# Study Questions to Accompany International Energy Markets

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## Chapter 18. Energy Futures Markets for Managing Risk

**18.1.** The U.S. EIA publishes a variety of energy data in its Monthly Energy Review. Access its index at https://www.eia.gov/totalenergy/data/monthly/index.php. Scroll down and click on energy prices.

**18.1a.** What are the energy prices given. ·

**18.1b** Find energy prices for two of the following energy products in the *Monthly Energy Review* from the U.S. DOE. (Propane, heating oil, natural gas, electricity, crude oil, gasoline). Graph them in an Excel file to illustrate the price volatility of the two products. Discuss whether the patterns of volatility are similar or not.

**18.1c** What is the sample variance of each price, often designated $s^2$? Remember the sample variance is measured as

$$s^2 = \frac{\Sigma_{i=1}^{n}(x_i - \underline{x})^2}{n-1}. \qquad (708)$$

Where $\underline{x}$ is the sample mean or $x = \frac{\Sigma_{i=1}^{n}(x_i - \underline{x})^2}{n}$.

**18.1d.** What is the standard deviation of each price? Remember that standard deviation is the square root of the variance or

$$\sqrt{\frac{\Sigma_{i=1}^{n}(x_i - \underline{x^2})}{n-1}}.$$

Note you can compute means in Excel using the function =average(addresses of the variable). Thus, if your sample values are in an Excel file from A1 to A50, the Excel command for the mean of the sample values is =average(A1.A50). You can compute the sample variance of the sample using the function =var(addresses of the variables). You can compute the standard deviation of a sample using the function =stdev(addresses of the variables).

**18.1e.** What is the sample correlation coefficient between your two prices? Remember the correlation coefficient between two variables x and y is the sample covariance $(\sigma_{xy}) = \frac{\Sigma_{i=1}^{n}(x_i-\underline{x})(y_i-\underline{y})}{n-1}$ divided by the standard deviations of each variable, which can be computed as follows

$$\sigma_{xy} = \frac{\Sigma_{i=1}^{n}(x_i - \underline{x})(y_i - \underline{x})}{\sqrt{\Sigma_{i=1}^{n}(x_i - \underline{x})^2}\sqrt{\Sigma_{i=1}^{n}(y_i - \underline{y})^2}} \qquad (709)$$

Excel can be used to compute the correlation between two variables using the function =correl(addresses of variable x, addresses of variable y). The correlation, often designated by the Greek letter $\rho$ or $\rho_{xy}$, is a measure of the linear relationship between two variables. $-1 < \rho < 1$. If $\rho$ is positive, when x increases, y increases. If $\rho$ = 1 then there is a perfect positive linear relationship between x and y. For example, if $y = 10 + 2x$, then $\rho$ would be equalto 1. When $\rho$ is negative, when x increases, y decreases. If $\rho$ = -1 there is a perfect negative linear relationship between x and y. If $y = a + bx$, where $b < 0$, then $\rho$ is less than 1. The closer $\rho$ is to one in absolute value the more tight is the relationship. If $|\rho| > 0.9$, then the variables are often considered highly correlated or they tend to move together fairly closely. Even variables with correlations of $|\rho| > 0.8$ are considered to have significant correlation between themselves. Menus for these and other statistical functions can be found in Excel by going to Insert, Function, Statistical.

**18.2** Check the below table.

| Product | Traded Since | Delivery | Exchange Location | Web Page, http:// |
|---|---|---|---|---|
| Electricity, Base | 3/01 | No Delivery | EEX, Germany | *www. eex. de* |
| Electricity, Peak | 3/01 | No Delivery | EEX, Germany | *www. eex. de* |
| Brent Crude (Forward) | 6/88 | Sullom Voe | IPE, U.K. | *www. ipe. uk. com* |
| Gas oil | 4/81 | ARA | IPE, U.K. | *www. ipe. uk. com* |

