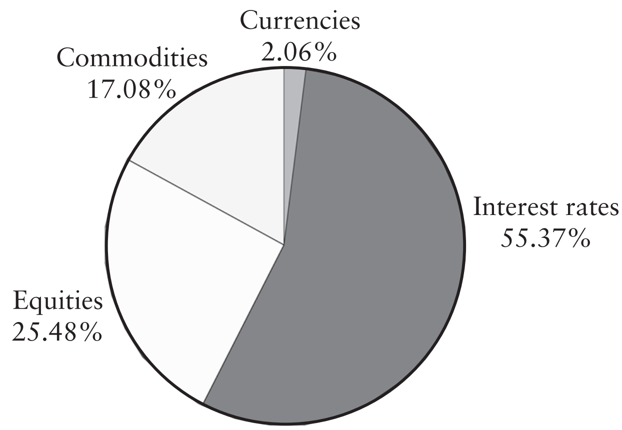
CHAPTER 21
Commodity Products

Commodities are physical assets. Examples include precious metals, base metals, energy stores (e.g., crude oil and natural gas), refined products (e.g., heating oil and gasoline), and food (e.g., wheat, and livestock). Commodity derivatives have been traded in over-the-counter markets for centuries. The first modern-day commodity futures exchange began operation in 1865, when the Chicago Board of Trade launched trading of standardized futures contracts calling for the delivery of grain. Other futures exchanges were formed shortly thereafter—the New York Cotton Exchange in 1870 to trade cotton futures, the Chicago Produce Exchange (a forerunner to today's Chicago Mercantile Exchange) in 1874 to trade butter, eggs, and poultry, the London Corn Trade Association in 1878 to trade corn futures in England, and the Winnipeg Commodity Exchange in 1904 to trade oat futures contracts in Canada. With the passage of time, nonagricultural commodities were introduced—precious metal (silver) futures were launched by the Commodity Exchange in the United States in 1933, wool futures by the Sydney Futures Exchange in Australia in 1960, and livestock by the Chicago Mercantile Exchange in 1961. Crude oil and oil products were introduced next—heating oil by the New York Mercantile Exchange in October 1978, crude oil in March 1983, and unleaded gasoline in December 1984. Liquefied propane appeared in August 1987, and electricity in March 1996.

This chapter focuses on derivatives contracts written on commodities. Given their long history, it may seem odd that we have deferred the discussion of commodities derivatives to the end of the book. The reason is that, while their history is long, their trading volume pales by comparison to financial derivatives. During 2003, exchange-traded commodity futures accounted for only 17% of total trading (see Figure 21.1), and exchange-traded commodity options for only 1% of total (see Figure 21.2). Their presence in OTC markets is even less. At the end of December 2003, commodity derivatives accounted for only 1% of the total notional amount outstanding (see Figure 21.3).

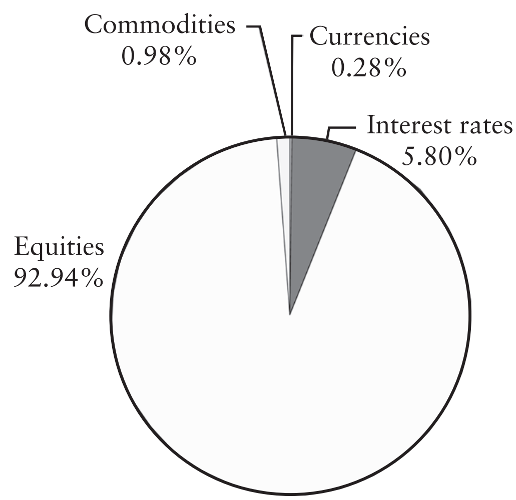
This chapter is organized differently than the other product chapters in that the sections of this chapter are arranged by underlying commodity. The reason is that the price relations of commodity derivatives are influenced by idiosyncrasies in the underlying commodity market. Understanding commodity derivatives price behavior therefore involves understanding the factors that influence com-

FIGURE 21.1 Millions of futures contracts traded on exchanges worldwide during 2003 categorized by type of underlying asset. Total trading volume was 2,848 million contracts.



Source: Data compiled from Bank for International Settlements (www.bis.org), *BIS Quarterly Review*, June 2004.

FIGURE 21.2 Millions of options contracts traded on exchanges worldwide during 2003 categorized by type of underlying asset. Total trading volume was 5,210 million contracts.

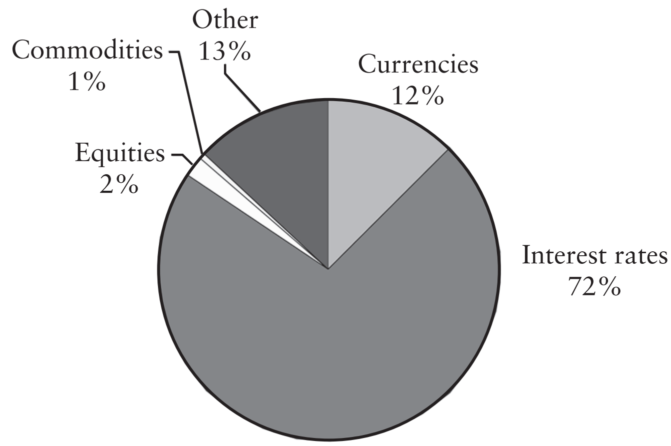


Source: Data compiled from Bank for International Settlements (www.bis.org), *BIS Quarterly Review*, June 2004.

modity price behavior. Thus we begin each section with a description of the underlying commodity market, and then provide descriptions of derivatives contract specifications and discussions of common risk management applications.

The sections of the chapter proceed as follows. In the first section, we discuss the fundamental differences between pricing commodity derivatives and pricing financial derivatives. Commodity derivatives require that we consider the storage costs such as warehouse rent and insurance as well as the convenience of having an inventory of the commodity on hand. Neither of these factors played an important role in the pricing of stock, stock index, currency, and interest rate

FIGURE 21.3 Percentage of total notional amount of derivatives outstanding worldwide on December 2003 by underlying asset category. Total notional amount of derivatives is USD 197.2 trillion.



Source: Data compiled from Bank for International Settlements (www.bis.org), *BIS Quarterly Review*, June 2004.

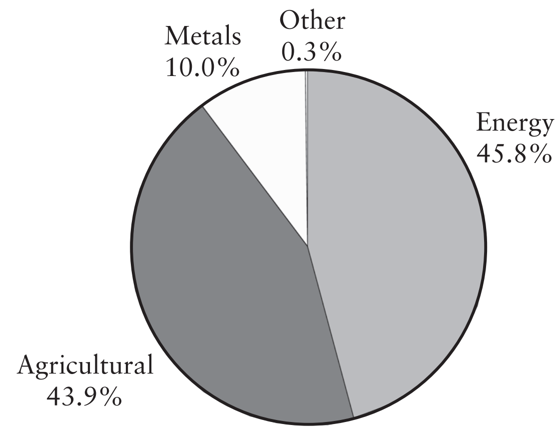
derivatives products. The remaining sections are organized by commodity. Figure 21.4 shows commodity futures and futures options trading volume during 2003 by the three major commodity categories—energy, agricultural, and metals. We illustrate the idiosyncrasies of each commodity using an example—petroleum, soybeans, and gold, respectively. Figure 21.5 shows the notional amounts of OTC commodity derivatives outstanding at the end of December 2003. While the breakdown among commodity categories is not as refined, the relative importance of precious metal derivative contracts in the OTC market is apparent.

NET COST-OF-CARRY RELATION

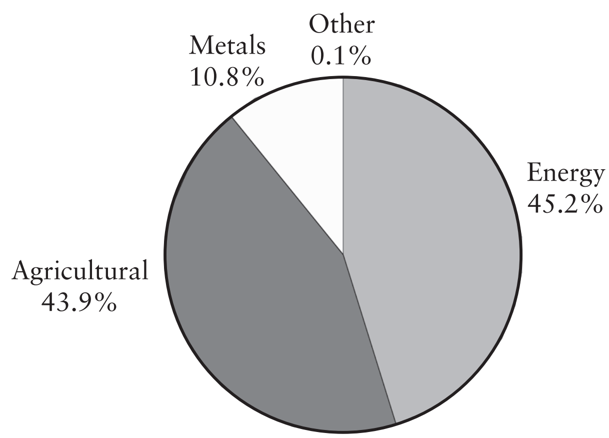
Chapter 4 contained the development of the no-arbitrage price relations for forwards, futures, and swaps. In the chapters that followed, we used the price relations in a variety of risk management strategies, however, the focus was almost exclusively on financial assets such as stocks and stock portfolios, currencies, and bonds. This section focuses on commodity price risk management, so we begin with a review of the net cost of carry pricing principles.

The *net cost of carry* refers to the difference between the costs and the benefits of holding an asset. A breakfast cereal producer who needs 5,000 bushels of wheat for processing in two months can lock in the price of the wheat today by buying it and carrying it for two months. If he does so, he incurs the opportunity cost of funds. In addition, he will pay *storage costs* such as warehouse rent and insurance. At the same time, by storing wheat, he may accrue *convenience yield*, that is, he may avoid some costs of possible running out of inventory before two months are up and having to pay extra for emergency deliveries or shutting down the production plant. Thus the net cost of carry for a commodity equals interest cost plus storage costs less convenience yield, that is,

FIGURE 21.4 Proportion of total commodity futures and futures options trading volume in U.S. during 2003 by commodity category. Total futures (futures options) trading volume in 2003 was 200,551,739 (45,377,075) contracts.
Panel A. Futures



Panel B. Futures options



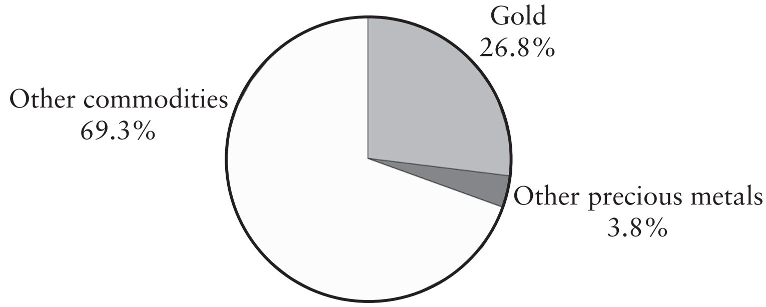
Source: Data compiled from Futures Industry Institute, 2005.

$$\text{Net carry costs} = \text{Cost of funds} + \text{Storage cost} - \text{Convenience yield} \tag{21.1}$$

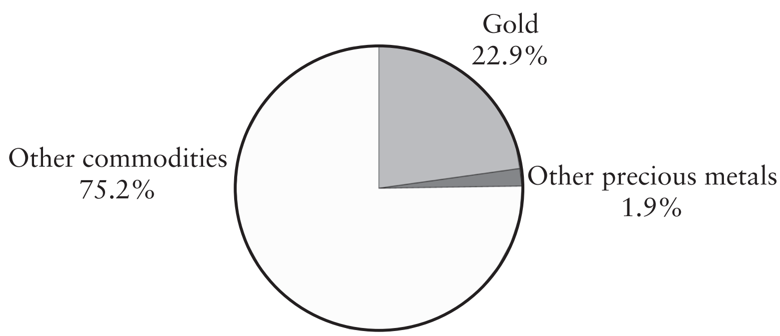
For expositional convenience, we will initially model all costs as constant continuous rates. The value of a cash-and-carry position at time T is $Se^{(r+s-y)T}$, where r is the risk-free interest rate, s is the storage cost rate, and y is the convenience yield rate.

To develop the forward pricing relation for a commodity, we need to consider how commodities are used and the types of traders in the marketplace. Consider a commodity like crude oil. An oil refiner draws convenience yield from holding an inventory of crude to avoid the costs associated with shutting

FIGURE 21.5 Proportion of total notional amount of commodity derivatives outstanding in OTC markets as of December 31, 2003. Total forwards and swaps (options) notional amount was USD 574B (USD 831B).
Panel A. Forwards and swaps



Panel B. Options



Source: Data compiled from Bank for International Settlements (www.bis.org), *BIS Quarterly Review*, June 2004.

down the refinery while more crude oil is pumped in.[1] Thus the refiner's net cost of carry is $r + s - y$. But many market participants do not accrue convenience yield from holding an inventory of crude. Like the refiner, they would incur storage costs, however, since they do not accrue convenience yield, their net carry cost is $r + s$. With these distinctions in mind, we now develop the commodity forward pricing relation.

