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Causal Relationship Between Spot Price & Future Derivative Prices – Case of Crude Oil

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This research aims to examine the theoretical and empirical connections between current and future crude oil prices using cutting-edge econometric methods. It surveys existing literature and theoretical frameworks, exploring theories like arbitrage, market efficiency, and risk management techniques. The study then conducts a comprehensive empirical investigation using a large dataset, including data from extreme market volatility and other significant events in the financial world. Time series econometric methods like Granger causality tests, Vector Autoregression (VAR), and impulse response functions are used to capture the causal connections between spot and future prices. The analysis uncovers insights on lead-lag dynamics, volatility spillovers, and both short- and long-term causal impacts between current and future crude oil prices. Market fundamentals, geopolitical developments, and speculative behavior are also highlighted as influencing the causal relationships studied. The findings shed light on the link between future and current crude oil prices and provide valuable insights into the factors influencing these prices. This paper examines the relationship between future and spot crude oil prices, offering valuable insights for energy policy, risk management, hedging techniques, investment allocation, and governmental interventions.

1-Introduction:

Futures trading has a significant impact on the economic framework by influencing prices through the interplay between production and consumption. However, it is crucial to consider natural origins rather than artificial creations. Zhang and Wong (2023) A comparative analysis is conducted between oil and its associated corporations in contrast to the broader market, oil-consuming industries, and firms involved in the production of oil substitutes. This study objects to elucidate the divergent effects of oil price uncertainty on the stock liquidity of large and small enterprises Speculative production and consumption can cause disruptions within the real economy. Future marketplaces aim to generate wealth, but optimal pricing in speculative trading is not possible. Jin Boon Wong , Qin Zhang (2022) Multiple indicators suggest that an increase in the Cash Reserve Ratio (CRR) has a significantly adverse impact on the stock price of smaller and less liquid companies, which are often not included in the S&P 500 index. Moosa and Al-Loughani (1995) found that individuals involved in acquisitions and gambling activities played a significant effect in finding futures and spot prices. v Durga, S., & Podile, V (2020) The introduction of derivatives has led to the emergence of many financial products that cater to the requirements of investors. Stock futures and stock options have proven to be beneficial tools for investors in economy. A comprehensive methodology is needed to account for diverse outcomes. Crude oil is chosen as a representative asset to assess the extent of damage inflicted. Crude oil futures trading has higher costs and global fluctuations, affecting both the cost of living and production expenses. The establishment of a commercialized spot market is crucial for assessing pricing efficiency, as stakeholders like shareholders, manufacturers, distributors, and purchasers participate directly. Future markets can quickly incorporate novel information into price fluctuations without concerns related to transportation and storage expenses. The objective of trading plays a crucial role in price determination, but global futures markets are dominated by speculators who lack the ability to represent real-world production and demand dynamics.

According to Marwa Talbi, Christian de Peretti and Lotfi Belkacem (2020) The pricing of futures contracts serve as a means of disseminating information to all participants in the economy. Producers sometimes rely on futures contract prices as a means of mitigating risks when making supply decisions. Similarly, physical traders may utilize futures contracts as a benchmark for determining the pricing of their goods. According to the market efficiency theory. Theoretically, it is assumed that both futures and spot prices will rapidly assimilate new information, given they both reflect the aggregate value of the underlying assets. Nevertheless, it is important to acknowledge that commodities markets do display faults in actuality. Frictional factors, such as transaction costs and asynchronous trading, contribute to differential responsiveness of markets to new information flows, leading to the emergence of a lead-lag connection between them. Silvapulle and Moosa (1999) propose that market prices demonstrate a delayed response due to the temporal requirements of spot trade barriers' execution. Bekiros and Diks (2008) analysed the causal relationship between current crude oil prices in developed and emerging markets, using panel regression techniques to analyze the relationship between futures and spot rates. Legal

limitations on futures trading in countries like India reinforce the assertion that futures prices exert a greater influence on spot pricing. Jin Boon Wong ,Qin Zhang (2022) Multiple indicators suggest that an increase in the Cash Reserve Ratio (CRR) has a significantly adverse impact on the stock price of smaller and less liquid companies, which are often not included in the S&P 500 index.

Futures in spot pricing may be flawed due to speculative activities, but it's crucial to recognize that crude oil market fluctuations are not directly linked to price discovery. Causality analysis can assess the relationship between spot and future petroleum product prices on casualties. Management of crude oil prices relies on exchange rates, while speculators could also influence price determination.

