Role of Energy Futures Markets: Hedging Effectiveness against Speculative Forces

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I. Introduction

When crude oil price was skyrocketing toward 150 dollars per barrel in 2008, commodity-market regulators began to investigate whether energy-market players were injecting false data into the marketplace to influence perceptions about energy market supply and demand. Of course, this investigation was mainly prodded by public outcry and Congress searching for villains of the day. One aspect of the concerns of the regulators was that companies might be reporting inventory levels that were inaccurate to benefit their own trading positions. For example, a company could theoretically underreport barrels in their tanks at a key hub to suggest oil was scarcer than it really was, and then sold its physical oil at a premium when oil prices jump on misleading news. Another concern was whether companies conduct some physical oil sales and purchases solely to influence short-term pricing on energy markets.

In addition, the recent financial turmoil dubbed as “the worst financial crisis since the Great Depression” was a direct result of the changes in FASB accounting principles into the “marked to market” values, many argued. However, reviewing financial statements that incorporate unfamiliar assets and leverage, whose characteristics include high volatility, may be too complex for routine audits where suggestions are made based primarily on the grounds of *book* values. In volatile markets, top decision makers should steer the course of companies based on "real time" or “marked to market” information rather than on historical values.

Energy companies, countries dependent on foreign oils, or even investors or traders in the energy markets, may pay high prices if they can not establish reliable hedges against vicious energy price swings. Unfortunately, it can be shown that establishing a reliable hedge is extremely difficult. In addition, energy markets are very sensitive to international politics as well as global uncertainties. Since energy is indispensable to our daily lives, understanding the mechanism of energy hedging becomes more than a financial matter.

As one way to study the role of energy futures markets against speculator manipulations, this study investigates the optimal timing for hedging in natural gas spot market utilizing both natural gas futures and heating oil futures. Many of the previous studies took a slightly different approach to hedging problems. Some studies have shown that the optimal number of futures contracts to be sold is the number that minimizes the variance of net profit of the hedged positions (Johnson 1960; Stein 1961). Others have tried optimal hedging techniques to minimize the variance of earnings (McKinnon 1967; Overdahl 1987; Newberry 1988). More recent studies on the stock market include those on the dynamic efficiency between spot and futures markets in the case where short-selling restrictions were lifted. (Jiang,Gung, and Cheng 2001)

Since the effectiveness of minimum-risk hedge ratios may differ under various market conditions, the optimum size of futures positions can be analyzed for periods of rising and falling natural gas prices. Given the extreme nature of the price volatility of natural gas, it is

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worthwhile studying the possibility of hedging natural gas market with both natural gas and other alternatives such as heating oil futures, since both natural gas and heating oil is used for heating, sometimes for the same premises. Recall, during the latter part of 2000 and the early part of 2001, natural gas prices had run up from $2 per unit (1 mil btu) to around $10 per unit. In California, natural gas prices peaked at $59 per unit during January of 2001.
A futures hedge is usually initiated by buying (selling) futures contracts and terminated by closing out the position when the spot market transaction occurs. The position is typically closed by selling (buying) the same contract in the futures market rather than taking delivery of the underlying asset. An investor can reduce part of their natural gas market exposure between the time of natural gas purchases and sales by selling futures contracts. This statement is especially true for energy companies who produce and hold large volumes of natural gas. These companies can offset short-term losses in their natural gas holdings by selling natural gas or heating oil futures contracts. Price risk is reduced to the extent that the gain in the futures position offsets the losses in the value of the spot holdings and vice versa.

The paper first provides a review of prior studies and defines an appropriate measure of hedging effectiveness. The next section is the data analysis where hedging effectiveness and minimum-risk hedge ratios for the natural gas and heating oil futures are determined using the daily natural gas spot prices. Additionally, the risk-reduction measures are examined across futures contracts with different numbers of day remaining. The final section is the conclusion of the paper.

II. Hedging Effectiveness for Natural Gas

The effectiveness of a hedged spot position is dependent on the size of the futures position and the degree of correlation between changes in the value of the spot position and changes in futures prices over the hedging period. During any particular hedging period, the co-movement between the natural gas futures market and the natural gas spot market may not be perfect since they are basically two different markets. Their co-movements are not the same for the following reasons:

1. The differences between investors perceived present value of cash versus futures may fluctuate as economic and other conditions change.
2. The futures price is influenced by factors that do not necessarily affect the spot price.
3. Since spot and futures are different markets, their price changes can be random and independent over time.

