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Can Hedging With Oil Futures Contracts Help Oil Producers?

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1.0 Introduction

India is the world's third-largest energy consumer, after China and US. Over the past two decades, India's energy consumption has grown at a CAGR of more than 5%, while global growth has stagnated at around 2%. Such high energy demand has largely been met by fossil fuels, and oil has played a significant role in fulfilling this demand. As per India Energy Outlook 2021, this demand is expected to increase further.

It is well known that India is a net importer of crude oil. So, volatility in oil prices, as evident from Figure 1, is likely to have major fallouts in the economy. In a May 2020 interview with Business Standard[1], the chief economist of CII projected that a $1 increase in crude oil prices can translate into an outflow of Rs. 11,800 crores per annum. The prognosis becomes grimmer – a price increase of $10 per barrel can swing Gross Domestic Product (GDP) by 10-15 basis points, increase inflation by 15-20 basis points, widen fiscal deficit by 0.1-0.5 per cent of GDP, and negatively impact current account deficit by 0.5 per cent of GDP.

The significant crude price risk, coupled with exchange rate risk, faced by oil producers is also likely to be critical, given the high capital-intensive nature of the business and the dependence on imports of crude oil. Some of the first lines of defence against this risk are optimising operational costs, introducing subscription-based revenue models, and digitalisation of operations. But, these measures are time-consuming and difficult to implement, as they require substantial re-engineering of processes, costly investments, policy interventions and other external dependencies. It is in this context, that financial hedging with futures contracts attains an important role in price risk mitigation.

Figure 1. Crude Oil Price of Indian Basket - 2001 to 2022.

2.0 Futures Contracts for Oil

Financial hedging with the use of futures contracts is a well-accepted and easily implemented method of price risk mitigation. A 'forward' contract is basically an agreement between a buyer and a seller to buy or sell some underlying commodity, say oil, at a specified price, on a specified date in the future. When such contracts are

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standardised in terms of quality and lot size and other parameters, they can be traded in an exchange. Exchange-traded forward contracts are known as 'futures'. For example, a crude oil futures contract launched on June 20, 2022, would specify the following[1]:

- Product: light sweet crude oil, with less than 0.42% sulphur by weight and between 37-42 degree API gravity
- Quantity: 100 barrels
- Settlement Date: December 24, 2022
- Maximum Order Size: 10,000 barrels

Once this contract is launched, three types of entities start trading – those who want to actually buy this oil, those who want to actually sell it and a host of investors who simply want to make a profit by speculating the future price of oil. Typically, these investors have informed traders – they keep abreast of all factors that may affect oil prices. Prices of this contract on any day from June 20, 2022, represent the collective expectations of the investors about the prices that are most likely to prevail on December 24, 2022. These prices change daily, depending on new information that comes to the market. For example, news about the discovery of a valuable reserve may lead to speculation about an increase in supply in the future, pushing futures prices down. On the other hand, news about arms build-up against a country producing crude oil may lead to speculation of an imminent war that could reduce supply in the future, pushing prices down. This incorporation of the latest information on fixing the future price is known as 'price discovery'.

When a large number of investors participate in this market, price discovery happens at a much better level. So, while current prices, also known as spot prices, reflect the current levels of demand and supply, futures prices reflect the expected spot price on the maturity date of the futures contract. Knowledge about future prices enables the companies in the industry, as well as policymakers, to undertake steps to manage the downside impact if any.

Oil companies in the petroleum value chain did use forward contracts to sell or buy crude at pre-determined prices. The Oil Crisis of 1973 led to restrictions on the sale of crude supply, after which price setting became dominated by spot market prices. This led to the proliferation of oil futures contracts. The first oil futures contracts were introduced in 1974 by New York Cotton Exchange, followed by New York Mercantile Exchange (NYMEX) in 1983. Other exchanges around the world followed suit. Today, the InterContinental Exchange (ICE) of London is the world's largest energy exchange. In India, two main exchanges have introduced oil contracts – Multi Commodities Exchange (MCX) and the National Commodities and Derivatives Exchange (NCDEX).

