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Hedging Efficiency of Energy Commodities between Indian and American Commodity Exchanges: Constant and Time-Varying Approaches

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ABSTRACT

This research paper investigates the hedging efficiency between spot and future prices of crude oil and natural gas commodities in the energy category of the commodity market. The study focuses on two major commodity exchanges, the Multi Commodity Exchange of India (MCX) and the New York Mercantile Exchange (NYMEX), which serve as the global benchmarking commodity market. Various econometric models have been incorporated to measure constant and time-varying hedging efficiency, we analyze the potential of futures contracts in mitigating price risks in these markets. The results indicate significant and consistent hedge ratios for both crude oil and natural gas in both the MCX and NYMEX markets. Moreover, the MGARCH model, which assesses hedging that varies over time, demonstrates the ability to adjust hedging positions based on market changes. Johansen's co-integration test endorses the presence of enduring connections between spot and future prices in both exchanges. Traders and investors can effectively use futures contracts to mitigate price risks in energy commodity markets, ensuring more dependable financial outcomes amid price fluctuations. Additionally, policymakers can utilize these research findings to promote the adoption of futures contracts, make well-informed choices, manage risks effectively, and enhance the overall efficiency and stability of energy commodity markets.

Keywords: Hedging Efficiency, Energy Commodity Markets, Constant Hedging, Time-Varying Hedging
JEL Classifications: Q02, Q40, C3

1. INTRODUCTION

The global energy industry faces a constantly changing landscape due to variable commodity prices (Kumar et al., 2008). In futures markets, risk management and price determination are central aspects. Within this framework, it's vital to employ effective risk management strategies to maintain stability for those involved in the market and the broader economy. Using futures contracts based on spot prices is recognized as a potent method to counter price fluctuations in the commodity market (Castelino, 1992). Nonetheless, the success of these strategies can differ notably among various markets, particularly between matured and emerging economies. Bekaert and Harvey (1997) and Antoniou and Ergul (1997) suggest that developing economies often face challenges like limited liquidity, sparse trading, increased price swings, and subpar hedging efficiency. A 2013 report by MCX indicates that the commodity markets in India (an emerging economy) and the US (a developed economy) show comparable hedging capabilities. Given the limited research comparing emerging and developed commodity markets, this study holds significant importance.

The intricacies of energy commodity markets, with a particular emphasis on comparing the hedging efficiency of Indian and leading global commodity exchanges were analyzed (Ranjan Sahoo, 2014). It examined the MCX as a representation of the commodity market of India and the NYMEX as the standard for global commodity exchanges (Acharya et al., 2013; Horsnell et al., 1995). The research seeks to explore alternative hedging approaches and their results within these exchanges.

Natural gas and crude oil are vital components of the energy sector within the commodity market, playing a pivotal role in various economic sectors and everyday life. Given their essential contribution to industrial processes and transportation, their price fluctuations considerably influence both manufacturers and consumers (Yu, 2013). To safeguard their financial stakes amidst the uncertainties of price changes, market players seek reliable strategies. Futures contracts stand out as a valuable tool in this context, allowing investors to lock in prices for upcoming transactions. The differences in regulatory frameworks, market configurations, and behaviors of participants in diverse exchanges necessitate a thorough examination of futures contracts' effectiveness as hedging tools. This research endeavors to provide a detailed econometric review of energy commodities' hedging efficiency, encompassing both static and evolving strategies, while juxtaposing the Indian and global benchmark exchanges. By studying the enduring connections between spot and future prices and pinpointing the effectiveness and adaptability of hedging to market fluctuations, the study sheds light on the pros and cons of hedging efficiency in these markets. The findings of research studies have tangible implications for a broad spectrum of stakeholders, from market players to policymakers and industry representatives. Effective hedging approaches can result in superior risk control, improved portfolio results, and a more stable market. Policymakers can harness these insights to devise initiatives that promote the uptake of instruments that diminish risks, fostering a robust energy sector. By grasping the nuanced differences in hedging efficiencies between the Indian and global standards, investors and traders are better equipped to make informed choices and fine-tune their risk-mitigation methods.

Following this, the paper will unfold an exhaustive econometric scrutiny of energy commodities' hedging efficiency, deliberating its impact on different stakeholders, and guiding informed discussions on risk strategies amid the tightly-knit framework of global and Indian commodity exchanges.

2. LITERATURE REVIEW

Research on hedging efficiency, specifically concerning commodity products, has garnered significant interest among scholars. Numerous studies in developed economies have explored the "hedge ratio" and "hedging effectiveness" in commodity markets employing spot and futures data (Choudhry, 2004; Figlewski, 1984; Floros and Vougas, 2006a; 2006b; Myers, 1991; Myers and Thompson, 1989). However, there's a noticeable gap in the literature concerning the Indian scenario, particularly when it comes to comparisons with global benchmark exchanges (MCX, 2013; Rout et al., 2021a; Rajesh and Satya Nandini, 2020).

Methods to decide the ideal hedging ratio are a central topic in academic literature. Researchers have explored numerous approaches, each tailored to specific aims. The primary objective of hedging strategy is to reduce the variability of the hedged portfolio (Bollerslev, 1990; Ederington, 1979; Lien and Yang, 2008; Myers and Thompson, 1989).