Note: Futures prices reflect levels of, and changes in, financing costs of the underlying instrument, because futures are in effect an alternative to purchasing the instrument today and carrying it until the delivery date, thereby incurring the financing charges. Hence, it is safe to say that the supply-and-demand conditions in the spot and futures markets may not be exactly the same.

Several earlier studies (Ederington 1979; Johnson 1960) concluded that significant portions of the risk of price changes accompanying cash positions could be eliminated using futures contracts in various financial products over specific time periods. Based on these studies, it can be shown that the minimum-risk hedge ratio and hedging effectiveness are related to the covariance, or correlation, between spot and futures price changes, and the variance of futures price changes over the period of the hedge. This hedge ratio can be interpreted as the weight of the futures position in a portfolio consisting of both spot and futures positions, or the proportion of the predetermined spot position that is hedged.

In order to find the size of the futures position that minimizes the exposure to price risk, we minimize the variance of the hedged portfolio with respect to the proportion of the portfolio held in futures contracts.

$$\min \mathrm{Var}(C_{ht}) = \mathrm{Var}(C_{st}) + X_f^2\,\mathrm{Var}(C_{ft}) + 2X_f\,\mathrm{Cov}(C_{st}\,C_{ft}) \qquad (1)$$

where C_{ht} is the change in the value during period t of the hedged spot position, C_{st} , C_{ft} are the changes in value during period t of the spot position and futures contracts, respectively, X_f is the proportion of the portfolio held in future contracts: X_f*would equal the optimal hedge ratio (HR*) with $X_f < 0$ representing a short position and $X_f > 0$ a long position in futures.

$$\frac{\delta\,\mathrm{Var}(C_{Ht},)}{\delta\,X_f} = 2X_f\,\mathrm{Var}(C_f) + 2\,\mathrm{Cov}\,(C_s\,C_f) = 0 \qquad (2)$$

$$\frac{-\mathrm{Cov}\,(C_S, C_f)}{\mathrm{Var}(C_f)} = X_f^* = HR^* \qquad (3)$$

Therefore, the optimum hedge ratio is the equivalent of the negative of the slope coefficient of a regression of spot price changes on futures price changes.

The use of absolute price changes instead of the percentage changes in value is warranted because of the unique circumstances associated with the hedging decision in the portfolio model. One of these circumstances is a result of the objective of a futures hedging strategy. The objective is to minimize potential losses from a fixed, predetermined, position of the portfolio. The futures position should not be viewed as a substitute for the cash position. Futures are combined with the cash position to minimize losses in value of the cash position. Accordingly, effective hedging depends on the amount of covariance between value changes of the spot and futures.

> Another basis for the reliance on price changes versus returns is that the futures positions have no initial investment value and thus do not provide returns on investment in the normal sense. The only costs associated with futures hedges are transaction costs, the opportunity cost of funds provided as margin before gains on the spot position are realized, and the costs associated with basis risk. The basis risk cost comes from the fact that with imperfect foresight, gains and losses on spot and futures positions may not exactly offset each other in every period.

The measure of hedging effectiveness (E_f*) for the minimum-risk hedge is defined as the proportional reduction in the variance of changes in the value of the spot position that comes from maintaining the hedge ratios determined above rather than holding an unhedged position ($X_f = 0$). E_f^* is the coefficient of determination for the regression of spot price changes on futures' price changes used to estimate HR*.

$$E_f^* = \frac{\mathrm{Var}(C_s) - \mathrm{Var}(C_H)}{\mathrm{Var}(C_s)} = 1 - \frac{\mathrm{Var}(C_H)}{\mathrm{Var}(C_s)} \qquad (4)$$

$$E_f^* = \frac{\mathrm{Cov}(C_s, C_f)^2}{[\mathrm{SD}(C_s)\mathrm{SD}(C_f)]^2} = R^2 \qquad (5)$$

To the extent that the variances and covariance are stable, historical data can be used appropriately to help solve for the minimum-risk hedge ratios and to estimate its potential effectiveness in reducing the variability in spot price changes. Hedge ratios and hedging effectiveness may change over time due to changes in market conditions and in market participants. Hedge ratios and effectiveness may also vary for contracts with different times to delivery.

The correlation structure of price changes can change over time as a function of the direction of natural gas price movements and their impact on various participants in the futures market. Investors with long positions in natural gas may increase their hedging activity when they expect price drops larger than anticipated by the market. The opposite behavior would be expected of investors with short positions. The relative amount of hedging participation, and the extent of spot futures arbitrage in rising and falling markets may impact hedge ratios. Also, the cheapest deliverable instrument may change and thereby alter hedging effectiveness.

