Part I

Introduction to Energy Commodities

Energy has been traded in one form or another for centuries, with modern energy markets emerging at the launch of the NYMEX[1] West Texas Intermediate (WTI) crude oil contract in 1983. Subsequent growth has been significant, with an expanding array of physical and financial instruments traded across almost all energy commodities. This evolution has been driven by a trend toward deregulation in markets such as natural gas and power that, until relatively recently, were essentially fully regulated. The past decade has also witnessed growing interest among institutional investors in energy, and commodities more broadly, as a new component of investment portfolios.

While the level of complexity of energy markets has increased rapidly, practitioners have often found themselves depending on analytical methods that were inherited directly from those used in other asset classes, often with only cosmetic modifications. Energy commodities, however, exhibit important differences from other markets, which at times imperil the validity of conventional approaches to valuation and hedging.

There are two basic features of energy that together result in price behavior that can be dramatically different from that of other asset classes. The first is that for a variety of reasons, including weather events and infrastructure failure, fluctuations in supply and demand for many energy commodities can change rapidly on daily or even hourly time scales. The second is that it costs real money to move a commodity through time or between locations. One cannot electronically transfer ownership and delivery of natural gas from Louisiana to Boston on a cold winter day as one could, for example, title to a bond.

[1] NYMEX, short for the New York Mercantile Exchange, is one of the primary exchanges for energy futures trading and clearing. Although NYMEX was acquired by the Chicago Mercantile Exchange (CME) in 2008, we will refer to legacy energy futures contracts as NYMEX contracts.

The facilities required to store or transport energy vary in cost, with coal and crude oil relatively easy to store and transport, natural gas much more challenging and costly, and electricity expensive to move and effectively unstorable in meaningful quantities at any cost. In each of these markets, however, storage capacity by region and transport capacity between regions is finite. When limits to infrastructure are tested, through mechanical failure, unusually high supply or demand, or extreme levels of inventory, price behavior is affected.

The first consequence of these fundamental aspects of energy markets is that energy prices are significantly more volatile than benchmarks in equities, rates, and currencies. Higher volatility affects an array of commercial considerations, including stability of pricing during the negotiation of potential transactions, investment decisions relating to asset development or acquisition, and the capital required to support trading operations and collateral requirements.

A second consequence is that energy markets exhibit a much higher degree of "specialness," that is to say, negative forward yields or rapid changes in relative pricing between closely related commodities. Liquidity in energy markets, as in most asset classes, is usually concentrated in a few benchmark commodities. The practical consequence of chronic specialness is that energy portfolios often have risk profiles that are very high dimensional – not in the sense of a large number of closely related tradables such as a few hundred Treasury bonds outstanding on any given day but in the sense of distinct locational and temporal delivery that can dislocate rapidly and unpredictably from the benchmarks most commonly used to hedge. Specialness, and the resulting high-dimensional attributes of typical portfolios, is the fundamental challenge in energy risk management.

In the next few chapters we will survey basic stylized facts about energy commodities prices, the typical framework in which commodities prices are analyzed, and essential fundamental facts underpinning the workings of energy markets.

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Glen Swindle
Excerpt
More Information

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Context

What makes energy commodities different from other asset classes?

Many seasoned risk managers in other asset classes consider energy trading as simply more of a "white knuckle" experience than other businesses. This view is often based in part on the empirical observation, easily gleaned from any screen with West Texas Intermediate (WTI) or Brent oil futures prices, that energy commodities can exhibit exceptionally high volatility. The relatively frequent blowups of energy trading desks reinforce the image. Noteworthy instances of abuse of market mechanics, such as in the case of Enron and other power marketers in California in the early 2000s, accompanied by index manipulation in natural gas, and culminating more recently with the Amaranth spectacle and FERC[1] actions against several power marketers, add credence to the notion that energy markets can be challenging environments in which to operate.

Much of this perception, however, is based on very high-level views of the more newsworthy mishaps, with only cursory knowledge of the commercial realities of energy markets and the risk-management practices that are required to run an energy trading operation. Energy markets serve much more of a purpose than simply providing a few well-capitalized hedge funds an arena in which to speculate on the direction of global energy prices. Most trading activity involves balancing variations in supply and demand across time and between locations. This occurs both on short time scales, so-called cash desks that move commodities from supply centers to demand centers on a daily basis, and on the long time scales involved in the construction of a new refinery, pipeline, or generator, activities which often require significant hedging programs to support the sizable financing required.

[1] The Federal Energy Regulatory Commission (FERC) is the U.S. regulator responsible for energy infrastructure and power markets.