Many studies have been undertaken to understand the dynamics of Indian and global commodity markets, focusing on evaluating different methods for determining hedging effectiveness. (Rout et al., 2021b) explored how successful the Indian commodity futures market has been in its roles of price discovery and effective hedging. To gauge hedging efficacy, several initial tests need to be carried out (Benada, 2017; Bhatia, et al., 2018; Lien et al., 2002). One key element is the Johansen co-integration test, which is crucial for identifying a long-term relationship in data and subsequently an effective hedging strategy. (Horsnell et al., 1995) point out that this long-term relationship isn't necessarily always positive; even negative results can provide valuable insights. A positive relationship suggests investors should adopt opposing positions in spot and futures markets. Conversely, a negative correlation implies investors should maintain consistent positions in both markets, either buying or selling. Furthermore, (Tejeda and and Feuz, 2014) examined the efficiency of ideal dynamic hedging for commodities, finding it to have superior efficiency relative to constant hedging analysis.

Selecting the optimal hedging strategy from a range of available methods has been a central focus for many scholars (Floros and Vougas, 2006a). The effectiveness of hedging in Greek stock index funds was examined using an array of econometric tests to pinpoint the strategy ensuring maximum variance reductions, with tests including OLS, VAR, VECM, and M-GARCH. Research by (Gupta et al., 2017; Halkos and Tsirivis, 2019; Lien and Yang, 2008; Yang and Allen, 2004) concluded that among the four techniques - OLS, ECM, VECM, M-GARCH - the constant hedging methods of OLS, VAR, and VECM yielded the most substantial hedging ratios. Meanwhile, the dynamic hedge analyzed using M-GARCH, as studied by (Bandhu Majumder, 2022; Ranjan Sahoo, 2014), showed the highest variance reduction. Further research (Deloitte and MCX, 2018; MCX, 2013, 2019) has shown that India's hedging effectiveness stands on equal footing with international commodity exchanges.

3. RESEARCH MATERIALS AND METHODS

This study aims to evaluate the long-run relationship and the hedging efficiency of the Indian commodity market in comparison to advanced commodity markets, specifically for energy commodities like Crude Oil and Natural Gas. In the context of the Indian market, the Multi Commodity Exchange (MCX) serves as the representative since it accounts for over 96% of India's trading activity. On the other hand, "The New York Mercantile Exchange" (NYMEX) in the USA is used as the benchmark commodity market for this analysis. Hedging efficiency can be categorized into two types: Constant hedging efficiency and time-varying hedging efficiency. The former is determined through methods like "Ordinary Least Square Regression", "Vector Auto Regression", and “Vector Error Correction Model”, while the latter is gauged using the “Multivariate Generalized Autoregressive Conditional Heteroskedasticity” (MGARCH) model.

3.1. Research Design

The “research design” section outlines the methodology employed in this study. The research relies on secondary data sources. Data on spot and future prices of energy commodities were sourced from the MCX portal for India, while data related to the NYMEX in the USA was gathered from Bloomberg. The study encompassed daily opening and closing prices of both the spot and futures prices of the selected commodities. To assess the hedging efficiency of energy commodities in India and advanced markets returns were analyzed. Descriptive statistics were utilized to establish the central tendency, dispersion, and normality of the spot and future price series. The series’ central tendency was deduced from its mean, while its dispersion was gauged using standard deviation. Normality was assessed through skewness, kurtosis, and the Jarque-Bera test. To check the normality of the acquired data, “the Augmented Dickey-Fuller” (ADF) test was applied. Before this, the series’ nature was visually inspected to ascertain if it represented an intercept, a trend, or both. Depending on the results regarding the stationarity of the series, appropriate statistical tools were chosen. Johansen’s co-integration test was then employed to identify long-term relationships of the energy commodities in both India and advanced markets.

3.2. Data Employed

The research utilizes secondary data sources. Information like the opening and closing prices of the spot and futures markets for energy commodities was sourced from the MCX website for the Indian context and from Bloomberg for the NYMEX market. The data collection spans from April 1st, 2016 to September 30th, 2022.

4. RESULTS

Descriptive statistics convey information about the nature of the data and provide a better understanding of the data. “Mean, standard deviation, skewness, kurtosis, and normality” are computed for returns of spot and future prices of energy commodity products.

Descriptive statistics for the returns from future and spot price data series of energy commodities, specifically crude oil and natural gas, traded on MCX are provided (Table 1). The results highlight a positive skewness for returns from these commodities’ future and spot price series. This means that the returns for both crude oil and natural gas have a pronounced right tail, or in other words, they exhibit more frequent large positive returns than negative ones. The kurtosis values point out that the returns from the future and spot price series of crude oil are leptokurtic, signifying a distribution with fatter tails and a sharper peak compared to a normal distribution since the kurtosis values surpass 3. Given that the Jarque-Bera values for the returns of the future and the spot price series of both crude oil and natural gas traded on MCX are below 0.05, it can be inferred that these returns are not normally distributed. Thus, the analyzed data sets demonstrate non-linear dynamics and don’t align with the characteristics of a normal distribution.

