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BACKWARDATION IN ENERGY FUTURES MARKETS: METALLGESELLSCHAFT REVISITED

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Abstract

In this paper, we revisit the debate on the merits of the stack-and-roll hedging strategy employed by Metallgesellschaft's American subsidiary, MGRM. Since the profitability of this hedging strategy depends on whether or not backwardation was the norm in energy futures contracts, we first provide the evidence on backwardation with an updated data set. We then examine the two major risks that such a hedging strategy faces – margin call risk due to price declines and contango risk. Based on the data up to 1992, we find that the strategy could be expected to be profitable while the risks were not very high. Based on the updated data (up to 2000), the program's expected profits are smaller but still significant, however, the risks are higher. The probabilities of encountering a similar problem to the one MGRM faced are twice as high with the updated data than with the data up to 1992. In other words, the risk-return pattern of such a strategy is less appealing now than when MGRM implemented its hedging program.

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1. INTRODUCTION

Headline debacles in derivatives markets during the last decade have attracted the attention of many observers. One of the most egregious was the billion dollar plus loss incurred by the German company Metallgesellschaft in the early 1990s. This arose as a result of long-term energy supply contracts that its U.S. subsidiary, Metallgesellschaft Refining and Marketing (MGRM), negotiated with its customers. The supply contracts were then hedged barrel-for-barrel using short-dated energy derivatives, which had to be rolled forward continuously. When the hedge program experienced difficulties, the derivatives positions were promptly liquidated by the parent company. The wisdom of these actions has been extensively debated in the literature. The debate centers around three related issues – the soundness of supply contracts, the manner in which they are hedged and the rapid unwinding of all positions.

On the one hand, it is argued that the use of short-dated instruments in a stack-and-roll strategy to hedge long-dated obligations amounted to a speculation on the term structure of energy prices (Mello and Parsons (1995)). To see this, note that in rolling the hedge forward, MGRM would have to sell the maturing contracts and simultaneously buy new short-dated contracts. As a result, this hedging technique would be profitable if the energy markets were typically in backwardation, defined as spot prices exceeding futures prices, and short-dated futures prices exceeding longer-dated futures prices. On the other hand, the technique subjected MGRM to a risk of loss if energy prices were to go into contango (the opposite of backwardation), which was what indeed happened soon after the hedge was implemented. In addition, Pirrong (1997) shows that MGRM's barrel-for-barrel hedge implied significant overhedging (from a variance-minimizing point of view). In fact, he shows that it would have been less risky to remain unhedged than to hedge barrel-for-barrel. Under this view, the parent company was right to shut the program down swiftly.

On the other side of the debate, Culp and Miller (1995b), citing a court document that contains a passage from MGRM's statements, argue that MGRM recognized that it did not engage in a pure risk-avoidance hedge. Rather, it was conducting a "carrying-charge" hedge designed to exploit their superior information about relative energy prices (short-dated vs. long-dated), while at the same time reducing risk. MGRM may have believed that prices of long-dated contracts were overvalued relative to those of short-dated ones. By using short-dated contracts to hedge its long-term supply obligations, MGRM was effectively attempting to undertake an arbitrage between prices of different maturities. For a carrying-charge hedger, Culp and Miller contend, the optimal strategy is a barrel-for-barrel hedge (subject to any tailing)[1]. As a result, they believe that the parent company should have weathered the storm, and were unwise to terminate the hedging program because of short-term liquidity problems.

Regardless of the view one has on this debate, it was clear that *MGRM* did not anticipate the persistent contango that occurred. Rather, its hedging technique suggests that it believed that backwardation was the norm in energy markets. In fact, empirical data up to the time its strategy was implemented (1993) appeared to support this belief. For example, Litzenberger and Rabinowitz (1995) report that during the period from 1984 to 1992, which was the inception of crude oil futures contracts), backwardation in the crude oil markets occurred over 70% of the time. Using futures data on crude oil, heating oil and gasoline from roughly the same period, Edwards and Canter (1995) report that energy markets show a high frequency of backwardation. This leads them to conclude that "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" (p. 224). However, as Edwards and Cantor point out, *MGRM*, in relying on past data, was implicitly assuming that the structure of energy markets would not change significantly in the future, and that a history of only ten years of available data is sufficiently long to provide reliable forecasts.

In this paper, we revisit the MGRM debate by exploring the latest evidence on backwardation in energy markets. We will first discuss theoretical reasons for backwardation. Then, we will examine the issue empirically, using two sets of data. The first set contains data that MGRM had at its disposal at the time of the hedge program (up to 1992). The second set also includes data that have subsequently become available (up to 2000). By using a more up-to-date data set covering a longer time period and controlling for the time-series properties of the data, we hope to provide more reliable empirical evidence on the behavior of energy futures prices. In addition, we want to compare the risk-return patterns of MGRM's hedging strategy under the two data sets.