If hedging effectiveness and ratios differ significantly in rising and falling markets, both passive and selective hedgers may want to incorporate these differences in their hedging strategies. A passive hedger is one who maintains a continuous futures hedge to eliminate all exposures caused by the fluctuations of natural gas prices. If hedging effectiveness and ratios change over time, proper adjustments may be needed in the size of their futures position over time. Selective hedging may be done by using the futures market as an alternative to liquidating or investing in a spot position based on natural gas market forecast. These hedgers may be interested in the hedge ratio that is most relevant to their forecasts. Note that the different optimal hedge strategies in rising and declining markets will not guarantee selective or passive hedgers that they will be able to capitalize on these differences. To capitalize on these differences would require the differences to be stable, and for hedgers to be able to identify the general direction of the market over the hedging period.

Minimum risk hedge ratios and hedging effectiveness may also change over time due to structural changes in natural gas markets that affect the volatility of spot price changes. Increased volatility of daily natural gas prices is transmitted to futures prices through the implied expected future values. An increase in natural gas market volatility, whatever the source, should increase the incentive to use futures hedges and, accordingly, should increase participation in the relevant futures market. On top of a changing energy environment, the term to delivery of the futures contract may be related with different levels of hedge ratios and hedging performance. Unlike other financial futures contracts, like stock index or

T-bond futures which have heavy trading volumes only for "front" month contracts, energy futures contracts (both natural gas and heating oil) have decent trading volumes throughout different expiration months. Generally, as the contract gets very close to delivery, investors who do not wish to execute delivery may liquidate their positions.

III. Data and Methodology

1) Data Set and Methodology

Daily data was acquired from January 3, 2003 to March 21, 2008 (1301 observations). All the price sets (natural gas spot and futures, heating oil futures) were drawn from a Bloomberg subscription terminal. Price changes for each contract are grouped according to the number of days remaining. For this study, we utilized 4 delivery futures (March, June, September, and December) both for natural gas, and heating oil futures. Both natural gas and heating oil futures price changes are matched with spot natural gas price changes. Ordinary least-square (OLS) regressions of spot price changes on contemporaneous futures price changes provide estimates of hedging effectiveness (R^2) and minimum-risk hedge ratios (regression coefficient on the spot price).

To determine if the estimated hedge parameters differ with respect to time to delivery, separate regressions are run for price changes on contracts with various days remaining to delivery. Days remaining to delivery are subdivided by 1-30 days, 30-60 days, and 60-102 days. Two types of statistical analysis are used to compare estimated levels of hedge ratios and effectiveness across subsets of the sample. First, separate OLS regressions are estimated for each subset of the sample to determine minimum-risk hedge ratios and effectiveness measures. Neter and Wasserman (1972) provide a procedure for estimating a confidence region for coefficients of determination (R^2). This procedure is used to analyze the significance and the stability of the hedging effectiveness measures. The second test gives statistical comparisons of hedge ratios over different market conditions. Two sets of slope and intercept terms, along with an interaction term, are added to the regression model to compare the several subsets of data under analysis. This procedure was first suggested by Gujarati (1970) and facilitates the testing of the hypothesis that hedge ratios are equal under rising vs. declining prices. The full model becomes

$$C_s = \alpha_o + \alpha_1 D(S) + \beta_1 C_f + \beta_2 D(S) C_f \qquad (6)$$

where

C_s, C_f = change in spot and futures prices
$D(S) = 1$ if $C_s < 0$ (natural as spot prices rose)
$= 0$ if $C_s > 0$ (natural gas spot prices declined)

2) Empirical Results and Analysis

Table I presents a comparison between the hedge ratio and hedging effectiveness estimates based on the full data set and selected subsets of the data. Results are reported for observations segmented by days remaining to delivery as well as for the full data set. Table II shows the summary of hedge ratio estimation for the full model with dummy variables. The numbers in parenthesis are t-statistics.