At first glance, a futures contract might seem unusable to a company in the oil value chain. After all, a futures contract specifies only one particular variant of oil, whereas there are four large oil references. To answer this, it may be noted that physical delivery of oil through futures contracts happens very less. Most participants 'close out' their positions before the maturity date of the contract, and sell or buy the oil through spot markets. The benefit can be explained by the use of an example given in Exhibit 1.

Say, an oil refiner is interested to buy OPEC basket on December 5, 2021, an oil producer wants to sell Brent Crude on December 15, 2021, and the MCX oil futures contract, specifying a light sweet crude oil, matures on December 24, 2021. Producer sells futures contracts to the exchange on June 30 2021, and the refiner buys the contracts from the exchange at the same time. Let prices on June 30, 2021, be INR 5000. On December 5, 2021, the refiner sells futures contracts to the exchange. Since the refiner has both bought and sold the contract to the exchange, the exchange nets it out, and 'closes out' the position of the refiner. The opposite transaction is undertaken by the producer on December 24, 2021, to close out. All transactions undertaken by these two participants from June to December are presented below.

In December, the refiner can buy 1000 barrels of OPEC oil at INR 5300/barrel from spot markets. Since the profit from the futures market is INR 100/barrel, the effective price at which the refiner buys is INR 5200/barrel. This was the exact futures price at which it had contracted to buy oil in June. Similarly, the producer sells 1000 barrels of Brent Crude oil at INR 5300/barrel in spot markets. But after accounting for the loss of INR 100/barrel from futures markets, the net price obtained by the producer is also INR 5200/barrel. This shows that, by entering into a futures contract, both buyer and seller effectively transact at the price prevailing at the time they entered into the contract. Although many nuances have been removed from the calculations shown in Table 1, the final effect is almost the same. It may be noted that, since exchanges allow participants to 'close out' their positions, the physical specification of the oil mentioned in the contract does not matter.

Exhibit 1: Mechanism of the Working of a Futures Market

Date	Spot price	Futures Price	Refiner: Cash in (out)	Producer: Cash in (out)	Remarks
June	4500	5200	0	0	Full amount: INR5000/Barrel * 1000 barrels of 1 contract = INR 5 mn. Neither pays or receives any amount. Both pay INR 0.5 mn (10%) to Exchange as 'margin'.
July	4800	5400	200,000	(200,000)	Futures prices increase by INR200/barrel So, oil value in contract increases by INR200/barrel*1000 barrel = INR 0.2 mn Refiner benefits,as his contract allows him to buy at INR 5200 instead of INR 5400. Refiner receives INR 0.2 mn from Exchange Producer loses since he has to sell at INR 5200 although he could have sold at INR 5400 Producer pays INR 0.2 mn to Exchange
Oct.	5000	6000	600,000	(600,000)	Futures prices increase by INR600/barrel So, oil value in contract increases by INR600/barrel*1000 barrel = INR 0.6 mn Refiner receives INR 0.6 mn from Exchange. Producer pays INR 0.6 mn to Exchange
Nov.	5100	5700	(300,000)	300,000	Futures prices decrease by INR300/barrel So, oil value in contract decreases by INR300/barrel*1000 barrel = INR 0.3 mn Refiner pays INR 0.3 mn to Exchange. Producer receives INR 0.3 mn from Exch.
Dec.	5300	5300	(400,000)	400,000	Futures prices decrease by INR400/barrel to match spot prices* So, oil value in contract decreases by INR400/barrel*1000 barrel = INR 0.4 mn Refiner pays INR 0.4 mn to Exchange. Producer receives INR 0.4 mn from Exch. Both close out their positions, and get the initial margin of INR 0.5 mm back
Net			100,000	(100,000)	
* As the futures contract approaches maturity, spot prices and futures prices start converging. On maturity date, both prices are exactly same.					