As Culp and Miller (1995a, 1995b) and Krapels (2001) argue, firms may use their hedges as a value-maximizing tool if they believe that they have superior information. Therefore, our findings also have an implication for energy firms who may be contemplating a similar hedging strategy as the one MGRM employed. To our knowledge, the use of an

[1] Tailing the hedge refers to an adjustment of the hedge ratio for the differences between the timing of cash flows from the underlying positions and the timing of cash flows from the hedging instruments.

up-to-date data set to examine the merits of MGRM's strategy has not been carried out before. Our findings are as follows:
Based on the data up to the time MGRM implemented its strategy (1992), we find that the sizable and significant rollover gains could be expected, while the risks of rollover losses due to contango and of cash drains due to margin calls (in case energy prices drop), are not high. When the up-to-date data (up to 2000) are used, we find that the expected rollover gains are lower but still significant. However, the risks are much higher. The probabilities of encountering the same problem as the one MGRM faced are twice as high as those based on the data up to 1992. As a result, the risk-return pattern of a stack-and-roll strategy is less appealing now than when MGRM implemented its hedging program.

The paper is organized as follows. In Section 2, we discuss the contractual position of MGRM and how they hedged it. We then review the existing theoretical and empirical literature on backwardation in energy markets. In the section 3, we examine the behavior of energy futures prices both prior to and subsequent to the liquidation of MGRM's positions. In Section 4, we measure and discuss the risks of MGRM's hedging strategy. The final section concludes.

2. MGRM's hedging strategy and a review of Literature on backwardation in energy markets

2.1. MGRM's hedging strategy

Between 1991 and 1993, MGRM entered into long-term contracts to supply a large amount (over 150 million barrels) of refined energy products such as gasoline and heating oil to its customers.[2] To hedge the price risk of its supply contracts, MGRM purchased energy futures contracts and entered into over-the-counter energy swaps. MGRM used short-date, especially near-month or next-to-expire, futures contracts, while the majority of its swaps were also of relatively short maturity (less than three months). MGRM hedged its supply obligations barrel-for-barrel.

To keep it general and simple, consider a distributor, which has just entered into a contract to supply one unit of a commodity at T. Further, it has decided to implement a hedging strategy based on buying a short-dated futures contract, which is to be rolled over continuously in order to maintain the hedge. Essentially, in such a rollover, it will sell the expiring contract and simultaneously buy a new near-month contract. The rollover is done until the delivery date under the supply contract is reached, at

[2] For more details of these supply obligations, see, for example, Mello and Parsons (1995) and Pirrong (1997).

which time the commodity is acquired in the spot market for delivery. Under this strategy and assuming that rollovers are done on the last trading day of the expiring contract, the profit is

$$\pi_T = C_0 + \sum_{t=1}^{T-1} [S_t - F_t(1)] - F_0(1), \qquad (1)$$

where π_T is the distributor's profit as of time T, C_0 is the long-term supply contract price negotiated at time 0, S_t is the spot price at time t, and $F_t(i)$ is the futures price at time t for delivery i periods ahead.[3]

In equation (1), each term in the summation is the gain or loss from the rollover done at time t, where we use the fact that the futures price converges to the spot price at maturity. Therefore, the profit of this hedged supply program equals the long-term supply contract price plus the sum of all gains/losses made on the futures contract rollovers minus the initial futures price. Obviously, the higher the cumulative rollover gain, the more profitable is the hedged supply program.

Define the gain/loss from a rollover done at time t in dollar and percentage terms as follows:

$$\text{Dollar Rollover Gain/Loss}\,(t) = Roll_t = S_t - F_t(1) \qquad (2)$$

$$\text{Percentage Rollover Gain/Loss}\,(t) = roll_t = \ln S_t - \ln F_t(1) \qquad (3)$$

There are two factors that determine whether the above "stack-and-roll" hedging strategy will generate cumulative rollover gains. The first factor is the frequency of backwardation in energy markets. Whenever backwardation (contango) occurs, a rollover will yield a gain (loss). Therefore, if backwardation (contango) is the norm in the energy markets, the strategy will over time generate cumulative rollover gains (losses) and thus increase (decrease) the profitability of the hedged supply program. The second factor is the typical magnitude of each rollover gain/loss. Suppose that for whatever reason, each rollover gain is typically higher in magnitude than each rollover loss. In this case, cumulative rollover gains can still be obtained even if backwardation and contango are equally frequent.

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[3] In this equation and throughout this paper, we omit from our analysis any interest charged (earned) on the day-to-day maintenance of the margin account. Including this would complicate the expressions without adding to the intuition of our arguments.

