THE COLLAPSE OF METALLGESELLSCHAFT: UNHEDGEABLE RISKS, POOR HEDGING STRATEGY, OR JUST BAD LUCK?

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INTRODUCTION

In late 1993 and early 1994 MG Corporation, the U.S. subsidiary of Germany's 14th largest industrial firm Metallgesellschaft A.G. (MG), reported staggering losses on its positions in energy futures and swaps.[1] Only a massive $1.9 billion rescue operation by 150 German and international banks kept MG from going into bankruptcy, an event which

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[1]MG's losses, which may ultimately exceed the $1.3 billion that it reported, represented about half of its total capital of DM3.672 billion as of September 30, 1994. See Protzman (1994) and Eckhardt and Knipp (1994).

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undoubtedly would have had far-reaching consequences for MG's creditors, suppliers, and some 58,000 of its employees. (Miller, 1994).

During 1993 MG's U.S. oil trading subsidiary, MG Refining and Marketing (MGRM), established very large derivatives positions in energy futures and swaps (equivalent to about 160 million barrels of oil), from which it would profit handsomely if energy prices were to rise. However, instead of rising, energy prices (crude oil, heating oil, and gasoline) fell sharply during the latter part of 1993, causing MGRM to incur unrealized losses and margin calls on these derivatives positions in excess of $900 million (Hanley, 1994).

Initial press reports indicated that MG's predicament was the result of massive speculation in energy futures and off-exchange (OTC) energy swaps by MGRM. Some members of MG's Supervisory Board also characterized MGRM's oil trading activities as "... a game of roulette." And when MG's Supervisory Board installed new management at MGRM near the end of 1993, the new management team declared that "... speculative oil deals ... had plunged Metallgesellschaft into the crisis." See Benson supplemental memorandum (1994).

Not all press reports, however, have held to this view. Some have suggested that MGRM's derivatives activities were, in fact, part of a complex oil marketing and hedging strategy. In particular, MGRM reportedly was using its derivatives positions to hedge price exposure on forward-supply contracts that committed it to supplying approximately 160 million barrels of gasoline and heating oil to end-users over the next ten years at fixed prices. The fixed supply prices in these contracts, negotiated at the time that the contracts were established, were typically three to five dollars a barrel higher than prevailing spot prices when the contracts were negotiated. (These were MGRM's profit margins or mark-ups).[2] See affidavit of Benson (1994).

The forward delivery contracts also contained a cash-out option for MGRM's counterparties. If energy prices were to rise above the contractually fixed price, MGRM's counterparties could choose to sell the remainder of its forward obligations back to MGRM for a cash payment of one half the difference between the prevailing near-month futures price and the contractually fixed supply price times the total volume remaining on the contract.[3]

[2] MGRM's mark-ups were the same regardless of the length of the contracts. Critics have argued that higher mark-ups should have been used for longer-term contracts, perhaps because of increasing credit risk. See Special Audit Report (1995).

[3] In some contracts MGRM also could exercise this option if prices rose above a specified exit price. See affidavit of Benson (1994).

Most of the forward delivery contracts were negotiated during the summer of 1993, when energy prices were low and falling. Energy end-users apparently saw an attractive opportunity to lock-in low energy prices for the future, and MGRM apparently saw an equally attractive opportunity to develop long-term profitable customer relationships that would help its long-run strategy of developing a fully-integrated oil business in the United States.[4] See affidavit of Benson (1994). MGRM's counterparties in these forward contracts were retail gasoline suppliers, large manufacturing firms, and some government entities. Although many of the end-users were small, some were substantial firms: Chrysler Corporation, Browning-Ferris Industries Corporation, and Comcar Industries (which has annual diesel fuel use of some 60 million gallons a year). See *Handelsblatt* (1994).

In 1989, as part of its efforts to develop a fully integrated oil business in the United States, MGRM also acquired a 49% interest in Castle Energy, a U.S. oil exploration company, which it then helped to become an oil refiner. To assure a supply of energy products in the future, MGRM agreed to purchase Castle's entire output of refined products (estimated to be about 126,000 barrels a day) at guaranteed margins for up to ten years into the future (Power, 1994). In addition, MGRM set about to develop an infrastructure to support the storage and transportation of various oil products. See affidavit of Benson (1994).

MGRM's fixed-price forward delivery contracts exposed it to the risk of rising energy prices. If energy prices were to rise in the future, it could find itself in the unprofitable position of having to supply energy products to customers at prices below prevailing spot prices. More importantly, if prices rose high enough and remained high, the profit margins in the contracts would be eroded and MGRM could end up taking substantial losses for years to come.

MGRM hedged this price risk with energy futures and OTC swaps.[5] Not to have hedged would have put MGRM (and therefore MG) in the position of making a substantial bet that energy prices would either fall or at least not rise in the future. Had MGRM been able to hedge its price risk successfully, it stood to make substantial profits. By locking-in an average contractual markup of $4 a barrel on its forward energy sales over ten years, it would have earned profits of approximately $640 million.

[4]Alternatively, it has been contended that MGRM entered into these contracts in order to book unrealized profits against the futures losses it had at the time.
[5]For a description of MGRM's business and hedging activities, see affidavit of Benson (1994).

The controversy surrounding MG's fate is whether MGRM's hedging strategy was, in fact, ever capable of locking-in these profits. Critics contend that its hedging strategy was fatally flawed, and exposed the firm to unacceptable risks (Falloon, 1994). The objective of this study is to examine the risks that MGRM was taking and to clarify the risk trade-offs that it was making. In addition, the study provides as many facts as are available so that readers can judge for themselves whether MGRM's hedging strategy exposed the firm to an unreasonable risk.

A complicating factor in evaluating a hedger's risk exposure is that all hedgers take some risk. Hedging seldom eliminates all of a firm's risk. As every student of futures markets knows, hedgers are "speculators on the basis," trading a greater price risk for a lesser basis risk.[6] To determine whether a particular hedger's strategy is sound, the risk assumed by the firm must be evaluated in the context of the firm's objectives. The objective of MGRM's hedging strategy was to protect the profit margins in its forward delivery contracts by insulating them from increases in energy prices. The overall strategic objective of MG, however, was to develop a fully integrated oil business in the United States. MGRM's role in this strategy was to market and supply petroleum products to end-users, which it did through its forward-delivery program. The soundness of MGRM's hedging strategy, therefore, should be judged against both its specific hedging objective and the firm's overall strategic objective.

MGRM'S SHORT-DATED STACK HEDGING STRATEGY

MGRM hedged the risk of rising energy prices with both short-dated energy futures contracts and OTC swaps. It acquired long futures positions on the New York Mercantile Exchange (NYMEX), and entered into OTC energy swaps entitling it to receive payments based upon floating energy prices while making fixed payments. (Taylor and Bacon, 1994). MGRM's counterparties in these swaps were large OTC swap

[6]The basis is the difference between the price of the instrument that is being used to hedge (in the case of MGRM, near-month futures and swaps) and the price of the instrument or commitment that is being hedged (forward sales in the case of MGRM). Basis risk is the volatility of the basis. All hedgers, by definition, choose to assume basis risk as a trade-off for eliminating the price risk they would have if they did not hedge, presumably because the basis risk is less than the price risk. See Edwards and Ma (1992), Chapter 5.

dealers, such as banks. By the fourth quarter of 1993 MGRM held long futures positions on the NYMEX equivalent to 55 million barrels of gasoline, heating oil, and crude oil (55,000 contracts), and had swap positions of 100 to 110 million barrels, substantial positions by any measure (Taylor and Sullivan, 1994). MGRM's total derivatives position was virtually identical to its forward-supply commitments: 160 million barrels. Thus, MGRM hedged its forward-supply commitments barrel for barrel (or with a hedge ratio of one).[7]

An important aspect of MGRM's hedging strategy was that its derivatives positions were concentrated (or stacked) in short-dated futures and swaps that had to be rolled forward continuously to maintain the position.[8] In general, its futures and swap positions were in contracts with maturities of, at most, a few months from the current date. It therefore had to roll these contracts forward periodically (probably monthly) to maintain its hedge. As MGRM rolled its derivatives positions forward each month, it reduced the size of its derivatives positions by the amount of the product delivered to customers that month, maintaining a one-to-one hedge.

This stack and roll strategy can be profitable when markets are in backwardation, but when markets are in contango it will result in losses.[9] In a backwardation market, a strategy of continually rolling short-dated positions forward yields rollover gains because oil for immediate delivery (nearby-oil) gets a higher price than does, say, three-month oil (or deferred-month oil). In a contango market, however, MGRM would incur rollover losses: it would be forced to purchase deferred month futures at higher prices than the prices it could sell these contracts for as they neared expiration. Thus, the

[7]See Exhibit C in affidavit of Benson (1994). This exhibit shows that as of October 1, 1993, MGRM had sold forward approximately 93 million barrels of heating oil and 67 million barrels of gasoline, and that it had hedged these commitments by buying futures and swaps in the approximate amount of 39 million barrels of heating oil, 16 million of gas-oil, 58 million of gasoline, and 47 million of crude.

[8]A stack hedge refers to a futures position being stacked or concentrated in a particular delivery month (or months) rather than being spread over many delivery months. In MGRM's case, it placed the entire 160 million barrel hedge in short-dated delivery months, rather than spreading this amount over many, longer-dated, delivery months. Rolling over this stacked position refers to the process of rolling it forward: selling contract months which will soon expire and purchasing (or replacing these contracts with) deferred-month contracts. Common reasons for using short-dated stack hedges are: that liquidity is much better in near-month contracts, that longer-dated derivatives may not be available on reasonable terms, and that hedgers hold certain expectations about how the term structure of forward prices will change in the future. In a recent article, MGRM's short-dated, stack, hedging strategy is referred to as a textbook hedging strategy. See Culp and Miller (1994a).

[9]Markets in which nearby prices are above deferred-month prices are commonly referred to as backwardation markets. Markets in which nearby prices are below deferred-month prices are generally referred to as contango markets.

success of MGRM's stack and roll strategy partially depended on whether energy markets were going to be in contango or backwardation.

WHAT WENT WRONG?

MGRM's problems surfaced in late 1993 when energy spot prices tumbled. As a result, it experienced large unrealized losses on its stacked long futures and swap positions and incurred huge margin calls.[10] MGRM's problems were further compounded by the fact that energy futures markets went into a contango price relationship for almost the entire year of 1993, causing it to incur substantial costs each time it rolled its derivatives positions forward.

If energy prices had risen rather than fallen, MGRM would not have had a problem. It would have had unrealized gains on its derivatives positions, and positive margin flows (or cash in-flows). Although it would also have had unrealized losses on its forward delivery obligations, no one would have cared. But energy prices did fall, from around $19 a barrel of crude oil in June, 1993 to less than $15 a barrel in December, 1993, causing MGRM to have to come up with enormous amounts of money to fund margin calls (see Fig. 1). In December, 1993, at the height of

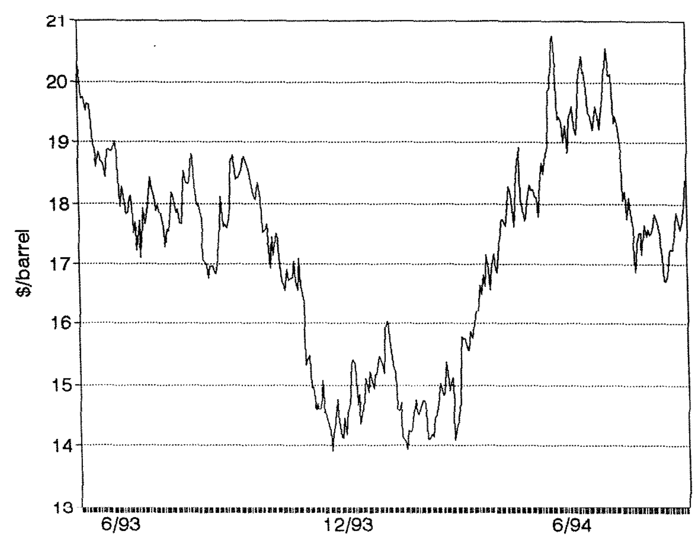

FIGURE 1
Crude oil near-month prices: June 1993–September 1994. Data Source: Knight-Ridder.

[10]Futures contracts are marked-to-market daily by exchanges, and traders are required to post with the exchange any losses they incur. While swap contracts usually are not formally marked-to-market, it is not uncommon for counterparties in swap agreements to call for additional collateral from losing counterparties as losses mount. In addition, swap contracts entail cash flows on settlement dates. Thus, in terms of cash flows, short-dated OTC swaps are very similar to futures contracts.

what to many seemed like a liquidity crisis, MG's Supervisory Board fired MGRM's management and brought in new management, which quickly made the decision to liquidate the bulk of MGRM's derivatives and forward delivery positions.

Was MGRM's short-dated, stack, hedging strategy fatally flawed? Critics assert that this strategy exposed it to three significant and related risks: *rollover risk, funding risk,* and *credit risk.* It was exposed to rollover risk because of uncertainty about whether it would sustain gains or losses when rolling its derivatives positions forward.[11] Critics also believe that MGRM was exposed to funding risk because of the mark-to-market conventions that applied to its short-dated derivatives positions. Finally, they claim that MGRM was exposed to credit risk because its forward delivery counterparties might default on their long-dated obligations to purchase oil at fixed prices. Each of these risks is examined in the sections of the article which follow.

PHYSICAL STORAGE AS AN ALTERNATIVE HEDGING STRATEGY

An alternative hedging strategy available to MGRM was physical storage. To better understand MGRM's rationale for choosing to hedge with short-dated derivatives, it is instructive to examine why it did not hedge by physical storage.[12] MGRM clearly could have hedged the price risk on its forward delivery contracts by purchasing and storing the amount of physical oil (or other energy products) needed to meet its forward-supply commitments, thereby locking-in today's energy prices. This strategy, however, while assuring that MGRM would have the oil it needed in the future, would have locked-in a *loss* rather than a profit.