Some points may be noted from the example. First, all parties who enter the contract get the prices fixed at the time of entering the contract. Irrespective of the prices that exist in the future, all transactions happen based on the fixed price. So, futures contracts can be used by oil producers and refiners to fix prices well into the future, thereby enabling them to plan towards mitigating the risk and ensuring profits. Currently, various technological breakthroughs have enabled shale producers to change output flexibly[2]. Facing higher prices, a producer can increase output, while a refiner can stock up early while reducing purchases in the future. Second, the exact physical commodity specified in the contract does not have any bearing on the commodity purchased or sold by the participants. Thirdly, and most importantly, due to the 'closing out' facility provided by exchanges, anyone can take buy or sell positions with the exchange, even without owning a single drop of oil. This invites investors whose sole interest is to find news/information that can impact prices, and then trade based on prices expected in the future. These traders make the markets informationally rich, leading to price discovery. Thus, markets are freed from the clutches of a few powerful players on the upstream side, who could otherwise dictate prices.

An empirical question here is, can the oil industry truly benefit from future markets? There is a large volume of literature (for Indian studies[3,4]; for a review of all literature, see Chhabra and Gupta, 2014)that addresses the extent to which exposures to commodity price risk, coupled with exchange rate risk, can be mitigated by futures contracts. Most of these studies provide evidence of the efficiency of futures contracts on agricultural commodities, with very few studies on energy commodities. Specific to the oil industry, studies have shown positive effects of using oil futures contracts on firm profitability[5,6] and firm value[7]. Mirroring the lack of interest in academic circles on energy futures, hedging is not a common practice in any oil-importing country. The public sector companies in India do use hedging instruments, but at very low levels, matching only their import requirements. Futures markets are still considered risky gambles and hence are looked at with distrust.

This study explores whether hedging with futures contracts can benefit the oil industry as a whole, informing practitioners about the benefits of futures contracts in the oil sector, and also adding evidence to the academic literature on the same.

The rest of the paper is organised as follows. Section 3 describes the methodology employed to find whether futures contracts are beneficial. Section 4 explains the data. Section 5 presents the results and analysis. Finally, Section 6 concludes by giving managerial implications, and suggesting future improvements in the analysis.

3.0 Methodology

This section builds the basic framework of analysis, wherein utility from profits is derived for a hedged producer, vis-a-vis an unhedged one.

Let NH be an oil-producing enterprise, which does not hedge the price risk by any futures contracts. It is assumed that NH is a price taker, that is, it cannot influence the market prices alone. So, NH's income depends on the spot price of oil in the market, P, and the quantity sold, Q. Let C be the cost of goods sold. Each of these is a random variable. Then, the net income of NH is a random variable which is given by:

$$NI_{NH} = PQ - C \qquad (1)$$

Let H be another exactly similar oil-producing enterprise as NH. Like NH, H is also assumed to be a price taker. So, H's net income depends on the spot price of oil in the market, P, the quantity sold, Q, and the cost of goods sold, C. The only difference between NH and H is that H hedges its price risk with futures contracts. That is, H takes sell positions in futures contracts three months before it wants to sell the oil. Suppose, 3 months before, the futures price for 1 BBL oil is f_0. Currently, the futures price for 1 BBL oil is f_1. The number of contracts to be bought or sold by H depends on the Hedge Ratio, h, of the oil contracts. Then, the net income of H is a random variable which is given by:

$$NI_H = PQ - C - h(f_1 - f_0) \qquad (2)$$

Here, if f_1 is more than f_0 then the seller makes a loss on the futures contract. That is why the difference is deducted from the net income of H.

The question is now, whether NI_H is a better choice than NI_{NH}. For this, the utility of these two alternate wealth streams will be compared.