Table 2 provides the descriptive statistics for the returns from future and spot price data series of energy commodities, specifically crude oil and natural gas, traded on NYMEX. The analysis shows that returns from both future and spot price series for these commodities are positively skewed, meaning that there’s a tendency for more significant positive deviations from the mean. Consequently, the returns for both crude oil and natural gas in NYMEX exhibit a pronounced right tail. The kurtosis values for these series surpass 3, indicating that the distributions of returns from the future and spot price series of both crude oil and natural gas are leptokurtic. This suggests that these distributions have thicker tails and a more pointed peak compared to a standard normal distribution. Using the Jarque-Bera test, a standard measure

Table 1: Descriptive statistics of energy commodity products traded in MCX

Particulars	Crude oil		Natural gas	
	Spot	Future	Spot	Future
Mean	4273.596	4284.885	238.7136	237.8426
Median	3911.007	3909.517	194.2385	194.9107
Maximum	9509.034	9523.037	3343.752	770.2370
Minimum	885.2345	935.5870	110.0966	116.6558
Std. Dev.	1503.825	1493.031	145.8961	124.9616
Skewness	1.286693	1.305367	7.210625	2.322008
Kurtosis	4.573422	4.562483	127.5187	8.021401
Jarque-Bera	631.5509	642.6102	1090736.	3247.406
Probability	0.000000	0.000000	0.000000	0.000000

Data source: MCX

Table 2: Descriptive statistics of energy commodities traded in NYMEX

Particulars	Crude oil		Natural gas	
	Spot	Future	Spot	Future
Mean	58.83973	58.85662	2.313004	2.314069
Median	55.54601	55.52513	1.877961	1.881804
Maximum	122.7348	123.8057	8.715537	8.809180
Minimum	−37.14448	−11.71679	0.404402	0.328194
SD	18.44113	18.37549	1.528287	1.528274
Skewness	0.866117	0.929804	2.157018	2.154802
Kurtosis	4.636891	4.406316	7.545587	7.534199
Jarque-Bera	401.1532	383.9080	2773.674	2763.673
Probability	0.000000	0.000000	0.000000	0.000000

Data source: Bloomberg

Table 3: Results of ADF test for energy commodities traded in MCX

Commodity	Type	t	Critical value	P-value*
Crude oil	Spot	−30.87	−3.43	0.000
	Future	−30.92	−3.43	0.000
Natural gas	Spot	−21.78	−3.43	0.000
	Future	−40.65	−3.43	0.000

Source: Computed, *Significant at a 1% significance

Table 4: ADF test for energy commodities traded in NYMEX

Commodity	Type	t	Critical value	P-value*
Crude oil	Spot	−36.50	−3.43	0.000
	Future	−32.96	−3.43	0.000
Natural gas	Spot	−36.02	−3.43	0.000
	Future	−53.42	−3.43	0.000

Source: Computed

for assessing data normality, it's evident that the returns for the future and the spot price series for both commodities are below 0.05. This signifies that the distributions of these returns are not consistent with a normal distribution. In summary, the returns data for crude oil and natural gas traded on NYMEX display non-linear dynamics and do not adhere to a normal distribution pattern.

The stationary of the series considered for the study has been checked using the ADF Test and the results of ADF are presented below.

The results of the ADF as shown in Tables 3 and 4 indicate that returns of future and spot price series of energy commodities such as crude oil and natural gas are integrated at D (1) at a 1% level of significance.

4.1. Analysis of Long-run Relationship

Johansen's co-integration test is a widely used method to identify long-term relationships between the chosen commodities, especially when the targeted group of time series is non-stationary at their levels. In this study, the future and spot prices of base metals, including aluminium, copper, nickel, and zinc, weren't stationary at their levels. Similarly, the future and spot prices of precious metals like gold and silver also displayed non-stationary characteristics at their levels. Given these conditions, Johansen's co-integration test was applied to determine the long-term relationship between the future and spot prices of the selected commodities. Introduced by Soren Johansen in 1988, this test aimed to rectify the shortcomings of the Engel and Granger co-integration methodology. The hypotheses for Johansen's co-integration test are:

H_0: No long-term co-integration exists (R=0).

H_1: A long-term co-integration is present (R=1).

Before performing the test, the appropriate lag length for the Johansen co-integration is selected using Vector Auto Regression (VAR) lag length criteria. In this particular study, the required lag length was determined using the VAR Schwarz Information Criteria (SIC) (Bouri et al., 2017).

P-values of Johansen's trace statistics and P-values of maximum Eigenvalue statistics indicate that null hypotheses have been rejected at a 5% level of significance (Tables 5 and 6). Hence, it can be deduced that enduring connections exist between forthcoming and current prices of crude oil and natural gas traded on MCX and NYMEX.