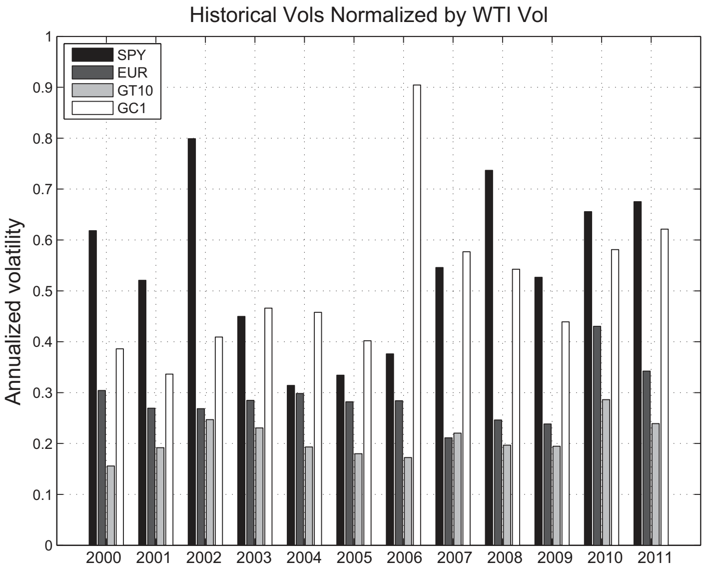

Figure 1.1. Ratio of realized volatilities by calendar year for various assets to WTI.

The distinguishing features of energy price dynamics affect market participants in different ways, an understanding of which is central to the development of useful risk-management and valuation frameworks.

Volatility

There are several reasons to view energy commodities as fundamentally different from other traded assets. First among them is that energy prices consistently exhibit higher levels of volatility compared with other asset classes. Figure 1.1 shows the realized volatility for a set of historical prices representing a cross section of commonly traded assets normalized by the realized WTI volatility by calendar year. Given a price series $p(n)$, the realized volatility (often referred to as *historical volatility*), is defined as

$$\left[250 \sum_n R^2(n)\right]^{1/2} \tag{1.1}$$

where $R(n) = \log[p(n)/p(n-1)]$ denotes the price returns. The factor 250 is approximately the number of trading days in a year. We have chosen the Standard & Poor's (S&P 500) Exchange-Traded Fund (ETF) Index (SPY) for equities, the euro (EUR) denominated in U.S. dollars (USD) for currencies, the first traded futures contract for gold (GC1), the generic 10-year U.S. Treasury bond (GT10) for rates,[2] and the first futures contract for WTI

[2] GT10 volatility was proxied by the product of duration (assumed to be 7.5 years) and change in yield.

Table 1.1. *Returns statistics (2000–2011)*

Statistic	WTI 1st Month	WTI 1 Year	NG 1st Month	NG 1 Year
σ (1 day)	0.024	0.020	0.034	0.022
$p_{1,99}$ (1 day)	0.067	0.055	0.091	0.059
σ (10 day)	0.072	0.058	0.104	0.068
$p_{1,99}$ (10 day)	0.225	0.170	0.269	0.177

crude oil. WTI is an abbreviation for West Texas Intermediate, which is a particular specification of crude oil deliverable at Cushing, Oklahoma; the futures contract serves as one of the world benchmarks for energy prices.[3]

The realized volatility of WTI has been consistently and meaningfully higher than that of the other series, with the exception of the gold contract, which reached volatilities of roughly 90 percent of WTI in 2006. The average annual volatility ratios were much lower across all the references assets, with a low of 21 percent for GT10 to a high of 55 percent for SPY.

While the realized volatility in energy commodities is systematically higher than that of other comparables, options markets exist on numerous energy benchmarks, often with considerable depth. Given that options can be used to mitigate volatility risk, one might be tempted to dismiss high energy volatility as merely a curiosity. On the contrary, higher volatility affects the commercial operations of a business in many ways, some of which simply cannot be easily managed using options.

Consider Table 1.1, which shows returns statistics for the WTI and Henry Hub natural gas (NYMEX NG) futures contracts. These results are for the first contract and the first calendar strip prices[4] over one- and ten-trading-day intervals. The statistics shown are the standard deviation σ as well as the greater of the absolute value of the first and 99th percentiles, denoted by $p_{1,99}$. One can expect prices to move routinely 6 to 7 percent over a ten-business day (two-week) period, with changes of over 15 percent not unexpected.

These statistics, while just another way of restating the high-volatility premise, do help to add perspective to transaction mechanics. Most sizable transactions involve exposure to multiple years of commodity prices, so the calendar strip statistics are the more pertinent. Suppose that you are negotiating the purchase or sale of an energy asset, for example, a collection of

[3] Most global crude oil trading references the other benchmark, namely, the Brent futures contract. We will use both WTI and Brent throughout as context requires.