Recall that, in Chapter 4, we developed the net cost of carry relation,

$$f = Se^{(r-i)T} \tag{21.2}$$

by showing that, if either $f > Se^{(r-i)T}$ or $f < Se^{(r-i)T}$, someone could earn an arbitrage profit. We will use the same approach here to show that the net cost of carry relation for a commodity is

$$Se^{(r+s-y)T} \leq f \leq Se^{(r+s)T} \tag{21.3}$$

[1] Another such cost is lost customer goodwill when deliveries are missed.

TABLE 21.1 Costless arbitrage trades where $f > Se^{(r+s)T}$.

Trades	Initial Investment	Value on Day T
Buy e^{sT} units of commodity	$-Se^{sT}$	$\tilde{S}_T$
Sell risk-free bonds	Se^{sT}	$-Se^{(r+s)T}$
Sell forward contract		$-(\tilde{S}_T - f)$
Net portfolio value	0	$f - Se^{(r+s)T}$

TABLE 21.2 Arbitrage trades where $f < Se^{(r+s-y)T}$.

Trades	Initial Investment	Value on Day T
Sell $e^{(s-y)T}$ units of commodity from inventory	$-Se^{(s-y)T}$	$\tilde{S}_T$
Buy risk-free bonds	$Se^{(s-y)T}$	$-Se^{(r+s-y)T}$
Buy forward contract		$\tilde{S}_T - f$
Net portfolio value	0	$f - Se^{(r+s-y)T}$

Consider the case where $f > Se^{(r+s)T}$, that is, the forward price is too high relative to the commodity price. To earn an arbitrage profit, we can borrow money at the risk-free rate, buy the commodity, and sell the forward contract to earn $f - Se^{(r+s)T} > 0$. The transactions are shown in Table 21.1. The trading strategy involves no investment and a terminal value that is certain to be positive. We would continue to engage in the strategy until $f \leq Se^{(r+s)T}$.

Now suppose that $f < Se^{(r+s)T}$. The forward price appears to be too low relative to the commodity price, so it appears that we can earn a costless arbitrage profit by selling the commodity, buying risk-free bonds, and buying the forward contract. But therein lies the problem. Unlike financial assets, commodities are frequently in short supply and are unavailable to borrow and sell short. The only person able to execute such an arbitrage is someone, like a refiner, who holds an inventory of the commodity. When the forward price falls below $f < Se^{(r+s-y)T}$, the refiner will find it profitable to sell some of his existing inventory and buy a forward contract, as shown in Table 21.2. The prepaid forward price of the commodity, $fe^{-rT} < Se^{(s-y)T}$ is less than the cost of storing the commodity even after the convenience yield is subtracted.[2]

Commodity Swap Contracts

An increasingly popular risk management strategy is a commodity swap. Commodity swaps have been around since the mid-1970s, and are an effective means of locking in input and output prices. In a typical fixed-for-floating commodity

[2] One is tempted to reconsider the first inequality in which we engaged in the arbitrage and ask why the refiner, who gathers convenience yield from holding does not step in and buy more of the asset and sell the forward contract. The answer is that the refiner likely holds all the inventory he wants. Additional holdings will only serve to increase storage costs. Without gathering increment convenience yield, the refiner has the same cost structure as we do in executing the arbitrage strategy.

swap, one party agrees to pay a fixed price per unit of the underlying commodity each period throughout the life of the agreement. The length of the contract is negotiable, as is the length of each period during the contract's life (e.g., one month). The contract will also specify the amount to be delivered each period, although the quantity need not be uniform through time. The nature of the settlement each period is also negotiable. Some contracts specify delivery at a particular location. Others are cash-settled with a net payment equal to the difference between the prevailing spot price on the settlement date and the fixed price of the contract times the promised delivery quantity.

ENERGY: PETROLEUM

Within the energy category, derivative contracts on petroleum are the most active. All exchange-traded contracts in the United States are traded on the New York Mercantile Exchange (NYMEX division). Table 21.3 shows the most active futures and futures options. The petroleum contracts (i.e., crude oil, heating oil, and gasoline) constitute about 74 (56)% of total futures (futures options) trading volume during 2003. Natural gas contracts account for 21.7 (42.6)%. The "other" category includes more than 70 different underlyings including other commodities (e.g., electricity), spreads (e.g., the crack spread), and swaps. While many of these contracts are innovative and potentially useful, none have gathered much interest from a market standpoint. The primary focus of this section is on petroleum and petroleum products.

Production and Consumption

Petroleum[3] is the generic term applied to oil and oil products. Crude oil is petroleum in its natural state—the dark liquid extracted from the ground—and is the world's largest cash commodity. This is hardly surprising considering our day-

TABLE 21.3 Summary of New York Mercantile Exchange (NYMEX division) energy futures and futures options trading volume during 2003.

	Futures		Futures Options	
Commodity	Volume	Percent	Volume	Percent
Crude Oil	45,436,931	49.45%	10,237,121	49.90%
No. 2 Heating Oil, NY	11,581,670	12.60%	668,859	3.26%
Unleaded Reg. Gas., NY	11,172,050	12.16%	616,245	3.00%
Natural Gas	19,037,118	20.72%	8,742,277	42.61%
Other	4,654,332	5.07%	250,305	1.22%
Total	91,882,101	100.00%	20,514,807	100.00%

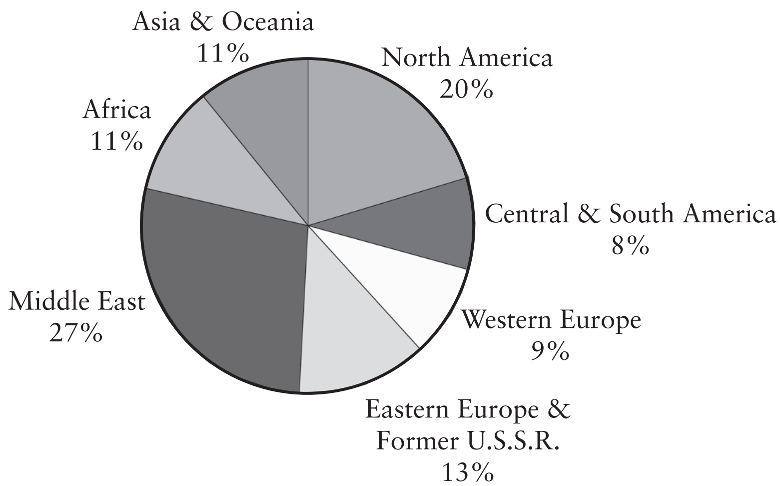
Source: Data drawn from *Futures Industry Institute*, 2005.

[3] The term *petroleum* is derived from the Latin words *petra*, meaning rock, and *oleum*, meaning oil.

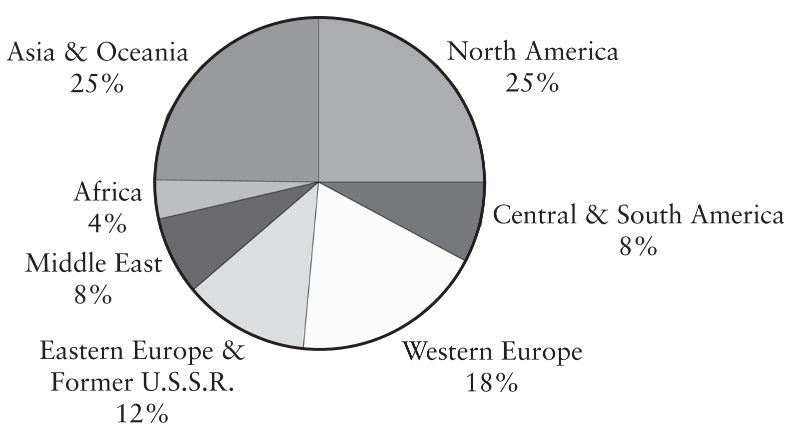
to-day reliance on refined products such as heating oil, gasoline, and jet fuel, not to mention a limitless number of petrochemical-derived products ranging from ball-point pens to toothbrushes and deodorant to lipstick.

Generally speaking, the crude oil refining takes place in the areas where the consumption of petroleum products is highest. One reason for this is that it is cheaper to move crude oil than petroleum product. Another is that it is easier to respond to weather-induced spikes in demand and gauge seasonal shifts. To illustrate this phenomenon, consider Figure 21.6, which shows (1) the production of crude oil by world region and (2) the corresponding refining capacity in

FIGURE 21.6 World production of crude oil and refining capacity by region for the calendar year 2002.
Panel A. Production



Panel B. Refining capacity



Source: Underlying data drawn from Energy Information Administration, *International Energy Annual* 2002.

2002. While the Middle East and Africa produced 38% of the world's oil in 2002, their combined refining capacity was 12%. At the same time, while Asia, North America, and Western Europe account for 40% of production, they have 68% of the world's refining capacity.

The cost of the crude constitutes about 85% of total refining costs. The core refining process is *fractional distillation*. Crude oil is heated until it boils and vaporizes. The vapors are captured in a distillation column, and, as they rise in the column, they cool and condense. Different products condense at different temperatures. The lighter products—liquid petroleum gases, naphtha, and gasoline—are recovered at the lowest temperatures (highest levels within the column). The middle distillates—jet fuel, kerosene, home heating oil, and diesel fuel—are next. Finally, at the lowest levels (highest temperatures), the heaviest products—residuum or residual fuel oil—are recovered. The heavier molecules have fewer uses so they are often further transformed into lighter-end gasoline products by a *catalytic cracking process*. On average, 42 gallons of crude produces 21 gallons of gasoline, 3 gallons of jet fuel, 9 gallons of heating oil and diesel fuel, 4 gallons of lubricants, and 3 gallons of heavier residues.

Derivatives Markets

The trading of petroleum futures and futures options in the United States is conducted exclusively on the New York Mercantile Exchange (NYMEX). The heating oil futures contract market was launched in December 1978, followed by crude oil in March 1983 and unleaded gasoline futures in December 1984. Relative to many other commodities, petroleum derivatives were late to enter the marketplace. The reason is simple. In the 1960s and 1970s, crude oil prices were tightly controlled by OPEC together with large globally integrated oil companies. With little or no commodity price variability, there is no need for producers and end-users to hedge. By the early 1980s, competition from non-OPEC oil-producing countries began to undermine OPEC's influence on oil markets, and energy prices began to move more freely in response to market conditions. Such an environment creates a new opportunity for risk management tools.

Table 21.4 summarizes the key features of the petroleum futures contracts traded on NYMEX. The crude oil contract calls for the delivery of 1,000 barrels of crude in Cushing, Oklahoma. Several grades of domestic and internationally traded foreign crudes are eligible for delivery. The contracts are traded in an open outcry format on the exchange floor during the day, and electronically at other times. The last day of trading is the third business day prior to the 25th calendar day of the month preceding the delivery month.

The heating oil (also called "no. 2 fuel oil") and gasoline futures contracts call for the delivery of 42,000 gallons in New York Harbor. Note that size of the heating oil and gasoline contracts is the same as the crude oil contract (i.e., 42,000 gallons equals 1,000 barrels). This was done deliberately to facilitate trading of crack spreads. A *crack spread* refers to the simultaneous purchase (sale) of the crude oil futures and sale (purchase) of a heating oil or unleaded gasoline futures. The last day of trading for the heating oil and gasoline contracts is the last business day of the month preceding the delivery month.

TABLE 21.4 Selected terms of major petroleum futures contracts traded on the New York Mercantile Exchange.

	Crude Oil (CL)	Heating Oil (HO)	Unleaded Gasoline (HU)
Contract unit	1,000 barrels (42,000 gallons)	42,000 gallons (1,000 barrels)	42,000 gallons (1,000 barrels)
Tick size	$.01 per barrel	$.0001 per gallon	$.0001 per gallon
Tick value	$10 per contract	$4.20 per contract	$4.20 per contract
Trading hours	Open outcry trading is conducted from 10 AM until 2:30 PM.	Open outcry trading is conducted from 10:05 AM until 2:30 PM.	Open outcry trading is conducted from 10:05 AM until 2:30 PM.
	After hours trading is conducted via the NYMEX ACCESS internet-based trading platform beginning at 3:15 PM on Mondays through Thursdays and concluding at 9:30 AM the following day. On Sundays, the session begins at 7 PM.		
Contract months	30 consecutive months plus long-dated futures initially listed at 36, 48, 60, 72, and 84 months prior to delivery.	18 consecutive months.	12 consecutive months
Last day of trading	Third business day prior to 25th calendar day of month preceding delivery month.	Last business day of month preceding delivery month.	Last business day of month preceding delivery month.
Final settlement	Physical	Physical	Physical

Table 21.5 shows futures settlement prices of the petroleum futures on January 25, 2005. For crude oil futures, contract maturities extend out seven years, although trading volume is quite light in the most distant months. For heating oil futures, the maximum contract tenure is 18 months, and, for gasoline futures, 12 months. The table shows that all three contract markets are in backwardation. This is a common characteristic of energy futures prices. Backwardation implies that there are significant convenience yields on energy products for immediate or near-term delivery. The prices also reflect the seasonal nature of the demand for heating oil and gasoline. With heating oil, for example, demand is highest in the cold winter months. Consequently, we see that the heating oil futures prices reported in Table 21.5 are higher for the contract months November through February than they are for other months during the year. Conversely, gasoline futures prices are highest during the summer months when people travel more.[4]

The NYMEX launched trading of unleaded gasoline futures options in December 1984. The options are American-style, and each contract is written on one underlying futures contract. Exercising a call on the unleaded gasoline futures, for example, means that a long position in one unleaded gasoline futures will appear in your trading account at the end of the day, and you will be marked-to-market at the difference between the futures price and the option's exercise price. The last day of trading of the unleaded gasoline futures contract is the last business day of the month preceding the delivery month of the underlying futures. Options on crude oil and heating oil futures were launched in November 1986 and June 1987, respectively. The terms of the contract are very similar to the unleaded gasoline futures. For details, see www.nymex.com.