2-Literature Review

Stock market indices should reflect the equivalent value of commodities, excluding time value. However, if this is not the case, trading would be employed to rectify any discrepancies. There is considerable variation in the findings of studies, particularly when examining the impact of futures on market prices, especially in relation to crude oil. Futures trading offers a more accessible avenue for acquiring new knowledge due to the straightforward nature of transactions, the availability of leverage, and the inclusion of derivatives trading.

According to Qin Zhang, Jin Boon Wong (2023) A comparative analysis is conducted between oil and its associated corporations in contrast to the broader market, oil-consuming industries, and firms involved in the production of oil substitutes. This study objects to elucidate the divergent effects of oil price uncertainty on the stock liquidity of large and small enterprises. Garbade and Silber (1983) introduced a price finding mechanism centered around futures contracts, determining that future prices were the primary driver of trade flows. Several investigations have discovered that causality exhibits a bi-directional relationship, with cash and futures prices having a mutual influence. Quan (1992) suggests spot prices incorporate information regarding exchange rates, while exchange rates do not encompass any data pertaining to spot prices. Schwarz and Szakmary (1994) aimed to examine the causal connection between spot and futures commodity prices, revealing the presence of bidirectional causation or a feedback loop between the two variables. Moosa and Al-Loughani (1995) found that individuals involved in acquisitions and gambling activities played a significant effect in finding futures and spot prices.v Durga, S., & Podile, V (2020) The introduction of derivatives has led to the emergence of many financial products that cater to the requirements of investors. Stock futures and stock options have proven to be beneficial tools for investors in India. The National Stock Exchange (NSE) and the Bombay Stock Exchange (BSE) exhibit disparities in terms of the number of trades conducted. The current study also demonstrated the presence of a tenuous correlation between the two variables, indicating that they engage in distinct and disparate trading patterns.

According to Marwa Talbi,Christian de Peretti and Lotfi Belkacem (2020), the pricing of futures contracts serve as a means of disseminating information to all participants in the economy. Producers sometimes rely on futures contract prices as a means of mitigating risks when making supply decisions. Similarly, physical traders may utilize futures contracts as a benchmark for determining the pricing of their goods. According to the market efficiency theory.Theoretically, it is assumed that both futures and spot prices will rapidly assimilate new information, given they both reflect the aggregate value of the underlying assets. Nevertheless, it is important to acknowledge that commodities markets do display faults in actuality. Frictional factors, such as transaction costs and asynchronous trading, contribute to differential responsiveness of markets to new information flows, leading to the emergence of a lead-lag connection between them.. Silvapulle and Moosa (1999) propose that market prices demonstrate a delayed response due to the temporal requirements of spot trade barriers' execution. Bekiros and Diks (2008) analysed the causal relationship between current crude oil prices in developed and emerging markets, using panel regression techniques to analyse the relationship between futures and spot rates. Legal limitations on futures trading in countries like India reinforce the assertion that futures prices exert a greater influence on spot pricing. Jin Boon Wong ,Qin Zhang (2022) Multiple indicators suggest that an increase in the Cash Reserve Ratio (CRR) has a significantly adverse impact on the stock price of smaller and less liquid companies, which are often not included in the S&P 500 index.

Kaufmann and Ullman (2009) and Chevallier (2010) found a tenuous causal relationship between crude oil futures and exchange rates in regions like Africa, North America, Europe, and the Middle East. Zhou and Wu (2016) found a notable relationship between CSI 300 index futures prices on the underlying spot marketplace. The divergent outcomes of the research underscore the necessity of reassessing the causal relationship between futures and spot crude oil prices through a more expansive statistical model and appropriate methodology.

3-Research Methodology:

Previous studies examined the relationship between spot prices and global oil prices using the Vector Autoregression (VAR) model and the Granger Causality Test. VAR is a logical extension of Granger Causality, combining multivariate time series and single equation models. When there is high correlation across time series, the VECM model is recommended. Analysis begins with normality assumptions and serial correlation using the Jarque-Bera test and ADF unit-root test. The Granger Causality Test has been used to establish causality, followed by VAR for optimal lag length and VECM for enduring and transitory connections between futures and spot prices.