| Product | Traded Since | Delivery | Exchange Location | Web Page, http:// |
|---|---|---|---|---|
| Natural Gas | 1/97 | NBP | IPE, U.K. | www.ipe.uk.com |
| Crude Oil, Light Sweet | 6/02 | No Delivery | Merchant Exchange, U.S. | www.merchants-exchange.net/ |
| Crude Oil, Brent | 6/02 | No Delivery | Merchant Exchange, U.S. | www.merchants-exchange.net/ |
| Natural Gas | 5/02 | No Delivery | Merchant Exchange, U.S. | www.merchants-exchange.net/ |
| Gas Oil, European | 1/02 | No Delivery | Merchant Exchange, U.S. | www.merchants-exchange.net/ |
| Gasoline Unleaded | 6/02 | No Delivery | Merchant Exchange, U.S. | www.merchants-exchange.net/ |
| Heating Oil #2 | 1/02 | No Delivery | Merchant Exchange, U.S. | www.merchants-exchange.net/ |
| Electricity (forward) | 93 | No delivery | NordPool (Scandinavia) | www.nordpool.com |
| Electricity | 95 | No delivery | NordPool (Scandinavia) | www.nordpool.com |
| Coal, Central Appalachian | 7/01 | Ohio/Big Sandy Shoal Rivers | NYMEX, U.S. | www.nymex.com |
| Crack Spreads | | NYH | NYMEX, U.S. | www.nymex.com |
| Gasoline, Unleaded | 12/84 | NYH | NYMEX, U.S. | www.nymex.com |
| Heating Oil #2 | 10/74 | NYH | NYMEX, U.S. | www.nymex.com |
| Propane | 8/87 | TEPPCO | NYMEX, U.S. | www.nymex.com |
| Crude Oil, Light Sweet | 3/83 | Cushing, Oklahoma | NYMEX, U.S. | www.nymex.com |
| Crude Oil, Brent | 4/01 | No Delivery | NYMEX, U.S. | www.nymex.com |
| Natural Gas | 4/90 | Henry Hub, Louisiana | NYMEX, U.S. | www.nymex.com |
| Crude Oil, Lt Sweet EminNY | 6/02 | No delivery | NYMEX, U.S. | www.nymex.com |

| Product | Traded Since | Delivery | Exchange Location | Web Page, http:// |
|---|---|---|---|---|
| Natural Gas EminNY | 6/02 | No delivery | NYMEX, U.S. | www.nymex.com |
| Gasoline | 7/99 | Tokyo, Kanagawa, Chiba | TOCOM, Japan | www.tocom.or.jp/ |
| Kerosene | 7/99 | Tokyo, Kanagawa, Chiba | TOCOM, Japan | www.tocom.or.jp/ |
| Middle Eastern Crude | 9/01 | No Delivery | TOCOM, Japan | www.tocom.or.jp/ |
| Electricity, NSW-peak | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, NSW-base | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, Vict-peak | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, Vict-base | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, SAus-peak | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, SAus-base | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, Queen-peak | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity, Queen-base | 9/02 | No Delivery | SFE, Sydney, Australia | www.sfe.com.au and www.d-cyphatrade.com.au/what_we_offer.html |
| Electricity | 05/01 | Delivery point unknown | Gielda Energy SA, Poland | www.polpx.pl/news/230402.htm |
| Electricity, green | 07/01 | Delivery point unknown | Gielda Energy SA, Poland | www.polpx.pl/news/230402.htm |

| Product | Traded Since | Delivery | Exchange Location | Web Page, http:// |
|---|---|---|---|---|
| Electricity, peak | 12/01 | Delivery point unknown | Gielda Energy SA, Poland | www.polpx.pl/news/230402.htm |
| Electricity, base | 06/00 | | UKPX, England | www.ukpx.com |
| Electricity, peak | 06/00 | | UKPX, England | www.ukpx.com |
| Heating Oil | 04/02 | No Delivery | Hannover Commodity Exchange, Germany | www.wtb-hannover.de/ |

**18.2a.** Which of the above contracts are traded by open outcry (oo) and which are traded electronically (et)?

**18.2b.** Find contract volumes for the above contracts.

**18.3.** Suppose the spot price for natural gas is \$2.50 per Mcf, the futures price is also \$2.50. You own 1 Mcf of gas and you sold one Mcf on the futures market.