Derivatives Valuation

The valuation of petroleum derivatives follows the principles outlined in the first section of this chapter. Storage costs play a significant role in pricing and convenience yield for refined products varies by time of year as demand rises and falls. In valuing petroleum derivatives and in measuring their risk, the forward curve, as illustrated by the relation between futures prices and their time of expiration in Table 21.5, plays a critical role.

ILLUSTRATION 21.1 Compute fixed price of commodity swap.

Based on the heating oil futures prices reported in Table 21.5, compute the fixed price on a heating oil swap that allows you to buy 50,000 gallons of heating oil per week for 26 weeks. Assume that today's date is January 25, 2005 and that the zero-coupon yield curve for risk-free bonds is given by

$$r_i = 0.0178 + 0.01\ln(1 + T_i)$$

The first delivery date is February 7, 2005.

To solve this problem, we assume that the forward curve is given by the structure of futures prices in Table 21.5. The last day of trading of heating oil futures contract is the last day of the month preceding the contract month. Thus, the February 2005 contract expires on January 31, 2005. The points along the forward curve are therefore:

[4] Approximately 75% of gasoline is consumed by individuals.

Heating Oil Forward Curve		
Contract Month	**Settlement Price**	**Time to Expiration**
Feb-05	1.4248	0.0192
Mar-05	1.4088	0.0959
Apr-05	1.3608	0.1808
May-05	1.3153	0.2658
Jun-05	1.2883	0.3507
Jul-05	1.2823	0.4356
Aug-05	1.2833	0.5205
Sep-05	1.2898	0.6055
Oct-05	1.2983	0.6904
Nov-05	1.3068	0.7753
Dec-05	1.3153	0.8603
Jan-06	1.3203	0.9452
Feb-06	1.3133	1.0301
Mar-06	1.2868	1.1151
Apr-06	1.2478	1.2000
May-06	1.2198	1.2849
Jun-06	1.2013	1.3699
Jul-06	1.1978	1.4548

The next step is to set up a table that contains the delivery dates, and the corresponding interest rates and forward prices. The forward prices corresponding to each delivery date can be computed by interpolating between adjacent forward prices. Recall the OPTVAL function

OV_IR_TS_INTERPOLATE(*sterm, term, rate*)

where *sterm* is the time to delivery, *term* is the vector of times to delivery for the forward contracts, and *rate* is the vector of forward prices, performs this operation. With the interest rates and forward prices computed, you compute the discount factor and prepaid forward price for each delivery, and then sum. The results are shown as follows:

Delivery No.	Delivery Date	Time to Delivery	Interest Rate	Forward Price	Discount Factor	Prepaid Forward	PV of Fixed 1.3321
1	2/7/05	0.0356	1.815%	1.4214	0.9994	1.4205	1.3312
2	2/14/05	0.0548	1.833%	1.4174	0.9990	1.4159	1.3307
3	2/21/05	0.0740	1.851%	1.4134	0.9986	1.4114	1.3302
4	2/28/05	0.0932	1.869%	1.4094	0.9983	1.4069	1.3298
5	3/7/05	0.1123	1.886%	1.3995	0.9979	1.3965	1.3293
6	3/14/05	0.1315	1.904%	1.3887	0.9975	1.3852	1.3287
7	3/21/05	0.1507	1.920%	1.3778	0.9971	1.3739	1.3282
8	3/28/05	0.1699	1.937%	1.3670	0.9967	1.3625	1.3277
9	4/4/05	0.1890	1.953%	1.3564	0.9963	1.3514	1.3272

Delivery No.	Delivery Date	Time to Delivery	Interest Rate	Forward Price	Discount Factor	Prepaid Forward	PV of Fixed 1.3321
10	4/11/05	0.2082	1.969%	1.3461	0.9959	1.3406	1.3266
11	4/18/05	0.2274	1.985%	1.3358	0.9955	1.3298	1.3261
12	4/25/05	0.2466	2.000%	1.3256	0.9951	1.3191	1.3255
13	5/2/05	0.2658	2.016%	1.3153	0.9947	1.3083	1.3250
14	5/9/05	0.2849	2.031%	1.3092	0.9942	1.3016	1.3244
15	5/16/05	0.3041	2.046%	1.3031	0.9938	1.2950	1.3238
16	5/23/05	0.3233	2.060%	1.2970	0.9934	1.2884	1.3232
17	5/30/05	0.3425	2.075%	1.2909	0.9929	1.2818	1.3226
18	6/6/05	0.3616	2.089%	1.2875	0.9925	1.2778	1.3220
19	6/13/05	0.3808	2.103%	1.2862	0.9920	1.2759	1.3214
20	6/20/05	0.4000	2.116%	1.2848	0.9916	1.2740	1.3208
21	6/27/05	0.4192	2.130%	1.2835	0.9911	1.2721	1.3202
22	7/4/05	0.4384	2.144%	1.2823	0.9906	1.2703	1.3196
23	7/11/05	0.4575	2.157%	1.2826	0.9902	1.2700	1.3190
24	7/18/05	0.4767	2.170%	1.2828	0.9897	1.2696	1.3184
25	7/25/05	0.4959	2.183%	1.2830	0.9892	1.2692	1.3177
26	8/1/05	0.5151	2.195%	1.2832	0.9888	1.2688	1.3171
				Totals	25.8519	34.4366	34.4366

From Chapter 4, you know that the fixed price on a commodity swap with uniform quantities can be computed by dividing the sum of the prepaid forward prices by the sum of the discount factors, that is,

$$\bar{f} = \frac{34.4366}{25.8519} = 1.3321$$

Another alternative is to set up an additional column in the table that contains the present value of the fixed price and let SOLVER find the price that equates the sum of the present values of the fixed payments to the sum of the prepaid forwards, that is, 34.4366. Finally, OPTVAL contains a function that computes the fixed price on a commodity swap with uniform deliveries each period, that is,

OV_SWAP_COMMODITY(*t, f, r, vr*) = 1.3321

where *t* is the vector of times to delivery, *f* is the vector of forward prices and *r* is the vector of risk-free rates corresponding to the delivery times, and *vr* is an indicator variable that signals the function to determine the swap's value "v" or fixed price "r". The function

OV_SWAP_COMMODITY_QUANTITY(*t, f, r, quan, vr*)

computes the fixed price of a commodity swap where the quantity delivered each period, *quan*, is time-varying.

TABLE 21.5 Summary of trading activity for NYMEX petroleum complex on Tuesday, January 25, 2005.

	Crude Oil			Heating Oil			Unleaded Gasoline		
	1,000 Barrels (dollars per barrel)			42,000 Gallons (cents per gallon)			42,000 Gallons (cents per gallon)		
Contract Month	Settlement Price	Total Volume	Open Interest	Settlement Price	Total Volume	Open Interest	Settlement Price	Total Volume	Open Interest
Feb-05				1.4248	23,063	26,626	1.3445	23,094	21,704
Mar-05	49.64	72,155	223,551	1.4088	17,538	62,051	1.3594	22,781	56,794
Apr-05	49.80	39,777	68,599	1.3608	6,288	20,270	1.4259	5,923	25,975
May-05	49.70	21,533	30,622	1.3153	1,684	9,249	1.4299	4,531	25,936
Jun-05	49.42	9,650	40,248	1.2883	963	12,267	1.4229	1,079	10,802
Jul-05	49.03	4,911	22,749	1.2823	250	7,923	1.4064	94	5,224
Aug-05	48.63	633	12,674	1.2833	0	3,091	1.3799	713	6,369
Sep-05	48.23	1,422	15,549	1.2898	5	5,895	1.3469	1,054	7,050
Oct-05	47.83	525	11,892	1.2983	0	808	1.3054	972	3,248
Nov-05	47.49	650	15,531	1.3068	7	1,491	1.2819	115	323
Dec-05	47.18	5,154	57,870	1.3153	405	8,253	1.2684	1	1,697
Jan-06	46.82	122	10,804	1.3203	0	1,619	1.2629	873	29
Feb-06	46.46	54	5,242	1.3133	0	737			
Mar-06	46.13	156	9,226	1.2868	80	2,355			
Apr-06	45.84	225	4,769	1.2478	0	439			
May-06	45.56	0	2,690	1.2198	0	410			
Jun-06	45.28	1,487	25,683	1.2013	0	567			
Jul-06	45.04	0	2,639	1.1978	0	362			
Aug-06	44.81	0	1,921						
Sep-06	44.58	145	3,823						
Oct-06	44.36	2	1,400						
Nov-06	44.14	150	1,428						
Dec-06	43.92	2,253	39,328						
Jan-07	43.74	0	1,711						
Feb-07	43.57	100	1,167						
Mar-07	43.41	0	743						
Apr-07	43.25	0	450						
May-07	43.10	0	90						
Jun-07	42.95	50	11,537						
Dec-07	42.14	415	21,073						
Dec-08	41.14	761	23,734						
Dec-09	40.49	106	16,842						
Dec-10	40.06	394	18,721						
Dec-11	39.96	186	2,495						

Source: Information drawn from www.nymex.com.

Spread Contracts One unusual feature of the petroleum complex traded on NYMEX is that they list futures and futures options on spreads. Earlier we described the crack spread as being the difference between the price of heating oil (or gasoline) and crude oil. This spread is a petroleum refiner's *gross margin*. Because both the prices of crude oil and the finished products (e.g., heating oil and gasoline) vary with supply and demand in each market, refiners are at risk when, say, the price of crude rises and the product prices remain flat or fall.

To facilitate the risk management needs of refiners, the NYMEX permits trading of the crack spread directly, that is, both legs of the trade are combined into a single futures transaction. They also list crack spread options. Upon exercise, the option holder receives two offsetting futures positions. The exercise of a call option on the heating oil/crude oil crack spread, for example, results in a long heating oil futures/short crude oil futures position.

ILLUSTRATION 21.2 Compute value of spread option.

Based on the heating oil and crude oil futures prices reported in Table 21.5, compute the value of an American-style put option on the September 2005 crack spread between the heating oil and crude oil futures. Assume that the option's exercise price is 6, that today's date is January 25, 2005 and that the zero-coupon yield curve for risk-free bonds is given by

$$r_i = 0.0178 + 0.01\ln(1 + T_i)$$

Assume also that the volatility rate of the September 2005 heating oil futures is 43.90%, that the volatility rate of the September 2005 crude oil futures is 35.27%, and that the correlation between the heating oil and crude oil returns is 0.85.

According to its contract specifications, the NYMEX crack spread option expires on the day before the underlying crude oil futures contract.[5] The last day of trading for the crude oil futures contract, in turn, is three business days before the 25th calendar day of the month preceding the delivery month. The crack spread option therefore expires on August 19, 2005 and has 206 days to expiration.

Also according to the contract specifications, the option is expressed in dollars per barrel. Thus the September 2005 heating oil futures price, 1.2898, which is expressed in dollars per gallon, must be multiplied by 42 gallons per barrel. Thus the September 2005 heating oil futures price is 54.17, and the current level of the crack spread is 54.17 − 48.23 = 5.94, that is, the put is slightly in the money.