Physical storage is not costless. Funds must be committed to the immediate purchase of oil (financing costs), and there are storage costs—storage tanks, insurance, and so forth. In MGRM's case, these costs would have exceeded the profit margins built into its forward-supply contracts, so that it would have ended up losing money on its forward delivery contracts.[13] In fact, if total storage costs were to exceed 7.33 cents per barrel per month, a strategy of physical storage would have resulted in a net loss for MGRM (see Appendix 1A). The actual

[11]Rollover risk can be viewed as a particular type of intertemporal basis risk.

[12]Physical storage is defined simply as purchasing and storing oil, and not physical storage in conjunction with reverse cash-and-carry arbitrage to take advantage of backwardation. The latter would involve continually making and taking delivery of oil.

[13]Physical storage also may not have been a feasible alternative for MGRM because there simply may not have been sufficient storage facilities available.

cost of physical storage is considerably higher.[14] Thus, while a strategy of physical storage could have successfully eliminated MGRM's price risk, it also would have eliminated the profits on its forward sales.[15]

By using short-dated derivatives, or a synthetic storage strategy, MGRM believed that it could successfully hedge its price risk while having to pay what in effect was a lower cost of storage.[16] More specifically, it believed that, because energy futures markets are often in backwardation, when it rolled its short-dated derivatives positions forward through time, it would receive a convenience yield that would offset or reduce the implicit costs of storing oil. The success of MGRM's hedging strategy, therefore, depended on the belief that it would profit from rolling forward its short-dated derivatives positions.[17]

MGRM'S BELIEF THAT ROLLOVERS WOULD BE PROFITABLE

Some idea of what MGRM believed its rollover gain was likely to be can be obtained from data on historical price relationships in energy markets. To estimate likely rollover gains and losses, however, two assumptions are made about how MGRM went about rolling its positions forward. (No information is available on exactly how MGRM conducted its rollovers.) First, it is assumed that each month MGRM purchased the futures contract with the second closest delivery date (hereafter referred to as the second-month futures), requiring delivery in approximately one month from the purchase date. Second, it is assumed that four days prior to the end of trading on these contracts (or three days prior to the last day of trading on the contracts), MGRM sold these contracts and again purchased second-month futures contracts.[18] This rolling-forward trading strategy is referred to as the three-day rollover rule. The rollover

[14]The statistics in Table I suggest that carrying costs would be about \$0.24/barrel per month. Litzenberger and Rabinowitz (1993) reported that storage space for oil above ground is limited and entails an "extremely high cost per unit value".

[15]A strategy of physical storage would also have exposed MGRM to some risk. First, there would have been some funding risk because of uncertainty about future carrying costs (such as interest rates). Second, because of the customer cash-out options in MGRM's forward delivery contracts, MGRM was exposed to market risk. Had customers exercised their options, MGRM would have had to sell a large volume of physical oil at short notice to produce the cash needed to meet its cash-out obligations.

[16]Culp and Miller (1994b) refer to MGRM's hedging program as synthetic storage.

[17]Culp and Miller (1994b), in contrast, suggest that backwardation (and therefore rollover profits) was not essential to the success of MGRM's hedging strategy.

[18]The last day of trading for heating oil and gasoline is the last business day of the month preceding the delivery month; for crude oil it is the third business day prior to the 25th calendar day of the month preceding the delivery month.

gains and losses which result from this rule are calculated as the near-month futures price minus the second-month futures price on the third day prior to the last day of trading.[19] Closing (or settlement) prices are used for all calculations. Other rollover rules were also analyzed with similar results. (Specifically, a ten-day rollover rule using a near-month stack and a three-day rule using a stack in six-month futures were analyzed. See Appendices 2 and 3 for these results. These methods and the three-day rollover rule were found to yield similar results for the 1983–1992 period.)

Table I shows how MGRM would have fared using the three-day rollover rule during the nearly 11-year period from April 1983 to

TABLE I
Summary of Rollover Gains and Losses
(April 1983–December 1992)[a] Three-Day Rollover Rule

Summary Statistics (April 1983–December 1992)[b]

	Crude Oil	*Heating Oil*	*Gasoline*
Mean Rollover	0.25	0.32	0.45
Mean of All Rollover Gains	0.48	1.10	0.86
Mean of All Rollover Losses	−0.24	−0.33	−0.51
Cumulative Rollover Gain	29.63	37.69	43.58
Frequency of a Rollover Gain	67%	45%	70%

Frequency of a Rollover Gain

	Crude Oil	*Heating Oil*	*Gasoline*
Jan	67%	89%	50%
Feb	78%	78%	13%
Mar	67%	100%	38%
Apr	80%	100%	75%
May	40%	70%	88%
Jun	50%	10%	88%
Jul	70%	0%	88%
Aug	60%	0%	100%
Sep	80%	0%	88%
Oct	70%	0%	88%
Nov	80%	50%	75%
Dec	70%	60%	56%

continued

[19]Alternatively, roll gains (losses) can be calculated as the change in the second-month futures price minus the change in the spot price over the same period. This methodology yielded nearly identical results.

TABLE I (Continued)

Cumulative Rollover Gains by Month[b]			
	Crude Oil	*Heating Oil*	*Gasoline*
Jan	3.70	13.20	0.02
Feb	3.80	10.68	−2.75
Mar	1.99	9.77	−3.18
Apr	2.09	8.41	5.95
May	2.03	1.71	5.59
Jun	2.24	−1.46	6.17
Jul	1.82	−3.76	5.63
Aug	0.71	−3.89	6.88
Sep	3.17	−3.74	7.00
Oct	2.39	−3.29	8.94
Nov	2.66	−1.02	3.10
Dec	3.03	11.09	0.23

Cumulative Rollover Gains by Year[b]			
	Crude Oil	*Heating Oil*	*Gasoline*
1983	1.14	−0.60	
1984	−0.55	6.18	−0.25
1985	9.50	6.75	11.75
1986	1.53	5.32	3.36
1987	3.64	0.70	0.17
1988	1.42	2.83	8.58
1989	7.96	12.15	6.35
1990	1.15	2.33	7.47
1991	4.23	3.97	7.56
1992	−0.39	−1.94	−1.41

[a]All rollovers are calculated using a three-day rollover rule: on the third day prior to the last day of trading the near-month contract is sold and the contract month which is the second closest to delivery is bought. The rollover gain or loss is calculated as the near month price minus the second month price. Data for gasoline begin in December 1984. When these statistics are recalculated after excluding the extreme observations associated with the Gulf War in late 1989, the results do not change appreciably, except for heating oil, where the mean rollover becomes 0.20 and the mean of all rollover gains becomes 0.85.
[b]All rollover gains, losses, and means are reported in $/barrel. Heating oil and gasoline are traded on a $/gallon basis. There are 42 gallons per barrel.
Data Source: Knight-Ridder Futures Markets Database.

December 1992.[20] These results are based on daily data for crude oil, heating oil, and gasoline, using closing (or settlement) prices. Several results in Table I are noteworthy. First, energy markets show a high *frequency of backwardation*, or a high frequency of rollover gains. For

[20]This period was chosen because trading in crude oil futures did not begin until 1983. Also, gasoline futures did not start trading until December, 1984. The period of analysis ends in December, 1992 to make the results comparable with what happened to MGRM in 1993. Data are from the Knight-Ridder Futures Markets Database.

example, for crude oil futures, on about 67% of the rollover dates the price of the second-month futures contract was below the price of the spot futures contract (or the contract closest to delivery). Thus, in crude oil futures MGRM would have made a positive return, or had a rollover gain, on 67% of its rollovers. The corresponding figures for heating oil and gasoline futures are 45% and 70%, respectively. (Monthly rollover gains and losses are shown in Figs. 2–4 for crude oil, heating, oil, and gasoline.)

Second, dividing all rollover dates into two categories based on whether the market was in contango or backwardation on that date, the *average monthly rollover gain far exceeds the average monthly rollover loss*. The average monthly rollover losses and gains in crude oil, heating oil, and gasoline are, respectively, \$−0.24/barrel vs. \$0.48/barrel; \$−0.33/barrel vs. \$1.10/barrel; and \$−0.51/barrel vs. \$0.86/barrel. Given these disparities in the magnitude of average rollover gains and losses, rollovers would have produced a net loss only if the frequency of contango in these markets were to far exceed the frequency of backwardation. This, as discussed earlier, turned out not to be the case.

In markets prone to backwardation, as are energy futures markets, it is not surprising to find that average price backwardation exceeds average price contango. The amount of contango is limited by arbitrage to the full cost-of-carry (cash-and-carry arbitrage). In contrast, when markets are in backwardation, there is no arbitrage-limiting boundary to restrict the amount of backwardation.[21] This asymmetrical characteristic can be seen in Figures 2–4, which plot monthly rollover gains and losses for crude oil, heating oil, and gasoline, from 1983 to 1994.[22]

Finally, aggregating all rollover gains and losses produces a *net average monthly rollover gain* for all three energy futures: \$0.25/barrel for crude oil; \$0.32/barrel for heating oil; and \$0.45/barrel for gasoline (see Table I). Thus, if past price relationships in energy futures markets are a good predictor of future price relationships, MGRM could have expected to make a profit by rolling its short-dated derivatives position forward through time. Stated another way, the price characteristics of energy futures markets appear to reward a synthetic storage hedging strategy by permitting hedgers in effect to avoid the full costs (or any

[21]The ability to do reverse cash-and-carry arbitrage is limited because a shortage of the physical commodity makes it difficult and costly to borrow the physical commodity to short it. For a discussion of arbitrage bounds when there are restrictions on short-selling, see Modest and Sundaresan (1983).

[22]This characteristic is especially obvious for heating oil (Fig. 3). Further, if the exceptional Gulf War period late in 1989 were excluded from Figures 2 and 4, this asymmetric characteristic would be more obvious for crude oil and gasoline.

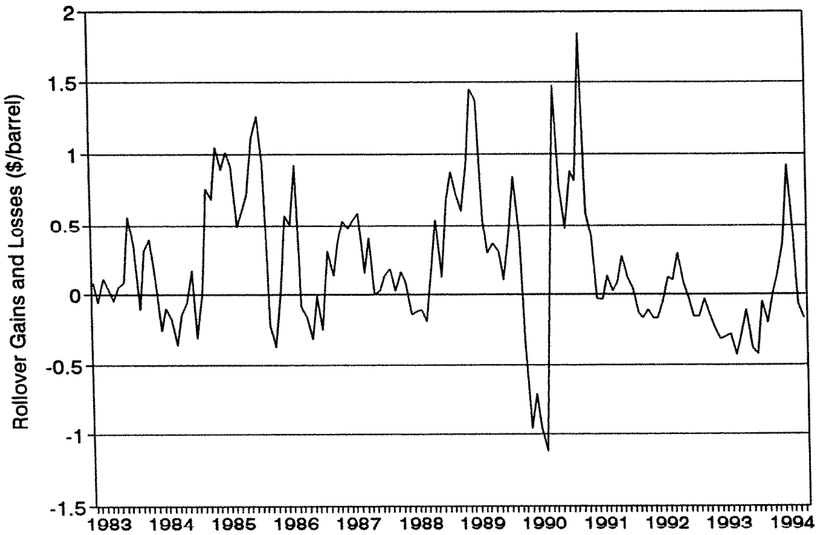

FIGURE 2
Crude oil monthly rollover gains and losses: April 1983–September 1994. Data Source: Knight-Ridder.

cost) of storage. The intuition behind this result is that energy markets are characterized by frequent (seasonal) shortages of the physical commodity, and at these times there is a substantial convenience yield embedded in futures prices. For commercial reasons, energy-supplying firms are willing to hold the physical commodity even though expected

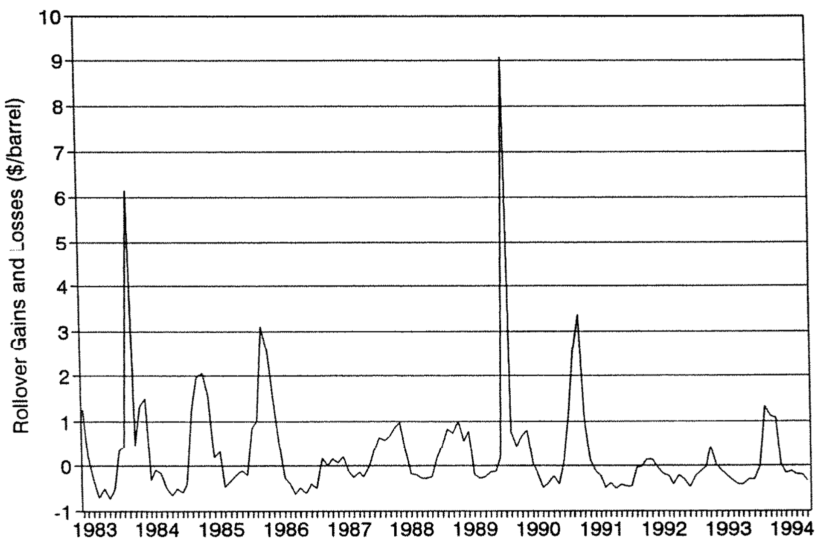

FIGURE 3
Heating oil monthly rollover gains and losses: April 1983–September 1994. Data Source: Knight-Ridder.

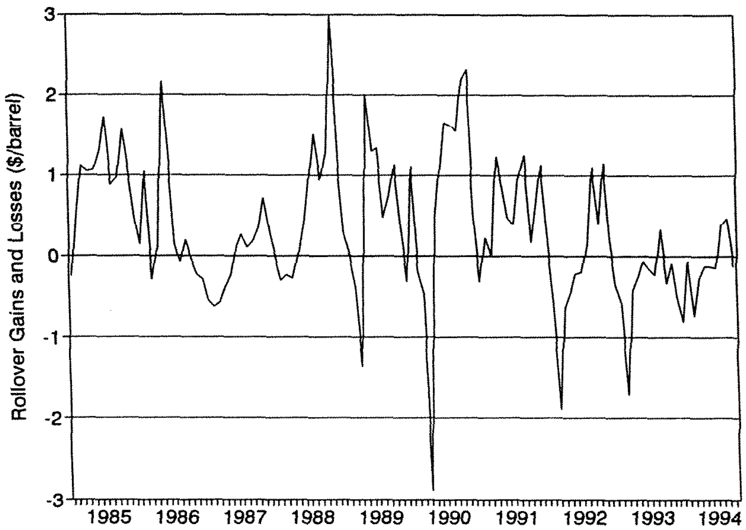

FIGURE 4
Gasoline monthly rollover gains and losses: December 1984–September 1994. Data Source: Knight-Ridder.

spot prices are considerably below current spot prices, providing an opportunity for others to purchase forward oil at prices that do not reflect storage costs for the physical product.