There are at least two possible explanations for *MGRM*'s use of short-dated contracts. First, it may have been concerned with the lack of liquidity of long-dated contracts. Although contracts with maturity months that were several years into the future were available in 1993, their trading volumes were generally low. Krapels (2001) calculates average monthly volume of crude oil futures trading for 1993 and finds that 76% of the trade took place in the first two contract months, and 90% in the first four months. Secondly, and perhaps more likely, as argued by Culp and Miller (1995a, 1995b) and supported by *MGRM*'s internal documents, *MGRM* may have believed that it had superior information about short-dated energy prices *relative* to long-dated ones. In other words, *MGRM* may have conducted an arbitrage between short-dated prices and the prices of its long-term supply contracts.[4]

2.2. Theoretical arguments and prior empirical evidence

There are several theoretical arguments for backwardation to be common in energy markets. One argument, based on the theory of storage, points to the role of convenience yield (see, for example, Working (1948) and Brennan (1958)). Convenience yield exists because inventories provide holders with consumption/production flexibility. Markets are in backwardation if the convenience yield, net of storage costs, exceeds the interest rate. This is likely to happen when the supply level is low and thus spot energy prices are high.[5]

Under the theory of storage argument, energy markets have characteristics that make them prone to short supply and thus backwardation. A shortage of storage facilities, an uncertainty in OPEC production decisions, and, especially for heating oil and gasoline, seasonal spikes in demand, all contribute to the markets generally being in short supply. Therefore, it is reasonable to expect backwardation to be the norm in energy markets.

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[4] It may help some to think in terms of the term structure of futures prices. The existence of backwardation is tantamount to a negatively sloped term structure of futures prices, where futures prices at a given point in time are plotted against delivery. Conversely, contango implies a positive slope. The arbitrage explanation is exactly analogous to what is known in fixed-income markets as rolling down the yield curve, whereby one seeks to capitalize on the tendency for longer rates of interest to be greater than shorter rates due to the existence of a term premium by periodically swapping short-term bonds for longer-term bonds (see, for example, Deaves (1998)).

[5] The empirical tests by Bessembinder *et al* (1995) show that the difference between convenience yield and interest rates is positively related to the level of crude oil prices.

Another argument for backwardation is based on production decisions. Litzenberger and Rabinowitz (1995) argue that ownership of oil reserves can be thought of as holding a call option with an exercise price equal to the extraction costs. In this framework, *weak* backwardation, defined as *discounted* futures prices being below spot prices, must occur for owners to have an incentive to exercise the option to produce oil now. They also show that if uncertainty about futures prices is substantial, *strong* backwardation, defined similarly to our definition, may be required to induce current production. Therefore, their model predicts that backwardation should be the norm in energy markets.[6]

Available empirical evidence from energy markets, though sparse, appears to support the backwardation prediction. To our knowledge, the available evidence only covers the period up to 1993. For example, Litzenberger and Rabinowitz (1995), using data on crude oil futures prices from February 1984 to April 1992, calculate the frequencies and magnitude of backwardation for various contract lengths. For the near-month contracts, they report that weak (strong) backwardation occurred over 80% (70%) of the time, with an average magnitude of $0.29 ($0.24).[7] For longer contracts, the frequencies and magnitude increase monotonically.

Edwards and Canter (1995) provide more detailed evidence of backwardation in energy markets. Using data on crude oil, heating oil and gasoline futures from April 1983 to December 1992,[8] they calculate the frequency and magnitude of rollover gains that could be obtained under a stack-and-roll hedging strategy, assuming that near-month contracts are used and rollovers are done three days prior to the contracts' last trading day. For crude oil, they report that backwardation occurred 67% of the time, yielding an average rollover gain of $0.25. The corresponding numbers for heating oil are 45% and $0.32, while those for gasoline are 70% and $0.45. Note that, although the frequency of backwardation for heating oil is only 45%, the average rollover gains are positive. This is due to the fact that the magnitude of backwardation is larger than that of

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[6] A somewhat similar argument is made by Thompson (2001). The major difference is that Thompson divides production decisions into two major steps – development of oil wells and daily production. He then provides empirical evidence to show that daily production of already-developed wells is usually at full capacity, whether the markets are in backwardation or contango. In his model, therefore, backwardation is necessary to induce owners to develop their wells.

[7] Litzenberger and Rabinowitz state that daily data were used in these calculations. Their exact procedure, however, was not given.

[8] Data for gasoline begin in December 1984.

contango. Therefore, based on data up to the beginning of 1993, it appeared that the stack-and-roll hedging strategy could, *ex ante*, be expected to yield rollover gains.

3. Results on Backwardation

Our dataset consists of daily closing future prices of crude oil, heating oil and gasoline contracts for the period from January 1984 (January 1985 for gasoline) to December 2000.[9] To determine whether backwardation exists, we generate gains/losses from rolling over futures contracts assuming that near-month contracts are used and rollovers are done on the last trading day of the expiring contracts.