No valuation equation exists for the NYMEX crack spread options. The reasons are twofold. First, if the heating oil and crude oil futures prices are each lognormally distributed, the difference between the prices (i.e., the crack spread) is not log-normally distributed and the BSM model cannot be applied. Second, the NYMEX options are American-style. You can, however, use numerical methods like the binomial method. A discussion of the procedure is described in Chapter 9. For current purposes, however, you can simply use the OPTVAL function developed for this valuation problem, that is,

OV_APPROX_SPRD_FOPT_BIN(*f1, f2, x, t, r, v1, v2, rho, n, cp, ae*)

where *f1* and *f2* are the heating oil and crude oil futures prices, respectively, *x* is the exercise price of the crack spread option, *t* is its time to expiration, *v1* and *v2* are the volatil-

[5] The most reliable way of finding the product specifications of exchange-traded derivatives is to go directly to the exchange's website. The crack spread specifications were taken from www.nymex.com.

ity rates of heating oil and crude oil, *rho* is the correlation between the rates of return of heating oil and crude oil, *n* is the number of time steps to be used in the binomial valuation, *cp* is a (c)all/(p)ut indicator variable, and *ae* is an (A)merican/(E)uropean-style option type indicator. Using the problem information, we find

OV_APPROX_SPRD_FOPT_BIN(54.17,48.23,6,0.5644,0.0223,0.4390,0.3527,0.85, 100,“p”,“a”) = 3.8558

An option premium of 3.8558 protects its holder in the event that the crack spread falls below 6 between now and August 19, 2005.

Risk Management Strategies

The strategies used to manage petroleum price risk depend on the nature of the problem. In the petroleum derivatives markets, refiners or producers are big players. They face uncertainty in their input (i.e., crude oil) cost as well as their output (i.e., heating oil and gasoline) sales price. Another important set of players are end-users who hedges to lock-in the price at which he can purchase a commodity. Airlines, for example, frequently hedge to lock in the price of the jet fuel. Rather than demonstrate the mechanics of a particular strategy once again, let us consider what particular firms report that they do.

Firms are required to report the nature of their derivatives use in their financial statements.[6] The passage below is drawn from Southwest Airlines 2003 Annual Report:

> . . . the Company has hedges in place for over 80 percent of its anticipated fuel consumption in 2004 with a combination of derivative instruments that effectively cap prices at about $24 per barrel, including approximately 82 percent of its anticipated requirements for the first quarter 2004. . . . The majority of the Company’s near term hedge positions are in the form of option contracts, which protect the Company in the event of rising fuel prices and allow the Company to benefit in the event of declining prices.

Apparently, Southwest’s favored strategy is buying call options on jet fuel. In order to cap the purchase price at $24 per barrel, they must have purchased call options with an exercise price of about $24. In the event that the price of jet fuel exceeds $24, Southwest will buy at the market price and exercise their call whose value equals the market price less $24.

American Airlines 2003 Annual Report reveals a similar hedging strategy but not nearly as aggressive:

> As of December 31, 2003, the Company had hedged, with option contracts, approximately 12 percent of its estimated 2004 fuel requirements, or approximately 21 percent of its estimated first quarter 2004 fuel requirements, 16 percent of its second quarter 2004 estimated fuel

[6] The U.S. accounting rules for derivative instruments and hedging activities are contained in FASB Statement No. 133.

> requirements and six percent of its estimated fuel requirements through the remainder of the year. . . . the Company's credit rating has limited its ability to enter certain types of fuel hedge contracts. A further deterioration of its credit rating or liquidity position may negatively affect the Company's ability to hedge fuel in the future.

In reading the first sentence of the passage, one may wonder why American Airlines hedges so little, at least compared with Southwest Airlines. Can the two airlines have completely different views about what the cost and variation of jet fuel prices will be over the next year? Reading a little further into the paragraph provides a different explanation, however. Apparently American Airlines's counterparties are growing increasingly concerned about American's worsening financial condition and are limiting the degree to which they are willing to enter new contracts—risk management of yet a different type!

A couple of other notes regarding the practice of hedging jet fuel costs are worthwhile. First, average-rate derivatives contracts can be very effective and cost-efficient. Consider the airline's risk management problem—it needs a steady flow of jet fuel day by day throughout the year, where the market price it pays each day is uncertain. One hedging alternative is to buy a portfolio of 365 call options with a fixed exercise price (i.e., a cap on the price of fuel throughout the year), with one expiring each day. Assuming the options are cash-settled, the airline receives a cash payment every day that the market price of jet fuel exceeds the exercise price of the call and nothing on the other days. A second hedging alternative is to buy 12 average-rate call options with the same exercise price, with one expiring each month. At the end of the month, the average price of jet fuel over the days during the month is computed. If the average price is above the exercise price of the call, the airline receives the difference in price times the stated quantity over the entire month. The cost of the second alternative is considerably less than the first.

Second, cross-hedging is usually less effective but can be more cost effective. As a practical matter, the market for jet fuel forwards and swaps is not as liquid as it is for heating oil and gasoline. Consequently, airlines are often willing to cross hedge using heating oil contracts to save on trading costs. Why use heating oil rather than gasoline? To answer this question, recall that heating oil and jet fuel are middle distillates in the refining process. Gasoline, on the other hand, is a light distillate. Hence, heating oil and jet fuel are closer substitutes than are gasoline and jet fuel, which means that we expect the heating oil contract to provide a more effective hedge. To test this proposition, we downloaded the weekly prices of jet fuel New York Harbor, crude oil Cushing Oklahoma, heating oil New York Harbor, and unleaded gasoline New Work Harbor from January 1995 though January 2005, compute returns, and estimate cross-correlations. The higher the correlation, the more effective the prospective hedge. Table 21.6 reports the results. As expected, the correlation between the jet fuel and heating oil is 0.844, much higher than the correlation with gasoline, 0.595, or with crude oil, 0.627.

TABLE 21.6 Correlation between weekly returns of jet fuel, crude oil, heating oil, and gasoline during the period January 1995 through January 2005.

	Jet fuel	Crude oil	Heating oil	Gasoline
Jet fuel	1			
Crude oil	0.627	1		
Heating oil	0.844	0.575	1	
Gasoline	0.595	0.687	0.547	1

RISK MANAGEMENT LESSONS: MG REFINING & MARKETING

In December 1991, MG Refining and Marketing (MGR&M), a U.S. subsidiary of the Germany conglomerate, Metallgesllschaft AG (MG), embarked on a program in which they committed to deliver petroleum products at fixed prices over a period up to 10 years. To hedge these "long-term, fixed-supply contracts," they purchased short-dated futures contracts and short-term OTC swap agreements[7] with total underlying volume equal to the total commitments, a so-called "one-to-one stacked hedge." When the futures approached maturity, they were "rolled" into new positions by selling the nearby maturing contracts and buying the second nearby, reducing the size of the position by the amount of product delivered that month.

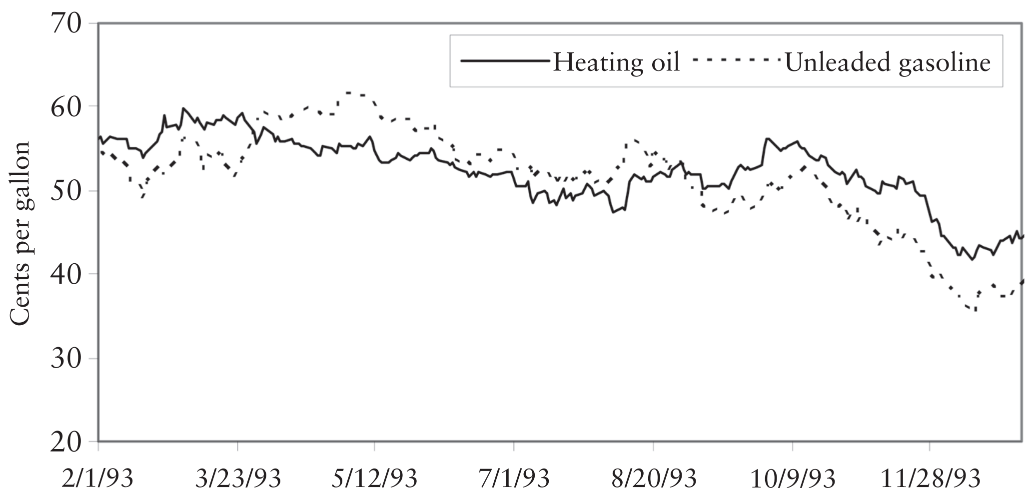
In the early days, this combined marketing/hedging program was very successful. Among the reasons was that the margin between the fixed price and the average spot price was about $.08 per gallon on average. To further capitalize on these seemingly profitable margins, MGR&M expanded the program, taking on larger and ever larger positions. By December 1993, the company had sold forward approximately 160 million barrels (6.72 billion gallons) of petroleum product. Customers included retail gasoline suppliers, large manufacturing firms, and governmental entities. While many end-users were small, customers also included the likes of Chrysler and Browning-Ferris Industries.

Along with the program expansion in 1993 was an unusual and steady decline in petroleum product prices. As Figure 21.7 shows, petroleum product prices were hovering at about the $0.58 per gallon at the beginning of the year, but then they fell to levels well below $0.50. Indeed a sharp drop in late 1993 took the price of heating oil (unleaded gasoline) to $0.4172 ($0.3537).[8] In and of itself, the decline in price should not have been of concern. MGR&M was, after all, hedged. But since MGR&M was long futures and the futures positions were market-to-market each day, MGR&M was facing a severe cash flow drain.[9] On the other side of the hedge, of course, was the increasing value of MGR&M's fixed-supply contracts, however, these gains were not marked-to-market (realized). The firm needed cash to weather the storm. They turned to MG, but MG refused to supply the additional funding. Indeed they replaced

[7] Under the terms of these swap agreements, MGR&M received floating and paid fixed, making them the economic equivalent of a strip of forward contracts.

[8] Both prices reached their lowest levels of the year on December 13, 1993.

FIGURE 21.7 Daily prices of heating oil and unleaded gasoline over the period February 1, 1993 through January 31, 1994.



management at MGR&M, closed the futures positions at loss, and *rescinded* the fixed supply contracts. After all was said and done, MGR&M reportedly lost over USD 1.4 billion.

The MGR&M controversy was hotly debated in academic, industry, and regulatory circles. Most of the points of view and specific details regarding corporate actions are contained in a volume of essays edited by Culp and Miller (1999). Our purpose here is to review some basic risk management principles in the context of corporate practice.

This first principle focuses on what it means to hedge. In Chapter 5, we discussed risk-minimizing hedges. These are hedges constructed to reduce price risk to its lowest level independent of any other consideration. But risk minimizing hedges are not always optimal. For one thing, we discussed, in Chapter 3, the tradeoff between expected return and risk and how different individuals/entities will make different decisions depending on their degrees of risk aversion. For another, a subset of market participants may have a comparative advantage in understanding prices (and, therefore, expected returns) in a particular market by having intimate knowledge of supply and demand factors.[10] The management of MGR&M, for example, believed strongly that oil markets should normally be in backwardation and any change to a contango structure would be fleeting. Consequently, they tailored their risk management strategy accordingly, by buying more futures contracts than a risk-minimizing hedge would demand.

The one-to-one stacked hedge employed by MGR&M was not intended to be a risk-minimizing hedge. The ideal risk-minimizing strategy is to buy a strip

[9] For ease of exposition, we talk about the futures contracts as being the only hedge used by MGR&M. As noted earlier, however, OTC swap contracts were also used. While these positions were not marked-to-market daily, provisions are often made for losing counterparties to provide additional collateral when market prices move against them.

[10] See Stulz (1996).

of heating oil and unleaded gasoline futures contracts matching the quantities and delivery dates of the long-term fixed-supply contracts. While on its face, this appears to be a one-to-one hedge ratio, recall that the futures hedges need to be “tailed” by an appropriate discount factor so that the optimal risk-minimizing hedge ratio is below one.[11] In MGR&M’s case, a strip hedge was not feasible because, even today, heating oil contracts do not extend beyond eighteen months and unleaded gasoline contracts extend out only one year.[12] In addition, the trading volume in distant contracts is quite modest (see Table 21.5). A second alternative is to cross-hedge using the crude oil futures contracts whose maturities extend out five years or more. But, this would expose MGR&M to considerable basis risk, and, like the petroleum product futures, the distant maturities of the crude futures are not particularly active.

To set a risk-minimizing hedge using only nearby futures contracts requires the use of the regression technique that we described in Chapter 5. Suppose that MGR&M had decided that they wanted to hedge their fixed-supply contract position using only the nearby futures contracts. This practice is not uncommon because the nearby contracts typically offer greater liquidity and lower trading costs. An appropriate way to set the hedge ratio would be to run a regression of the changes in the value of the fixed-supply contracts on the changes in the nearby futures price. If the prices of all futures contract maturities shifted by an equal amount each day, the estimated hedge ratio would be near one. In practice, however, the coefficient estimate will likely be considerably less since the day-to-day price movement in distant contracts is more muted than nearby contracts. With declining correlation between the nearby and distant futures decreasing as maturity increases, fewer and fewer contracts are needed to hedge more distant flows from a risk-minimization standpoint.