These results need to be qualified in two ways. First, in reality, MGRM need not have been so inflexible about when it rolled its positions forward. It could, for example, have rolled on days when particularly favorable price relationships existed. In that case, the findings reported here would understate the potential benefits to MGRM in holding short-dated futures and rolling these forward through time. On the other hand, this analysis implicitly assumes that MGRM would have been able to execute at the observed prices, which may not always have been possible.

The seasonality of price relationships in energy markets is also evident. Table I provides data on rollover frequencies for each calendar month and on cumulative rollover gains or losses by both calendar month and year. In general, heating oil is in backwardation and exhibits rollover gains from December through March; gasoline is in backwardation and exhibits rollover gains from April through November. Further, backwardation in heating oil and gasoline markets coincides with the approach of the end of the heating oil and gasoline high-demand seasons, when energy suppliers are reducing their inventories in anticipation of falling demand. Backwardation appears to be a general characteristic of crude oil futures. See Litzenberger and Rabinowitz (1993).

Given this seasonality, it is possible that MGRM could have further increased its net rollover gain by moving futures and swap positions from one commodity to another, depending on the time of year and the expected backwardation in the respective markets. (MGRM apparently did this. See affidavit of Benson.) Although such a strategy entails some additional (cross-hedging) basis risk, the high correlations which exist among the different energy prices suggest that this additional risk is not large.[23]

Thus, at least on the basis of past price relationships, it does not seem unreasonable for MGRM to have expected that over a long period of time (such as ten years) its hedging strategy would have produced a net rollover gain.

DID MGRM HAVE A ROLLOVER RISK?

A key issue is whether MGRM was exposed to a significant rollover risk.[24] If markets were to experience an uncharacteristic long period of contango, MGRM could have been exposed to significant rollover losses–it would consistently have been forced to buy high and sell low in rolling its positions forward. This study estimates that had a typical contango market occurred at the beginning of MGRM's hedging program and lasted for a period of only one year and two months, its entire profit mark-up could have been wiped out. See Appendix 1B. This calculation assumes an average contractual markup of \$4, a constant interest rate of 6%, and an average monthly rollover cost of \$0.24—the average monthly rollover loss in crude oil during the 1983–1992 period when crude oil was in contango. (See Table I.) In addition, it assumes that MGRM rolled forward its entire position every month.

Some idea of the likelihood of MGRM's experiencing rollover losses for extensive periods of time can be gleaned from past data on the volatility of the second-month basis.[25] The standard deviations of the daily second-month basis for the 1983–1992 period for heating oil and

[23]The simple correlation coefficients for daily changes in near-month futures prices are: 0.84 between crude oil and gasoline, and 0.88 between crude oil and heating oil.

[24]See Hutchinson (1994). Culp and Miller (1994b) seem to say that rollover risk was not a significant aspect of MGRM's hedging method.

[25]The daily second-month basis is calculated by subtracting daily nearby closing futures prices from daily closing second-month futures prices.

gasoline are, respectively, \$0.89/barrel and \$0.85/barrel.[26] Thus, given a mean rollover gain in the range of \$0.25 to \$0.45/barrel per month, the possibility of rollover losses occurring is not insignificant.

It is revealing, however, to compare this rollover risk to the price risk that MGRM had on its forward-supply commitments. MGRM's price risk depended on the expected volatility of spot prices for heating oil and gasoline over the ten-year contractual period. Using data from the 1983–1992 period, the respective standard deviations of daily heating oil and gasoline prices were \$5.96 and \$5.17/barrel.[27] Thus, if the respective basis and price standard deviations are used to measure MGRM's respective risk exposures, its short-dated hedging strategy exposed it to rollover risk on the order of 15% of its price risk.

Despite these statistics, 1993 turned out to be a disaster for MGRM. In 1993 crude oil was in contango every month, heating oil was in contango every month except March and April, and gasoline was in contango every month except August. Thus, virtually every time that MGRM rolled its positions forward, it sustained losses. If it is assumed that MGRM had positions on for the entire year and had to roll these forward every month, *its cumulative roll losses for the year would* have been \$1.86/barrel for heating oil, \$4.87/barrel for gasoline, and \$3.10/barrel for crude oil (see Table II). Had MGRM sustained roll losses of this magnitude for very long, its profit margins of \$3–5 would have been quickly eroded.[28]

How predictable were the contango markets that occurred in 1993? The monthly rollover gain and loss frequencies reported in Table I suggest that the probability of a string of contango months occurring in the particular months in which they occurred in 1993 is extremely small—on the order of zero.[29] However, there have been periods in the past when unusual strings of contango months did occur. In particular, for the 12-month period from May 1991 through May 1992, heating oil was in contango ten out of 12 months; from July 1986 through June 1987, gasoline was in contango nine out of 12 months; and from January

[26]Daily settlement prices are used for over 2400 trading days, from April 1983 to September 1994. In calculating *daily* basis volatilities, a random rollover date is implicitly assumed. The standard deviations of the second-month basis are calculated using only the roll dates generated by the three-day rollover rule. These are \$1.25/barrel for heating oil, and \$0.89 for gasoline, which are higher than the volatilities calculated assuming a random rollover date.

[27]Near-month futures prices are used as proxies for spot prices because data on spot prices are notoriously bad.

[28]MGRM's exact positions during each month of 1993 have not been disclosed. Judging from press reports, however, most of MGRM's positions were not put on until the summer of 1993.

[29]This assumes that monthly rollover gains and losses are independent of one another. If this were not true, the probability of MGRM's experiencing a string of contango months would be higher.

1992 through December 1992, crude oil was in contango eight out of 12 months. Thus, the string of contango months that occurred in 1993 was unusual but not without some precedent.

Alternatively, 1993 can be compared to a worst-case scenario constructed with past data. Figures 5–7 plot the rollover losses for crude oil, heating oil, and gasoline that occurred in each month during 1993 against the *maximum* (or worst-case) rollover losses (or contango) that occurred in the past in each of the calendar months (using data from the period April 1983–December 1992). In other words, the *maximum*

TABLE II
Rollover Gains and Losses (Using a Three-Day Rollover Rule) and Changes in Spot Prices, 1993[a]

Crude Oil

Rollover Date	*Rollover Gain or Loss*	*Changes in Spot Prices*
01/15/93	−0.16	−0.54
02/17/93	−0.03	0.46
03/17/93	−0.13	0.84
04/16/93	−0.24	−0.03
05/17/93	−0.32	−0.63
06/17/93	−0.30	−0.81
07/16/93	−0.28	−1.49
08/17/93	−0.43	0.71
09/17/93	−0.30	−0.85
10/15/93	−0.11	1.20
11/17/93	−0.38	−1.23
12/16/93	−0.42	−2.81
Total	−3.10	−5.18

Heating Oil

Rollover Date	*Rollover Gain or Loss*	*Changes in Spot Prices*
01/26/93	−0.12	−1.09
02/23/93	−0.03	0.85
03/26/93	0.44	0.17
04/27/93	0.01	−0.97
05/25/93	−0.11	−0.46
06/25/93	−0.24	−0.83
07/27/93	−0.33	−0.27
08/26/93	−0.42	0.51
09/27/93	−0.43	0.09
10/26/93	−0.30	−0.38
11/23/93	0.30	0.77
12/27/93	−0.03	−2.52
Total	−1.86	−5.67

continued

TABLE II (Continued)

	Gasoline	
Rollover Date	*Rollover Gain or Loss*	*Changes in Spot Prices*
01/26/93	−0.58	0.20
02/23/93	−1.71	−0.14
03/26/93	−0.43	1.86
04/27/93	−0.26	0.17
05/25/93	−0.07	−0.21
06/25/93	−0.16	−1.64
07/27/93	−0.23	−0.87
08/26/93	0.32	0.17
09/27/93	−0.34	−2.00
10/26/93	−0.09	−0.07
11/23/93	−0.50	−1.62
12/27/93	−0.81	−3.21
Total	−4.87	−7.34

[a]All rollovers are calculated using a three-day rollover rule: on the third day prior to the last day of trading the near-month contract is sold, and the contract month which is the second closest to delivery is bought. The rollover gain or loss is the near month price minus the second-month price. To proxy for changes in spot prices, changes in near-month futures prices are used. Spot price changes are from one rollover date to the next. All prices are reported in $/barrel. Total figures differ from the sum of monthly figures because of rounding.
Data Source: *Knight-Ridder Futures Markets Database.*

calendar-month rollover losses consist of the worst January rollover loss that occurred in any of the previous ten years, the worst February rollover loss in any previous year, and so forth, for every calendar month. This is obviously a very strong test, since it uses not the worst-case scenario for any single year, but rather a worst-case scenario based on the largest rollover costs ever incurred in a particular calendar month, irrespective of the year in which they occurred. Figures 5–7 show that, with some exceptions, the monthly rollover losses that occurred in 1993 were generally quite similar to the maximum rollover losses that occurred in earlier years. Thus, while the contango price relationships that occurred in 1993 were unusual, similar contango price relationships had occurred before.

Critics also contend that MGRM's rollover strategy was fatally flawed because of the size of its derivatives positions. They argue, first, that its derivatives positions were large enough to move the market from backwardation into contango; and second, that MGRM's counterparties (or traders) were in a position to extract from MGRM a monopoly price when it rolled positions forward, forcing it to sell at a lower price and buy at a higher price because of their market power vis-à-vis MGRM.

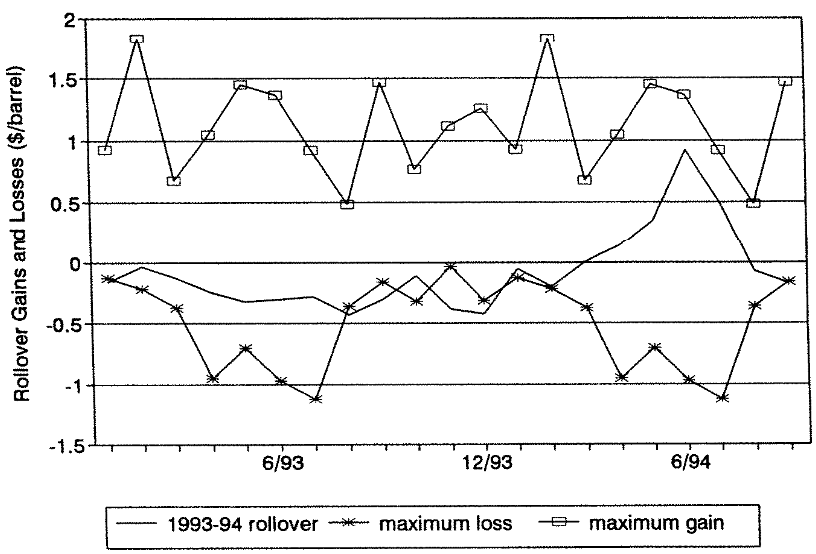

FIGURE 5
Crude oil monthly rollover gains and losses in 1993–1994 vs. maximum roll gains and losses prior to 1993. Data Source: Knight Ridder.

MGRM's positions, however, were not large relative to total open interest. Its total futures positions constituted only about 6.7% of total open interest, and its combined futures and swaps positions constituted

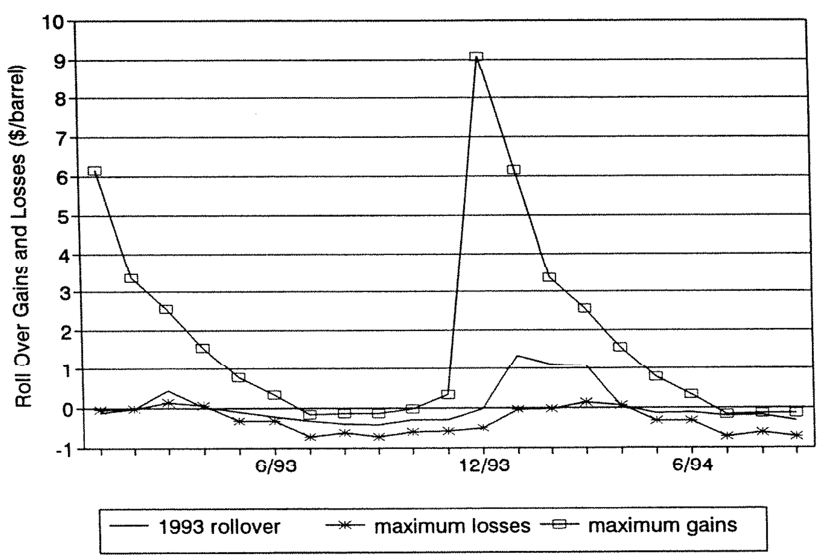

FIGURE 6
Heating oil monthly rollover gains and losses in 1993–1994 vs. maximum rollover gains and losses prior to 1993. Data Source: Knight-Ridder.