Utility analysis[8] is one of the basic building blocks in financial decision-making under uncertainty. Facing a random wealth W, an economic agent is expected to maximise his utility, U(W). For a risk-averse individual, the utility function U(W) should be strictly increasing in W and concave. This mathematical requirement satisfies two conditions that define a risk aversion individual:

- Higher wealth should lead to higher utility.
- As wealth increases, the additional utility derived from the unit increase of wealth becomes smaller and smaller.

It can be shown that for any risk-averse Individual, with a constant degree of risk aversion λ, the expected utility is given as:

$$E[U(W)] = \bar{W} - \frac{\lambda}{2}\sigma^2(W) \qquad (3)$$

It may be noted here that, the actual value of utility is not of any economic significance. Since U(W) is strictly increasing in W, it is used to rank alternative wealth variables W_i. That is, if $E[U(W_1)]>E[U(W_2)]$ then W_1 is preferred over W_2. For this study, if it is found that $E[U(NI_H)]>E[U(NI_{NH})]$, then it can be concluded that it is better to be hedged than stay unhedged. This is tested statistically, using the t-test of difference in means. Specifically, a one-tailed test is conducted assuming equal variances, with a null hypothesis as no difference, and an alternate hypothesis is, the utility of hedged income is greater than the utility of unhedged income.

Calculation of Hedge Ratio can be done by multiple methods, namely ordinary Least Squares Regression

(OLS), Vector AutoRegression Model (VAR), Vector Error Correction Model (VECM), and different forms of Multivariate Generalised Auto-Regressive Conditional Heteroskedasticity model (M-GARCH)[9]. In this study, OLS was applied to estimate the monthly value of h, over a rolling window of 12 months. The choice of OLS was motivated by the small size of the dataset. For employing VAR, VECM and M-GARCH models much larger dataset would be necessary. This would take up most of the data, leaving a smaller dataset for the actual utility calculations. Besides, the time encompasses multiple shocks, so it is not advisable to train one model over a longer dataset. So, h has been calculated as:

$$r_{st} = \alpha + hr_{ft} \quad (4)$$

Here r_{st} and r_{ft} are the returns on spot and futures prices respectively. Returns are calculated as log (P_t/P_{t-1}).

4.0 Data

The data required for this analysis were collected from multiple sources. The time period considered for the study was from January 2005 to May 2022, at a monthly frequency.

The monthly average price of crude oil of the Indian basket was obtained from **Indiastat.com.** This data was in terms of USD/BBL. To convert USD to INR, monthly USD/INR exchange rates were collected from the RBI website. By multiplying the price with exchange rates, the price of crude oil in INR was obtained. This formed the data for P.

From the CMIE - Prowess Database, the list of firms in the oil sector was identified. Three companies were selected based on data availability, namely, Oil and Natural Gas Corporation Ltd. (ONGC), Oil India Ltd., and Invenire Petrodyne Ltd. Sales in terms of Value and Quantity and Cost of goods sold (COGS) for each of these companies were obtained on an annual basis. Unit cost was obtained by dividing COGS by Sales in terms of value. The average across each of these companies was taken. Piece-wise linear spline was fitted to each of these averaged variables, and monthly interpolations were obtained from the resulting functions. Thus, from the monthly values of Sales in terms of quantity, the data of Q was taken. From the monthly values of COGS/Sales, the values of c were obtained. To get the monthly values of C, the product of c, P and Q was taken every month.

Crude Oil Futures prices, every month, were obtained from the website of Multi Commodities Exchange (**mcxindia.com**), one of the leading commodity derivatives exchanges in India. Two commodity exchanges were established by the Government of India in 2003-04. These exchanges have seen a burgeoning growth in commodity trades since their inception. Crude oil futures contracts started trading in MCX in 2005. For any month, f_0 was taken as the futures prices three months before the current month, while f_1 was taken as the futures price of the current month. The assumption is that producer or refiner H will enter into 3-month rolling contracts, in order to hedge the price risk.