| $S_T$ | $S_T - S_t$ Spot Market | $F_t^T - S_T$ Forward market | Combined Market |
|---|---|---|---|
| \$17 | -\$1 | \$1 | 0 |
| \$18 | \$0 | \$0 | 0 |
| \$19 | \$1 | -\$1 | 0 |

**18.3a.** Using a Table similar to that above, show how the losses and gains in the spot market are offset by the losses and gains in the futures market at time $T$ for $S_T$ = \$1.50, \$2, \$2.50, \$3.00, \$3.50. What is your mean return for the combined markets? What is the variance of your mean return for the combined market?

**18.3b** Now suppose the spot is \$2.50, but the futures price is \$3.00. Do the same analysis. What are the losses and gains in each market and the combined market? What is your mean return for the combined markets? What is the variance of your mean return for the combined market?

**18.4.** Suppose that gas spot prices ($G_t$) on Agricentauri are perfectly correlated with spot turnip prices ($T_t$) with $G_t = 0.25(T_t)$. Currently gas and turnip spot prices are 2.5 per Mcf and \$10 per turnip, respectively. The turnip futures price is $T_t^T = \$11$. You are long 4 Mcf of gas and you short 1 turnip contract at $T_t^T$.

| $T_T$ | $S_T$ | Spot Crude Market $S_T - S_t$ | Turnip Forward Market $3(T_t^T - T_T)$ | Combined Market |
|---|---|---|---|---|
| \$9 | \$27 | -\$3 | \$3 | \$0 |
| \$10 | \$30 | \$0 | \$0 | \$0 |
| \$11 | \$33 | \$3 | -\$3 | \$0 |

**18.4a.** Using a Table similar to above and the same prices at $S_T$, what are the losses and gains in each market and the combined market?

**18.4b.** What is your mean return for the combined markets?

**18.4c**. What is the variance of your mean return for the combined market?

**18.5.** If $F_t^t > 958.3$ in the below example, what should you do to make money? Explain exactly how you make money on your transactions as in the below example.

You own a 1-year discount bond that has just been issued that you will want to sell in six months. The risk free rate is 6% per annum. The current bond price is \$930.

**18.6.** Suppose you are holding a futures contract on a T-bill that matures in 3 months at a price of \$9442. The 3 month risk free rate is 5% per year. The current spot price for the T-bill is \$9300. Is this market in equilibrium or could you make money by arbitrage? If so what would you buy and/or sell to make money?

**18.7.** Consider a 10-month forward contract on a Duke Power Stock with a current price $S_t = \$500$. The risk-free rate is 8% and the term structure over a two-year period is flat. (e.g. shorter-term borrowing has the same risk-free rate as longer term borrowing up to 2 years). Dividend payments of \$75 are paid after 3, 6, and 9 months.

**18.7a** What is the equilibrium forward price for this bond?

**18.7b.** If the price were greater than this forward price, how could you make money by arbitrage?

**18.7c.** If the price were less than this forward price, how could you make money by arbitrage?

**18.8.** Explain how arbitrage would make the following equation hold.

$$F_t^T = (S_t + U_t)e^{r(T-t)}$$

The forward price would be bid up or down until it were equal to future spot price discounted by the risk free rate.

**18.9.** Show that $F_t^t$ for further out contracts decreases in a backward market where $r = 1\%$, $\mu = 1\%$, $\delta = 3\%$, $S_t = 20$.

Carrying costs, or the sum of finance (r) and storage (u) is less than convenience yield (δ).

| Years until maturity | Futures Price |
|---|---|
| 0 | $ 20.00 |
| 1 | $ 19.80 |
| 2 | $ 19.60 |
| 3 | $ 19.41 |
| 4 | $ 19.22 |
| 5 | $ 19.02 |
| 6 | $ 18.84 |

**18.10.** Suppose that United Airlines will buy 500,000 gallons of jet fuel in three months. The standard deviation of the price for jet fuel is 0.028 per gallon. The company uses heating oil contracts for hedging since there is no futures market for jet fuel. The standard deviation of the futures price for heating oil is 0.05. The correlation coefficient between the changes in the jet fuel price and the changes in the heating fuel future price = 0.9.