Examination of these results leads to several points that are worthy of further discussion. In the case where we utilize natural gas futures to hedge natural gas spot positions, hedges of the spot using the minimum-risk hedge ratio can provide an average proportional reduction in variability from 1.8% to 44.9%, i.e. an increase in effectiveness. Hedging with 1-30 days-to-delivery futures contracts provides a better hedge than any other subset of time-to-delivery for natural gas futures contract. In addition, the estimate of the hedge ratios and levels of effectiveness for the nearest days-to-delivery seem to occur because futures and spot price behave similarly as futures contracts near delivery. 61-91 days-to-delivery futures contracts have the second highest hedging effectiveness. 31-60 days-to-delivery futures contracts perform the poorest. Simply put, a futures contract with one to two months-to-delivery is not a good hedging vehicle compared with other delivery month futures. Similar results can be seen in the heating oil futures case. However, in this case, the estimate of the hedge ratio is highest with 61-91 days-to-delivery futures. The next best futures contract for hedging is 1-30 days-to-delivery futures. Generally speaking, as is expected, the natural gas contract is a better hedging tool than the heating oil futures to hedge the spot natural gas position.

IV. Conclusion

The extreme volatility of energy prices, which often occurs when we are not so well prepared for it, and the collapse of financial markets in general have compelled us to delve into the possibility of using energy futures contracts as means of reducing the variability of energy markets. One of the essential energy sources is natural gas. Natural gas is notorious for its volatility and cheap substitutes are not easily found. In this paper, we studied the optimal timing for hedging in natural gas spot with heating oil futures as well as natural gas futures.

When natural gas futures are used to hedge natural gas spot positions, a proper choice of timing and contract can achieve an average proportional reduction in variability from 1.8 % to 44.9%. Hedging with the front month futures provides a better hedge than any other subset of time-to-delivery for natural gas futures contracts. Also, the estimate of the hedge ratio is highest with 1-30 days-to-delivery futures. The large hedge ratios and levels of effectiveness for the nearest days-to-delivery contracts seem to occur because futures and spot prices behave similarly as futures contracts near delivery. 61-91 days-to-delivery futures contracts have the second highest level of hedging effectiveness. 31-60 days-to-delivery futures contracts perform the poorest. These results roughly state that a futures contract with one to two months to delivery is not a good hedging vehicle compared with other delivery month futures.

Similar results can be seen when the heating oil futures contracts are used for hedging. The 31-60 days-to-delivery futures contracts show the lowest hedge ratio and hedging effectiveness. But in this case, the estimate of the hedge ratio is highest with 61-91 days-to-delivery futures. The next best futures contracts for hedging is the 1-30 days-to-delivery futures. Overall, as is expected, the natural gas futures contract is a better hedging tool than the heating oil futures contract to hedge the spot natural gas position. Given a different data set, different outcomes might have resulted. Further analysis of different sets of data is needed to reach conclusions regarding optimal energy futures strategies for hedgers.

Table I

Hedge Ratios and Effectiveness Estimates
(Jan 3, 2003 – Mar 21, 2008)
(Daily Natural Gas Cash and Natural Gas or Heating Oil Futures Prices Changes)

	Days to Delivery	Hedge Ratio (HR)	Hedging Effectiveness (R^2)	N
Natural Gas Futures	1-30	0.8492	0.458	444
	31-60	- 0.2180	0.018	445
	61-91	0.3882	0.3492	412
	All	0.5342	0.0232	1301
Heating Oil Futures	1-30	0.0121	0.2768	444
	31-60	0.0328	0.0210	445
	61-91	0.0061	0.3488	412
	All	0.2134	0.0322	1301

Table II

Results of Hedge Ratios Estimation with Dummy Variables

	Natural Gas Futures				Heating Oil Futures			
Variables	1-30 Days	31-60 Days	61-91 Days	All Data	1-30 Days	31-60 Days	61-91 Days	All Data
D(S)	-1.258	-0.435	-0.175	-0.258	-0.194	-0.389	-0.189	-0.263
	(-12.01)	(-2.83)	(-13.01)	(-4.8)	(-11.96)	(-2.64)	(-14.26)	(-5.52)
C_f	0.937	-0.268	0.392	0.427	0.007	0.0838	0.004	0.012
	(12.31)	(-0.26)	(3.65)	(1.30)	(0.94)	(1.05)	(1.71)	(0.85)
$D(S)C_f$	-0.339	-0.558	-0.283	-0.404	0.015	-0.079	-0.001	-0.008
	(-2.79)	(-0.37)	(0.12)	(-0.95)	(-1.22)	(-0.73)	(-0.35)	(-0.38)
Multiple R^2	0.449	0.018	0.359	0.022	0.266	0.019	0.338	0.021
No. of Observations	444	445	412	1301	444	445	412	1301

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