[4] A calendar strip price is the average of the futures or forward prices for a given calendar year and should be thought of as the price for delivery of the commodity over the course of the next twelve months. In this case we are using the arithmetic average without discounting and the volumetric considerations discussed in Chapter 2.

oil or natural gas production fields, or a large natural gas power-generation asset. The value of each of these examples is approximately linear in the underlying fuel price. For an acquirer paying significant sums, often in excess of $1 billion, as well as for the lenders supporting such an activity, a 15 percent change in value over two weeks can be highly problematic. Simply converging on an acquisition price in the course of negotiations can be challenging. Hedging the exposure of a large transaction, once completed, must also occur on relatively short time scales in order to avoid the potentially large changes in value.

High volatility also affects collateral postings and increases credit exposure, resulting in higher capital requirements for energy trading operations. Whether exchange-traded or over the counter (OTC),[5] hedging activities are almost always accompanied by collateral posting requirements. The larger the potential swings in the mark-to-market of trading operations, the more cash or functional equivalents such as letters of credit (LCs) are required for daily operations.

A more subtle but severe consequence of high energy price volatility arises when the underlying business premise involves an inherent asymmetry in collateral posting requirements. A relatively recent example is the case of retail energy providers (REPs), which are companies that contract and serve the energy requirements of end users; these could be residential consumers, commercial customers (e.g., stores, restaurants, and the like), and some industrial customers. The REP is short energy to each of its customers. To hedge its aggregate short position, the REP typically makes forward purchases of the energy commodities via exchange-traded or OTC markets.

A collateral posting asymmetry arises from the fact that the customers to whom the REP is short are not margined (imagine if your utility or REP was calling you for margin against your expected future annual energy usage!), whereas the energy purchases are margined. Everything works fine, provided that macro energy price levels don't change too much or, better yet, if they increase. However, if prices decrease, the REP must post collateral against its long energy hedges. If the price decrease is severe enough, the collateral calls can be lethal.[6]

Figure 1.2 shows the time series of rolling calendar strips for WTI, NYMEX natural gas and PJM[7] power prices. PJM is a power market in the eastern United States and the largest such market in North America.

[5] Over-the-counter trades are bilateral trades between two counterparties that are not exchange trades.

[6] The history of commodities trading is replete with examples of cash-flow crises sustained by market participants due to collateral posting asymmetries, the most notorious though somewhat dated example being that of Metallgesellschaft.

[7] PJM stands for the original states involved in the market, namely, Pennsylvanin, New Jersey, and Maryland. The PJM Interconnection now spans a large swath of the Midatlantic states.

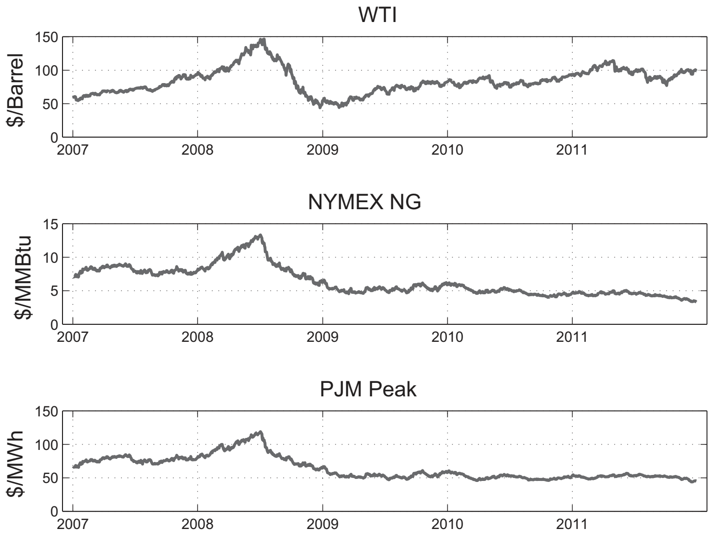

Figure 1.2. History of rolling calendar strips for U.S. energy benchmarks.

Imagine that, as manager of an REP, you purchased significant hedges in mid-2008. This would be a routine aspect of your portfolio-management practices, arguably even more sensible at the time given that many commodities research teams were forecasting ever-increasing energy prices. Fast forward a few months after energy prices had collapsed by a factor of roughly three; cash-flow distress among many natural shorts such as the REPs with long hedges was unprecedented and resulted in many companies exiting the business.