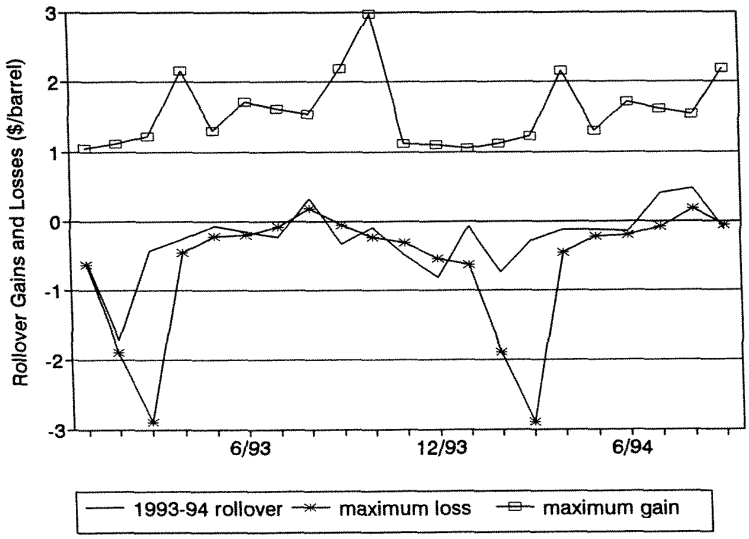

FIGURE 7
Gasoline monthly rollover gains and losses in 1993–1994 vs. maximum roll gains and losses prior to 1993. Data Source: Knight-Ridder.

about 20% of total open interest.[30] In addition, it seems unlikely that traders would have had monopoly power vis-à-vis MGRM. There are no significant barriers to entry into trading futures on an exchange, and in OTC swap markets there are a large number of potential counterparties. MGRM could have moved positions from one energy market to another, from exchange to off-exchange positions, and could have rolled positions forward on many different dates.[31]

In summary, past data provides reasonable support for MGRM's presumption that it could expect to earn a net rollover gain.[32] However, in relying on past data to predict future rollover gains, MGRM was implicitly making two critical assumptions: that the structure of energy futures markets would not change significantly in the future (that history would repeat itself), and that a history of only ten years is long enough to provide accurate long-term forecasts of rollover returns. While such

[30]Taking only MGRM's futures positions, MGRM constituted about 6.7% [55,000/(160,000 + 200,000 + 450,000)] of the combined highest total open interest of gasoline, heating oil, and crude oil during December 1993. If MGRM's swap positions are also included (because its swap counterparties would have been hedging with futures), these combined positions would have constituted about 20% (160,000/810,000) of total open interest in December 1993.
[31]All large buy and sell orders, of course, may experience bad fills from time-to-time.
[32]MGRM would, of course, have had to finance periods of rollover losses, which would have imposed additional costs on it. However, its rollover gains would have produced a return. MGRM's potential funding problem is discussed later.

assumptions may seem heroic to many observers, there is some reason to believe that periodic price backwardation is a permanent feature of energy markets. Seasonal spikes in demand coupled with a shortage of storage facilities appear to assure that backwardation will continue to exist. On the other hand, institutional speculators in commodity markets (such as commodity pools), which have been growing rapidly in recent years, may in the future compete away the positive roll returns on which MGRM's strategy depended.[33]

Finally, although hedgers commonly assume a stable market structure in formulating their hedging policies, a characteristic that may distinguish MGRM from other hedgers is that its strategy required an assumption that the market structure would be stable for a very long period of time.[34] Further, even with a stable market structure, MGRM could only be assured of a net rollover gain if it were able to continue its hedging program for a long period of time. In the short-run almost any outcome was a possibility, as MGRM's experience in 1993 clearly revealed. In addition, the early cash-out options in MGRM's forward delivery contracts could have caused it to end its hedging strategy unexpectedly.[35] In particular, had its customers exercised their options subsequent to a period during which MGRM incurred rollover losses, it would have had to end its hedging program before being able to offset these losses with rollover gains. Finally, to reap the expected long-term rollover gains, MGRM implicitly assumed that it could fund whatever rollover losses it sustained in the short-run. The soundness of MGRM's short-dated hedging strategy, therefore, must be judged on the basis of the reasonableness of these assumptions.

ROLLOVER RISK: LESSONS FROM OTHER COMMODITIES

To get some idea of the reliability of using past price data to predict future rollover returns, two commodity futures with longer price histories than energy futures are examined: soybeans and copper. These

[33]An example of a recent institutional investment product aimed directly at taking advantage of the well-known price backwardation in energy futures markets is Goldman Sachs' commodity index. Petroleum products have a heavy weight in this index, and a substantial portion of the advertised return on this index is predicated on the continued existence of price backwardation in energy futures markets.

[34]For example, when hedgers rely on regression analysis to choose both the commodity contract with which to hedge and the hedge ratio to use, they are relying on historical data being a good predictor of future price relationships. See Edwards and Ma (1992), Chapters 5 and 6.

[35]According to the Special Audit Report (1995) of MGAG, MGRM believed that the average life of a typical forward delivery contract that included the cash-out option was between 2.5 and 3 years.

commodity futures are similar to energy futures in that they also exhibit periods of recurring contango and backwardation price relationships. Data for soybean and copper futures are available for the 30-year period 1965–1994, permitting an analysis of three separate ten-year periods.

Tables III and IV provide, for each of these periods, various statistics for soybean and copper futures on the frequency of contango and backwardation price relationships as well as summary statistics on

TABLE III
Summary of Rollover Gains and Losses–Soybeans and Copper (1965–1994): Three-Day Rollover Rule

Soybeans
Summary Statistics for Soybeans (1965–1994)

	1965–1974	*1975–1984*	*1985–1994*
Mean rollover	5.52	−4.56	−0.50
Mean of all rollover gains	16.74	10.14	9.59
Mean of all rollover losses	−3.50	−8.91	−6.86
Cumulative rollover gain	386.12	−319.00	−34.75
Frequency of a rollover gain	44%	23%	36%

Frequency of a Rollover Gain for Soybeans

	1965–1974	*1975–1984*	*1985–1994*
Jan	20%	0%	10%
Mar	20%	0%	0%
May	10%	30%	50%
Jul	80%	70%	70%
Aug	90%	50%	60%
Sep	70%	10%	60%
Nov	20%	0%	0%

Cumulative Rollover Gains by Month for Soybeans

	1965–1974	*1975–1984*	*1985–1994*
Jan	−21.25	−110.00	−58.00
Mar	−0.88	−107.50	−57.75
May	25.13	−13.75	−15.75
Jul	161.25	26.25	62.25
Aug	197.75	47.00	92.75
Sep	53.13	−44.50	2.50
Nov	−29.01	−116.50	−60.75

continued

TABLE III (Continued)

Copper
Summary Statistics for Copper (1965–1994)

	1965–1974	1975–1984	1985–1994
Mean rollover	1.47	−0.94	1.65
Mean of all rollover gains	2.64	1.15	3.87
Mean of all rollover losses	−0.48	−1.03	−0.53
Cumulative rollover gain	88.03	−56.60	97.60
Frequency of a rollover gain	62%	3%	49%

Frequency of a Rollover Gain for Copper

	1965–1974	1975–1984	1985–1994
Jan	70%	10%	40%
Mar	70%	0%	60%
May	80%	0%	50%
Jul	50%	0%	30%
Sep	60%	0%	60%
Dec	40%	10%	56%

Cumulative Rollover Gains by Month for Copper

	1965–1974	1975–1984	1985–1994
Jan	12.80	−16.30	16.25
Mar	25.02	−8.70	22.80
May	16.51	−9.15	13.20
Jul	9.85	−8.55	3.40
Sep	15.40	−14.10	33.30
Dec	8.45	0.20	8.65

All rollovers are calculated using a three-day rollover rule: on the third day prior to the last day of trading we sell the near-month contract and buy the contract month which is the second closest to delivery. The rollover gain or loss is calculated as the near-month price minus the second-month price. For soybeans all rollover gains, losses, and means are reported in cents per bushel; for copper they are reported in cents per pound. Our data ends in September, 1994. Data Source: Knight Ridder.

the magnitude of rollover gains and losses (similar statistics were provided earlier in Table I for crude oil, heating oil, and gasoline futures).[36] In the first period, 1965–1974, both soybeans and copper were in backwardation much of the time (44% and 62%, respectively) so that

[36]Similar to the earlier procedure for energy futures, a three-day rollover rule is used to calculate rollover gains and losses. The last day of trading in the soybean futures contract is seven days prior to the last business day of the delivery month. The last day of trading in copper futures is the third-to-last business day of the month. Rollovers occur in the main contract months for each of the commodities: January, March, May, July, August, September, and November for soybeans; and, January, March, May, July, September, and December for copper.

TABLE IV
Cumulative Rollover Gains by Year: Soybeans and Copper

	Soybeans	*Copper*
1965	31.14	21.67
1966	42.37	5.85
1967	16.24	3.66
1968	9.25	13.50
1969	18.12	10.60
1970	−17.62	8.05
1971	−14.50	−1.30
1972	23.87	−2.80
1973	297.75	19.80
1974	−20.50	9.00
1975	−9.25	−3.50
1976	−29.00	−1.90
1977	54.25	−2.90
1978	−1.75	−4.20
1979	−58.50	−2.05
1980	−94.75	−16.35
1981	−69.25	−9.45
1982	−27.75	−6.50
1983	−63.50	−5.35
1984	−19.50	−4.40
1985	−2.25	−3.30
1986	56.75	−2.60
1987	12.00	5.45
1988	−53.25	46.40
1989	29.25	16.05
1990	−61.75	29.25
1991	−29.00	7.35
1992	−12.25	−2.10
1993	3.25	−2.55
1994	22.50	3.65

All rollovers are calculated using a three-day rollover rule: on the third day prior to the last day of trading we sell the near-month contract and buy the contract month which is the second closest to delivery. The rollover gain or loss is calculated as the near-month price minus the second-month price. For soybeans all rollover gains, losses, and means are reported in cents per bushel, for copper they are reported in cents per pound. Our data ends in September, 1994. Data Source: Knight Ridder.

the average rollover gains were, respectively, 5.52 cents per bushel and 1.47 cents per pound.[37] During the second period (1975–1984), however, rollover returns for soybeans and copper were quite different. Rather than rollover gains, both soybeans and copper experienced rollover losses on average. Further, the frequency of backwardation

[37]In order to compare these rollover gains with the earlier findings for energy futures, they can be restated as average percentage returns by dividing the average rollover gains by the respective average prices during the period. Thus, in the 1965–1974 period, the average rollover returns were 1.48% and 2.4% for soybeans and copper while for crude oil, heating oil, and gasoline the average rollover returns during the 1983–1992 period were, respectively, 1.12%, 1.24%, and 1.80%.

dropped precipitously, to 23% for soybeans and 3% for copper. In the third period (1985–1994), rollover gains and losses were again quite different than they were in the second period. Thus, these data suggest that in commodity futures markets it would not be atypical to find that average rollover returns during any ten-year period would not be a good predictor of average rollover returns during any successive ten-year period.

A striking parallel to what happened to MGRM in 1992 and 1993 also can be seen in the soybeans and copper data. During the last year of the first time period (1974) and the first year of the second time period (1975), rollover returns for soybeans and copper turned sharply negative, similar to what happened to rollover returns for energy futures in 1992 and 1993. (Compare Table IV and Appendix 4.) If one were standing in 1974 or 1975, what would one have concluded about rollover returns for soybeans and copper in the future: that they would soon revert to being positive, or that they would remain negative for an indefinite period of time? As it turned out, rollover returns remained negative for most of the next ten years, finally reverting to being positive in 1986 and 1987. Thus, in 1975 a bet that rollover returns would soon turn positive again would have gone sadly awry.

There are several possible explanations for the unreliability of past price data in predicting future rollover returns. First, a period of ten years may simply not be long enough to identify the true (structural) price relationship, or to infer long-run equilibrium rollover returns. Second, markets and structural price relationships can change from one period to the next, as fundamental economic events occur. If this happens, equilibrium rollover returns can be quite different in different time periods. Finally, because the distribution of rollover returns in commodity futures tends to be characterized by relatively high variances (relative to mean rollover returns), relying solely on past mean rollover returns for any finite period of time can result in large prediction errors. MGRM's hedging strategy, which depended on positive rollover returns, was vulnerable to any one (or to all) of these possibilities.

MG'S ALLEGED FUNDING PROBLEM

A combination of falling energy prices and a contango market caused MGRM to have to fund sizeable cash outflows in 1993. Between June and December, 1993, crude oil prices declined by nearly $6.00/barrel (see Fig. 1), resulting in MGRM having to post nearly $900 million to maintain its hedge positions. See Hanley (1994). In response, MG's Supervisory Board replaced MG's top management and liquidated MGRM's derivatives and forward-supply contracts positions, ending MG's foray into the U.S. oil market.

MG's funding needs in 1993 can be decomposed into two components: funds to finance margin calls (or unrealized losses) on its derivatives positions due to declines in energy prices[38]; and funds to finance rollover losses due to contango markets (discussed above). Falling energy prices and contango markets, of course, may not be unrelated phenomena. Falling energy prices are usually an indication that there are no product shortages, and in the absence of such shortages contango price relationships are normal. See French (1986). The bulk of MGRM's funding needs in 1993, however, arose from having to meet margin calls due to price declines, rather than from rollover losses (see Table II).

It is not obvious why MGRM would have had a problem funding these margin calls. Consider, for example, the following hypothetical situation. Suppose that MGRM's hedge was such that falling energy prices, although resulting in unrealized losses on its derivatives positions, also resulted in unrealized *gains* on its fixed-price, forward-supply contracts of exactly the same magnitude as the unrealized losses on its derivatives positions.[39] Since MGRM's forward-supply contracts locked-in a fixed sale price for future deliveries, these contracts could be expected to increase in value as energy prices fell because MGRM's expected cost of supplying oil in the future also would fall, making the contracts more profitable. Given equal and offsetting gains and losses on its derivatives and forward delivery contracts, therefore, it is not clear why MGRM would have had a funding problem.[40] Arguably, it should have been able to borrow against the collateral of its now more valuable forward delivery contracts.

