for a very high percentage of variance in actual prices.

Initially, the predicted values closely resemble the actual prices, with deviations of less than 1%. But as the month went on and volatility in the markets picked up, the accuracy of the model decreased, with deviation percentages of more than 8% by April 21. The greatest observed deviation was in the third and fourth weeks, which pointed toward the model's inability to register sharp rises in gold prices.

Directional precision (POCID) was somewhat lower at 44.1%, showing that the model had a hard time accurately forecasting direction of change in price. Performance in-sample was much higher, with an R^2 of 0.997 and MAPE of 0.7%, which, although showing a good fit to past data, can also suggest some overfitting.

Date	Day	Price Forecast	Actual Price	Deviation from Actual Price	% Deviation compared to Actual Price

01-04-2025	Tuesday	3147.95	3146	-1.95	-0.06%
02-04-2025	Wednesday	3149.16	3166.2	17.04	0.54%
03-04-2025	Thursday	3148.23	3121.7	-26.53	-0.85%
04-04-2025	Friday	3148.22	3035.4	-112.82	-3.72%
07-04-2025	Monday	3147.33	2973.6	-173.73	-5.84%
08-04-2025	Tuesday	3147.28	2990.2	-157.08	-5.25%
09-04-2025	Wednesday	3146.43	3079.4	-67.03	-2.18%
10-04-2025	Thursday	3146.34	3177.5	31.16	0.98%
11-04-2025	Friday	3145.52	3244.6	99.08	3.05%
14-04-2025	Monday	3145.4	3226.3	80.9	2.51%
15-04-2025	Tuesday	3144.62	3240.4	95.78	2.96%
16-04-2025	Wednesday	3144.47	3346.4	201.93	6.03%
17-04-2025	Thursday	3143.72	3328.4	184.68	5.55%
21-04-2025	Monday	3143.54	3425.3	281.76	8.23%
22-04-2025	Tuesday	3142.81	3419.4	276.59	8.09%
23-04-2025	Wednesday	3142.61	3294.1	151.49	4.60%
24-04-2025	Thursday	3141.91	3348.6	206.69	6.17%
25-04-2025	Friday	3141.68	3298.4	156.72	4.75%
28-04-2025	Monday	3141	3333	192	5.76%
29-04-2025	Tuesday	3140.76	3333.6	192.84	5.78%
30-04-2025	Wednesday	3140.1	3319.1	179	5.39%
01-05-2025	Thursday	3139.84	3,222.20	82.36	2.56%
02-05-2025	Friday	3139.19	3,243.30	104.11	3.21%
05-05-2025	Monday	3138.91	3,322.30	183.39	5.52%
06-05-2025	Tuesday	3138.29	3,422.80	284.51	8.31%
07-05-2025	Wednesday	3137.99	3,391.90	253.91	7.49%
08-05-2025	Thursday	3137.38	3,306.00	168.62	5.10%
09-05-2025	Friday	3137.08	3,344.00	206.92	6.19%
12-05-2025	Monday	3136.48	3,228.00	91.52	2.84%
13-05-2025	Tuesday	3136.16	3,247.80	111.64	3.44%

Table 5.2.1: Forecasted Values - Gold (Source: Author's Work)

5.2.2 Metals – Silver**:**

The ARMA (1,0,2) model shows strong predictive capability for April 2025 silver futures, with low mean errors, MAPE = 1.8%, MAE = 0.555, and RMSE = 0.727, and an R^2 value of 0.684, which represents a good fit in out-of-sample predictions. The model did well throughout the first and final weeks of the month with little difference from actual prices.

But in a tumultuous week from April 3 to 11, accuracy fell sharply, with the highest deviation at 17.87% on April 4, a sign of its weakness in sensing rapid market fluctuations. Still, directional accuracy (POCID) of the model was just above random at 54.2%, and it improved stability from the second half of the month with deviations being primarily less than 6%. In-sample performance was considerably better, with an R^2 of 0.988 and smaller error values, which signifies an extremely good fit to past data.