3.1-Data Sets

The dataset analyzes commodity prices for West Texas Intermediate (WTI) crude oil, a globally recognized benchmark. The study uses 7,816 data points from January 1992 to March 6, 2023, obtained from the Energy Information Administration's website. The study includes five

discrete time series, including the initial spot rate and four additional time series representing crude oil futures pricing. Wholesale energy agreements typically have a volume of 100 barrels and durations ranging from one to four months. Despite empirical evidence establishing a causal relationship between crude oil prices and costs associated with crude oil inputs, the issue of petroleum product prices has received insufficient attention.

4-Analysis and Results

According to Chevallier (2010), sudden surprises are strategically employed to deliberately deviate future market prices from exchange rates. This is achieved through the implementation of a risk-neutral approach and adherence to fundamental principles. The conceptual relationship between spot and future is positive if the specified assumptions are true (table 2).

The forthcoming coefficient for rates should be set to one, the test statistic should ideally be zero, and the standard error for noise cancellation should have a mean of zero in this particular relationship. Nevertheless, establishing this ideal correlation proves to be challenging in speculative markets. Exploring causality may present a more effective approach. Table 1, presents the characterization statistics, which aim to analyse the essential statistical properties of the data.

Table No 1: Descriptive Statistics

	OIL_SPOT	OIL_FUTURE_1	OIL_FUTURE_2	OIL_FUTURE_3	OIL_FUTURE_4
Mean	42.02247	42.0583	42.1658	42.23422	42.24558
Median	27.3	27.245	26.985	26.515	26.075
Maximum	144.31	144.29	144.86	145.13	145.43
Minimum	10.85	10.72	10.84	10.98	10.91
Std. Dev.	30.42658	30.22085	30.33713	30.58383	30.77439
Skewness	0.977772	0.989688	0.956633	0.943903	0.943806
Kurtosis	2.578998	2.570701	2.714791	2.677969	2.64058

All five time-series exhibit similar characteristics in their descriptive analytics, including properties such as frequency distribution, microemulsions, and deviation, among others. This approach is deemed rational as it solely takes into account short-term new agreements. As

Chevallier (2010) asserted, spot and futures values should accurately reveal the actual value of the underlying asset category. Nevertheless, the current scenario assumes the presence of causality. Regression analysis can be used to strengthen this conclusion by examining the degree to which various series are moving together, prior to explicitly confirming causation.

Table No 2: Correlation & t statistics

	OIL_SPOT	OIL_FUTURE_1	OIL_FUTURE_2	OIL_FUTURE_3	OIL_FUTURE_4
OIL_SPOT	1				
OIL_FUTURE_1	0.999931	1			
	7044.034	-----			
OIL_FUTURE_2	0.999585	0.999749	1		
	2753.263	3334.703	-----		
OIL_FUTURE_3	0.998767	0.998984	0.999701	1	
	1764.799	1948.645	4424.202	-----	
OIL_FUTURE_4	0.997889	0.998165	0.999441	0.999872	1
	1355.815	1454.198	2435.298	5312.992	-----

There exists a considerable interrelationship among all components, as evidenced by the predictor variables being in close proximity to one another. Furthermore, all correlations have statistical significance based on the t-statistics, as depicted in the aforementioned chart. This implies that the movement of all five data series exhibits a high degree of proximity. This suggests that there exists a causal relationship between them, however the causality may be either one-sided or capable of being reversed. Before testing the Granger Causation test to ascertain the nature and impact on economic growth, it is imperative to thoroughly scrutinize the data for the analysis hypotheses that underlie the reliability of the correlation analysis and VAR.

Table No 3: Pairwise Granger Causality Tests

Null Hypothesis:	Obs.	F-Statistic	Prob.
D_FUTURE_1 does not Granger Cause D_SPOT	6967	8.64325	2.00E-04
D_SPOT does not Granger Cause D_FUTURE_1		0.41443	0.6601
D_FUTURE_2 does not Granger Cause D_SPOT	6967	15.6337	2.00E-07
D_SPOT does not Granger Cause D_FUTURE_2		4.94309	0.0072

D_FUTURE_3 does not Granger Cause D_SPOT	6967	8.26007	0.0003
D_SPOT does not Granger Cause D_FUTURE_3		5.19617	0.0056
D_FUTURE_4 does not Granger Cause D_SPOT	6967	5.77774	0.0031
D_SPOT does not Granger Cause D_FUTURE_4		6.00298	2.50E-03

The investigation uncovers a unidirectional causal association between spot and one-month futures contracts, wherein only one equation has a unilateral impact. The remaining three formulas show bidirectional causality between spot and one-month market indexes. Null hypotheses (H0) are rejected at a 5% significance level, suggesting that spot prices do not have a Granger causality effect on one-month futures prices. This suggests that speculation plays a significant role in determining crude oil and petrochemical prices. However, this price supremacy is only applicable to the one-month future option and has diminished for other future options. This suggests that financial speculation has a greater influence than fundamental trade, potentially affecting the financial industry.