Rollover gains/losses are calculated for the whole sample period, as well as during two roughly equal subperiods. The first subperiod is from 1984 to 1992 (or 1985-92 for gasoline). This span is apt because it runs from close to futures contract inception to just before MGRM implemented its hedging strategy and should therefore provide us with some insight into the futures price patterns that the company observed. The second subperiod is from 1993 to 2000. This period is examined in order to ascertain whether the price patterns observed in the first period continued to hold. If backwardation is the norm in energy markets, then in all periods gains should occur more often than losses and on average rollovers should be profitable.

3.1. Preliminary Results

Prior to discussing our results, we first show the graphs of rollover gains/losses for the three commodities over the entire sample periods. Figures 1 (a), (b), and (c) display rollover results of crude oil, heating oil and gasoline respectively. Two patterns are of note in all three graphs. First, rollover gains and losses occurred intermittently and secondly, the magnitude of rollover gains appears to be higher than that of rollover losses.

[9] The data were obtained from the Futures Industry Association.

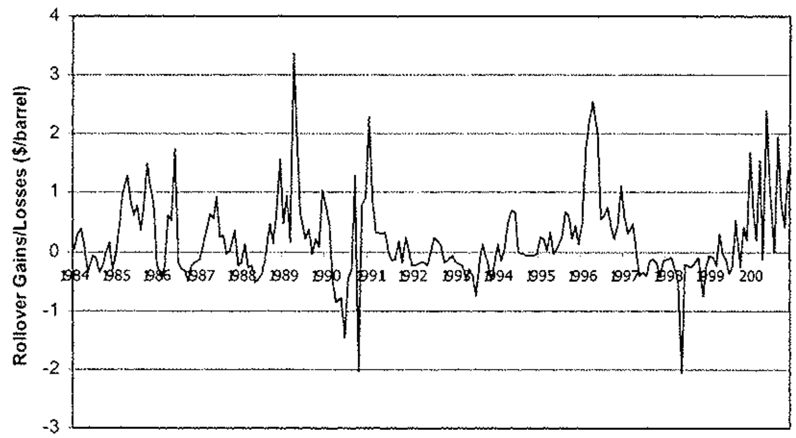

Figure 1(a): Crude Oil Monthly Rollover Gains/Losses 1984 – 2000

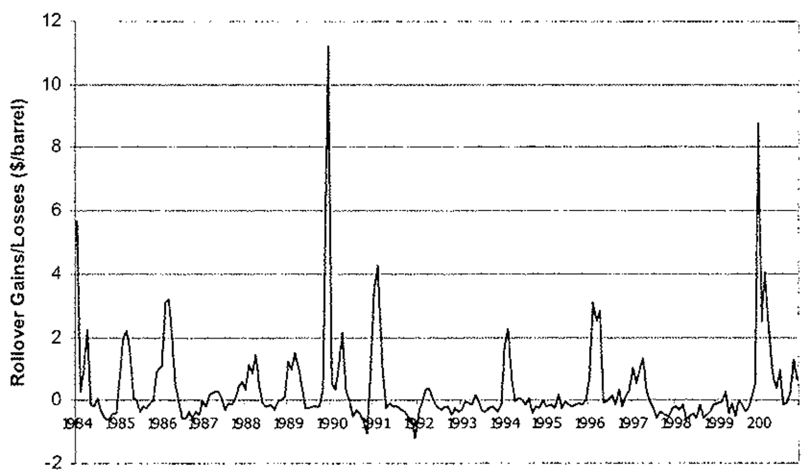

Figure 1(b): Heating Oil Monthly Rollover Gains/Losses 1984 – 2000

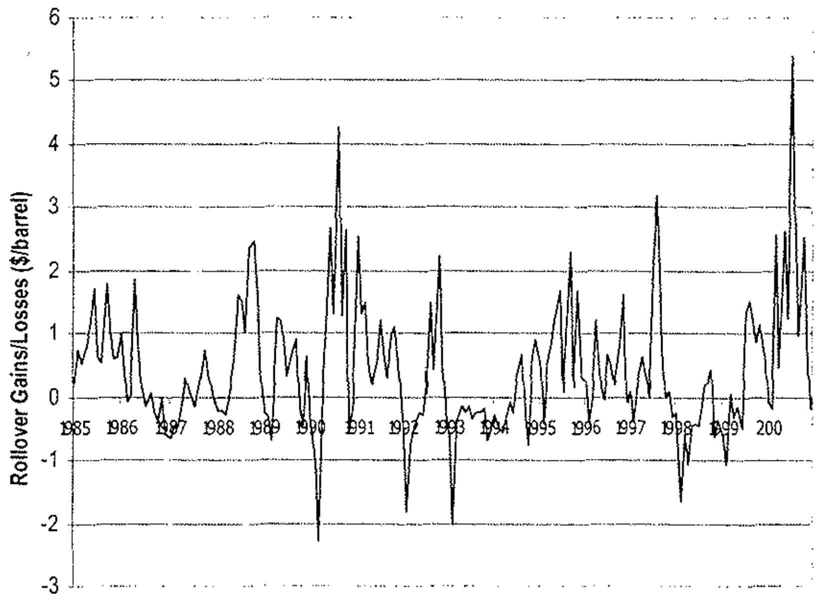

Figure 1(c): Gasoline Monthly Rollover Gains/Losses 1985 – 2000

These two patterns are reflected in the rollover results, reported in Table 1. For the first subperiod (1984 to 1992), the frequencies of backwardation are 56%, 46% and 67% for crude oil, heating oil and gasoline respectively (Panel A). These numbers suggest that backwardation was more common than contango in the crude oil and gasoline markets, and was approximately as common as contango in the heating oil markets. The average monthly rollovers in dollar (percentage) term are $0.22/barrel (0.93%) for crude oil; $0.43/barrel (1.59%) for heating oil; and $0.50 (1.83%) for gasoline. For all three commodities, the averages of all rollover gains are much higher than the averages of all rollover losses, which explains why the average rollovers are significantly positive even though backwardation was not exceedingly more common than contango.

Table 1: Summary of Gains/Losses from Rollovers

Panel A: From 1984 to 1992

	Crude Oil		Heating Oil		Gasoline	
	$	%	$	%	$	%
Average of All Rollovers	0.22	0.93%	0.43	1.59%	0.50	1.83%
Average of All Rollover Gains	0.65	3.00%	1.28	4.92%	0.98	3.74%
Average of All Rollover Losses	-0.32	-1.69%	-0.32	-1.30%	-0.47	-2.00%
Frequency of Rollover Gains	56%		46%		67%	

Panel B: From 1993 to 2000

	Crude Oil		Heating Oil		Gasoline	
	$	%	$	%	$	%
Average of All Rollovers	0.21	0.64%	0.29	0.84%	0.35	0.90%
Average of All Rollover Gains	0.71	3.00%	1.12	4.02%	1.04	3.55%
Average of All Rollover Losses	-0.27	- 1.65%	-0.25	-2.40%	-0.45	- 2.20%
Frequency of Rollover Gains	49%		40%		53%	

Panel C: From 1984 to 2000

	Crude Oil		Heating Oil		Gasoline	
	$	%	$	%	$	%
Average of All Rollovers	0.21	0.79%	0.36	1.24%	0.43	1.36%