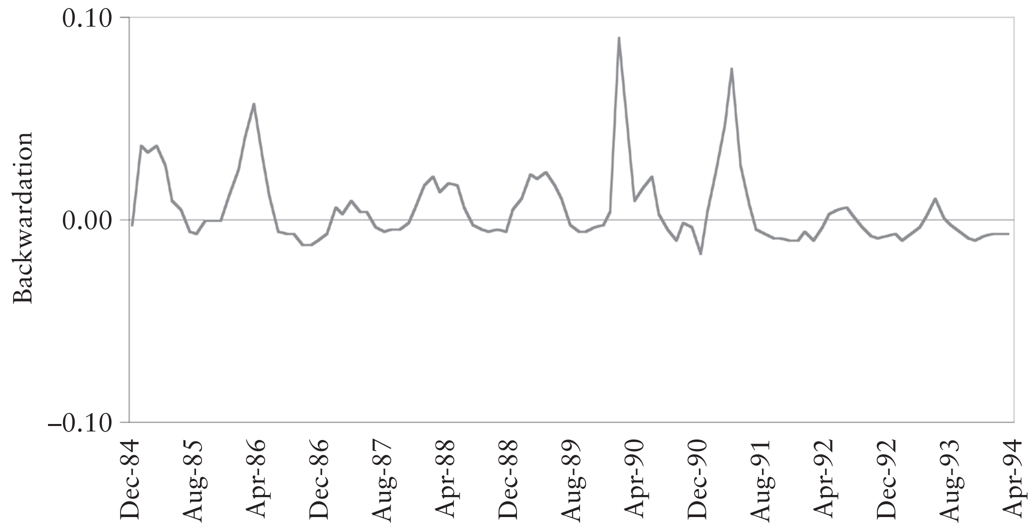
In using the one-to-one stacked hedge, MGR&M was clearly banking on a relatively stable pattern of backwardation in the petroleum product markets. If such a pattern persisted through time, the rolling of the futures position from the nearby to second nearby contract would produce an extraordinary gain each month since the price of the nearby contract is above the second nearby in a market with backwardation. In other words, MGR&M was posturing its hedge in such a way that they were willing to accept more risk for the prospect of greater expected return. It should also be noted that if the market moved to contango, the rolling of the futures position from the nearby to the second nearby contract would produce an unrecoverable loss.

Was the bet on market backwardation sensible? Who is to say? Different people hold different views. Figure 21.8 shows the pattern of backwardation in the heating oil market from December 1984 through December 1993. The vertical axis is in dollars per gallon. The value plotted is the difference between the average daily nearby futures contract price and the average daily second nearby futures contract price during each month. Positives values indicate that the market was in backwar-

[11] The mechanics of tailing the futures hedge ratio were discussed in Chapter 4.

[12] If strips of heating oil and unleaded gasoline contracts were available at the time, it is unlikely that MGR&M’s sales program would have been so successful since end-users could create “synthetic” fixed supply contracts on their own.

FIGURE 21.8 Average difference between the price of the nearby and second nearby heating oil futures prices on a monthly basis from December 1984 through December 1993. (Positive value implies backwardation and negative value implies contango.)



dation; negative values contango. Across the entire horizon, the average difference was about ½ cent. The variation from month to month, however, was considerable.

By comparing Figure 21.7 to Figure 21.8, we can better assess the primary driver behind MGR&M losses. The petroleum product price declines shown in Figure 21.7 are on order of 20 cents per gallon and more. Typical levels of contango, conditional on the market being in contango were well below a penny. Thus, the cumulative effect of the daily marking-to-market of the futures position appears to swamp the size of the average rollover cost. Consequently, the funding crisis appears to have been caused by declining oil prices and the attendant margin calls of the futures market.

Finally, was the situation predictable? Bollen and Whaley (1998) attempt to make this assessment using simulation analysis based on (1) the behavior of the NYMEX heating oil and unleaded gasoline futures contract prices during the period December 1985 through November 1991, the period just before MGR&M began its sales program; and (2) the structure of the fixed supply contracts in MGR&M's book as of December 1993. Their simulation results indicate that, given the structure and size of the positions, the probability of MGR&M needing funding in excess of USD 500 million at some time during the contract lives was in excess of 36%. Understanding and planning for expected funding needs beforehand is critical to being able to maintain a viable hedging strategy.

AGRICULTURAL: SOYBEANS

Within the agricultural category, derivative contracts on soybeans are the most active. Table 21.7 contains a summary of U.S. futures and futures options trading by underlying agricultural commodity for the year 2003. The agricultural

TABLE 21.7 Summary of agricultural futures and futures options trading volume in the United States during 2003.

Product Subcategory	Commodity	Exchange	Futures Volume	Futures Percent	Futures Options Volume	Futures Options Percent
Oilseed	Soybeans	CBT	17,545,714	19.95%	4,885,399	24.53%
	Soybean Meal	CBT	8,158,445	9.28%	546,267	2.74%
	Soybean Oil	CBT	7,417,340	8.43%	665,532	3.34%
	Mini Soybeans	CBT	250,447	0.28%		0.00%
	Soybeans MIDAM		97,163	0.11%		0.00%
	Total oilseed		33,469,109	38.06%	6,097,198	30.62%
Grain	Corn	CBT	19,118,715	21.74%	4,515,240	22.67%
	Wheat	CBT	6,967,416	7.92%	1,788,500	8.98%
	Wheat	KCBT	2,632,033	2.99%	465,381	2.34%
	Spring Wheat	MGE	1,066,489	1.21%	39,764	0.20%
	Oats	CBT	318,898	0.36%	36,163	0.18%
	Rice	CBT	265,234	0.30%	34,978	0.18%
	Mini Corn	CBT	53,404	0.06%		0.00%
	Corn	MIDAM	39,555	0.04%		0.00%
	Mini Wheat	CBT	22,288	0.03%		0.00%
	Hard Red Winter Wheat Index	MGE	16,535	0.02%	5,773	0.03%
	Wheat	MIDAM	5,580	0.01%		0.00%
	National Corn Index	MGE	3,996	0.00%	1,174	0.01%
	Total grain		30,510,143	34.69%	6,886,973	34.58%
Foodstuff	Sugar #11	NYBOT	7,140,724	8.12%	1,690,190	8.49%
	Coffee "C"	NYBOT	3,211,031	3.65%	1,328,081	6.67%
	Cocoa	NYBOT	2,128,206	2.42%	497,188	
	Orange Juice, Frozen Concentrate	NYBOT	652,715	0.74%	195,541	0.98%
	Class III Milk	CME	191,351	0.22%	79,901	0.40%
	Sugar #14	NYBOT	133,811	0.15%		0.00%
	Butter	CME	8,544	0.01%	800	0.00%
	Mini Coffee	NYBOT	332	0.00%		0.00%
	Nonfat Dry Milk	CME	230	0.00%		0.00%
	Class IV Milk	CME	137	0.00%	41	0.00%
	Total foodstuff		13,467,081	15.31%	3,791,742	19.04%
Livestock	Live Cattle	CME	4,436,089	5.04%	664,291	3.34%
	Lean Hogs	CME	2,164,155	2.46%	129,227	0.65%
	Feeder Cattle	CME	704,852	0.80%	179,347	0.90%
	Pork Bellies, Frozen	CME	161,329	0.18%	7,991	0.04%
	Total livestock		7,466,425	8.49%	980,856	4.93%
	Fiber Cotton #2	NYBOT	3,035,992	3.45%	2,157,441	10.83%
	Total fiber		3,035,992	3.45%	2,157,441	10.83%
Total agricultural commodities			87,948,750	100.00%	19,914,210	100.00%

Source: Information drawn from *Futures Industry Institute*, 2005.

commodities are further subcategorized in order to identify precisely where the greatest trading interest resides. As the table shows, the greatest trading interest is in soybeans and soybean products—soybean meal and soybean oil, with 38 (31)% of total agricultural futures (futures options) trading volume during 2003. Like NYMEX and its dominance in the petroleum contract market, the Chicago Board of Trade (CBT) dominates the exchange-traded soybean contract market,[13] as well as other markets such as wheat and corn. The second largest interest is in the grain contracts, which account for 35 (35)% of the agricultural futures (futures options) trading volume.

Production and Consumption

Soybeans are a relatively new crop in the United States, but not by world standards. They have been grown in China for more than 5,000 and are used to produce a wide variety of soy foods. Gradually soybean production spread across much of the Pacific Basin. Until the early 1930s, however, little soybean production took place outside the Orient. At that time, the Western world began to recognize the value of the soybean as a source of high-protein meal and edible oil. Large-scale production of soybeans in the United States began in the mid-1930s as a result of a trade embargo by China that cut off soybean supply and acreage restrictions placed on cotton, corn, and wheat to curb oversupply.[14]

More than 150 varieties of soybeans grown in the United States. The dominant class in the commercial market (and the class underlying the CBT's futures and futures option contracts) is Yellow soybean. Planting usually takes place in late May or early June, and harvest usually runs from early September through October. The soybean is a bushlike plant that grows to heights ranging from 12 inches to six feet. One of the notable features of the plant is that it has an extensive root system that makes it resistant to drought. After flowering, the plant develops several pods containing beans. Combine machinery is used to harvest and thresh the soybeans. Threshing refers to the process of separating the beans from the pods. After threshing, the beans are dried until they reach a suitable moisture level for storage or processing.

The processing of soybeans into soybean oil and meal is called *crushing*. The first step in the crushing process involves cracking them to remove the hull and then rolling them into full-flat flakes. The rolling process facilitates the second step, solvent extraction of the oil. After the oil has been extracted, the solvent is removed by evaporation and saved for reuse. The flakes are dried, creating defatted soy flakes. Most of the defatted soy flakes are further processed into soybean meal, although they can also be ground to produce other products such as soy flour. As a rule of thumb, one bushel of soybeans (about 60 pounds) yields 11 pounds of oil, 44 pounds of 48% protein meal, and five

[13] The Mid American Exchange was an affiliate of the CBOT when it was decommissioned in 2001. At that time, the CBT converted the most viable MidAm financial contracts into mini-sized contracts traded exclusively on the CBT's electronic system. The soybean contract listed in Table 21.7 as being traded on the MidAm is one such contract.

[14] Soybeans seedings were a natural alternative since, like cotton, corn and wheat, soybeans grow best on fertile, sandy loam.

pounds of waste.[15] The main demand for soybean meal is from the livestock industry. Nearly 90% of the soybean meal produced is used to satisfy the basic protein and amino acid requirements of cattle, hogs, and poultry. The major demand for soybean oil is from the food industry, where it is used to produce a variety of products including shortening, margarines, salad oils, and cooking oils. Soybean oil accounts for about 20% of the total world edible oil consumption.

The *gross processing margin* (GPM) of soybeans has seasonal variation. It is usually highest in the fall because of the increased supply from the soybean harvest and the increased demand for soybean meal in anticipation of colder weather, lack of grazing, and heavier livestock feeding requirements. Processing margins tend to decline later in the crop year. As demand for livestock feed declines, soybean meal prices fall, and, as the crop year progresses, soybean prices are higher as a result of lower supplies and the accumulation of carry costs.

Derivatives Markets

The trading of soybean futures and futures options in the United States is conducted exclusively on the Chicago Board of Trade. The soybean oil futures contract market was launched in October 1936, very shortly after the beginning of the large-scale production of soybeans in the United States noted earlier. The soybean oil futures was launched in July 1950, and the soybean meal futures in August 1951. Table 21.8 summarizes the key features of the soybean futures contract complex. The soybean contract calls for the delivery of 5,000 bushels of soybeans. The deliverable grade is No. 2 yellow, however, No. 1 yellow can be delivered at a premium of six cents per bushel over the contract price, and No. 3 yellow can be delivered at a six cent per bushel discount.[16] The contracts are traded in an open outcry format on the exchange floor during the day, and electronically at other times. The last day of trading is the business day prior to the 15th calendar day of the contract month.

The soybean meal futures contract calls for the delivery of 100 tons (2,000 lbs) of soybean meal with minimum protein of 48%, and the soybean oil contract calls for the delivery of 60,000 pounds of oil. Trading the *crush spread* (called the *Board Crush*) means simultaneously selling (buying) the soybean oil and meal futures contracts and buying (selling) the soybean futures contract. While the Board Crush can be traded in a 1:1:1 ratio (i.e., one soybean futures, one soybean meal futures, and one soybean oil futures), a more precise ratio is 10:11:9. To see this, recall that 60 pounds of soybeans produces 44 pounds of meal and 11 pounds of oil. Thus, 10 soybean futures contracts calls for the delivery of

$$10 \times 5{,}000 \times 60 = 3{,}000{,}000 \text{ pounds of soybeans}$$

[15] Of the five pounds of waste, four pounds are the soybean hulls and one pound is foreign matter (dirt, stones, seeds, etc.).