There are two potential economic explanations for why MGRM may have encountered difficulty in using its forward delivery contracts as collateral to fully fund its margin outflows.[41] First, it may not in fact have had equal and offsetting unrealized gains on its forward delivery

[38]Press reports suggest that the unexpected failure of OPEC to reach agreement on limiting oil production in late November 1993 was the cause of the sharp fall in energy prices in late 1993.
[39]This assumes that MGRM wanted to use a hedge that yielded equal but offsetting gains and losses. However, according to the Special Audit Report (1995) this was never MGRM's intention.
[40]Culp and Miller (1994b), argue that MGRM's synthetic storage strategy was self-financing for precisely this reason.
[41]Economic obstacles should be distinguished from legal obstacles. It is possible, for example, that there may have been some difficulty in creditors perfecting legal title to MGRM's forward delivery contracts in the event of a default by MG.

contracts. In that event, it would have had to increase its general debt obligations to obtain the necessary funding, and its creditors may have balked if MG was already heavily indebted. Second, MGRM's forward delivery contracts may have lacked the necessary transparency for creditors to lend against them, or at least for creditors to lend an amount necessary to cover its margin needs. In particular, it may have been difficult for MG's creditors to evaluate the counterparty credit risk embedded in MGRM's forward delivery contracts.

THE FUNDING RISK IMPLICIT IN MGRM'S HEDGING STRATEGY

MGRM's hedging strategy had two features that, as it turned out, may have had important funding implications. First, it used a one-to-one hedge, instead of a minimum-variance hedge.[42] Second, it did not take into consideration the mismatch that existed in the timing of its expected cash flows (or, it did not tail its hedge).

MGRM's One-to-One Hedging Strategy

MGRM's strategy of using a one-to-one hedge could have caused a potential funding problem because it did not result in equal and offsetting unrealized gains in its forward delivery contracts when energy prices fell.[43] Alternatively stated, when energy prices fell, the value of MGRM's forward contracts did not increase by as much as the value of its derivatives positions declined, creating an imbalance in unrealized gains and losses.

MGRM's one-to-one hedge strategy had this consequence for two reasons. First, for this strategy to produce equal and offsetting changes in the value of MGRM's forward delivery contracts, there would need to be a one-to-one price relationship between forward and spot energy prices, which is not the case in energy markets. More specifically, changes in the value of its forward delivery contracts depended on changes in *forward* energy prices, while changes in the value of its short-dated derivatives positions depended on changes in *spot* energy prices. Because MGRM's forward-supply contracts called for it to

[42] A minimum-variance hedge attempts to minimize the variance in the value of the firm's per unit hedge revenues.

[43] As noted earlier, MGRM held short-dated derivatives positions of equal magnitude to its total forward delivery obligations in the future (or over the next ten years).

delivery energy products over many years in the future, changes in the value of these contracts should have reflected expectations about what spot prices were likely to be at the various times when MGRM was expected to make deliveries. A reasonable procedure for valuing these forward delivery contracts, therefore, would have been to use forward prices as predictors of future spot prices. In contrast, MGRM's derivatives positions were short-dated and their value depended solely on current spot prices. Thus, since the valuation of MGRM's derivatives and forward delivery contracts depended on different prices, a one-to-one hedge strategy would result in equal and offsetting unrealized gains and losses on its forward and derivatives positions only if there were also a one-to-one relationship between spot and forward prices.

There is good reason to believe that a one-to-one relationship between spot and forward prices does not exist in energy markets. Theoretically, one would expect a \$1 change in spot prices to cause less than a \$1 change in forward prices. Changes in contemporary demand and supply conditions, which cause changes in current spot prices, can be expected to have less of an effect on prices five or ten years from now, and therefore to generate smaller changes in forward prices than spot prices. See French (1986).

The evidence confirms this intuition: the volatility of more distant futures prices in considerably less than the volatility of spot energy prices.[44] Table V shows standard deviations (SD) of daily futures prices for spot, second-month, third-month, six-month, and nine-month futures contracts for heating oil and gasoline. In addition, Figure 8 plots forward price curves for selected dates, using available energy futures prices.[45] It is clear that the volatility of forward prices is considerably less than that of spot prices, and that the price volatility of distant-month futures declines sharply even over a period as short as a year. For example, the volatility of nine-month futures is from 50 to 65% of the volatility of spot prices.

A reasonable estimate of the price relationship between spot and forward energy prices over a ten-year period is 0.50: a \$1 increase (decrease) in the current spot price will, on average, result in only a \$0.50 increase (decrease) in forward prices over a ten-year period. (See

[44] Distant futures prices are used as proxies for forward energy prices.

[45] Reliable price data for futures contracts more distant than nine months are not available. There is little trading in many distant months, so that settlement prices are often not realistic prices. They may, for example, be interpolated prices.

TABLE V
Price Volatilities of Different Contract Months and Volatilities of Intertemporal Bases (1990–1992)[a]

Contract Maturity	*Heating Oil Futures (SD)*	*Gasoline Futures(SD)*
One Month	4.91	4.03
Two Months	4.91	3.53
Three Months	4.70	3.19
Six Months	3.36	3.23
Nine Months	2.48	3.19

Intertemporal Basis	*Heating Oil Intertemporal Bases (SD)*	*Gasoline Intertemporal Bases(SD)*
One Month–Two Month	0.84	1.01
One Month–Three Month	1.39	1.68
One Month–Six Month	2.69	2.48
One Month–Nine Month	3.07	2.44

[a]All volatilities are calculated using daily closing futures prices on the New York Mercantile Exchange. The volatilities are calculated using price levels. All figures are reported in $/barrel. To create continuous time series for the different contract months, all contracts are rolled into the next month three days prior to the last trading day of the near-month contract. Data Source: Knight-Ridder Futures Markets Database.

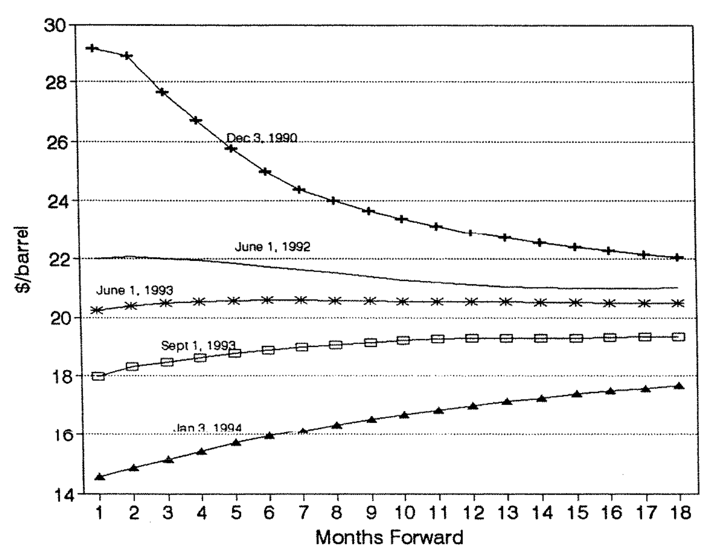

FIGURE 8
Crude oil forward price curves: selected dates. Data Source: Wall Street Journal.

TABLE VI

Regression Estimates of Relationship Between Spot and Forward Prices, 1990–1992

$$\Delta F(t,T) = \alpha + \beta \Delta F(t, t+1) + \varepsilon^{a}$$

	Heating Oil Futures		*Gasoline Futures*	
Time to Expiration	β	R^2	β	R^2
Two month futures	0.735	0.84	0.740	0.80
Three month futures	0.625	0.79	0.650	0.75
Six month futures	0.513	0.80	0.562	0.76
Nine month futures	0.492	0.79	0.520	0.72

[a] $F(t, T)$ is the futures price at time t for delivery at time T. Δ signifies the daily change in price. Separate regressions are run for the cases where $T = t + 2, t + 3, t + 6, t + 9$. Thus for $t + 2$, changes in two-month futures prices are regressed on changes in near-month futures prices, for $t + 3$ changes in three-month futures prices are regressed on changes in near-month futures prices, etc. To create continuous time series for the different contract months, all contracts are rolled into the next month three days prior to the last trading day of the near-month contract. The β coefficients reported in the table are the regression coefficients and represent the minimum-variance hedge ratio that should be used to hedge a forward obligation in month T. All of the estimated regression coefficients are statistically significant at the 1% level. A Durbin-Watson test showed little serial correlation in the error terms in all cases.

the regression estimates reported in Table VI.[46]) Given this estimate, when spot energy prices fell in 1993, MGRM's one-to-one hedge ratio would have resulted in an increase in the value of its forward delivery contracts that was only half as large as the unrealized loss that it sustained on its short-dated derivatives contracts.

The second reason that MGRM's one-to-one hedging strategy would not have resulted in equal and offsetting gains on its forward-supply contracts is that it did not account for the mismatch that existed in the timing of the expected cash flows on its forward-supply contracts and its hedge positions. Even assuming a one-to-one relationship between spot and forward prices, the later realization of the cash flows on MGRM's forward delivery contracts would have resulted in a smaller change in the net present value of these contracts than on its derivatives contracts for *a given change in price*. In contrast to MGRM's short-dated derivatives, most of the cash flows (or revenues) from its forward-supply contracts would not have occurred until many years later. Consequently, to produce equal and offsetting unrealized gains and losses, MGRM would have had to adjust (or tail) its hedge to put the expected cash flows from its forward delivery contracts on an equivalent footing to

[46]The forward price curves plotted in Figure 8 also suggest that forward prices quickly flatten out, so that price volatility for more distant forward prices may not be much different than that reflected in nine-month futures prices. It is presumed, therefore, that the price relationship reflected in the regression of spot prices on nine-month futures (shown in Table IV) would hold for more distant forward prices as well.

the cash flows generated by its derivatives positions.[47] The use of a one-to-one hedge ratio did not accomplish this.

Taking both the likely price relationship between spot and forward energy prices and the tailing factor into consideration (and for the moment ignoring the options embedded in the forward delivery contracts), it is estimated that MGRM would have needed a derivatives position of less than half of the position that it actually held to equate changes in the net present value of its forward-supply contracts to changes in the net present value of its derivatives positions.[48] More specifically, it would have needed a derivatives position of about 61 million barrels to hedge forward commitments of 160 million barrels. See Appendix 5.

Had MGRM used this smaller hedge position, its funding situation in 1993 when energy prices fell would have been significantly altered. First, with a derivatives position less than half as large as it actually held, its *net* unrealized losses (on both its forward delivery contracts and derivatives positions) would have been virtually zero. Second, its margin calls would have been less than half of what they were. Finally, while not exclusively a funding problem, had MGRM held a smaller short-dated derivatives position in 1993, its rollover losses also would have been reduced substantially. Of course, if prices had risen instead of falling as they did in 1993, and had markets remained in backwardation, MGRM's one-to-one hedge would have worked out beautifully: it would have produced substantial net unrealized gains, would have resulted in substantial cash (or margin) inflows, and would have reaped substantial rollover profits.

The Customer Cash-Out Option

An argument has been made that MGRM, nevertheless, needed a one-to-one hedge ratio because of the customer cash-out options embedded in its forward-supply contracts. Specifically, in the event of an increase in spot energy prices, its customers had an option to cash-out, or to liquidate their forward obligations to purchase oil and receive a cash

[47] Adjusting the hedge ratio for differences in the timing of cash flows is known as tailing the hedge. It is well-known that failure to tail the hedge " . . . could force the premature liquidation and seriously disrupt a well-considered hedging or trading strategy" [Kawaller and Koch (1988) p. 41]. See also, Figlewski, Landskroner, and Silber (1991).

[48] There are other ways to derive the appropriate hedge ratio. Gibson and Schwartz (1990) use a two-factor contingent claims pricing model to estimate hedge ratios for oil deliverable in the future. They find, for example, a hedge ratio of about 0.5 would be appropriate for hedging oil deliverable in five years, and a ratio of about 0.25 would be appropriate for oil deliverable in ten years. The authors wish to thank John Parsons for bringing this article to their attention.

payment from MGRM based on the future value of these contracts to customers.[49] The formula on which its cash-out payments were to have been based was:

$$\text{Cash-Out Payment} = \sum_{i=1}^{T} \frac{n_i(F_0 - z)}{2}$$

where n_i is the amount of oil to be delivered in the ith month, F_0 is the spot (or near-month) futures price at the time of exercise, z is the contractually-fixed forward supply price, and T is the number of months remaining on the forward contract at the time of exercise.

Two aspects of this formula are noteworthy. First, the cash payment depends on near-month (or spot) energy prices, and not on forward energy prices (or expected spot prices). Second, MGRM and the customer shared equally in the customer's prospective gains due to higher energy prices (hence the divisor of 2). Thus, these options would be in-the-money for a customer only if the cash-out payment were greater than the net present value of the remaining forward deliveries on the contract. This could occur, for example, if near-month futures prices rose much faster than forward prices. Alternatively, even if the forward delivery contracts were not in-the-money for MGRM's customers (or even though the net present value of the forward contracts exceeded the option's value), they may nevertheless have exercised their cash-out options if they needed liquidity.

In either case, MGRM had to be prepared to make such up-front, lump sum, payments. Notwithstanding this possibility, it still did not need a one-to-one hedge. Suppose, for example, that a \$10/barrel increase occurred in spot energy prices within a year of MGRM writing the forward delivery contracts; and that, for whatever reason, all of its customers opted to exercise their early cash-out options. What futures position would MGRM have needed to generate gains sufficient to cover its option payouts? Clearly, it would not have needed a one-to-one hedge because the maximum that customers could receive was 50% of the gain from the \$10 increase in spot prices. In the more general case, where the probability of exercise is less than one, a hedge ratio of 0.5 would more than cover MGRM's potential option payments.[50] Thus, the customer

[49]There were no customer options that could be triggered by a decline in energy prices.

[50]The textbook procedure for hedging this option is to delta hedge it. Even under these more realistic assumptions, however, MGRM's option delta would never have been greater than 0.5. Further, to the extent that customers could be expected to exercise these options only after many years, present value concepts again come into play, and the delta hedge would also have to be tailed accordingly.

cash-out options embedded in MGRM's forward delivery contracts did not necessitate its use of a one-to-one hedging strategy.