Average of All Rollover Gains	0.68	3.00%	1.21	4.53%	1.01	3.66%
Average of All Rollover Losses	-0.30	-1.67%	-0.28	-1.27%	-0.46	- 2.12%
Frequency of Rollover Gains	52%		43%		60%	

Notes: 1) All dollar rollover gains and losses are reported in $/barrel. Since heating oil and gasoline futures are traded on a $/gallon basis, their dollar rollover gains and losses are multiplied by 42.
2) Data for gasoline futures begin in January 1985.

The average monthly rollovers suggest that a stack-and-roll hedging strategy would be profitable in the first subperiod. To put the results in perspective, consider that in September 1993 (i.e., soon after MGRM implemented its hedging), MGRM's hedging stack consisted of approximately 154 million barrels in short-dated futures contracts and over-the-counter swaps (Culp and Miller (1995a, p. 108)). If we assume that the average dollar rollover of crude oil (i.e., 0.22/barrel, which is the lowest among the three commodities) applies to all the contracts in the stack, then historical data (i.e., up to 1992) indicate that MGRM could expect to receive, on average, rollover gains of approximately $34 million per month.[10]

Our results for the first subperiod are consistent with those reported by Edwards and Canter (1995), with two exceptions. First, their frequency of backwardation in the crude oil markets is slightly higher (67%) than ours (56%). Secondly, their average rollover for heating oil is $0.32/barrel compared to $0.42/barrel in ours. We attribute the discrepancies to the difference between their rollover rules and ours. Edwards and Canter use

[10] Of course, the number of barrels in the hedging stack would decline during the life of the supply program, depending on the supply schedule that MGRM had with its customers. Therefore, $34 million per month is the rollover gain at the peak of its hedging positions.

what they term the "three-day rollover rule," where rollovers are done three trading days prior to the last trading day of the expiring contracts. In contrast, we roll the contracts over on the last day. Note that the difference in the magnitude of gains has no significant effect on our conclusion regarding the expected profitability of MGRM's hedging strategy. This is because in practice, MGRM did not have to follow a rigid rollover rule and could have rolled on days when prices were favorable to them.[11]

For the second subperiod (1993 to 2000), the frequencies of backwardation are 49%, 40% and 53% for crude oil, heating oil and gasoline respectively (Panel B). These numbers appear to suggest that backwardation was no longer more common than contango in the crude oil and gasoline markets, and was less common than contango in the heating oil markets. However, when we compare these frequencies to those from the first subperiod, we cannot reject the null hypothesis that the frequencies of backwardation are the same in both subperiods at the 5% level for all three commodities.[12]

The average monthly rollovers for the second subperiod in dollar (percentage) term are $0.21/barrel (0.64%) for crude oil; $0.29/barrel (0.84%) for heating oil; and $0.35 (0.90%) for gasoline. These numbers appear to suggest that a stack-and-roll hedging strategy would also be profitable in the second subperiod.