[16] The short futures right to deliver the cheapest of the deliverable grades is called the *quality option*.

TABLE 21.8 Selected terms of soybean futures contracts traded on the Chicago Board of Trade (CBT).

	Soybeans (S)	**Soybean Meal (SM)**	**Soybean Oil (BO)**
Contract unit	5,000 bushels	100 tons (2,000 lbs/ton)	60,000 lbs
Tick size	1/4 cent per bushel	10 cents per ton	1/100 cent per lb
Tick value	$12.50 contract	$10 per contract	$6 per contract
Trading hours	Open outcry trading is conducted from 9:30 AM until 1:15 PM, Monday through Friday. Electronic trading is conducted from 7:31 PM until 6:00 AM (CT), Sunday through Friday.		
Contract months	September, November, January, March, May, July, August.	October, December, January, March, May, July, August, September.	October, December, January, March, May, July, August, September.
Last day of trading	The business day prior to the 15th calendar day of the contract month.		
Last delivery day	Second business day following the last trading day of the calendar month.		
Final settlement	Physical	Physical	Physical
Deliverable grade	No. 2 yellow at par, No. 1 yellow at 6 cents per bushel over contract price, and No. 3 yellow at 6 cents per bushel under contract price.	One grade of soybean meal only with minimum protein of 48%.	Crude soybean oil meeting exchange-approved grades and standards.

Three million pounds of soybeans yields

$$\frac{44}{60} \times 3{,}000{,}000 = 2{,}200{,}000 \text{ pounds}$$

of soybean meal, and

$$\frac{11}{60} \times 3{,}000{,}000 = 550{,}000 \text{ pounds}$$

of soybean oil. Eleven soybean meal futures calls for the delivery is 2.2 million pounds of meal, and nine soybean oil futures calls for the delivery of 540,000 pounds of oil.

Table 21.9 shows futures settlement prices of the CBT's soybean complex on Thursday, January 25, 2005. The nearby months have the greatest contract volume and open interest. The cost of soybeans appears monotonically increasing from March 2005 through the September 2005 contracts. This arises from the carry costs on existing soybean inventories (from the fall 2004 harvest) as well as that the fact supplies are being depleted. The November 2005 also appears

TABLE 21.9 Summary of trading activity for CBT's soybean complex on Thursday, January 27, 2005.

	Soybeans			Soybean Meal			Soybean Oil		
	5,000 bushels (cents per bushel)			100 tons (dollars per ton)			60,000 lbs (cents per pound)		
Contract Month	Settlement Price	Total Volume	Open Interest	Settlement Price	Total Volume	Open Interest	Settlement Price	Total Volume	Open Interest
Mar-05	515¼	35,370	132,784	19.43	10,465	76,893	154.90	13,505	54,714
May-05	514	10,234	61,992	19.58	4,119	27,570	154.50	5,948	30,678
Jul-05	518½	4,366	34,537	19.74	3,501	30,414	156.90	3,556	36,202
Aug-05	521¾	179	3,493	19.75	306	5,969	158.10	331	11,261
Sep-05	522¼	23	1,274	19.76	167	5,266	159.50	214	7,995
Oct-05				19.80	253	4,778	160.10	361	7,308
Nov-05	531¼	1,370	19,565						
Dec-05				19.80	863	11,963	163.00	439	8,916
Jan-06	537½	42	204	19.93	65	579	163.50	11	360
Mar-06	540	8	109	20.02	4	560	166.10	102	428
May-06	538	0	64	20.03	0	444	167.50	0	99
Jul-06				20.05	0	250	170.00	0	22
Aug-06				20.05	0	92			
Sep-06				20.10	0	120			
Oct-06				20.10	0	88			
Nov-06	548	1	3						

Source: Data drawn from www.cbot.com.

somewhat active. This is the first contract of the next crop year (the fall 2005 harvest). The December 2005 soybean meal and soybean oil contracts correspond to product prices based on the fall 2005 harvest.

The figures in the table also allow us to compute the crush spread per bushel. Consider the March 2005 contract, for example. The cost of soybeans is \$5.1525 per bushel. The price of soybean meal is \$154.90 per ton, which means \$0.07745 per pound. With 44 pounds produced per bushel, the price of meal is \$3.40780 per bushel. Finally, the price of soybean oil is 19.43 cents per pound. With 11 pounds produced per bushel, the price of oil is \$2.1373. The price of the crush spread is therefore \$0.3926 per bushel. In other words, the gross processing margin of soybeans appears to be on order of 39 cents per bushel.

The CBT also lists options contracts on soybeans, soybean meal, and soybean oil. The soybean option contracts were launched in October 1984, and the meal and oil contracts were launched in February 1987. All of the option contracts are American-style, and each contract is written on one underlying futures contract. The last day of trading of all of the contracts is the same—the last Friday preceding the first notice day of the underlying futures contract by at least five business days. For more details regarding the contract specifications, see www.cbt.com.

Derivatives Valuation

The valuation of petroleum derivatives follows the principles outlined in the first section of this chapter. In the soybean market, storage costs play a significant role in pricing. Consider the prices of the Jul/05 and Aug/05 soybean futures reported in Table 21.9, for example. If we insert them into the cost of carry relation, we get

$$521.75 = 518.50e^{b(1/12)}$$

The implied net cost of carry rate is b = 7.50%. Considering that short-term interest rates are no more than half that rate, we can infer that storage costs are at least 1.625 cents per bushel per month. The forward curves for soybean meal and soybean oil are also upward sloping and in excess of what would be expected given the level of interest rates. Table 21.9 shows little or no evidence that convenience yield plays a significant role in soybean futures pricing.

Risk Management Strategies

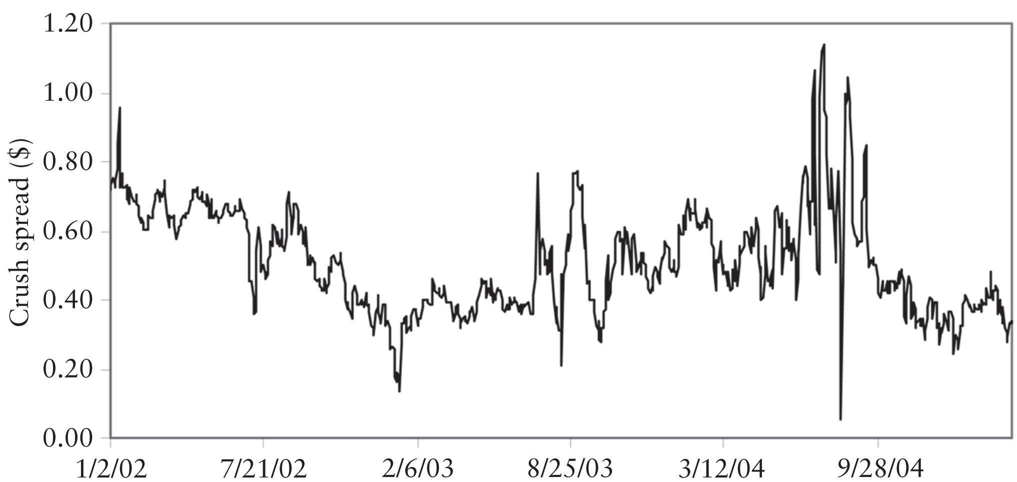
The primary users of soybean contracts are soybean processors. Like other product producers, soybean processors are subject to both input and output risks. A price increase in soybeans increases costs, while declines in soybean oil and meal prices reduce revenue. Futures contracts on all three commodities allow a processor either to hedge each of these price risks separately or to use the crush spread to hedge against an unfavorable change in the gross processing margin. A crush spread involves simultaneously buying futures contracts on soybeans and selling soybean meal and soybean oil futures and is usually done at the 10:11:9 ratio discussed earlier. The soybean position is carried into the delivery month when the soybeans need to be purchased. The short soybean meal and oil futures positions are carried into the months in which the products are sold.

Speculators are also present in the marketplace. Some market participants follow the crush spread quite closely. Figure 21.9 shows the daily levels of the crush spread based on the nearby soybean futures contracts during the period January 2, 2002 through March 22, 2005.[17] When the crush spread becomes less than the actual processing margin, it may be advantageous to put on a *reverse crush spread*—sell the soybean futures and simultaneously buy meal and oil futures. The spread is likely to revert back to a higher level shortly thereafter. The reason is that, if soybean processors are losing money, they will cut back or even stop production. This reduces the supply of soybean product in the marketplace and drives product prices higher. At the same time, with production shut down, processors will demand fewer soybeans, resulting in lower soybean prices. When markets revert back to normal, the reverse spread position can be closed at a profit.

METALS: GOLD

Within the metals category, derivatives contracts on gold have the largest presence. Table 21.10 shows breakdown of exchange-traded futures and futures options by type of metal. Market interest in precious metals is strongest, with gold being the

FIGURE 21.9 Daily closing levels of the soybean futures crush spread during the period January 2, 2002 through March 22, 2005. Crush spread is computed on the basis of the nearby settlement prices of the soybean, soybean meal, and soybean oil futures prices.



[17] The spike downward in the crush spread on August 12, 2004 resulted from a market reaction to a USDA announcement that the fall 2004 harvest would fall below the average analysts forecast. On that day, the August 2004 futures closed up 50.5 cents a bushel from the previous day's close. The crush margin closed at 5.5 cents.

TABLE 21.10 Summary of metal futures and futures options trading volume in the U.S. during 2003.

Metal Subcategory	Commodity	Exchange	Futures		Futures Options	
			Volume	Percent	Volume	Percent
Precious	Gold	COMEX	12,235,689	60.91%	4,310,318	87.59%
	Silver	COMEX	4,111,190	20.47%	560,018	11.38%
	Platinum	NYMEX	268,305	1.34%	633	0.01%
	Mini–New York Gold	CBT	145,173	0.72%		
	Palladium	NYMEX	95,613	0.48%		
	Mini–New York Silver	CBT	34,804	0.17%		
	Total precious metal		16,890,774	84.09%	4,870,969	98.98%
Nonprecious	High Grade Copper	COMEX	3,089,270	15.38%	47,326	22.67%
	Aluminum	COMEX	107,490	0.54%	2,679	8.98%
	Total nonprecious metal		3,196,760	15.91%	50,005	31.65%
Total metal commodities			20,087,534	100.00%	4,920,974	100.00%

Source: Information drawn from Futures Industry Institute, 2005.

dominant contract. But even base metals like copper have active markets. Note that, where the NYMEX division of the New York Mercantile Exchange dominates the exchange-traded energy contract markets and the Chicago Board of Trade dominates the exchange-traded agricultural contract markets, the COMEX division of the New York Mercantile Exchange dominates the exchange-traded metals market. In the OTC market, the dominance of gold can be seen both at the precious metals category level specifically and the commodities category level more generally. Figure 21.5, for example, shows that the notional amount of gold forward and swap contracts accounted for 26.8 (22.9)% of the notional value of all commodity forwards and swaps (options) outstanding at the end of 2003. The figure also allows us to infer that 87.6 (92.3)% of the notional amount of the precious metals forwards and swaps (options) were written on gold. With such a large presence in the metals market, therefore, gold is the focus of discussion in our metals category.