Date	Day	Price Forecast	Actual Price	Deviation from Actual Price	% Deviation compared to Actual Price
01-04-2025	Tuesday	34.5751	34.309	-0.2661	-0.78%
02-04-2025	Wednesday	34.5282	34.65	0.1218	0.35%
03-04-2025	Thursday	34.4907	31.97	-2.5207	-7.88%
04-04-2025	Friday	34.4533	29.23	-5.2233	-17.87%
07-04-2025	Monday	34.4161	29.604	-4.8121	-16.25%
08-04-2025	Tuesday	34.3791	29.686	-4.6931	-15.81%
09-04-2025	Wednesday	34.3422	30.415	-3.9272	-12.91%
10-04-2025	Thursday	34.3056	30.759	-3.5466	-11.53%
11-04-2025	Friday	34.2691	31.91	-2.3591	-7.39%
14-04-2025	Monday	34.2328	32.167	-2.0658	-6.42%

15-04-2025	Tuesday	34.1967	32.297	-1.8997	-5.88%
16-04-2025	Wednesday	34.1607	32.98	-1.1807	-3.58%
17-04-2025	Thursday	34.1249	32.47	-1.6549	-5.10%
21-04-2025	Monday	34.0893	32.521	-1.5683	-4.82%
22-04-2025	Tuesday	34.0539	32.905	-1.1489	-3.49%
23-04-2025	Wednesday	34.0186	33.547	-0.4716	-1.41%
24-04-2025	Thursday	33.9835	33.503	-0.4805	-1.43%
25-04-2025	Friday	33.9486	33.01	-0.9386	-2.84%
28-04-2025	Monday	33.9138	33.165	-0.7488	-2.26%
29-04-2025	Tuesday	33.8793	33.577	-0.3023	-0.90%
30-04-2025	Wednesday	33.8448	32.828	-1.0168	-3.10%
01-05-2025	Thursday	33.8106	32.469	-1.3416	-4.13%
02-05-2025	Friday	33.7765	32.259	-1.5175	-4.70%
05-05-2025	Monday	33.7426	32.474	-1.2686	-3.91%
06-05-2025	Tuesday	33.7088	33.381	-0.3278	-0.98%
07-05-2025	Wednesday	33.6752	32.791	-0.8842	-2.70%
08-05-2025	Thursday	33.6418	32.617	-1.0248	-3.14%
09-05-2025	Friday	33.6085	32.914	-0.6945	-2.11%
12-05-2025	Monday	33.5754	32.624	-0.9514	-2.92%
13-05-2025	Tuesday	33.5425	33.1	-0.4425	-1.34%

Table 5.2.2: Forecasted Values - Silver (Source: Author's Work)

5.2.3 Agricultural – Wheat**:**

The ARIMA (1,0,1) model used in forecasting wheat futures for April 2025 shows generally good short-term predictive validity but becomes more divergent towards the end of the month. The model indicates out-of-sample RMSE of 11.9 and MAE of 8.154, showing a relatively small average error, with MAPE at 1.7%. Early predictions are extremely close to true prices, with deviations being predominantly below 1%. But from mid-to-late April, the deviations become larger, reaching a high of more than 5.5% on April 29.

The trend has the implication that the model is less sensitive to sudden price falls or market instability. Directional precision (POCID) is at 52.5%, which means it is slightly better than chance when forecasting direction of price change. R^2 is comparatively low at 0.698 for the out-of-sample set, which suggests that the model only accounts for some 70% of variance in actual prices, even though the in-sample fit is considerably better at 0.985. Regardless of the excellent short-term predictions, the increase in forecast error towards month-end indicates the model's lack of responsiveness to unexpected market movements in wheat futures.

Date	Day	Price Forecast	Actual Price	Deviation from Actual Price	% Deviation compared to Actual Price
01-04-2025	Tuesday	538.169	540.5	2.331	0.431%
02-04-2025	Wednesday	538.8	539.25	0.45	0.083%
03-04-2025	Thursday	539.428	536	-3.428	-0.640%
04-04-2025	Friday	540.053	529	-11.053	-2.089%
07-04-2025	Monday	540.676	536.5	-4.176	-0.778%
08-04-2025	Tuesday	541.296	540	-1.296	-0.240%
09-04-2025	Wednesday	541.913	542.25	0.337	0.062%
10-04-2025	Thursday	542.527	538	-4.527	-0.841%
11-04-2025	Friday	543.139	555.75	12.611	2.269%
14-04-2025	Monday	543.748	561.75	18.002	3.205%
15-04-2025	Tuesday	544.354	556	11.646	2.095%
16-04-2025	Wednesday	544.957	561	16.043	2.860%
17-04-2025	Thursday	545.558	562.25	16.692	2.969%
21-04-2025	Monday	546.155	552.25	6.095	1.104%
22-04-2025	Tuesday	546.751	550.25	3.499	0.636%
23-04-2025	Wednesday	547.343	543.5	-3.843	-0.707%
24-04-2025	Thursday	547.933	544.5	-3.433	-0.630%