The results for the entire sample period (1984 to 2000) are given in Panel C of Table 1. Based on 17 years of data, it appears that backwardation is less common than contango in the heating oil markets, about equally common as contango in the crude oil markets and slightly

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[11] To ensure that our rollover results are not due to the rollover rule that we use (i.e., selling the expiring contracts on their last trading day and simultaneously buying new near-month contracts), we also calculate rollover gains/losses under two other rules. First, we assume that rollovers are done on the 10^{th} day prior to the expiring contracts' last trading day and near-month contracts are used. If the 10^{th} day prior to the last trading day falls on a weekend or is a holiday, rollovers are done on the closest business day. Second, we assume that rollovers are done on the last trading day but 2^{nd}-month contracts are used. Both assumptions yield qualitatively similar results to those reported in Table 1. The only difference is that when the 2^{nd}-month contracts are used, the magnitude of gains and losses is larger, which is to be expected since the bases are bigger for longer-dated contracts than for shorter-dated ones.

[12] However, the hypothesis would be rejected at the 10% level for gasoline.

more common than contango in the gasoline markets. Nevertheless, the average rollovers are positive in all markets. Again, this is due to the fact that the average of all rollover gains is larger than the average of all rollover losses for all three commodities. Therefore, a stack-and-roll hedging strategy appears to be profitable over the entire sample period.

3.2. Statistical Tests of Results

To conduct statistical tests on our results, we need to take into account the time-series properties of energy prices. Previous studies have shown that energy prices exhibit (i) mean reversion (see, for example, Gibson and Schwartz (1990) and Bessembinder et al (1995); (ii) volatility clustering (see, for example, Deaves and Krinsky (1992, 1995)); and (iii) price seasonality, especially for heating oil (see, for example, Girma and Paulson (1998) and Mazaheri (1999)). Both mean reversion in price and seasonality can cause autocorrelation, while volatility clustering produces heteroscedasticity.

To obtain information on the presence of seasonality in our data, we calculate the average rollovers and the frequencies of rollover gains by month for our three energy commodities. They are reported in Panels A and B of Table 2. Casual observation of the table suggests that seasonality may exist, especially in the first subperiod, for heating oil and gasoline, but likely not for crude oil. Heating oil rollovers tend to be positive in the winter and negative in the late summer and fall, while the opposite relationship emerges for gasoline. These patterns are less pronounced in the second subperiod.

To properly account for all time-series properties alluded to below, we regress dollar rollovers or percentage rollovers on a constant and, when necessary, seasonal dummy variables and an appropriate number of autoregressive terms (lags of rollovers).

Table 2
Panel A: Average Rollovers by Month ($/barrel)

Mo.	1984 – 1992			1993 – 2000			1984 – 2000		
	Crude Oil	**Heating Oil**	**Gas**	**Crude Oil**	**Heating Oil**	**Gas**	**Crude Oil**	**Heating Oil**	**Gas**
Jan	0.31	1.40	0.21	0.34	1.42	-0.13	0.32	1.41	0.04
Feb	0.30	1.31	-0.24	0.30	1.00	-0.83	0.30	1.16	-0.53
Mar	0.12	1.24	-0.31	0.27	1.01	0.23	0.19	1.13	-0.04
Apr	0.55	1.20	0.50	0.53	0.71	0.17	0.54	0.97	0.33
May	0.25	0.21	0.66	-0.03	0.03	0.43	0.12	0.12	0.55
Jun	0.21	-0.09	0.92	0.32	-0.08	0.20	0.26	-0.08	0.56
Jul	0.02	-0.29	0.61	0.03	-0.04	1.14	0.02	-0.18	0.88
Aug	0.00	-0.26	1.10	0.07	-0.21	1.22	0.03	-0.24	1.16
Sep	0.24	-0.31	0.90	0.41	-0.23	0.65	0.32	-0.27	0.77
Oct	-0.11	-0.34	1.19	0.05	-0.20	0.48	-0.03	-0.28	0.84
Nov	0.34	-0.21	0.39	-0.01	0.00	0.58	0.18	-0.11	0.48
Dec	0.40	1.26	0.08	0.28	0.12	0.05	0.34	0.73	0.06

Note: Data for gasoline futures begin in January 1985.