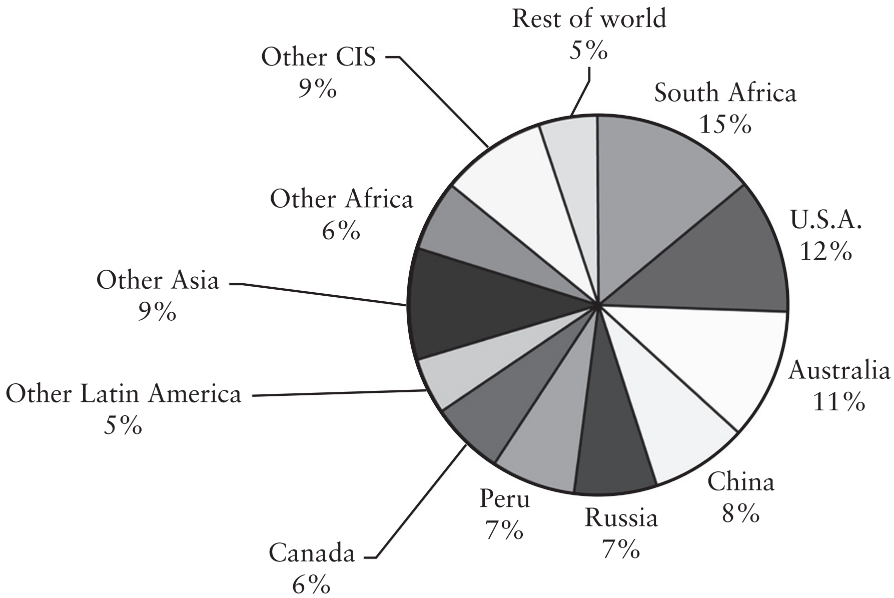
Production

Gold has been mined for thousands of years. The World Gold Council[18] reports that the Egyptians may have produced as much as a metric ton or tonne annually as early as 2000 BCE.[19] Production grew to about five to ten tonnes during the Roman empire, with the ore coming from Spain, Portugal and Africa. Production fell back to about a tonne during the Dark and Middle Ages, with the ore coming largely from the mountains of central Europe. From the middle of the 15th century, the Gold Coast of West Africa (now known as Ghana) became an important source of gold, providing perhaps five to eight tonnes per year. In the early 16th century, the Spanish conquests of Mexico and Peru opened up a further source of gold. By the close of the 17th century, 10 to 12 tonnes a year were provided by the Gold Coast and South America together. Gold was first discovered in Brazil in the mid-16th century but the significant output did not emerge until the early 18th century, considerable supplies began to come from Russia as well, and annual world production was up to 25 tonnes. By 1847, the year before the Californian gold rush, Russian output accounted for 30 to 35 tonnes of the world total of about 75 tonnes. The gold rushes, and later the South African discoveries, radically altered the picture but Russian production continued to rise, reaching around 60 tonnes in 1914.

Today the countries producing gold are many and diverse. South Africa remains the world's largest gold producer, accounting for 15% of the 2,593 tonnes mined in 2003. The United States was second at 12 pecent, and Australia followed with 11%. China had 8%, Russia and Peru were tied at 7%, and Canada followed with 6% of total production. The shares of these and other gold producing countries are shown in Figure 21.10.

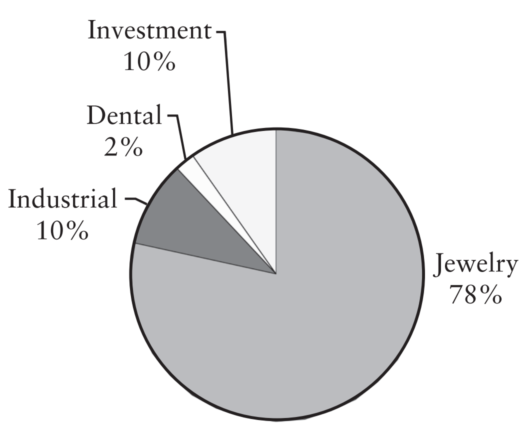
[18] The World Gold Council is a nonprofit association of the world's leading gold producers dedicated to promote the use of gold. It is headquartered in Geneva, Switzerland and is represented by a network of offices in major centers of gold demand around the world. Its website, www.gold.org, contains a wealth of information regarding the history and use of gold as well as supply and demand statistics. Much of the material in this section is drawn from the myriad of pages and links contained at its website.
[19] One metric ton equals 2,240 pounds.

FIGURE 21.10 World gold production during 2003 by country. Total world production was 2,593 metric tons.



Source: Underlying data drawn from *World Gold Council*, www.gold.org, 2004.

FIGURE 21.11 Demand for gold by use during 2003. Total demand was 3,223 metric tons.



Source: Underlying data drawn from *World Gold Council*, www.gold.org, 2004.

Consumption

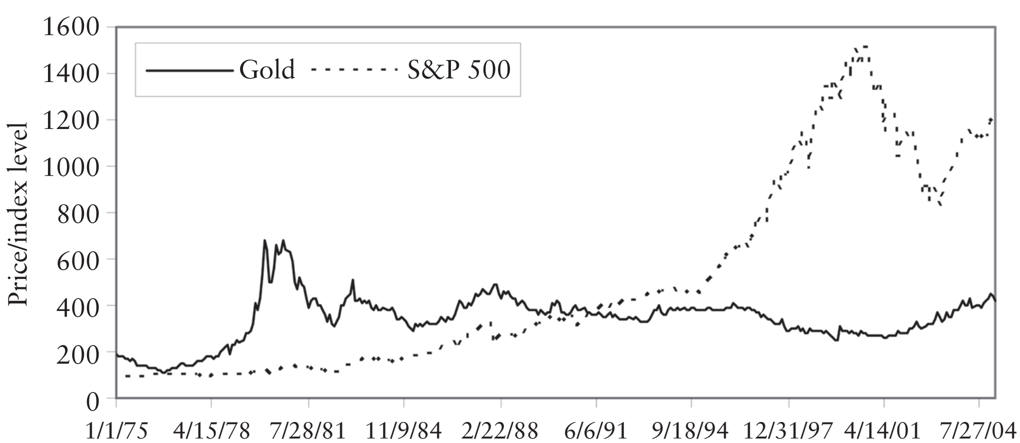
The locations of the demand for gold differ significantly from supply. Before focusing on the location of demand, however, it is useful to understand gold's main uses. Figure 21.11 gives a breakdown. Not surprisingly, perhaps, 78% of the 3,223 tonnes of total gold consumption in 2003 was in the manufacture of jewelry. About 10% of gold is used in industrial applications. Gold is an excellent conductor of electricity, is extremely resistant to corrosion, and is one of the most chemically stable of the elements, making it ideally suited for applications in electronic devices such as computers, televisions, DVD players, video cameras, and mobile phone, even with its prohibitive cost. Another 10% is investment in gold bars and coins. The price of gold tends to have a counter-cyclical relation to the level of the stock market, as shown in Figure 21.12. When the stock market falls, investors tend to reduce stock holdings for the "safe haven" of gold, and vice versa. Finally, about 2% of gold consumption is for dental applications.

With nearly 80% of gold consumption being in the form of jewelry, it should not be surprising to see the location of the demand being influenced by cultural considerations. Figure 21.13 shows consumption by country/region. The largest country with the largest consumption of gold is India, accounting for 23% of total world consumption in 2002. Perhaps no other country has gold as deeply woven into the fabric of society. It is commonly involved in weddings, not only adorning the bride, but also constituting a significant value to her dowry. Gold jewelry is regarded as a woman's personal property, and is a means of safeguarding her against financial misfortune and of passing on family wealth along maternal lines. The U.S. demand is next largest at 16%. In the United States, the demand is less culturally tied. The demand is largely as a result of individual wealth and gold's perceived value. It is also used as a hedge against stock market decline. The demands by countries in the Middle East, the South East, Europe, and Greater China follow in size of demand.

Derivatives Markets

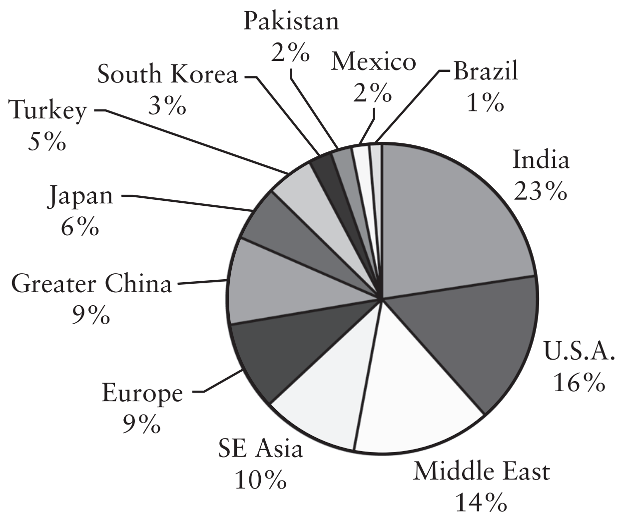
Like in the case of petroleum derivatives, gold derivatives are a relatively recent development. Gold derivatives markets arose in the United States in the 1970s, in the aftermath of two important events. The first was the suspension of the

FIGURE 21.12 Price of gold bullion and level of S&P 500 index on a monthly basis from January 1975 through January 2005.



Source: Datastream.

FIGURE 21.13 World gold consumption during 2002 by country.



Source: Data drawn from *World Gold Council*, www.gold.org, 2004.

Bretton Woods Agreement in 1971. The agreement, originally signed in 1944, fixed all the world's paper currencies to the U.S. dollar, which, in turn, was tied to gold. In 1971, President Nixon effectively cancelled the Bretton Woods agreement by ending its convertibility into gold. The second was lifting of the U.S. ban on private ownership of gold bullion on December 31, 1974. Exchange-traded futures were launched by the Commodity Exchange in New York on the very same day. Futures options followed on October 4, 1982.[20]

The COMEX division of the New York Mercantile Exchange remains the world's largest market for exchange-traded gold contracts. The COMEX futures contract is written on 100 Troy ounces of gold. The contract calls for delivery, and the gold delivered must bear a serial number and identifying stamp of a refiner approved and listed by the exchange. Trading terminates at the close of business on the third to last business day of the maturing delivery month. The first delivery day is the first day of the delivery month; the last delivery day is the last business day of the delivery month.

The COMEX futures option contract is American-style and is written on one COMEX gold futures contract. Option expiration occurs on the fourth business day prior to the underlying futures delivery month. The option may be exercised on any day prior to expiration until one hour after the market close.

[20] In the United States, options on domestic agricultural commodities had been banned by the Commodity Exchange Act of 1936, and it was not until the 1980s that the Commodity Futures Trading Commission took steps to rescind this ban. Specifically, under a pilot program instituted in December 1981, the CFTC approved options for a limited number of futures contracts on commodities *other than* agricultural commodities. It was under this pilot program that the COMEX launched gold futures options. Agricultural futures options were introduced in a second pilot program in March 1984. For further details, see Stoll and Whaley (1985, p. 215).

The OTC market offers a much broader array of gold derivatives products. Forwards and swaps, together with call and put options, are the staple products. But, like with OTC contracts written on other underlying assets, the specific terms of the generic derivatives have limitless flexibility in setting maturity dates, contract size, style of option exercise, and option exercise price. Among the nonstandard forward-style products are spot deferred contracts, participating forwards, advanced premium forwards, and short-term averaging forwards, and, among the nonstandard options are caps and collars, barrier options, and convertible forwards. These contracts are beyond the level of detail appropriate for this, however, many of the products have unique, albeit idiosyncratic, risk management properties.[21]

Net Cost of Carry Relation

The net cost of carry relation for gold is usually written

$$f = Se^{(r-l)T} \tag{21.4}$$

where r is the zero-coupon rate on a risk-free bond maturing at time T, and l is the gold lease rate at the same maturity. Note that this relation more closely resembles the carry relation for a stock index or a currency than a commodity. Neither a storage cost rate nor a convenience yield rate appears in (21.4), as it did in the generic commodity forward pricing relation earlier in the chapter. Storage costs of gold are excluded because gold trades in certificate form. Gold certificates are a means of holding gold without taking physical delivery. They are issued by individual banks, particularly in countries like Germany and Switzerland, and confirm an individual's ownership. The bank, however, holds the metal. In this way, the individual does not incur storage cost or personal security issues, and yet has the ability to unwind his position in a liquid market. Finally, convenience yield does not appear because central banks are the largest holder of gold inventories and accrue no intrinsic benefit from holding the gold.[22]

What does appear in (21.4) and has not appeared before is the gold lease rate. As it turns out, over the past two decades, an active gold loan market has evolved. In a typical gold loan, a mining company borrows gold bullion from a commercial bank to, say, develop a new mine or expand an existing operation. The commercial bank, in turn, borrows the bullion from a central bank. The mining company sells the gold in the spot market, raising the needed cash. In place of paying an interest rate on a cash loan, the borrower pays a *lease rate* on the gold. For each ounce of gold borrowed, the borrower returns e^{lT} when the loan matures. Often the mining company will simultaneously buy a forward contract at the time the loan is drawn. The net position of the combined gold loan/forward position is shown in Table 21.11. Note that the gold loan is equivalent to borrowing cash. The amount borrowed is Se^{-lT}, and the amount repaid

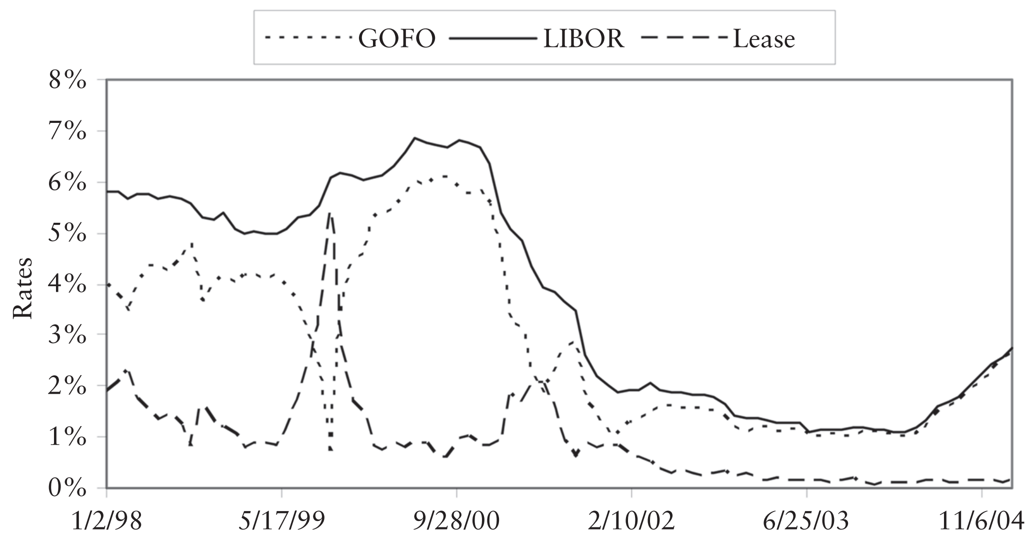
[21] Cross (2000) provides desciptions of a large number of the gold derivatives contracts traded in the OTC market.