The degree of absolute risk aversion, λ, is an unobservable value. Following Ranganathan and Anantha kumar[4], the partial degree of risk aversion is taken as 0.5. The coefficient of absolute risk aversion was obtained by dividing this value by the net income per unit of sales. For each of the 3 companies considered, the average net income per unit of sales was taken. The final value came to 0.003.

Using Eqns 1 and 2, the monthly values of NI_{NH} and NI_H were calculated. It may be noted here that, NI_{NH} could be calculated from the beginning of the data period. But the estimation of NI_H requires the futures prices three months before the current month. Calculation of the hedge ratio also requires past data. Since OLS has been used to estimate the hedge ratio, six data points are used up for the estimation of h. As a result, NI_H loses six data points from the beginning.

Using Eqn 3, monthly values of utility corresponding to NI_{NH} and NI_H were estimated. Here again, the past 12 values were used to estimate the average and standard deviation of the NIs. Thus, finally, monthly values of utilities were obtained from April 2006 to May 2022.

5.0 Results and Discussion

Oil prices used for this analysis have been presented in Figure 1 above. Figure 2 shows the spot and futures prices together. It may be noted that futures prices are lower than spot prices before any imminent price drops.

Table 1 presents the descriptive statistics of the variables used, viz., Oil spot price P, Quantity produced Q, Cost of goods sold per unit of Sales, c Futures prices f, and hedge ratio h. Interestingly, there is not much variability in the quantity produced as well as the cost of

Table 1. Descriptive Statistics of variables used

	Price, P (INR/MT)	Quantity, Q (MT)	Cost of Goods Sold /Sales,c	Futures Price, f (INR/MT)	Net Income Unhedged	$E[U(NI_{NH})]$	Hedge Ratio h	Net Income Hedged	$E[U(NI_{H})]$
Mean	4158.63	34.54	0.63	3984.62	54359.8	32071.63	0.91	54958	35237.80
Median	3816.04	35.42	0.63	3706.40	48223.6	27874.35	0.94	49276	29101.81
Standard Deviation	1430.55	2.78	0.08	1246.04	27030.2	32662.32	0.17	26938	30846.92
Kurtosis	-0.39	2.22	-0.69	0.59	-0.42	0.26	0.11	-0.46	0.24
Skewness	0.55	-1.68	0.04	0.83	0.85	0.10	-0.73	0.84	0.25
Note: The number of Data points is 193									

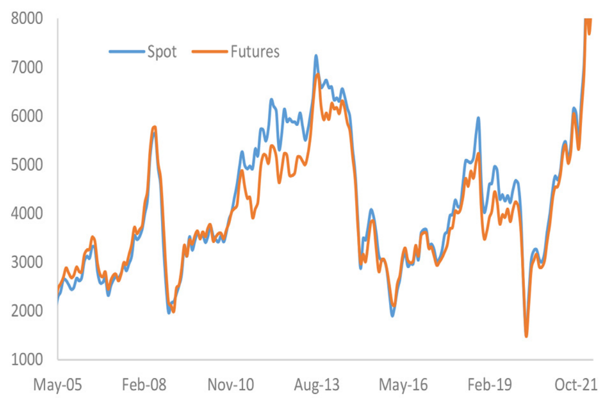

Figure 2. Spot and futures prices of crude oil.

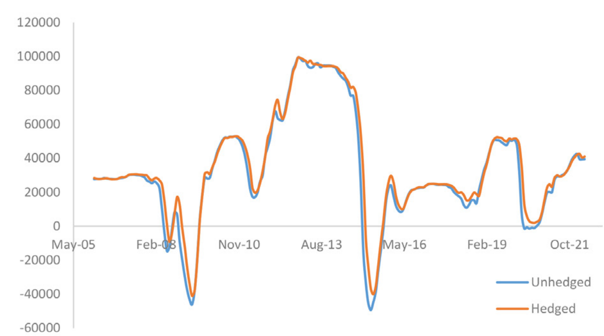

Figure 3. Utility from net incomes of unhedged and hedged firms.

goods sold over the years. This is evident from the low standard deviations of Q and c.