25-04-2025	Friday	548.52	545	-3.52	-0.646%
28-04-2025	Monday	549.105	531	-18.105	-3.410%
29-04-2025	Tuesday	549.687	525.5	-24.187	-4.603%
30-04-2025	Wednesday	550.266	530.75	-19.516	-3.677%
01-05-2025	Thursday	550.843	531	-19.843	-3.737%
02-05-2025	Friday	551.417	543	-8.417	-1.550%
05-05-2025	Monday	551.989	531.25	-20.739	-3.904%
06-05-2025	Tuesday	552.558	536	-16.558	-3.089%
07-05-2025	Wednesday	553.124	534.25	-18.874	-3.533%
08-05-2025	Thursday	553.688	529.25	-24.438	-4.617%
09-05-2025	Friday	554.249	521.75	-32.499	-6.229%
12-05-2025	Monday	554.808	499	-55.808	-11.184%
13-05-2025	Tuesday	555.364	501.5	-53.864	-10.741%

Table 5.2.3: Forecasted Values - Wheat (Source: Author's Work)

5.2.4 Energy – Crude Oil**:**

The ARIMA (8,1,1) model of crude oil futures reports excellent forecasting performance in the beginning, with an out-of-sample RMSE of only 1.525 and MAE of 1.19, which records high accuracy in a stable environment. The model also records a low MAPE of 1.7%, meaning early forecasts were proportionally close to real prices.

But from there, this precision quickly drops as we progress in April 2025. While the initial days are barely off (e.g., 0.327% on April 1st), by halfway through the month the model begins to seriously underestimate real price falls, e.g., a 14.27% discrepancy on April 4th and an 18.65% discrepancy on April 8th.

Towards the end of the month, the model does not even catch the downtrend, with errors going as high as more than 21% on April 30th. For all its good R^2 of 0.786 out-of-sample and POCID of 57.6%, however, the model's failure to follow sharp moves attests to its essential weakness.

The predictions are stagnant at $70.7 as real prices drop consistently, indicating that the model is insensitive to the most recent shocks and turning points in trends. The inflexibility indicates that although ARIMA (8,1,1) is appropriate when there are short-run stable conditions, it is not capable of adapting dynamically as needed during times of volatility and structural change in the crude oil market.

Date	Day	Price Forecast	Actual Price	Deviation from Actual Price	% Deviation compared to Actual Price
01-04-2025	Tuesday	71.4327	71.2	-0.2327	-0.327%
02-04-2025	Wednesday	71.167	71.71	0.543	0.757%
03-04-2025	Thursday	70.792	66.95	-3.842	-5.739%
04-04-2025	Friday	70.8376	61.99	-8.8476	-14.273%
07-04-2025	Monday	70.862	60.7	-10.162	-16.741%
08-04-2025	Tuesday	70.7308	59.58	-11.1508	-18.716%
09-04-2025	Wednesday	70.8102	62.35	-8.4602	-13.569%
10-04-2025	Thursday	70.6938	60.07	-10.6238	-17.686%
11-04-2025	Friday	70.6589	61.5	-9.1589	-14.893%
14-04-2025	Monday	70.6564	61.05	-9.6064	-15.735%
15-04-2025	Tuesday	70.709	60.75	-9.959	-16.393%
16-04-2025	Wednesday	70.7269	62.47	-8.2569	-13.217%
17-04-2025	Thursday	70.7147	64.68	-6.0347	-9.330%
21-04-2025	Monday	70.725	63.08	-7.645	-12.120%
22-04-2025	Tuesday	70.7214	64.31	-6.4114	-9.970%
23-04-2025	Wednesday	70.7277	62.27	-8.4577	-13.582%
24-04-2025	Thursday	70.7293	62.79	-7.9393	-12.644%
25-04-2025	Friday	70.7316	63.02	-7.7116	-12.237%
28-04-2025	Monday	70.7282	62.05	-8.6782	-13.986%
29-04-2025	Tuesday	70.7243	60.42	-10.3043	-17.054%