For all of the reasons discussed above, MGRM's one-to-one hedge exposed the firm to funding risk that it could have avoided had it used a minimum-variance hedge ratio. In particular, a derivatives position about half as large as the one it actually used would have substantially reduced its funding needs in 1993 while at the same time providing reasonable protection against unpredictable fluctuations in energy prices. Further, had MGRM held a smaller short-dated derivatives position in 1993, its rollover losses would have been less.

Why, Then, a One-to-One Hedge Ratio?

It is not known why MGRM chose to use a one-to-one hedge, but the following is a feasible rationale. To illustrate the logic of using a one-to-one hedge, suppose that MGRM had been able to hedge with a strip (or series) of forward contracts, where the contractual amounts and the expiration dates exactly matched the dates and the amounts of MGRM's forward-delivery obligations. In this case it is clear that a one-to-one hedge would have locked-in all futures delivery prices, and as such would have locked-in the profit margins on MGRM's forward delivery contracts. (Whether, in fact, this hedging strategy was likely to be profitable for MGRM is discussed later.) This hedging strategy also would not have been exposed to rollover risk and possibly not to funding risk (assuming an absence of settling-up provisions in the forward contracts).

The point of this strip hedge example is to show that ultimately MGRM would have needed a one-to-one hedge against all of its forward-supply obligations to insulate itself from rising energy prices. Thus, had it used a hedge ratio of less than one, as suggested by this study's previous analysis, it would have had to increase this ratio to one as the dates of its forward delivery commitments drew near—or to adjust dynamically its hedge through time. Such adjustments could have imposed significant costs on MGRM, and may have deterred it from using a hedge ratio of less than one.

A simple example illustrates the risk that MGRM may have faced in using a smaller hedge ratio and dynamically adjusting it. Suppose that a firm promises to delivery 2000 barrels of oil in two months at a price of \$25/barrel, and chooses to hedge this commitment by buying near-month (or short-dated) futures. Assume that the current spot price is \$20/barrel, so the firm has a profit margin of \$5/barrel incorporated into its forward-delivery contracts. Assume also that the firm estimates that the relationship between near-month futures prices and two-month forward prices is 0.5, so that it figures it needs a minimum-variance hedge ratio of only 0.5. Thus, the firm purchases one near-month futures contract (1000 barrels) at the current price of $20/barrel as a hedge against its 2000 barrel-forward commitment, planning to adjust the hedge at the end of the first month when it rolls the hedge forward into the second month.

At the end of the first month, both spot prices and near-month futures prices rise to $25/barrel. In addition, since the firm will now be hedging a one-month forward delivery obligation, it needs to increase its hedge to a one-to-one ratio, or to two futures contracts (2000 barrels). (The relevant price relationship will now be one-to-one.) Thus, at the end of the first month the firm rolls forward its one-contract futures position and purchases an additional futures contract at $25/barrel, for a total of two contracts. At the end of the second month, spot and near-month futures prices both rise to $30/barrel; so the firm sells (or offsets) the two futures contracts at $30/barrel, purchases spot oil at $30/barrel, and delivers the 2000 barrels of oil at $25/barrel.

What is the firm's net profit on the forward sale of 2000 barrels? It bought one futures contract (1000 barrels) at $20/barrel and rolled this contract forward at $25/barrel, bought one futures contract (1000 barrels) at $25/barrel, and sold (or offset) both contracts at $30/barrel. Its average profit on the futures position, therefore, was $7.50/barrel. Finally, the firm purchased 2000 barrels spot oil at $30/barrel and delivered this oil at $25/barrel, sustaining a $5/barrel loss. Thus, on net, the firm's average profit on the forward sale is $2.50/barrel, just half of the $5/barrel profit margin that the firm sought to lock-in with its hedge.

Suppose instead of using a minimum-variance hedge, the firm had used a one-to-one stack hedge, initially purchasing two near-month futures contracts and rolling over both at the end of the first month. In this case it would have purchased the oil at $20/barrel, rolled them forward at $25/barrel, and sold both contracts at $30/barrel, for a profit on its futures position of $10/barrel. These profits would have completely offset the firm's losses on its forward sale due to rising energy prices, and would have locked-in its profit margin of $5/barrel. It is assumed throughout this example that there are no rollover costs.

Thus, in a scenario of rising energy prices, which MGRM probably expected, a minimum-variance hedge would have failed to protect MGRM against rising prices and would have failed to lock-in its profit margins. In contrast, a one-to-one hedge would have accomplished MGRM's objectives. Of course, if energy prices had fallen instead of rising, the opposite would have been true: dynamically adjusting the hedge would have produced higher profits than a one-to-one stack hedge. Alternatively, were a hedger to have no priors about the future direction of energy prices, but rather believe that there was an equal likelihood of rising or falling prices, it would be indifferent about having to dynamically adjust its hedge. Finally, in choosing a one-to-one hedging strategy, MGRM consciously made a risk trade-off: in exchange for better protection against rising energy prices, it exposed itself to both greater funding risk and to greater rollover risk. Presumably, it had reasons to believe that the latter risks were less significant than were the potential consequences of rising energy prices.

NON-TRANSPARENCY AND CREDIT RISK

A second potential funding obstacle for MGRM was that its forward delivery contracts may have lacked the transparency necessary for creditors to be willing to accept them as collateral. In particular, the enhanced value of its forward delivery contracts due to falling energy prices was dependent on the willingness and the ability of its counterparties to meet their future obligations. Critics argue that MGRM was exposed to substantial non-performance risk because of the long-duration of its forward-supply contracts. Further, as energy prices fell, this risk could be expected to increase because of the growing disparity between the contractually-fixed sales prices and prevailing spot prices. Thus, without concrete information about the characteristics of MGRM's counterparties, its creditors might have been reluctant to lend against the collateral of its forward delivery contracts. (Such information also was probably not readily available to creditors.)

There is something to this argument. It is well-known that the probability of a firm defaulting rises with time—or that cumulative default rates rise with time. For example, studies of bond defaults by Moody's Investors Service suggest that the probability of an issuer defaulting by the tenth year after issuance is considerably larger than the probability of its defaulting during the first year. For an A-rated issuer, the probability of default during the first year is only 0.01%, but by the tenth year this probability rises to 1.96%. See Fons (1994). Similarly, for a B-rated issuer, the probability of default during the first year is 8.31%, but rises to an impressive 39.96% by the tenth year.

MGRM apparently recognized this default risk and sought to mitigate it by contracting to supply only a fraction of a customer's energy needs. If energy prices fell, customers would still be able to purchase most of the product they needed at the lower market prices. Further, when energy prices are falling, end-users typically have higher than normal profits for some time because retail prices commonly lag wholesale prices in energy markets.

Whatever the validity of these arguments, the key issues are whether MGRM's non-performance exposure was such that it could have reasonably predicted its losses arising from non-performance, and, if so, whether its profit markups were sufficiently high to cover the expected credit losses. Well-diversified credit risks are insurable risks. The fundamental question, therefore, is whether MGRM's charged a self-insurance risk premium that was high enough to cover its expected credit losses.

Given the available information, it is difficult to answer either of these questions. For example, without knowing how many customers MGRM had, or what businesses its customers were in, it is not possible to determine whether MGRM was sufficiently diversified. Further, without information about the balance sheets and income statements of MGRM's customers, it is impossible to attach a likelihood of default to them as a group. Until such information becomes available, therefore, there is no way of judging MGRM's credit exposure. Nevertheless, if MGRM's creditors did not have the necessary information to evaluate the nature and magnitude of MGRM's credit exposure, they may have been reluctant to lend against the collateral of its forward delivery contracts.

THE CONFUSING ROLE OF MG'S FINANCIAL STATEMENTS

The application of conflicting and confusing accounting conventions to MG also created confusion among its creditors and investors. In particular, MG's U.S. and German auditors issued substantially conflicting reports on its condition during the critical months in 1993. On November 19, 1993, just before the Supervisory Board meeting at which MG's then Chairman's contract was extended for another five years, MG's U.S. auditor, Arthur Andersen, disclosed that MGRM had a $61 million profit before taxes for the fiscal year ending September 30, 1993. Further, it reported that MG Corporation had a profit of $30 million for the fiscal year. See Eckhardt and Knipp

(1994). Just a short time later, however, MG's German auditor, KPMG, reported a loss of hundreds of millions of dollars for MG's U.S. operations for the same fiscal year. See Knight-Ridder Money Center (1994). Which set of figures gave the more accurate picture of MG's financial health?

This confusion was created by the application of both U.S. and German accounting conventions to MGRM's activities. Under German accounting principles, unrealized *losses* on open forward positions have to be recognized at the end of the financial year, but unrealized *gains* on open forward positions are not allowed to be recognized.[51] Applied to MGRM, this meant that, when energy prices fell in late 1993, MG had to recognize the unrealized losses on MGRM's derivatives positions (futures and swaps) but was unable to recognize any unrealized gains that it may have had on its forward-supply contracts. Thus, MG reported huge derivatives-related losses, leaving the impression that these losses were incurred by inappropriate and possibly speculative trading in derivatives. Not recognizing the gains on MGRM's forward-supply contracts resulting from the fall in energy prices distorted the true picture of its financial position. MGRM would certainly have had some unrealized gains on its forward-supply contracts, which would have offset some of its unrealized derivatives losses. Thus, had both its unrealized gains and unrealized losses been recognized, MGRM would have been able to report smaller losses than it did.

In contrast to German accounting conventions, U.S. hedge accounting principles recognize this reporting asymmetry and impose different disclosure requirements on hedgers. U.S. hedge-deferral accounting principles do not require that either unrealized gains or unrealized losses on hedged positions be recognized. Thus, had MGRM adhered to U.S. accounting principles, it may not have had to report its unrealized losses at all. It would not have had to report these losses until realized, which would presumably have occurred at the time that it also recognized the gains it had on its forward-supply contracts. Alternatively, U.S. accounting conventions allow a firm with a hedged position to mark both sides (or positions) to market. In particular, MGRM could have marked-to-market both its forward-supply contracts and its derivatives positions, permitting the immediate recognition of the respective gains and losses on both positions. See Edwards (1995). Presumably, MG's

[51]One reason for these accounting principles may be that in Germany financial statements are used for tax purposes as well. Thus, if the objective is to maximize tax losses, recognizing only unrealized losses accomplishes this.

U.S. auditor, Arthur Anderson, was applying these hedge accounting principles when it reported profits for MG for the 1993 fiscal year.

Conflicting financial statements about the condition of MG, therefore, undoubtedly created confusion among MG's creditor's and investors, making it more difficult for MG to raise the funds needed to continue its operations.

DID MGRM REALLY HAVE A FUNDING PROBLEM?

Notwithstanding numerous press reports that MGRM's hedging strategy unraveled because of a liquidity problem—or an inability to raise the necessary funds to meet its margin calls, this view is questionable. See Diekhoff and Jungbluth (1994). While MGRM's need to raise substantial funds clearly resulted in a complete reassessment of its strategy, it seems highly unlikely that MG's Supervisory Board would have jettisoned an otherwise sound strategy simply because of a short-term liquidity need. This view is based upon two considerations: the particular ownership structure of MG, and the fact the MG did not avail itself of funding that, in fact, was available to it.

MG is a classic German firm: ownership is concentrated in the hands of a few large owners with easy access to credit. Seven institutional investors hold just over 65% of its stock. Deutsche Bank and Dresdner Bank, Germany's largest and second largest commercial banks, together directly own 33.82% of the stock. See Table VIII in Roe (1993). This does not include MG stock that these banks hold (or control) through mutual funds or as a custodian. Other large stockholders are the Emir of Kuwait (20%); the giant automaker Daimler-Benz (10%); the Australian Mutual Provident Society (6%); M.I.M. Holdings Ltd. of Australia (3.5%); and the German insurance firm, Allianze (through a holding company jointly-owned with the Dresdner Bank). See Protzman (1994) and Director's Monthly (1994). However, Deutsche Bank and Dresdner Bank together control 60.58% of the voting stock of Daimler-Benz, and probably exercise control over a considerable amount of the stock held by the other investors in MG as well. See Table II in Roe (1993). It seems clear, therefore, that ownership and control of MG rests squarely in the hands of Germany's two largest banks: Deutsche Bank and Dresdner Bank. Not surprisingly, the Chairman of MG's Supervisory Board also is a prominent member of the Management Board of Deutsche Bank.

In addition, as is typical of German firms, MG relied extensively on banks for credit. As of December 7, 1993, banks held DM 4.4 billion of MG's debt. See *Euromoney* (1994). MG's largest creditor was Deutsche Bank, which also effectively controlled MG. The Dresdner Bank, another major stockholder, also was a substantial creditor.

Thus, MG's ownership and debt structure makes it unlikely that its problem was that of a liquidity-constrained firm. If its owners—some of the largest financial institutions in the world—viewed its business and hedging strategies as sound, they clearly had the deep-pockets to finance it through short-run reversals.[52] Further, potential conflicts between the equity and debt holders were greatly mitigated by the ownership and debt structure of MG. Finally, the non-transparency of MGRM's forward delivery contracts should not have been a critical factor for a closely-held firm such as MG. While such non-transparency may be a severe obstacle to raising external funds, MG's owners were in a position to obtain complete information without compromising the propriety of the firm's operations.

There is also evidence that in late 1993 funding was, in fact, available to MG. First, it had an unrestricted DM 1.5 billion Euro-credit line with 48 banks that it chose not to draw on. See *Euromoney* (1994) and Eckhardt and Knipp (1994). This credit line, arranged in May, 1992, by Dresdner Bank, was never used. Second, on December 7, 1993, Chemical Bank (and possibly other banks) reportedly approached MGRM about the possibility of providing financing on the basis of securitizing its forward-supply contracts. See Eckhardt and Knipp (1994). The precise terms offered by these banks, of course, is unknown. However, the fact that MG did not avail itself of these financing opportunities suggests that its Supervisory Board believed that the real problems lay elsewhere.