Panel B: Frequency of Rollover Gains

Mo.	1984 – 1992			1993 – 2000			1984 – 2000		
	Crude Oil	Heat -ing Oil	Gas	Crude Oil	Heat-ing Oil	Gas	Crude Oil	Heat-ing Oil	Gas
Jan	44%	78%	38%	63%	50%	38%	53%	65%	38%
Feb	78%	78%	25%	50%	50%	0%	65%	65%	13%
Mar	56%	100 %	38%	63%	63%	63%	59%	82%	50%
Apr	67%	89%	75%	75%	50%	50%	71%	71%	63%
May	56%	78%	88%	25%	50%	50%	41%	65%	69%
Jun	44%	22%	88%	50%	38%	25%	47%	29%	56%
Jul	44%	11%	75%	38%	38%	75%	41%	24%	75%
Aug	44%	0%	100 %	25%	13%	88%	35%	6%	94%
Sep	56%	0%	88%	63%	13%	75%	59%	6%	81%
Oct	44%	11%	75%	38%	13%	63%	41%	12%	69%
Nov	78%	33%	63%	50%	38%	75%	65%	35%	69%
Dec	56%	56%	50%	50%	63%	38%	53%	59%	44%

Note: Data for gasoline futures begin in January 1985.

When volatility clustering is detected through an ARCH Lagrange multiplier test on the residuals, we model the residuals' volatility, $\sigma^2(\varepsilon_t)$, using an ARCH process of appropriate order. As a result, when all three time-series properties are present, our model becomes

$$roll_t = c + \sum_{j=2}^{12} a_j m_j + \sum_{n=1}^{N} b_n roll_{t-n} + \varepsilon_t, \tag{4}$$

where

$$\sigma^2(\varepsilon_t) = \delta_0 + \sum_{p=1}^{P} \delta_p \varepsilon_{t-p}^2, \tag{5}$$

c is a constant; m_j, j = 2 to 12, are dummy variables for the months of February to December. m_j takes on the value of one if $roll_t$ comes from month j and zero otherwise.[13]

The above regression models are applied individually to each rollover measure (dollar or percentage) of each commodity in each period. For example, since crude oil's dollar rollovers in the first period exhibit autocorrelation but not seasonality or volatility clustering, we find that the most appropriate and parsimonious model for re-estimating the average dollar rollover for this period is an ordinary least squares method with AR terms. On the other hand, heating oil's percentage rollovers for the whole sample period exhibit all three characteristics. In this case, we re-estimate the percentage rollover average using an ARCH model with seasonal dummy variables and AR terms.[14]

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[13] For example, if the last trading day of the old contract (i.e., the rollover day) falls in the month of February, m_2 is equal to 1 while m_3 to m_{12} are equal to zero.

[14] To arrive at the most appropriate model for each combination of rollover measure/commodity/period, we employ the following procedure. First, we perform an OLS regression of rollovers on a constant. We then examine the behavior of the residuals. If autocorrelation is detected (through the Durbin-Watson statistics and the Ljung-Box Q-statistics), we correct for it by introducing seasonal dummy variables and/or autoregressive (AR) terms. If autoregressive conditional heteroscedasticity is detected (through an ARCH LM test), we correct for it by modeling the volatility of the residuals using the needed number of ARCH terms. After the residuals are reduced to white noise, we then check again

Note that our adjustment approach implies that different combinations of rollover measure/commodity/period are adjusted differently, depending on their time-series properties. One major advantage of this approach, compared to, for example, one single set of adjustments for each commodity in all periods, is that the models are most appropriate for the time-series properties present in each combination. As a result, the models are parsimonious, and the estimated average rollovers reflect only the information in that period. That is, the estimated average rollovers are what one would predict the future rollovers will be, given the values of past rollovers and the properties of the data.[15]

The estimates of average rollovers are reported in Table 3. For crude oil, the average rollovers, in both dollar and percentage terms, are marginally significant (at the 10% level) in the first subperiod and the entire period. However, they are not significant in the second subperiod. For heating oil, the average rollovers are significant at the 5% level for the first subperiod and the entire period, but not at all significant in the second subperiod. A similar significance pattern exists for gasoline futures, except that in the second subperiod, the average dollar (but not percentage) rollover is marginally significant.

Table 3: Re-estimations of Average Dollar and Percentage Rollovers

Period	Crude Oil		Heating Oil		Gasoline	
	$	%	$	%	$	%
1984 to 1992	0.22#	0.92#	0.43*	1.42*	0.50*	1.81*
1993 to 2000	0.23	0.90	0.38	1.16	0.40#	1.21
1984 to 2000	0.25#	0.77#	0.33*	1.21*	0.41*	1.35*

the significance of the changes that we made. For example, it is possible that by introducing an ARCH process, the AR terms may no longer be significant, in which case they will be removed from the final model.