30-04-2025	Wednesday	70.7248	58.21	-12.5148	-21.499%
01-05-2025	Thursday	70.7246	59.24	-11.4846	-19.387%
02-05-2025	Friday	70.725	58.29	-12.435	-21.333%
05-05-2025	Monday	70.7245	57.13	-13.5945	-23.796%
06-05-2025	Tuesday	70.7245	59.09	-11.6345	-19.689%
07-05-2025	Wednesday	70.7243	58.07	-12.6543	-21.791%
08-05-2025	Thursday	70.7244	59.91	-10.8144	-18.051%
09-05-2025	Friday	70.7248	61.02	-9.7048	-15.904%
12-05-2025	Monday	70.7249	61.56	-9.1649	-14.888%
13-05-2025	Tuesday	70.7249	63.25	-7.4749	-11.818%

Table 5.2.4: Forecasted Values – Crude Oil (Source: Author's Work)

6. Limitations

This study focuses primarily on price trends and volatility but does not account for macroeconomic variables such as inflation, interest rates, geopolitical events, or policy changes that significantly influence the prices of commodities. Both the GARCH and ARIMA models rely on specific assumptions about market behavior, such as stationarity and normality in returns, which may not fully capture real-world complexities.

The GARCH (1,1) model assumes that future volatility is driven mainly by historical volatility and shocks, which could ignore major external drivers like macroeconomic conditions, geopolitical events, or structural changes in the market framework. In addition, the recurring volatility exhibited by some commodities, particularly crude oil, is indicative of long-memory effects, which a standard GARCH model cannot fully address.

Furthermore, the ARIMA model used to forecast prices is effective for short-term predictions but may not accurately capture long-term shifts in the market and unexpected events can impact the accuracy of the forecasted prices. ARIMA models, as good as they are at projecting future prices through historical data, struggle during sudden market fluctuations, policy changes, or unexpected incidents, leading to possible inaccuracies in projections.

The low and moderate POCID values, which show accuracy of the model applied, across multiple commodities point to the challenges of precisely predicting direction of price, underscoring the need for models with more explanatory variables.

A short time frame of 10 years has been used, which may not fully reflect the changing market trends. This study has been focused around four commodities from three sectors which does not encompass the whole range of commodities that are available.

7. Conclusion

The study shows that the GARCH (1,1) model correctly captures volatility clustering in commodity markets with varying degrees of persistence and sensitivity to shocks. Precious metals like gold and silver reveal high volatility persistence, indicating past price movements leave lasting impacts. Wheat returns faster to its means. Interestingly, crude oil indicates volatility behavior almost explosive in nature, highlighting geopolitical and macroeconomic influences.

ARIMA models achieve a good enough level of predictive ability for use in price forecasting, as their in-sample performance exceeds that of out-of-sample predictions, an area of concern for the possibility of overfitting. While the models give valuable information on price and volatility behavior, their limitations are such that there is a need for more sophisticated methodologies that consider extrinsic factors and capture non-linear market dynamics.

8. Future Research Agenda

Future studies should consider more advanced models, like those of GARCH variants (e.g., EGARCH and TGARCH), that are specifically developed to allow for asymmetric responses of volatility to positive as well as negative shocks. While ARIMA and GARCH models provide useful insights, using machine learning and hybrid models may improve forecasting capabilities by capturing nonlinear patterns and shifts. Additionally, incorporating external macroeconomic influences such as inflation, interest rates, and geopolitical events, future research could focus on constructing models that account for these external shocks.

Event-driven analysis can assist investors better understand market resiliency and refine their trading methods in unpredictable markets can greatly enhance the accuracy of forecasting and capture the impact of external market forces more effectively. Extending the time horizon beyond ten years would provide more detailed insights into long-term market trends, cyclical behavior, and the impact of significant changes in the economy.

Furthermore, future research can look at a broader selection of commodities across many industries rather than just four used in this study. This would provide a more complete picture of pricing dynamics and diversification tactics in the United States commodities market. Incorporating new asset classes such as cryptocurrency, real estate, and ESG investments could potentially provide a comparative view of alternative investments options.

Future research can compare commodities to traditional asset classes like equities, bonds, and mutual funds to acquire a better understanding of the risk-return trade-off. This comparative method would assist investors in determining the role of commodities in a diversified portfolio and if they function as a reliable hedge against inflation and market volatility.

By filling these gaps, future research can provide a more comprehensive perspective on the growing landscape of commodities trading and alternative investing techniques. Future research that addresses these shortcomings can contribute to a more thorough understanding of commodity trade and alternative investments.

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