4.2. Constant Hedging Analysis

In the OLS regression, the focus is on regressing the returns of the spot price (dependent variable) against the returns of future prices (independent variable). This is done because understanding how spot and future prices interact is crucial for effective hedging. In essence, the objective is to conduct a linear regression that elucidates the connection between alterations in future prices and alterations in spot prices. "The Minimum-Variance Hedge Ratio" is equivalent to the incline coefficient derived from this OLS regression (Rajesh, 2023). It is calculated by dividing "the covariance of spot prices and future prices by the variance of future prices". The efficiency of the hedge is measured by the R-square value of the OLS regression. This value reflects how well the regression equation accounts for the variability in the dependent variable based on changes in the independent variable. The OLS regression equation is provided below.

$$\Delta R_{S,t} = \alpha + H\Delta R_{Ft} + \varepsilon_t$$

Where ΔR_{St} and ΔR_{Ft} are spot and futures price changes, the slope coefficient H is the ideal hedge ratio and ε_t is the error term in the OLS equation.

The hedge ratio of MCX is a larger one (1.005) than the hedge ratio of NYMEX (1.002). The hedging efficiency of the crude oil is higher in NYMEX, USA (99.8%) than MCX, India (99.5%) (Table 7).

The hedge ratio of NYMEX is a larger one (0.999) than the hedge ratio of MCX (0.984). The hedging efficiency of natural gas is higher in NYMEX, USA (99.9%) than MCX, India (71.0%) (Table 8).

VAR is commonly utilized for predicting a set of interconnected time series and for examining how unforeseen disruptions

Table 5: Johansen's co-integration test

Crude oil	Vector (r)	Trace statistics		Max-Eigen statistics		Result
		λ trace	P-value	λ max	P-value	
MCX	H_0: r=0	223.17	0.000	221.37	0.000	Co-integration exists
	H_1: r≥1	1.7917	0.180	1.7917	0.180	
NYMEX	H_0: r=0	309.54	0.000	306.52	0.000	Co-integration exists
	H_1: r≥1	3.0182	0.082	3.8414	0.082	

Source: Computed

Table 6: Johansen's co-integration test

Natural gas	Vector (r)	Trace statistics		Max-Eigen statistics		Result
		λ trace	P-value	λ max	P-value	
MCX	H_0: r=0	300.80	0.000	300.16	0.000	Co-integration exists
	H_1: r≥1	0.6368	0.424	0.6368	0.424	
NYMEX	H_0: r=0	273.26	0.000	271.31	0.000	Co-integration exists
	H_1: r≥1	1.9516	0.162	1.9516	0.162	

Source: Computed

Table 7: OLS regression model estimates

Particulars	MCX crude oil	NYMEX crude oil
α	−33.10	−0.1837
β (Hedge Ratio)	1.005	1.002
R^2	0.995	0.998

Source: Computed

Table 8: OLS regression model estimates

Particulars	MCX natural gas	NYMEX natural gas
α	4.653	−0.0002
β (Hedge Ratio)	0.984	0.999
R^2	0.710	0.999

Source: Computed

dynamically influence the array of variables. The VAR methodology circumvents the necessity for structural modeling by considering each endogenous variable within the system as reliant on past values of all endogenous variables. Opting for a bivariate VAR Model proves advantageous over simple Ordinary Least Squares (OLS) estimation, as it resolves issues related to autocorrelation among errors and treats futures prices as an inherent variable. This VAR model is depicted in the following manner:

$$R_{st} = \alpha_s + \sum_{t=1}^{k} \beta_{St} R_{St-i} + \sum_{j=1}^{l} \gamma_{Fj} R_{Ft-j} + \varepsilon_{st}$$

$$R_{Ft} = \alpha_F + \sum_{t=1}^{k} \beta_{Ft} R_{Ft-i} + \sum_{j=1}^{l} \gamma_{Sj} R_{st-j} + \varepsilon_{st}$$

The error terms in the equations, ε_{st}, and ε_{ft} are independently identically distributed (IID) random vectors.

The hedge ratio (HR) is computed using the following equation.

$$\text{HR} = \frac{\sigma_{sf}}{\sigma^2 f}$$

Hedging effectiveness (HE) is expressed as given below. Hedging effectiveness is defined as the difference in variances of unhedged portfolios and hedged portfolios over the variance of the unhedged portfolio.

$$\text{HE} = \frac{Var(U) - Var(H)}{Var(U)}$$

Vector Auto Regression (VAR) is applied to overcome the limitations of OLS regression in determining the HR and HE of spot and future price returns of the commodities considered for the study. VAR estimates the HR and HE of Energy Commodities in MCX India and NYMEX, USA are presented below:

VAR estimates the HR and HE of crude oil traded in MCX are presented in Tables 9 and 10. The hedge ratio of crude oil traded in MCX is 0.878. Hedging efficiency is estimated as U – H divided by U. Similarly, the hedging efficiency of MCX is 98.7%.