Figure 1.2 also illustrates the common macro structure in the price dynamics in the run-up to and the aftermath of the credit crisis. Although the price dynamics of each distinct energy commodity is affected by idiosyncratic drivers, prices at times can be broadly coupled by global events.

Specialness

Another feature of energy commodities that distinguishes them from other asset classes is the concept of "specialness." This term is borrowed from bond markets, in which demand for a particular bond is high, often due to the fact that it is "cheapest to deliver" (CTD) into a bond futures contract; see [BBLP05] for a more detailed discussion. Such bonds can trade at a significant premium to roughly comparable bonds and are said to be *trading special*. Figure 1.3 shows a snapshot of yields for U.S. Treasuries as a function of duration. Several bonds stand out as having anomalously low yields; these are the CTDs into their respective bond futures contracts.

The supply of a CTD bond available for delivery into a futures contract is limited. Finite issuance at inception is an a priori limit to supply. In addition,

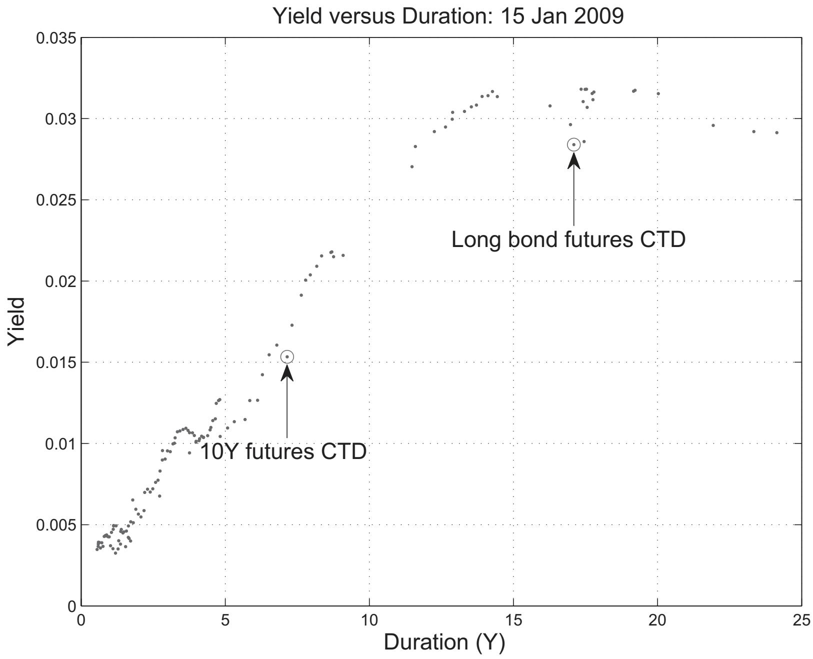

Figure 1.3. U.S. Treasury yields versus duration. (*Credit Suisse–Global Market Analytics Group*.)

passive investors often hold much of the original issuance, reducing the amount of the bond available for trading. The result can be a higher price for the CTD and a commensurately lower yield. The way this works in practice is that traders who have a short position in bond futures contracts need to procure the CTD for delivery. Once delivery is made, the supply stress on the CTD is alleviated, and yields will (probably) return to normal. The CTD is obtained via a reverse repo, where the bond is borrowed from someone who has it, and cash is lent in return at the repo rate. If the supply stress on the CTD is significant, the repo rate can be very low – to obtain the CTD you are lending at rates far below market rates.

This phenomenon is well understood by bond traders, although now and again surprises occur when market participants fail to predict a low supply of a CTD. If you are hedging your risk using liquid on-the-run (most recently issued) bonds and some part of your portfolio unexpectedly goes special, portfolio management becomes challenging. The term *special* is also used more broadly in financial markets in reference to any particular asset that is trading at an unusual premium to comparables. Major economic disturbances can result in extreme levels of specialness with severe consequences for some. The Russian financial crisis of in 1998 resulted in a global drop in commodities prices that had its origins in the Asian financial crisis roughly a year earlier. During the ensuing turbulence, U.S. swap spreads (the spread between dollar interest-rate swaps and U.S. Treasuries) widened to historic levels. Treasuries "went special" relative to swaps as a result of a flight to safety, causing some well-known hedge funds to fail. The credit crisis of 2008 also witnessed the breakdown of many ostensibly stable relationships between financial and cash instruments.

Although financial markets have certainly experienced dramatic and painful periods of widespread specialness, these are sporadic and certainly not the norm. Financial markets are stabilized by various institutions, such as the Federal Reserve and the European Central Bank (ECB), that have historically been successful at controlling the supply of credit as needed and that act in a generally predictable manner. In addition, electronic transfer of ownership of assets has reduced transaction costs and time lags, increasing the efficiency of the marketplace.