[22] That is not to say that no one accrues convenience yield from holding gold. Anyone producing a good using gold as a raw material may accrue such a benefit.

TABLE 21.11 Mechanics of gold loan by mining company.

Trades	Initial Investment	Value on Day T
Borrow e^{-lT} ounces of gold	Se^{-lT}	$-\tilde{S}_T$
Buy forward		$\tilde{S}_T - f$
Net position	Se^{-lT}	$-f$

FIGURE 21.14 Three-month GOFO, LIBOR, and gold lease rates at the beginning of each month during the period January 1998 through January 2005.



Source: Rates drawn from *London Bullion Market Association*, www.lbma.org.

is f at time T. Since repayment amount is fixed, the gold loan at rate l is tantamount to a USD loan at rate r, that is, $Se^{-lT} = fe^{-rT}$.

In the relation (21.4), the difference between the risk-free interest rate and the gold lease rate is called the *GOFO* or *gold forward rate*, g. In general, the GOFO rate is positive because the gold market is in contango (i.e., $f > S$). Unlike base metals, a backwardation (i.e., $f < S$) in the gold market is rare. The reason is simple. Gold is not in short supply. Market participants such as central banks continue to believe that gold remains an important element of global monetary reserves and therefore hold large inventories in reserve.[23] If the forward price of gold happens to slip below the spot price at any point in time, they will simply sell a portion of their inventory in the spot market and enter a forward contract to buy it back again a short time later, and earn an arbitrage profit. Since such trades are easy and relatively cheap to execute, the spot and forward prices would quickly return to the familiar contango structure.

Figure 21.14 shows monthly GOFO, LIBOR, and gold lease rates during the period January 1998 through January 2005. The data were downloaded from

[23] As of September 2002, central banks around the world held about 33,000 tons in reserve.

the London Bullion Market Association website, www.lbma.com. The figure shows that the GOFO rate was positive during the entire period, with an unusual spike downward in the fall of 1999. To understand the reason for this spike, first consider Figure 21.14, which shows the price of gold bullion over a slightly longer interval. What the figure shows is that the price of gold had been falling at a fairly steady rate since mid-1996. The European central banks, with significant inventories of gold, became concerned. On Sunday, September 26, 1999 in Washington, D.C., 15 European central banks agreed to limit sales of gold to 400 tonnes per year over five years as well as limit lending gold to the market to the extent that they had already done so (i.e., no new gold would be placed on deposit). The so-called "Washington Agreement" struck fear into the gold community. From the close of trading on Friday, September 24 to the close of trading in October 5, the gold price shot up by more than USD60. See Figure 21.12. At the same time, the gold lease rate naturally spiked upward. And, with a spike in the lease rate and virtually no change in the LIBOR rate, the *GOFO* rate spiked downward.

Risk Management Strategies

Important players in the use of gold derivatives contracts are gold refiners. The process of extracting gold ore from a mine and refining it into gold bullion is slow. Indeed, it may take years for the gold in a particular mine to be depleted. Given that the mine's output and output rate over the next few years is all but certain, the only significant risk that a refiner faces is price risk. If the refiner chooses not to hedge, he sells his gold as it is produced at the prevailing spot price. This leaves his future revenue per ounce of gold uncertain, while his cost per ounce of gold is fairly stable. Entering into certain types of derivatives trades can help the refiner manager this gold price risk.

Among the plain-vanilla gold derivatives used by a refiner are forward contracts, call options, and put options. In the gold market, a variety of forward contracts are traded. The simplest is the standard fixed price forward that is commonplace in commodities markets. The refiner agrees to sell a fixed amount of gold at fixed price on a fixed date. Indeed, the refiner may have a strip of these contracts extending out a number of years. Another risk management alternative is to buy out-of-the-money put options to insure the minimum price at which future production will be sold. While this is an effective strategy, it is expensive in the sense that the put premiums must be paid at the outset. To subsidize this cost, the refiner often simultaneously sells out-of-the-money call options in the same quantities and with the same maturity dates. The call premium is used, at least in part, to cover the purchase of the puts. Zero-cost collars are easily designed by tailoring the exercise prices of the options.

ILLUSTRATION 21.3 Determine cap exercise price on collar agreement in competitive OTC gold and gold derivatives market.

Suppose that you are a gold refiner and want to hedge the price at which you will sell your monthly production over the next 12 months. Currently, the zero-coupon yield curve for risk-free bonds is

$$r_i = 0.04 + 0.01\ln(1 + T_i)$$

the term structure of GOFO rates is

$$g_i = 0.03 + 0.009\ln(1 + T_i)$$

and the term structure of the gold volatility rate is

$$\sigma_i = 0.15 + 0.05\ln(1 + T_i)$$

If the current gold price USD 400 per ounce and you want to sell all 12 deliveries at a minimum price of USD 390 per ounce, what is the maximum price that you should expect to receive? Assume the amount of production is uniform from month to month and all deliveries are at month-end.

The first step is to transform the above three term structures into option valuation parameters for each maturity option. You use the zero-coupon and GOFO yield curves to deduce the term structure of forward prices. Recall

$$f_i = Se^{g_i T_i}$$

Thus based upon the problem information, the term-specific option valuation parameters are as summarized here:

Month	Years to Expiration	Risk-Free Rate	GOFO Rate	Forward Price	Volatility Rate
0	0.000000	4.00%	3.00%	400.00	15.00%
1	0.083333	4.08%	3.07%	401.03	14.60%
2	0.166667	4.15%	3.14%	402.10	14.23%
3	0.250000	4.22%	3.20%	403.21	13.88%
4	0.333333	4.29%	3.26%	404.37	13.56%
5	0.416667	4.35%	3.31%	405.56	13.26%
6	0.500000	4.41%	3.36%	406.79	12.97%
7	0.583333	4.46%	3.41%	408.04	12.70%
8	0.666667	4.51%	3.46%	409.33	12.45%
9	0.750000	4.56%	3.50%	410.65	12.20%
10	0.833333	4.61%	3.55%	411.99	11.97%
11	0.916667	4.65%	3.59%	413.37	11.75%
12	1.000000	4.69%	3.62%	414.76	11.53%

The next step is to compute the value of the floor on the sales price of gold. This value is computed as the sum of 12 European-style put option values, one corresponding to each monthly delivery. Since you have the forward prices of gold, you can value the options directly from the forward curve using the OPTVAL function

OV_FOPTION_VALUE(*f, x, t, r, v, cp, ae*)

where f is the forward price, x is the exercise price, t is the time to expiration, r is the risk-free rate of interest, v is the volatility rate, *cp*, is a (c)all/(p)ut indicator, and *ae* is an indicator variable for whether the option is (A)merican- or (E)uropean-style . For the first option in the series, the value of the put is

OV_FOPTION_VALUE(401.03, 390, 0.08333, 0.0408, 0.1460, “p”, “e”) = 2.5319

Repeating the valuation procedure for the remaining 11 put options, you find that the sum of the put option values is 82.5243. The individual put option values are shown in the table below.

The final step is to compute the value of the cap on the sales price of gold. Since you do not have the exercise price of the calls, you must set up your Excel worksheet in a fashion that relies on a particular cell as containing the exercise price. You then use *SOLVER* to identify the call exercise price that makes the sum of the call premiums also equal to 82.5243. That exercise price is 428.72, as shown:

						Exercise Prices	
Month	Years to Expiration	Risk-Free Rate	GOFO Rate	Forward Price	Volatility Rate	390.00 Put Value	428.72 Call Value
0	0.000000	4.00%	3.00%	400.00	15.00%		
1	0.083333	4.08%	3.07%	401.03	14.60%	2.5319	0.4199
2	0.166667	4.15%	3.14%	402.10	14.23%	4.3380	1.6318
3	0.250000	4.22%	3.20%	403.21	13.88%	5.5566	2.9551
4	0.333333	4.29%	3.26%	404.37	13.56%	6.4268	4.2370
5	0.416667	4.35%	3.31%	405.56	13.26%	7.0611	5.4529
6	0.500000	4.41%	3.36%	406.79	12.97%	7.5235	6.6049
7	0.583333	4.46%	3.41%	408.04	12.70%	7.8545	7.7009
8	0.666667	4.51%	3.46%	409.33	12.45%	8.0822	8.7492
9	0.750000	4.56%	3.50%	410.65	12.20%	8.2266	9.7574
10	0.833333	4.61%	3.55%	411.99	11.97%	8.3031	10.7323
11	0.916667	4.65%	3.59%	413.37	11.75%	8.3233	11.6794
12	1.000000	4.69%	3.62%	414.76	11.53%	8.2967	12.6036
				Sum of premiums		82.5243	82.5243

OTHER: WINE

OTC markets for wine futures have existed in the United States for decades, beginning with French wines in the 1970s and including Californian wines in the late 1980s. Customers execute contracts with wine merchants for the delivery of fixed number of bottles of vintage wine from a particular château (e.g., the 2003 Château Margaux). In essence, the customer buys the wine after it is made, but before it is bottled. Cask samples of wines are made available for tasting to wine journalists and the large wholesale buyers in the spring following the vintage. The wine is generally bottled and shipped about two years later.

The term *wine futures* is a misnomer. The contracts are actually prepaid forward contracts. Upon agreeing to terms with a wine merchant, the customer is required to pay the merchant in full, as much as two years before delivery. Do not expect significant cost savings. The buyer's contract with the wine merchant is only one mark-up in a chain. The wine merchant, in turn, has a futures contract with the distributor, who in turn has a futures contract with an importer, who has a futures contract with a broker. Only the broker deals directly with the château.

From château to consumer, the total markup in price may be several hundred percent, just as if the customer had purchased the wine off the store shelf.

In a typical year, the wines are released in a sequence of tranches, with each tranche being priced at a different level depending on how the previous one sold. In good vintages, the initial release prices are usually the lowest at which the wines will ever be sold. But what is and what is not a good vintage is not known until the wine has matured. The 1997 Bordeaux, for example, had an initial release price that was too high, and its price declined in the following years. The 2000 Bordeaux, on the other hand, had an initial release price that was too low. Even those buying in the second and third tranches saw prices appreciate quickly. Thus buying wine futures is speculation in most cases (no pun intended), except, of course, if the contract is used as a means of acquiring a highly allocated, small-production wine that may never see a store shelf. For a wine producer, selling wine futures may be an effective short hedge in which he receives cash upfront for a delivery that will not be made for two years.

SUMMARY

This chapter focuses on derivatives contracts written on commodities. It is organized differently than the other product chapters in that the sections of the chapter are arranged by underlying commodity. The reason is that the price relations of commodity derivatives are influenced by idiosyncrasies in the underlying commodity market. Understanding commodity derivatives price behavior, therefore, involves understanding the factors that influence commodity price behavior. At the outset, we discuss the fundamental differences between pricing commodity derivatives and pricing financial derivatives. Commodity derivatives require that we consider the storage costs such as warehouse rent and insurance as well as the convenience of having an inventory of the commodity on hand. Neither of these factors played an important role in the pricing of stock, stock index, currency, and interest rate derivatives products. We then turn to derivative contracts written on the three major commodity categories—energy, agricultural, and metals. We illustrate the idiosyncrasies of each commodity using an example—petroleum, soybeans, and gold, respectively.

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