From Table 2, it may be observed that the expected utility from hedging is higher than the expected utility from not hedging. The time-varying utilities are presented in Figure 3. From the figure also, it is evident that the utility of hedged income is generally higher than the utility of unhedged income.

One-tailed t-test of the difference in means is conducted to test whether the difference in utilities is indeed significant statistically. The details are provided in Table 3. From the significance value, it is inferred that the difference is significant at a 10% level of significance. Thus, it may be said that it is better to hedge using futures contracts, although the benefit is weakly significant.

Table 2. t-Test: Two-sample assuming equal variances

Mean	32071.63	35237.80
Variance	1.08E+9	0.96E+9
Observations	193	193
df	384	
t Stat	1.311	
P(T<=t) one-tail	0.095	

The results are all based on actual data, except for the coefficient of risk aversion, λ. This coefficient was taken from a study that was concerned with agricultural commodities. Hence, a sensitivity analysis was conducted on the t-statistic, by changing the coefficient. The results are provided in Table 3. It may be observed that the results are not very sensitive to the choice of risk aversion. For higher levels of risk aversion, the significance of the difference between the two utilities reduce. This is logical since risk-averse individuals will require higher levels of utility from hedging, in order to get convinced about the benefit of this strategy.

One last comment should be made. From the above analysis, the benefit of hedging is demonstrated, although the evidence is weakly significant. To ensure that this benefit accrues when it is needed most, a simple correlation is found between crude prices and the benefits

Table 3. Significance Values of t-test of difference with varying degrees of Risk Aversion λ

λ	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
t-stat	0.031	-1.246	-1.309	-1.311	-1.309	-1.306	-1.304	-1.302	-1.300	-1.299
λ	0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	
	-1.298	-1.297	-1.296	-1.296	-1.295	-1.295	-1.294	-1.294	-1.294	

from hedging. For this, the benefit from hedging every month is calculated as follows:

$$Benefit = \frac{E[U[NI_H]) - E[U[NI_{NH}])}{E[U[NI_{NH}])} \quad (5)$$

This monthly benefit is found to be positively correlated with price, although the correlation is low, at 0.052. From this, it can be believed that whenever crude oil prices go up, the benefit from hedging increases, and vice versa. This corroborates the effectiveness of hedging as a risk management tool during difficult times. Similar findings were documented by Ferriani and Veronese[7], who found that oil prices were positively correlated to the extent of hedging undertaken by U.S. oil producers, although the correlations were not always significant.

The findings of this study can be used by oil corporations to justify hedging their price risk, especially those who need to import crude oil, and are thus open to the vagaries of crude oil prices. It may be reiterated that futures markets will prosper, and their price discovery role would be strengthened as more investors participate in the market. The entry of oil-producing companies into the futures markets will generate confidence among other investors as well.

6.0 Conclusion

This study explores the advantage that the oil industry can gain from hedging using crude oil futures. Using a utility approach, the industry average of net incomes of a hedged position vis-a-vis unhedged position are compared. It is found that the benefits from hedging are higher than the benefit from not hedging, although the difference is only weakly significant. It is also demonstrated that this benefit increases during periods of high prices, confirming its efficacy.

This study is based on a simplistic approach to Net Income. Future studies can explore the benefit of hedging by including other factors of production, like opportunity cost of capital, in the estimation of Net Income. These models can be used to explore the usefulness of other derivatives contracts, like options, swaps, and complex hedges considering both oil price risk and exchange price risk. In terms of methodology, improvements can be made by removing trend and seasonality from the data, and also employing more sophisticated models.

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