CONCLUSIONS

This study concludes that MG's fate was decided not by its inability to deal with a short-term liquidity need but by a sharp disagreement between its Supervisory Board and its old management about the fundamental soundness of MGRM's forward-delivery program. MGRM's losses in 1993 undoubtedly caused MG's Supervisory Board to reassess its priors about the potential risks involved in its forward-delivery

[52] Research by Hoshi, Kashyap, and Scharfstein (1991) suggests that an advantage of bank-owned firms is that they are not liquidity-constrained.

program. This reassessment probably focused on two basic risks: rollover risk and credit risk. The unusual contango price relationships that occurred in energy markets in 1993 made clear that sustained rollover losses were not only theoretically possible but could in fact occur. In addition, the sharp fall in energy prices in 1993 brought into sharper relief the potential non-performance risk that MGRM had on its forward delivery contracts. Thus, although there is no way of knowing exactly what motivated MG's Supervisory Board's actions to end MGRM's forward-delivery program, it appears that it acted on the belief that MGRM's strategy was fatally flawed—that its exposure to either or both rollover risk and credit risk did not justify the expected returns on its forward-delivery program.[53]

This article has examined both of these risks, and has provided statistical information where possible for readers to judge for themselves whether MGRM's judgments with respect to these risks were flawed. With respect to rollover risk, the reasonableness of MGRM's judgment that this risk was neither excessive nor unmanageable comes down to the reasonableness of its assumption that the last ten years of price history in energy markets can be relied on to make predictions about what price relationships will be for the indefinite future. With respect to credit risk, the issue is whether MGRM correctly evaluated its exposure and priced this risk accordingly. While MGRM's credit risk was not insignificant, there is no information which suggests that its exposure in this regard was excessive.

Perhaps one way to judge the soundness of MGRM's strategy is to ask whether it could have used a different, less risky, hedging strategy to reduce its risk exposure. For example, as shown, it could have used a minimum-variance hedging strategy which would have reduced its funding risk, but this strategy also would have exposed it to the risk of having to dynamically adjust its hedge. Alternatively, MGRM could have used strips of long-dated futures or forwards with delivery dates that matched those on its forward delivery contracts.[54] With this strategy it

[53]MG's Supervisory Board's rejection in December of alternative actions that could have protected MGRM against further margin outflows also is evidence that it did not believe that MGRM's forward-delivery strategy was fundamentally sound. For example, MGRM could have protected itself against further margin outflows due to price declines by purchasing put options on energy products, which were available in December 1993. This strategy would have neutralized further margin outflows on MGRM's long futures and swap positions and may have been able to lock-in the net gains that MGRM had as of that time. In addition, the characterization of MGRM's hedging strategy as "a game of roulette" by members of MG's supervisory board certainly suggests that the board believed that MGRM's strategy was fatally flawed.

[54]This strategy is suggested by Mello and Parsons (1994).

would not have needed to roll positions forward, and, therefore, would not have been exposed to rollover risk. However, exchange-traded long-dated futures were not available to MGRM, and had they been available from OTC dealers, the price would probably not have been attractive to MGRM.

What would this price have been? OTC dealers presumably would have had to hedge their own long-term exposure to MGRM by using a strategy very similar to that used by MGRM: stacking short-dated derivatives and rolling. Thus, they would have had to pass on to MGRM their expected rollover cost over the horizon of the contract, as well as a risk premium to cover the likelihood of a greater rollover cost than anticipated. In addition, they would have had to tack on a risk premium for the possibility that MGRM would default. Over a ten-year period, cumulative default rates for even highly-rated companies can be quite high.

Although the reasons that MGRM decided against hedging with long-dated forwards are not known, it can be presumed that MGRM believed that the costs of doing so would have been unacceptable. First, MGRM undoubtedly believed that OTC dealers did not possess a comparative advantage in hedging long-term price risk, and that it could manage this rollover risk at a lower cost than could an OTC dealer.[55] Second, long-dated OTC derivatives can be difficult and costly to terminate: such contracts are generally illiquid and must be terminated by direct negotiation with the originating dealers. This could have been a serious drawback for MGRM because of the early cash-out options embedded in its forward delivery contracts. Third, by not using long-dated derivatives, MGRM avoided having to pay the substantial credit risk premium that OTC dealers would probably have demanded.[56] Finally, the use of long-dated derivatives may have exposed MGRM to additional credit risk. OTC dealers can default as well, and this possibility undoubtedly increases with time. Thus, using long-dated OTC

[55]MGRM believed that by switching its hedges among the different energy markets depending on the time of year and existing price relationships, and by conducting various arbitrage operations, it could significantly reduce rollover costs. See affidavit of Benson (1994).

[56]The use of short-dated derivatives allowed MGRM to avoid having to pay this risk premium because they required that it make variation margin payments to collateralize losses as they occurred. Thus, MGRM was accepting a funding risk as a trade-off for not paying the risk premium to OTC dealers. As argued earlier, MGRM was in a better position to manage this funding risk. Alternatively, OTC dealers need not have charged MGRM a credit risk premium if they too had imposed on MGRM a form of variation margins. For example, dealers could have demanded the posting of additional collateral, or could have required periodic settling-up provisions. Such provisions would, of course, have imposed on MGRM the same kind of funding risk that it was exposed to because it used short-dated derivatives.

derivatives to hedge may have had some benefits, but these benefits would have come at a significant cost and would have imposed other risks on MGRM. On net, it is not clear that they would have provided a superior hedging strategy for MGRM.

A central controversy surrounding the MG case is whether MG's Supervisory Board took the right action when it ordered the liquidation of MGRM's positions in December, 1993. This action implicitly reflects two key decisions that the Board had to make: *whether* to abandon MGRM's program; and, if it decided to abandon the program, *when* to liquidate MGRM's positions. With respect to its decision to abandon MGRM's program entirely, the reasonableness of this decision is not clear cut. In particular, in December, 1993, there was no way to be certain that the price structure in energy markets had not already changed or would not change in the future, imposing higher rollover costs on MGRM. With respect to the Board's decision about when to liquidate MGRM's derivatives position, this decision clearly seems ill-timed, at least in retrospect. When the bulk of the liquidation occurred, between December 20 and December 31, 1993, energy prices were at their lowest in many years, resulting in substantial losses on MGRM's derivatives positions when they were sold.[57] Judging from daily closing prices for that period, its positions were liquidated at an average price of about $14 a barrel. Assuming that MGRM had acquired these positions at an average price of $18 a barrel, an average liquidation price of $14 a barrel would have meant a loss of $640 million on its 160-million-barrel derivatives position. In addition, to eliminate exposure on its forward supply contracts due to rising prices, MGRM liquidated these contracts as well, apparently waiving cancellation penalties on the contracts, thereby giving up potential unrealized gains that could have offset its derivatives losses. See Benson (1994).

Had MG's Supervisory Board not ordered the liquidation until sometime later, the situation would be far different today. From December 17, 1993, when the new management took control, to August 8, 1994, crude oil prices increased from $13.91 to $19.42 a barrel, heating oil prices increased from $18.51 to $20.94 a barrel, and gasoline prices increased from $16.88 to $24.54 a barrel. Given these price increases, MGRM would have had a massive in-flow of margin funds on its derivatives positions. However, it must also be recognized

[57] It is assumed that the liquidation began on December 17, 1993, when the new management took control of MG. See Reuters (1993a and b).

that if energy prices had continued to fall, say to $10 a barrel, rather than rising, MGRM would have sustained even greater losses than it did.[58] It is not clear, therefore, how much weight should be given to retrospective criticisms in judging the timing of the Supervisory Board's decision to liquidate MGRM's positions.

Irrespective of whether MG's Supervisory Board's decision to abandon MGRM's hedging strategy was the correct one, it is clear that at some point a lack of understanding at the Supervisory Board level played an important role in MGRM's fate. In particular, on November 19, 1993, the Supervisory Board decided to extend the contract of its then Management Board Chairman, Heinz Schimmelbusch, for another five years. But just four weeks later, the same Supervisory Board fired Schimmelbusch. See Eckhardt and Knipp (1994). Why the sudden turnaround? Did the Board not understand MGRM's hedging strategy prior to December, 1993? And if it did not, should it have? Alternatively, did the Board initially assess the risks that MGRM was taking and find them acceptable, but later change its collective mind and decide that these risks were unacceptable? Still another possibility is that the Board simply did not understand MGRM's strategy and panicked in the face of huge margin calls. Whatever the truth may be, it seems apparent that, at least in the case of MG, the German system of corporate governance failed. Concentrating the ownership and control of large firms in the hands of large banks clearly did not work well in this instance.[59]

EDWARDS AND CANTER VERSUS CULP AND MILLER: WHAT ARE THE CRITICAL DIFFERENCES?

To clarify the debate surrounding the MG case, it may be useful to contrast our views with those of Culp and Miller (1995). First, we agree with Culp and Miller that it is possible to hedge long-dated obligations with short-dated futures (or derivatives), but we believe that this strategy entails more risk than Culp and Miller appear to acknowledge. Hedging long-dated obligations with short-dated derivatives involves a potentially significant "rollover risk" because of the difficulty of predicting the term structure of forward energy prices over long periods of time. Culp and

[58]Culp and Miller (1994b, p. 12) argue that MG should not have liquidated in December 1993 because at that time the term structure of oil prices was upward sloping (contango). However, it should be noted that the term structure was also upward sloping for virtually all of 1993, during which time spot oil prices fell sharply.

[59]For a discussion of the alleged strengths of large ownership of industrial firms by financial institutions, see Edwards (1993) and Roe (1993).

Miller, in contrast, argue that all that counts "... is the program's profit potential over the long haul or, as finance specialists might prefer to put it, its expected net present value" (see p. 11). They minimize the importance of rollover risk, noting that "...the one-month net cost of storage and interest *averaged* less than zero over the last ten years" (see p. 10). Thus, Culp and Miller have greater faith than we in the efficacy of using past price relationships to predict future forward price relationships (or to predict future rollover returns). Although hardly definitive, we provide evidence from other commodity markets (soybeans and copper) that reliance on past price relationships to infer future "rollover returns" can be quite dangerous.

Second, we believe that a sound hedging strategy should not require the hedger to "stay in the game" until its long-run strategy pays off. A hedger should be able to unwind its positions at any time without sustaining substantial (or life-threatening) losses. Culp and Miller, by their use of the terms "gambler's ruin" and "hedger's ruin," suggest that MGRM should have been allowed to continue to operate until the long-run profit potential of its combined delivery/hedging program was realized (see pp. 7 and 9). In particular, they appear to argue that MGRM should have been allowed to stay in the game long enough to realize the anticipated rollover gains. In our view such a strategy would have entailed a nontrivial bet that contango markets would not prevail over any significant period of time in the future. In any case, as MGRM's experience in 1993 clearly shows, MGRM's hedging program turned out to be quite vulnerable to early exit. Further, because of the early cash-out options in MGRM's forward delivery contracts, it should not have come as a surprise to MGRM that it might have to unwind its hedged delivery program much sooner than the lengthy contractual periods stated in its forward delivery contracts (such as ten years).

Third, in contrast to Culp and Miller, we do not believe that MGRM's hedge was "self-financing": that the value of its forward delivery contracts increased in value by the same amount as its short-dated derivatives contracts decreased in value as energy prices declined. The difference here with Culp and Miller turns primarily on our different methodologies for calculating the net present value of MGRM's combined delivery and hedging program. We argue that, in valuing MGRM's positions at a given moment in time (say "t"), it makes sense to use the information contained in the term structure of forward energy prices at time t. Specifically, our methodology uses forward energy prices and current interest rates at time t to calculate net present values at time t. In contrast, Culp and Miller use an "expected basis" as the critical discount factor in their net present value formula, where this "expected basis" is not obtained from the term structure at time t. Rather, they use as their expected basis an average basis obtained from historical data (see p. 12). We are dubious about a procedure which uses such an average (or constant) basis to determine net present values at different times. In addition, neither our procedure for calculating net present values nor theirs takes into consideration the uncertain term (maturity) of MGRM's forward delivery contracts due both to the early cash-out options and to the "firm-flexible" provisions included in some of these contracts.[60] However, Culp and Miller have a point when they say: "How to compute the requisite net present value for a *hedged* delivery program is far from obvious . . ." (see p. 11). In any case, whether or not MGRM's program was self-funding is not the critical difference between us. We agree, albeit for different reasons, that MGRM did not have a funding problem.

Fourth, while we agree with Culp and Miller that MGRM's "funding problem" was probably not the critical factor in bringing down the firm, we argue that this is true because of MG's unique ownership structure, rather than because MGRM's hedged delivery program was self-financing. Both Culp and Miller and we contend that because MG was owned and controlled by "deep-pocket" investors—some of the largest financial institutions in the world—it should have had access to sufficient funding (see p. 16). Nevertheless, it is difficult to draw definitive conclusions about this issue because neither Culp and Miller nor we have all of the facts with respect to MG's funding situation.

Fifth, given our methodology for calculating the net present value of MGRM's hedged delivery program, we argue that MGRM could have substantially reduced its funding needs as well as its rollover losses by using a minimum-variance hedging strategy instead of a one-to-one hedge. But we show that in doing so MGRM would have exposed itself to potential dynamic hedging costs. In addition, we agree that if funding were no obstacle, as Culp and Miller believe, the case for MGRM using a minimum-variance hedging strategy is considerably weaker.

Finally, although we are uncertain about exactly what Culp and Miller's overall view of MGRM's hedged delivery program is, they seem to "lean to" the view that its program was "economically sound" but was "killed off prematurely" by the "unfortunate" and "precipitous liquidation of MGRM's futures hedge" in December, 1993 (see pp. 7, 18, 19).

[60]Approximately one third of MGRM's forward delivery contracts gave customers the right to request that deliveries be deferred until the last day of the contract. Thus, the timing of futures cash flows from these contracts was highly uncertain. See Special Audit Report (1995).

With respect to this liquidation decision, we are more agnostic than they. Succinctly stated, we believe that MGRM's rollover and credit exposures at that time were such that a reasonable case could have been made for the unwinding of its positions. However, we agree with Culp and Miller that "too many essential facts about [MGRM's] program and its liquidation have still not been made public . . ." for us to evaluate definitively the correctness of MG's liquidation decision (see p. 7).