4.1 Vector Auto-Regression (VAR)

Autoregressive models use multiple dependent variables, similar to co-integration models. Granger Causality Analysis uses a similar strategy but examines only two elements. VAR is an extension of Granger Causality, determining legitimacy based on linearity of time series. The VECM model evaluates causality in cointegrated data sets, aiming to find an optimal lag period. The lag order for VECM is based on minimizing the value of information criterion, using statistical measures like Sequentially adjusted LR test statistic, best classification error, Akaike importance value, Schwarz reference value, and Hannan-Quinn predicted value.

Table No 4. Lag Length Selection

Information

Criterion \ Lag	0	1	2	3	4	5	6	7	8
AIC: Akaike	11.781	-0.764	-0.957	-1.028	-1.071	-1.081	-1.133	-1.114	-1.11*
SC: Schwarz	11.787	-0.729	-0.893	-0.934	-0.948	-0.93*	-0.952	-0.883	-0.870

The AIC suggests the utilization of eight delays, while the SC proposes the incorporation of five lags. The selection of the Schwarz data criterion is made in order to ensure the validity and

soundness of the model VECM research. The subsequent displays the outcomes of a Pearson correlation analysis conducted on five time-series data sets, in addition to the prevailing price of oil and four unique future contracts spanning a duration of one to four months.

Table No 5: Unrestricted Cointegration Rank Test (Trace)

No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.103203	1257.253	69.84589	1
At most 1 *	0.072655	582.3536	47.84313	0.0001
At most 2 *	0.014227	116.8422	29.77807	0
At most 3 *	0.004732	28.78318	15.48771	0.0002
At most 4	0.000373	1.068883	3.845666	0.3014

The Johansen cointegration test requires high-quality data for its application. The test results show four co-integration variables with a significance level of 0.05, indicating a long-term relationship between deciduous forests and their functions. The Maximum Eigen test also shows initial correlation among the five variables. However, conceptual difficulties arise when considering the proportionality of connections relative to size. The use of VECM model with five error-correcting components supports the presence of five panel cointegration terms.

4.2 VECM Model

Table No 6: Long term Causality, Future to Spot

	Coefficient	Std. Error	t-Statistic	Prob.
Cointegration Equation 1	-0.65954	0.073665	-8.951932	0
Cointegration Equation 2	0.564838	0.107269	5.274526	0
Cointegration Equation 3	0.387979	0.259392	1.495925	0.1337
Cointegration Equation 4	-0.401295	0.364111	-1.099778	0.2725

The primary error correction term holds significance and exhibits negative characteristics, as evidenced by the data presented in Table 1.6. The significance of the second word lies in its positive nature, whilst the fourth phrase holds significance despite its lack of negativity. The third

term, on the other hand, does not possess any significant importance and does not exhibit a pessimistic quality. Consequently, it can be deduced that there exists a singular established correlation between futures and market prices. The computed regression coefficients exhibit a value of -0.658, suggesting that around 66% of spot prices undergo correction during a single day. In alternative terms, it may be inferred that market prices require approximately one and a half days to attain long-term stability. The predictor variables utilized in a VECM model analysis were future rates, with the aim of examining bidirectional causal links in the long run. The condensed findings are presented in Table 1.7.

Table No7: Long term causality taking each of the futures contract as dependent variable

Dependent Variable	Coefficient	Std. Error	t-Statistic	Prob.
One month's Futures	-0.14702	0.072546	-2.04222	0.0311
Two month's Futures	-0.13723	0.067632	-2.04789	0.0507
Three month's Futures	-0.15217	0.065732	-2.33271	0.0296
Four month's Futures	-0.15844	0.064368	-2.48193	0.0231

Four of the 16 error correction terms show significant negative values, with spot rates closely linked to spot price. An independent VAR analysis was performed, using futures project cost stream as the dependent variable and spot price as the predictor. Lag lengths were determined using Schwarz criteria, with one-month contracts having four lag lengths and two, three, and four-month contracts having six. The validity of the findings was confirmed using the Johansen cointegration test.