Table 9: Estimates of the VAR model for MCX crude oil

Particulars	MCX crude oil (Spot)	Particulars	MCX crude oil (Future)
α	−21.6529	α	21.5133
β_1 (Coefficient of future return)	0.0345	β_1 (Coefficient of spot return)	0.9041
β_2	0.1384	β_2	−0.2169
γ_1 (Coefficient of spot return)	0.9041	γ_1 (Coefficient of future return)	0.0345
γ_2	−0.2169	γ_2	0.1384

Source: Computed

Table 10: Estimation of hedge ratio (HR) and hedging efficiency (HE) for crude oil in MCX

Particulars	MCX crude oil
Akaike information criterion	23.6624
Schwarz criterion	23.6950
Covariance	0.000583
Variance (ε_f)	0.000664
Variance (ε_s)	0.000628
Hedge ratio	0.878
The variance of Unhedged Portfolio (U)	0.000628
The variance of Hedged Portfolio (H)	0.00000764
Hedging efficiency (HE)	0.987

Source: Computed

Table 11: Estimates of the VAR model for NYMEX crude oil

Particulars	NYMEX crude oil (Spot)	Particulars	NYMEX crude oil (Future)
α	0.0449	α	0.1851
β_1 (Coefficient of future return)	−0.6779	β_1 (Coefficient of spot return)	1.7311
β_2	−0.0964	β_2	0.1371
γ_1 (Coefficient of spot return)	1.7311	γ_1 (Coefficient of future return)	−0.6779
γ_2	0.1371	γ_2	−0.0964

Source: Computed

Alpha score is the value of the intercept and β is the value of the coefficient of the independent variable.

VAR estimates, hedge ratio, and hedging efficiency of crude oil traded in NYMEX are presented in Tables 11 and 12. The hedge ratio of crude oil traded in NYMEX is 0.730. Hedging efficiency is estimated as U – H divided by U. Similarly, the hedging efficiency of NYMEX is 90.7%.

VAR estimates, hedge ratio, and hedging efficiency of natural gas traded in MCX are presented in Tables 13 and 14. The hedge ratio of natural gas traded in MCX is 0.642. Hedging efficiency is estimated as U – H divided by U. Similarly, the hedging efficiency of MCX is 95.6%.

VAR estimates, hedge ratio, and hedging efficiency of natural gas traded in NYMEX are presented in Tables 15 and 16. The hedge ratio of natural gas traded in NYMEX is 0.694. Hedging efficiency is estimated as U – H divided by U. Similarly, the hedging efficiency of NYMEX is 81.1%.

When two prices are co-integrated over the long term, the suitable analytical technique to employ is the VECM. This model is designed to deal with the existence of serial correlation among residuals and is proficient in capturing both immediate and persistent connections between current and future returns. In cases where the series of futures and spot prices demonstrate co-integration, the formulation of the VECM for the series can be expressed as follows:

$$R_{st} = \alpha_s + \sum_{t=1}^{k} \beta_{si} R_{s,t-i} + \sum_{i=1}^{k} \gamma_{s,j} R_{f,t-i} + \eta_s E\alpha_{t-1} + \varepsilon_{st}$$

$$R_{f,t} = \alpha_f + \sum_{t=1}^{k} \beta_{fi} R_{s,t-i} + \sum_{i=1}^{k} \gamma_{f,j} R_{f,t-i} + \eta_f E\alpha_{t-1} + \varepsilon_{ft}$$

$$E\alpha_{t-1} = S_{t-1} - (a + bF_{t-1})$$

Where β_{si}, β_{fi} γ_{fi}, η_{fi} are VECM parameters and α_s and α_f indicate constant terms in the equation. $E\alpha_{t-1}$ represents the lag-one error correction term.

The application of the VECM enhances the rationale for establishing the HR and assessing the HE concerning the returns of spot and future prices for the examined commodities. The study presents VECM-derived estimations, hedge ratios, and hedging efficiencies for crude oil trading on MCX, showcased in Tables 17 and 18. Specifically, the hedge ratio determined for crude oil trading on MCX stands at 0.878, accompanied by a notable hedging efficiency of 98.7%.

Table 12: HR and HE for crude oil in NYMEX

Particulars	NYMEX crude oil
Akaike information criterion	6.0635
Schwarz criterion	6.0956
Covariance	0.0000687
Variance (ε_f)	0.000094
Variance (ε_s)	0.000069
Hedge ratio	0.730
U	0.000069
H	0.00000638
HE	0.907

Source: Computed

Table 13: Estimates of the VAR model for MCX natural gas

Particulars	MCX natural gas (Spot)	Particulars	MCX natural gas (Future)
α	4.4087	α	06701
β_1 (Coefficient of future return)	−0.0005	β_1 (Coefficient of spot return)	1.1339
β_2	0.0006	β_2	−0.1420
γ_1 (Coefficient of spot return)	1.1339	γ_1 (Coefficient of future return)	−0.0005
γ_2	−0.1420	γ_2	0.0006

Source: Computed

Table 14: HR and HE for natural gas in MCX

Particulars	MCX natural gas
Akaike information criterion	19.1257
Schwarz criterion	19.1583
Covariance	0.000631
Variance (ε_f)	0.000982
Variance (ε_s)	0.000836
Hedge ratio	0.642
U	0.000836
H	0.00003627
HE	0.956

Source: Computed

Table 15: Estimates of the VAR model for NYMEX natural gas

Particulars	NYMEX natural gas (Spot)	Particulars	NYMEX natural gas (Future)
α	0.0134	α	0.0134
β_1 (Coefficient of future return)	−0.4081	β_1 (Coefficient of spot return)	1.3849
β_2	−0.0265	β_2	0.2838
γ_1 (Coefficient of spot return)	1.3849	γ_1 (Coefficient of future return)	−0.4081
γ_2	0.2838	γ_2	−0.0265