**18.10a.** To hedge should United buy or sell futures contracts?

**18.10b.** What is the optimal hedge ratio (h)?

**18.10c.** How many 42,000 gallon heating oil contracts should United Airline buy or sell?

**18.11.** Answer the following about crack spreads.

**18.11a.** Compute a (3-2-1) crack spread using spot prices and refinery runs from the most recent *Oil and Gas Journal*. Use Gulf Coast Prices.

**18.11b.** Compute a 3-2-1 crack spread using Nymex 3 month futures.

**18.11c.** Compute a 5-3-2 crack spread using Nymex 3-month futures. The *Wall Street Journal* is one popular source of the price data you will need. Indicate the trading day and data source. Also, you should be able to get the appropriate data from www.nymex.com.

**18.11d.** Suppose you are a refinery and you hedged 3 months ago with a 3-2-1 spread. Using actual spot and futures values from 3 months ago, show your gains or losses in the spot and future market and how they offset each other.

**18.12.** A third example is that by a subsidiary MG Refining and Marketing (MGRM) of Metallgesellschaft A.G, which was Germany's 14th largest industrial firm in 1993. In this more complicated trading strategy, MGRM contracted to supply gasoline and heating oil at fixed prices for 10 years. It then hedged these forward contracts with futures and other over the counter assets. So far, so good. Where the problem arose was that the hedging was in short term assets, whereas the forward contracts were long term. Thus, the short term assets had to be continuously rolled over. Such a strategy can work when markets are in backwardation but not when they are in contango as they were through 1993 and the beginning of 1994. Explain why their strategy could make money in an inverted market but not in a normal market?

**18.13.** Two popular exchanges for energy futures and options are NYMEX (http://www.cmegroup.com/company/nymex.html) and ICE (https://www.theice.com/index)**.** Surf each of these sites and find the specifications for one energy futures contract on each.

**18.14.** Suppose that the spot price for natural gas is $3.50 per Mcf, the futures price is also $3.50 per Mcf, transaction cost for a futures contract is $0.10 per Mcf. You own 1 Mcf of natural gas and you want to sell 1 Mcf at T periods from now. Table 2 shows the gain and loss in the spot and futures market and the probability (Contributed by Hayamizu).

Table 2. The gain and loss in the spot and futures market and the probability

| $S_T$ | $S_T$-$S_t$<br>Spot Market | $F_t^T$ - $S_T$<br>Futures Market | Probability |
|---|---|---|---|
| $3.00 | –$0.50 | $0.50 | 0.3 |
| $3.50 | $0.00 | $0.00 | 0.4 |
| $4.00 | $0.50 | –$0.50 | 0.3 |

**18.14a.** What is your mean return for the spot market? What is the standard deviation for the spot market?

**18.14b.** What is your mean return for the combined market of the spot and future market? What is the standard deviation for the combined market?

**18.14c.** If you are a risk averse person, what should you do? If you are a risk neutral person, what should you do? If you are a risk lover, what should you do?

**18.15.** Calculate convenience yield at each period, assuming Spot price is 80 $/bbl and three month Futures price is 81 $/bbl at period 1, and Spot price is 79 $/bbl and three month Futures

price is 81 $/bbl at period 2, and annual storage costs and interest rates (continuous) are 1% of the spot price and 5% respectively through the both periods. If the calculated convenience yield is negative, discuss what assumptions are not plausible.

**18.16**. You have $1,000,000 in T-bills (medium term Treasury bonds) with a duration of 12 years if the yield is 13%. Assume that the future has a price of $95,000, a duration of 8 years and a yield of 9%.

**18.17a**. Determine the optimal hedge ratio.

**18.17b**. If futures contract price was adjusted to $90,000, what would happen to the optimal hedge ratio?