The table no 8 shows no significant long-term causal relationship between future derivative and spot price, with only one error correction term showing significant magnitude. This contradicts the Granger Causality Test's bidirectional causality over two, three, and four months. The data supports the notion that spot prices are influenced by future derivatives. The VECM model analysis supports this notion, examining short-term causality through the Wald statistical test.

Table No 8: Long term causality with each of futures contract and spot prices separately

Dependent Variable	Coefficient	Std. Error	t-Statistic	Prob.
One month's Futures Contract	0.142609	0.058692	2.373328	0.0177
Two month's Futures Contract	0.028883	0.014657	1.782858	0.075
Three month's Futures Contract	0.013945	0.008098	1.313904	0.1893
Four month's Futures Contract	0.006505	0.005712	0.821199	0.4121

Table No 9: Wald Test - Short Run Causality

Hypothesis	Test Statistic	Value	Df	Probability
lags of Spot is causing Spot	Chi-square	15.24157	5	0.0147
lags of F1 is causing Spot	Chi-square	64.59171	5	0
lags of F2 is causing Spot	Chi-square	58.19897	5	0
lags of F3 is causing Spot	Chi-square	24.11464	5	0.0003
lags of F4 is causing Spot	Chi-square	4.500492	5	0.4933

The findings presented in Table no 9 demonstrate that the introduction of new values at one-month, two-month, and three-month intervals have a significant impact on short-term market prices, as well as on the temporal shifts observed in the current prices. The valuation for four-month estimated agreement is independent of the current spot pricing. However, it is imperative to thoroughly analyse the corroborating evidence for bidirectional causality in short-term

connections, specifically when utilizing the exchange rate as the control words. The analysis of little time based two-way connection is conducted in a related manner to that of long-term causation. Specifically, it involves assessing the causal relationship between the future derivative and spot price by examining them independently. In the context of long-term unilateral problem formulation, the factors that remain constant are the number of enabling the system, the duration of the lag, and the criterion. The joint Wald test was solely employed for the purpose of identifying delays, rather than delays in dependent futures contracts.

Table No 10: Short term Causality with Spot price as independent variable

Dependent Variables	Test Statistic	Value	Df	Probability
One month's Futures Contract	Chi-square	13.84016	4	0.0126
Two month's Futures Contract	Chi-square	47.57058	6	0
Three month's Futures Contract	Chi-square	37.18311	6	0
Four month's Futures Contract	Chi-square	34.33659	6	0

According to the results presented in table 2, spot prices have a significant impact on all four financial instruments in the near term. This conclusion is based on the statistical significance of all four equations. The combination of the facts from tables 9 and 10 suggests that there exists a bidirectional causality or support function between stock index prices in the short-term. The obtained results hold considerable significance as they challenge the primary assumption that crude oil spot prices are impacted by the futures market, particularly in the short term. The results obtained from the application of the VECM Model suggest that spot prices are affected by future prices over a prolonged period, although in the short term, there exists a mutually influential association for current and expected values.

5-Findings & Conclusion

This paper examines the causal relationship between futures and spot prices to understand the monetary transmission mechanism for the underlying commodity on which swaps are based. It posits that in the presence of choices, the determinants of product or service factors are mostly influenced by conjecture rather than fundamental principles. The study gathered daily pricing data

from five streaming sources, encompassing market prices for world price values and market ways different months' agreements for stock exchange.

The results indicate a bidirectional association between spot prices and one-month futures prices, as well as a correlated association between spot prices and the updated values of 2-month, 3-month, and 4-month intervals. The presence of a unidirectional causal relationship between 1-month future production levels and spot prices implies that crude oil prices are determined through speculative mechanisms. The utilization VECM model was employed in order to investigate the complexities of causation and validate the outcomes extracted from different econometrics techniques.

The research on regular crude oil prices reveals that long-term fluctuations in spot oil prices are mostly influenced by market speculation surrounding fuel or energy contracts. However, a transient feedback mechanism exists between exchange rates and the stock market. The dominance of market speculation in determining petroleum prices is evidenced by the unidirectional causality observed from the futures market to actual prices.

The practice of pricing through speculative investment banking using derivatives has detrimental effects on the real economy, including increased systemic risk and false price inflations. The inclusion of speculative trading and reliance on conjecture-based pricing have introduced disruptions to commercial and industrial budgeting, resulting in inefficiencies within corporate and state programs.

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