Source: Computed

Table 16: HR and HE for natural gas in NYMEX

Particulars	NYMEX natural gas
Akaike information criterion	−4.2142
Schwarz criterion	−4.1821
Covariance	0.000523
Variance (ε_f)	0.000753
Variance (ε_s)	0.000679
Hedge ratio	0.694
U	0.000679
H	0.0001283
HE	0.811

Source: Computed

Table 17: Estimates of the VECM model for MCX crude oil

Particulars	MCX crude oil (Spot)	Particulars	MCX crude oil (Future)
α	1.8500	α	2.2114
β_1 (Coefficient of future return)	−0.0162	β_1 (Coefficient of spot return)	0.3499
β_2	−0.0241	β_2	0.1794
γ_1 (Coefficient of spot return)	0.3499	γ_1 (Coefficient of future return)	−0.0162
γ_2	0.1794	γ_2	−0.0241

Source: Computed

Table 18: HR and HE for crude oil in MCX

Particulars	MCX crude oil
Akaike information criterion	23.6404
Schwarz criterion	23.6861
Covariance	0.000662
Variance (ε_f)	0.000546
Variance (ε_s)	0.000525
Hedge ratio	0.878
U	0.000525
H	0.00000659
HE	0.987

Source: Computed

VECM estimates, hedge ratio, and hedging efficiency of crude oil traded in NYMEX are presented in Tables 19 and 20. The hedge ratio of crude oil traded in NYMEX is 0.808, and the hedging efficiency of crude oil traded in NYMEX is 95.4%.

VECM estimates, hedge ratio, and hedging efficiency of natural gas traded in MCX are presented in Tables 21 and 22. The hedge ratio of natural gas traded in MCX is 0.632, and the hedging efficiency of natural gas traded in MCX is 96.4%.

VECM estimates, hedge ratio, and hedging efficiency of natural gas traded in NYMEX are presented in Tables 23 and 24. The hedge ratio of natural gas traded in NYMEX is 1.186, and the hedging efficiency of natural gas traded in NYMEX is 86.1%.

As evidenced by the data presented in Tables 17-24, the analysis conducted using the VECM on spot and future returns of commodity products, specifically crude oil, and natural gas, traded on the MCX and NYMEX markets, reveals notable hedge ratios and hedging efficiency for both commodities.

Table 19: Estimates of the VECM model for NYMEX crude oil

Particulars	NYMEX crude oil (Spot)	Particulars	NYMEX crude oil (Future)
α	0.0284	α	0.0284
$β_1$ (Coefficient of future return)	0.2033	$β_1$ (Coefficient of spot return)	−0.2387
$β_2$	0.1584	$β_2$	−0.2500
$γ_1$ (Coefficient of spot return)	−0.2387	$γ_1$ (Coefficient of future return)	0.2033
$γ_2$	−0.2500	$γ_2$	0.1584

Source: Computed

Table 20: HR and HE for crude oil in NYMEX

Particulars	NYMEX crude oil
Akaike information criterion	6.0594
Schwarz criterion	6.1044
Covariance	0.0000986
Variance ($ε_f$)	0.000122
Variance ($ε_s$)	0.000188
Hedge ratio	0.808
U	0.000188
H	0.00000851
HE	0.954

Source: Computed

Table 21: Estimates of the VECM model for MCX natural gas

Particulars	MCX natural gas (Spot)	Particulars	MCX natural gas (Future)
α	0.2311	α	0.3274
$β_1$ (Coefficient of future return)	0.0001	$β_1$ (Coefficient of spot return)	0.1438
$β_2$	0.0001	$β_2$	0.1228
$γ_1$ (Coefficient of spot return)	0.1438	$γ_1$ (Coefficient of future return)	0.0001
$γ_2$	0.1228	$γ_2$	0.0001

Source: Computed

4.3. Dynamic Hedging Analysis

The time series data depicting the returns of spot and future prices exhibit a volatility structure characterized by varying levels of heteroscedasticity, known as the Auto-Regressive Conditional Heteroscedasticity (ARCH) effect. Considering the existence of the "ARCH" effect within the returns of spot and futures prices, as well as their dynamic combined distribution, the precise calculation of HRs and HEs could be jeopardized. To tackle this issue, the "Multivariate Generalized Autoregressive Conditional Heteroskedasticity" (MGARCH) model becomes relevant. MGARCH considers the "ARCH" effect in the time series data and calculates a hedge ratio that adjusts dynamically over time, taking into consideration the evolving conditions of the data. This approach enables a more suitable and nuanced assessment of the hedging strategy in the context of evolving volatility patterns.