In contrast, energy commodities are often going special and frequently very special. One might even go so far as to say that specialness is the norm.

Supply and demand variations are more extreme in energy markets, and one cannot electronically wire a shipment of crude oil or natural gas to a location in which demand is high. Physical storage and transportation constraints can arise suddenly and result in significant locational and temporal price variations. Energy markets are also lacking the stability induced by large stabilizing bodies. The Organization of Petroleum Exporting Countries (OPEC), and Saudi Arabia in particular, attempt to stabilize energy prices, again with much less success than central banks have had in financial markets. National petroleum reserves also factor into the governing mechanisms of energy markets, but with much less predicability regarding both deployment and ultimate effect. In addition, the characteristic time scales for equilibration of structural supply-demand imbalances can be significant because of the substantial time and capital required to build the necessary infrastructure.

The upshot is that a single commodity delivered at two different times or locations can behave functionally as two entirely different assets.

Figure 1.4 shows the NYMEX natural gas (NG) futures price curve on a particular date. The points in the plot represent the prices for natural gas to be delivered in each of the contract months as of the end of the trading day January 25, 2010. The quasi-periodicity (and lack of monotonicity) of prices is due to seasonal variations in demand. Heating demand in the winter in North America results in far higher consumption than during the rest of the year; this results in the seasonal premia. The winter months are special relative to the summer; a chronic state of affairs. In the language of repos, if you wanted to borrow the commodity during the high-priced winter months and return it during the lower-priced summer months, you would be lending cash at negative (in some cases very negative) interest rates.

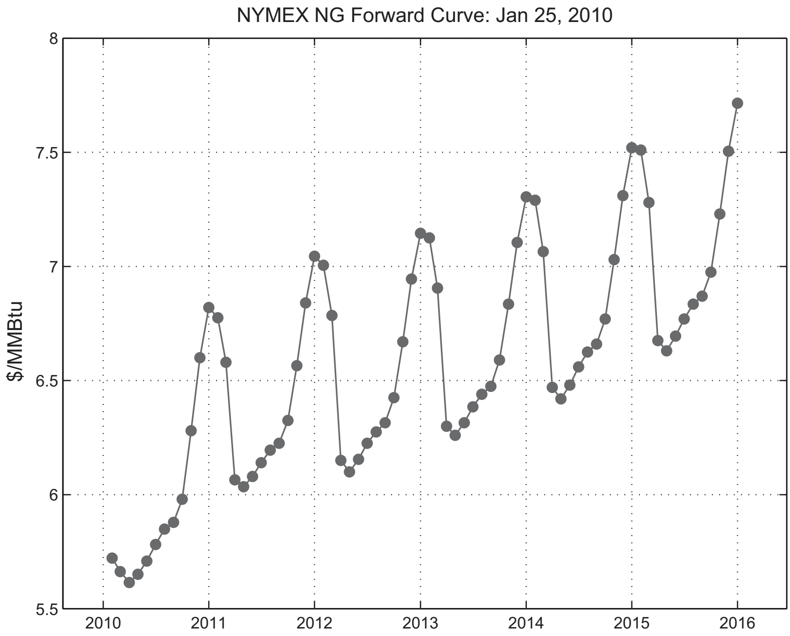

Figure 1.4. NYMEX natural gas forward curve.

Spot prices show even more dramatic and less predictable behavior. The term *spot price* refers to the price for delivery of a commodity *now*, that is, for nearly immediate delivery. The operational definition of *immediate delivery* always involves a lag that is a function of the time required for a supplier to arrange the logistics of shipping and delivery. For example, the spot price for natural gas is usually established the day before delivery.

Figure 1.5 shows daily spot prices and returns for Henry Hub, the delivery location underpinning the NYMEX natural gas contract (we will talk more about this in Chapter 2). By *spot returns*, we mean $\log(p_{d+1}/p_d)$, where p_d denotes the spot price on day d. We are taking liberties here, because returns are only well defined for a series of prices of the *same* underlying asset or deliverable. Commodity prices at two different delivery times are related only insofar as the commodity can be readily stored in the sense that an increase or decrease in inventory at known cost can be readily effected. An extreme case that illustrates this point is power, which is effectively unstorable, rendering this definition of returns highly questionable. Caveats aside, the results serve the purpose of illustrating the rapid variation in the value of a commodity at almost identical delivery times; daily returns are frequently in excess of 500 percent in magnitude.

Locational specialness also distinguishes energy commodities from other asset classes which are largely devoid of geographic disparities. Changes in demand and constraints in transportation can result in the appearance of rapid locational value disparities. Figure 1.6 shows results for a natural