APPENDIX 1A

A Physical Storage Strategy and Storage Costs

To estimate how large storage costs could be before a strategy of physical storage becomes unprofitable, consider the following. The net present value per unit of a physical storage strategy is the present value of the earnings flows per unit on the forward delivery contracts minus the present value of the costs per unit incurred in having to store the physical commodity. This net present value is negative when:

$$\sum_{i=1}^{T} \frac{(m)(n_i)}{(1+r)^i} - \sum_{i=1}^{T} \frac{(y)(n_i)(i)}{(1+r)^i} < 0 \qquad \text{(A1)}$$

where m is MGRM's fixed mark-up per unit ($4 a barrel), n_i is the number of units (barrels or gallons) that MGRM agrees to deliver in the ith month and, therefore, "i" is the number of months for which it needs to store n_i. T is the number of months remaining on the forward delivery contracts, y is a constant net storage cost per unit per month (inclusive of all costs), and r is a constant monthly interest rate.

Further, if one assumes that n_i is the same for all months, or $n_i = n$, eq. (A1) reduces to

$$m \sum_{i=1}^{r} \frac{1}{(1+r)^i} - y \sum_{i=1}^{T} \frac{i}{(1+r)^i} < 0 \qquad \text{(A2)}$$

If one assumes that $m = \$4$/barrel, $T = 120$ months, and $r = 0.5\%$, then a y greater than $0.0733 per unit per month would make hedging by physical storage unprofitable for MGRM.

By decomposing y into its two components, financing and physical storage costs, one can estimate MGRM's monthly financing cost as the spot price of oil times the monthly interest rate. Thus, if the spot price of oil were a constant $20/barrel and the monthly interest rate were

0.5%, MGRM's financing cost would be \$0.10 per barrel per month. This cost alone (assuming zero physical storage costs) would make a physical storage strategy unprofitable for MGRM.

If interest rates were zero, or there were no financing costs, eq. (A2) would reduce to

$$mT < y \sum_{i=1}^{T} i \tag{A3}$$

$$mT < y\left(\frac{T(T+1)}{2}\right) \tag{A4}$$

By solving for y, one can find the non-financing cost of storage that would make a physical storage hedging strategy unprofitable.

$$y > \frac{2m}{T+1} \tag{A5}$$

If one again assumes that m = \$4/barrel and T = 120 months, a y greater than \$0.067 per barrel per month would make hedging by physical storage unprofitable for MGRM.

APPENDIX 1B

The Effect of Sustained Rollover Costs

To estimate how many consecutive months the market could be in contango before MGRM's markup on its forward delivery contracts were completely eroded, one can use a version of eq. (A1) in Appendix 1A to solve for the number of months. First, assume that y is the constant monthly rollover cost per unit that MGRM incurs (rather than the storage cost). Second, instead of summing over $i = 1$ to $i = T$, sum over $i = 1$ to $i = X$. Third, use $(T - i)n_i$ to represent the number of units that must be rolled forward in the ith month. By solving the following equation for X, one obtains the number of consecutive months of rollover losses necessary to completely erode MGRM's markup:

$$m \sum_{i=1}^{T} \frac{n_i}{(1+r)^i} - y \sum_{i=1}^{X} \frac{(T-i)(n_i)}{(1+r)^i} < 0 \tag{A6}$$

If one assumes that m = \$4/barrel, T = 120 months (the intended length of the hedge), r = 0.5%, n_i is constant for all months, and

$y = \$0.24$, which is the average monthly rollover cost during periods when crude was in contango from 1983 to 1992 (See Table I), the above inequality holds when $X = 14$ or greater. Thus, had MGRM sustained a string of 14 consecutive monthly rollover losses beginning at the inception of its program similar in magnitude to those which had occurred in the past, the profit margins on its forward delivery contracts would have been wiped out.

In the case where the interest rate is zero, (eq. 6) reduces to:

$$mT < y \sum_{i=1}^{X} (T - i) \tag{A7}$$

$$\frac{mT}{y} < \left(XT - \frac{X(X + 1)}{2} \right) \tag{A8}$$

Again, assuming that $m = \$4$, $T = 120$ months, and $y = \$0.24$, MGRM's profit would have been completely eroded if $X = 19$ or greater.

APPENDIX 2

Summary of Rollover Gains and Losses (1986–1992)[a] Stack in a Distant Month (Month 6): Three-Day Rollover Rule

Summary Statistics (1986–1992)[b]

	Crude Oil	*Heating Oil*	*Gasoline*
Mean Rollover	0.14	0.13	0.16
Mean of All Rollover Gains	0.09	0.60	0.51
Mean of All Rollover Losses	−0.05	−0.28	−0.36
Cumulative Rollover Gain	7.67	10.51	12.94
Frequency of a Rollover Gain	74%	45%	58%

Cumulative Rollover Gains by Month[b]

	Crude Oil	*Heating Oil*	*Gasoline*
Jan	0.91	−1.70	3.25
Feb	0.47	−2.42	3.28
Mar	0.24	−2.25	5.52
Apr	0.31	−2.13	4.28
May	0.26	−2.24	2.71
Jun	0.24	−0.85	0.67
Jul	0.27	1.65	−1.18
Aug	0.65	6.25	−2.16
Sep	1.05	6.44	−6.05
Oct	1.65	4.63	−0.79
Nov	0.99	2.73	1.51
Dec	0.63	0.87	1.89

continued

APPENDIX 2 (Continued)

Frequency of a Rollover Gain

	Crude Oil	Heating Oil	Gasoline
Jan	100%	0%	86%
Feb	71%	0%	86%
Mar	86%	0%	100%
Apr	57%	0%	100%
May	71%	0%	100%
Jun	71%	0%	71%
Jul	57%	71%	0%
Aug	71%	100%	0%
Sep	86%	100%	0%
Oct	86%	100%	29%
Nov	86%	100%	57%
Dec	43%	71%	71%

Cumulative Rollover Gains by Year[b]

	Crude Oil	Heating Oil	Gasoline
1986	0.03	0.55	−0.66
1987	0.42	−0.01	0.29
1988	0.10	0.62	0.42
1989	1.65	2.20	4.29
1990	3.40	4.54	4.65
1991	1.30	1.89	3.19
1992	0.77	0.73	0.76

[a]All rollovers are calculated using a three-day rollover rule: on the third day prior to the last day of trading of the near-month contract, the sixth closest contract to delivery is sold and the contract month which is the seventh closest to delivery is purchased. The rollover gain or loss is calculated as the sixth month price minus the seventh month price.
[b]All rollover gains, losses, and means are reported in $/barrel. Heating oil and gasoline are traded on a $/gallon basis. There are 42 gallons per barrel.
Data Source: Knight-Ridder Futures Markets Database.

APPENDIX 3

Summary of Rollover Gains and Losses (April 1983–December 1992)[a]: Ten-Day Rollover Rule

Summary of Rollover Statistics (April 1986–December 1992)[b]

	Crude Oil	Heating Oil	Gasoline
Mean Rollover	0.21	0.19	0.39
Mean of All Rollover Gains	0.36	0.79	0.85
Mean of All Rollover Losses	−0.18	−0.35	−0.42
Cumulative Rollover Gain	24.52	22.76	38.20
Frequency of a Rollover Gain	73%	45%	70%

continued

APPENDIX 3 (Continued)

Frequency of a Rollover Gain

	Crude Oil	*Heating Oil*	*Gasoline*
Jan	78%	89%	25%
Feb	78%	78%	13%
Mar	67%	100%	25%
Apr	70%	100%	75%
May	70%	70%	88%
Jun	60%	10%	88%
Jul	60%	0%	88%
Aug	80%	0%	100%
Sep	70%	0%	100%
Oct	80%	0%	88%
Nov	80%	50%	63%
Dec	80%	60%	22%

Cumulative Rollover Gains by Month[b]

	Crude Oil	*Heating Oil*	*Gasoline*
Jan	3.58	10.19	−0.95
Feb	2.40	9.15	−4.21
Mar	1.07	8.39	−2.48
Apr	2.01	6.86	3.50
May	2.02	2.32	5.06
Jun	1.00	−2.16	6.46
Jul	1.11	−3.49	6.58
Aug	2.61	−2.62	10.97
Sep	1.42	−3.40	6.80
Oct	2.37	−5.01	5.00
Nov	2.60	−1.09	3.02
Dec	2.33	3.50	−1.55

Cumulative Rollover Gains by Year[b]

	Crude Oil	*Heating Oil*	*Gasoline*
1983	1.55	−0.73	
1984	0.20	2.48	−0.36
1985	6.92	6.10	11.26
1986	0.88	3.26	1.62
1987	2.35	1.94	0.16
1988	0.66	2.21	8.04
1989	6.12	4.42	3.64
1990	3.31	2.81	10.45
1991	2.81	2.24	6.02
1992	−0.28	−1.95	−2.63

[a]All rollovers are calculated using a ten-day rollover rule: on the tenth day prior to the last day of trading the near-month contract is sold and the contract month which is the second closest to delivery is purchased. The rollover gain or loss is calculated as the near-month price minus the second-month price. Data for gasoline begin in December 1984.

[b]All rollover gains, losses, and means are reported in $/barrel. Heating oil and gasoline are traded on a $/gallon basis. There are 42 gallons per barrel.

Data Source: Knight-Ridder Futures Markets Database.

APPENDIX 4
Summary of Rollover Gains and Losses
(April 1983–September 1994)[a]: Three-Day Rollover Rule

Summary of Rollover Statistics (April 1983–Septemberr 1994)[b]

	Crude Oil	*Heating Oil*	*Gasoline*
Mean Rollover	0.20	0.28	0.32
Mean of All Rollover Gains	0.48	1.06	0.84
Mean of All Rollover Losses	−0.24	−0.31	−0.46
Cumulative Rollover Gain	27.97	38.35	37.97
Frequency of a Rollover Gain	61%	43%	60%

Frequency of a Rollover Gain

	Crude Oil	*Heating Oil*	*Gasoline*
Jan	55%	82%	40%
Feb	64%	73%	10%
Mar	64%	100%	30%
Apr	75%	100%	60%
May	42%	58%	70%
Jun	50%	8%	70%
Jul	67%	0%	80%
Aug	50%	0%	100%
Sep	67%	0%	70%
Oct	64%	0%	78%
Nov	73%	45%	67%
Dec	64%	54%	50%

Cumulative Rollover Gains by Month[b]

	Crude Oil	*Heating Oil*	*Gasoline*
Jan	3.49	14.40	−0.63
Feb	3.57	11.77	−5.20
Mar	1.87	11.28	−3.89
Apr	1.99	8.44	5.56
May	2.06	1.44	5.40
Jun	2.86	−1.82	5.87
Jul	2.05	−4.30	5.80
Aug	0.21	−4.50	7.67
Sep	2.70	−4.50	6.54
Oct	2.28	−3.59	8.85
Nov	2.28	−1.33	2.60
Dec	2.61	11.06	−0.59

continued

APPENDIX 4 (Continued)

	Cumulative Rollover Gains by Year[b]		
	Crude Oil	*Heating Oil*	*Gasoline*
1983	1.14	−0.60	
1984	−0.55	6.18	−0.25
1985	9.50	6.75	11.75
1986	1.53	5.32	3.36
1987	3.64	0.70	0.17
1988	1.42	2.83	8.58
1989	7.96	12.15	6.35
1990	1.15	2.33	7.47
1991	4.23	3.97	7.56
1992	−0.39	−1.94	−1.41
1993	−3.10	−1.86	−4.87
1994	1.44	2.52	−0.74

[a]All rollovers are calculated using a three-day rollover rule: on the third day prior to the last day of trading, the near-month contract is sold and the contract month which is the second closest to delivery is purchased. The rollover gain or loss is calculated as the near-month price minus the second-month price. Data for gasoline begin in December 1984.
[b]All rollover gains, losses, and means are reported in $/barrel. Heating oil and gasoline are traded on a $/gallon basis. There are 42 gallons per barrel.
Data Source: Knight-Ridder Futures Markets Database.

APPENDIX 5

Tailing and the Minimum-Variance Hedge

MGRM might have wanted to tail its hedge to correct for the mismatch in the cash flows on its forward delivery contracts vs. its short-dated derivatives. In particular, MGRM's one-to-one hedge ratio did not take into consideration the mismatch in its cash flows due to the mark-to-market settlement features of futures contracts. To tail whatever hedge ratio (HR) it chose to use, MGRM could have used the following formula:

$$h = \sum_{i=1}^{T} \frac{(HR_i)(n_i)}{(1 + r)^i}$$

where n_i = the amount of oil (or units of product) it agreed to deliver in month i; T = the total number of months remaining on its forward delivery contracts; r = a risk-free monthly interest rate; and HR_i = the untailed hedge ratio the hedger is using to hedge its delivery commitment for month i ($HR = 1$ in the case of MGRM).

To see how tailing the hedge would have changed MGRM's one-to-one hedge ratio, assume the following: a constant interest rate, $r = 0.5\%$; $n_i = 1.33$ million barrels and is the same every month

(160 million barrels/120); and $T = 120$ months. Under these assumptions, an appropriately tailed hedge position for MGRM would have been a long position in futures of 120,098 barrels—or a hedge of about 75% of its forward delivery commitments would have allowed MGRM to match the present value of its respective cash flows.

Alternatively, had MGRM used this study's estimated minimum-variance hedge ratio of 0.5 and tailed it, instead of using a one-to-one ratio, it would have needed a futures position of only 61,000 barrels or about 38% of its forward delivery commitments.

The above calculation tails the hedge for the hedge horizon—ten years in the case of MGRM. Some argue that a hedge needs to be tailed only for the time-to-expiration of the hedging instrument, which for MGRM would have been only one to three months. This does not seem reasonable. (For a discussion of this issue see Figlewski, Landskroner, and Silber, 1991.)

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