Table 22: HR and HE for natural gas in MCX

Particulars	MCX natural gas
Akaike information criterion	19.1320
Schwarz criterion	19.1778
Covariance	0.000539
Variance ($ε_f$)	0.000852
Variance ($ε_s$)	0.000826
Hedge ratio	0.632
U	0.000826
H	0.00002894
HE	0.964

Source: Computed

Table 23: Estimates of the VECM model for NYMEX natural gas

Particulars	NYMEX natural gas (Spot)	Particulars	NYMEX natural gas (Future)
α	0.0036	α	0.0038
$β_1$ (Coefficient of future return)	−0.4332	$β_1$ (Coefficient of spot return)	0.1113
$β_2$	−0.3801	$β_2$	0.3025
$γ_1$ (Coefficient of spot return)	0.1113	$γ_1$ (Coefficient of future return)	−0.4332
$γ_2$	0.3025	$γ_2$	−0.3801

Source: Computed

Table 24: HR and HE for natural gas in NYMEX

Particulars	NYMEX natural gas
Akaike information criterion	−4.2217
Schwarz criterion	−4.1768
Covariance	0.000853
Variance ($ε_f$)	0.000719
Variance ($ε_s$)	0.000644
Hedge ratio	1.186
U	0.000644
H	0.0000893
HE	0.861

Source: Computed

MGARCH estimates, hedge ratio, and hedging efficiency of crude oil traded in MCX are presented in Tables 25 and 26. The hedge ratio of crude oil traded in MCX is 1.065, and the hedging efficiency of crude oil traded in MCX is 99.1%.

MGARCH estimates, hedge ratio, and hedging efficiency of crude oil traded in NYMEX are presented in Tables 27 and 28. The hedge ratio of crude oil traded in NYMEX is 0.526, and the hedging efficiency of crude oil traded in NYMEX is 94.4%.

MGARCH estimates, hedge ratio, and hedging efficiency of natural gas traded in MCX are presented in Tables 29 and 30. The hedge ratio of natural gas traded in MCX is 0.830, and the hedging efficiency of natural gas traded in MCX is 72.9%.

MGARCH estimates, hedge ratio, and hedging efficiency of natural gas traded in NYMEX are presented in Tables 31 and 32. The hedge ratio of natural gas traded in NYMEX is 1.140, and the hedging efficiency of natural gas traded in NYMEX is 88.4%.

The outcomes of the MGARCH Model analysis, as presented in Tables 25 and 32, unveil noteworthy variations in hedge ratios and hedging effectiveness over time within the realm of energy commodity products. Specifically, the spot and future returns of crude oil and natural gas, traded on the MCX and NYMEX exchanges, exhibit these significant time-varying attributes.

5. DISCUSSION

The study investigates the effectiveness of hedging strategies within both the Indian commodity market and the globally recognized

Table 25: Estimates of the MGARCH model for MCX crude oil

Particulars	MCX crude oil (Spot)	Particulars	MCX crude oil (Future)
α	27.220	α	−18.429
$β_1$ (Coefficient of future return)	0.994	$β_1$ (Coefficient of future return)	1.003
Standard Error	0.000	Standard Error	0.000
Z-Statistic	1649.16	Z-Statistic	1657.14
Significance	0.000	Significance	0.000

Source: Computed

Table 26: HR and HE for crude oil in MCX

Particulars	MCX crude oil
Akaike information criterion	10.394
Schwarz criterion	10.411
Covariance	0.000583
Variance ($ε_f$)	0.000547
Variance ($ε_s$)	0.000508
Hedge ratio	1.065
U	0.000508
H	0.00000438
HE	0.991

Source: Computed

Table 27: Estimates of the MGARCH model for NYMEX crude oil

Particulars	NYMEX crude oil (Spot)	Particulars	NYMEX crude oil (Future)
α	0.8411	α	−0.8256
$β_1$ (Coefficient of future return)	0.985	$β_1$ (Coefficient of future return)	1.014
Standard Error	0.000	Standard Error	0.000
Z-Statistic	2058.38	Z-Statistic	2195.63
Significance	0.000	Significance	0.000

Source: Computed

Table 28: HR and HE for crude oil in NYMEX

Particulars	NYMEX crude oil
Akaike information criterion	1.2419
Schwarz criterion	1.2580
Covariance	0.0000885
Variance ($ε_f$)	0.000168
Variance ($ε_s$)	0.000153
Hedge ratio	0.526
U	0.000153
H	0.00000851
HE	0.944

Source: Computed

Table 29: Estimates of the MGARCH model for MCX natural gas

Particulars	MCX natural gas (Spot)	Particulars	MCX natural gas (Future)
α	159.808	α	3.926
$β_1$ (Coefficient of future return)	0.170@	$β_1$ (Coefficient of future return)	0.985
Standard Error	0.008	Standard Error	0.078
Z-Statistic	20.847	Z-Statistic	12.593
Significance	0.000	Significance	0.000

Source: Computed

Table 30: HR and HE for natural gas in MCX

Particulars	MCX natural gas
Akaike information criterion	11.556
Schwarz criterion	11.572
Covariance	0.000651
Variance ($ε_f$)	0.000784
Variance ($ε_s$)	0.000761
Hedge ratio	0.830
U	0.000826
H	0.0002231
HE	0.729

Source: Computed

Table 31: Estimates of the MGARCH model for NYMEX natural gas

Particulars	NYMEX natural gas (Spot)	Particulars	NYMEX natural gas (Future)
α	0.0002	α	0.0019
$β_1$ (Coefficient of future return)	1.002	$β_1$ (Coefficient of future return)	0.998
Standard error	0.000	Standard error	0.000
Z-Statistic	1478.69	Z-Statistic	1504.61
Significance	0.000	Significance	0.000

Source: Computed

Table 32: HR and HE for natural gas in NYMEX

Particulars	NYMEX natural gas
Akaike information criterion	−4.3534
Schwarz criterion	−4.3374
Covariance	0.000788
Variance (ε_f)	0.000691
Variance (ε_s)	0.000683
Hedge ratio	1.140
U	0.000683
H	0.0000792
HE	0.884

Source: Computed

benchmark commodity market. The results of the ADF test for returns of future and spot price series of chosen commodities traded in MCX and NYMEX convey that they are integrated at D (1). The results of "Johansen's co-integration test" for energy commodities indicate that spot and future returns of crude oil and natural gas commodities traded in MCX and NYMEX have long-run relationships. The constant hedging efficiency was gauged using tools like OLS Regression, VAR, and VECM. The outcomes of the OLS Regression analysis conducted on energy commodities indicate that both the spot and future returns of the chosen commodities that are traded on the MCX and NYMEX exchanges, exhibit noteworthy hedge ratios and hedging efficiency. These significant findings hold valuable implications for market participants and investors, enabling them to handle price-related risks, enhance portfolio diversification, and make informed choices. Moreover, these findings have broader implications for energy sector policies, instilling greater confidence in the utilization of futures contracts for risk management purposes. Traders and investors can leverage these findings to develop effective hedging strategies that can be tailored to accommodate shifts in market circumstances.

The outcomes of the Vector Auto Regression (VAR) model applied to energy commodity products highlight the presence of significant hedge ratios and hedging effectiveness in both crude oil and natural gas spot and future returns traded on the MCX and NYMEX exchanges. This underscores the viability of employing futures contracts as an efficacious approach for traders and investors to mitigate price risks associated with these energy commodity products. These findings offer increased confidence to market participants, encompassing producers, and consumers, in utilizing the futures market to manage risks. By engaging in hedging through futures contracts, they can safeguard themselves against price fluctuations, leading to reduced overall portfolio volatility. The implications of these findings extend to policymakers as well. They can utilize this information to advocate for the adoption of futures markets as a strategic tool for curbing commodity price risks within the energy sector. By promoting such risk management strategies, policymakers have the potential to enhance stability and resilience within the energy market.

The VECM results indicate that investors can effectively navigate price risks associated with crude oil and natural gas through the utilization of futures contracts. Market participants stand to benefit from reduced overall price volatility achieved through the implementation of these contracts, thus fostering increased confidence in the market. The advantages associated with the adoption of futures contracts for risk mitigation could extend to the realm of policy. Decision-makers might consider promoting their utilization to cultivate greater stability within the energy market. The study also underscores the importance of further exploration in this domain, offering valuable insights that can shape future strategies aimed at mitigating risks.

The findings of MGARCH offer investors the capacity to dynamically adapt their hedging positions, thereby enhancing the efficacy of risk management strategies as market conditions evolve. Additionally, these insights contribute to the refinement of portfolio performance and the formulation of well-informed trading decisions. The results also shed light on the potential advantages of curbing market volatility and suggest pathways for devising effective risk management policies within the energy market. Moreover, the research identifies areas that merit further exploration. Delving deeper into the dynamics of hedging and its implications for energy commodity markets could yield a more comprehensive understanding of these intricate processes and their broader ramifications.

6. CONCLUSION

The research explores how effective hedging strategies are in the Indian commodity market and the internationally recognized benchmark commodity market. The study concentrates on energy commodities such as crude oil and natural gas, and it uncovers enduring connections between the current prices and future prices of these commodities. By utilizing various models like OLS, VAR, VECM, and MGARCH, the study produces reliable and noteworthy fixed hedge ratios for crude oil and natural gas in both the MCX and NYMEX markets. The MGARCH model stands out for estimating time-varying hedge ratios, reflecting the adaptability of hedging positions based on evolving market dynamics.

The outcomes of these models underline the viability of futures contracts for effectively mitigating price risks within energy commodity markets. This approach proves particularly valuable for managing exposure to price volatility, contributing to more stable financial outcomes. Johansen's co-integration test affirms the existence of long-term connections between spot and future prices of crude oil and natural gas in both the MCX and NYMEX markets. This finding implies that futures contracts hold potential for portfolio diversification and risk management. By integrating futures contracts into investor portfolios, the potential for improved risk-adjusted returns and overall portfolio performance becomes evident. The observed hedging efficiencies on MCX and NYMEX demonstrate varying degrees of effectiveness in reducing price risk using futures contracts. This information can influence market participants' preferences for exchanges, potentially enhancing liquidity and efficiency within energy commodities markets. These findings hold implications for policymakers as well.

Policymakers can formulate and implement measures to encourage the adoption of futures contracts for risk management in the energy market. By promoting hedging strategies, they contribute to market stability and mitigate the impact of price volatility on various market participants. This, in turn, enables more informed decision-making, better risk management, and an overall enhancement of efficiency and stability within energy commodity markets. The study also highlights avenues for future research, including expanding the analysis to encompass other global energy commodity markets and employing diverse econometric models to reinforce and validate the present findings.

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