[15] There is one disadvantage of this approach. The magnitude of the estimated average rollovers may not be strictly comparable between periods. This is because when our adjustments require the use of an ARCH model, the estimations will involve maximum-likelihood functions, and thus different parts of the data are weighted differently depending on the volatility at different points in a given period. Since our approach is period-specific, it is possible that the estimated average rollovers for the first and second subperiods may appear to be inconsistent with those of the entire sample period.

Note:
1) All dollar rollover gains and losses are reported in $/barrel. Since heating oil and gasoline futures are traded on a $/gallon basis, their dollar rollover gains and losses are multiplied by 42.
2) Data for gasoline futures begin in January 1985.
3)* denotes significance at the 5% (two-tailed) level, while # denotes significance at the 10% (two-tailed) level.

Altogether, these estimates show that for all three commodities and based on the data from 1984 to 1992, we could expect the stack-and-roll hedging strategy to be profitable. On the other hand, based on the data from 1993 to 2000, the profit from such a strategy could no longer be expected. Still, for the overall period (1984 to 2000), our results predict that the strategy should produce rollover gains for all three commodities.

4. Risks of a Stack-and-Roll Hedging Strategy

Since our results show that prior to 1993, average rollovers were positive and significant (though only marginally so for crude oil), this appears to provide some justification to MGRM's implementation of its hedging strategy.

With the benefit of hindsight, it is clear that the strategy turned out to be flawed. In 1993, there was a substantial over-supply of crude oil due to weaker than expected demand, an increase in production from non-OPEC countries and the possibility that Iraq would be allowed to return to the oil market. This over-supply caused energy prices to drop sharply and energy markets to go into contango.

It is important to separate the impact of the sharp price drop on the profitability of the hedged supply program from that of contango. As mentioned earlier, the program's profitability will be affected only if the slope of the futures term structure changes. Therefore, the sharp price drop by itself did not have to be catastrophic. Rather, the difficulties were caused by the rollover losses as a result of the market moving from backwardation to contango. That is, this shift in the term structure caused the rollover losses.

Nevertheless, in an important way, the price decline itself did cause difficulties to MGRM. This is because, in terms of cash flows, the drop created severe cash drains to MGRM through the marking-to-market procedure. To see the marking-to-market effect, note that equation (1) can be rearranged to yield:

$$\pi_T = c_0 + \sum_{t=1}^{T}[S_t - F_{t-1}(1)] - S_T. \qquad (6)$$

In equation (6), each term in the summation is the dollar return from holding futures contracts long. Therefore, this expression states that the firm's per-unit profit from the hedged supply program is the long-term contract price plus the sum of all dollar returns on the futures contracts minus the final spot price.

Through the marking-to-market procedure, these dollar returns will be settled on a daily basis. If futures prices are lower than expected future spot prices, futures prices are expected to rise over the contract's life. In this case, the expected dollar returns to long positions on futures contracts are positive and no margin call is expected.[16] On the other hand, if futures prices are higher than expected future spot prices, futures prices are expected to decline over the contract life. In this case, expected returns are negative and cash drains are expected.

As a result, a price drop (to the point where S_t is less than F_{t-1}) in any holding period can generate a large negative return and thus a large margin call *in that period*. This was indeed what occurred in 1993. The cumulative return from holding long 12 consecutive near-month crude oil, heating oil and gasoline futures contracts starting in December 1992 was -52%, -35% and -58% respectively. Considering that *MGRM* had a total hedging position of over 150 million barrels in September 1993, these declines in prices would have generated margin calls on the order of several hundred millions of dollars.[17]

How likely were the negative cumulative returns observed during 1993? Figures 2 (a), (b) and (c) display returns from holding near-month futures contracts for all three commodities from 1984 to 2000. As can be seen, monthly returns greater than 10% or less than -10% were not uncommon throughout the entire sample period. However, what is of greater interest is the likelihood of a cumulative 12-month negative return of similar or greater magnitude than what occurred in 1993.

To obtain an idea about this likelihood based on the parameters estimated from the data up to 1992 and also based on the parameters estimated using the data for the entire sample period, we run two sets of

[16] Since futures contracts cost nothing to enter into, percentage returns are not well defined. However, if the percentage return is defined as the log difference between the futures price when the contract is entered into and the future price when the contract is closed out, then the statements about dollar returns also hold true for percentage returns.

[17] In order to be precise, one would have to know MGRM's exact hedging positions in every month of 1993. This information is not available.

simulations of evolution of futures prices of crude oil over a 12-month period. The first set uses the data up to 1992. Based on 10,000 runs, the probability that the cumulative returns in the next 12 months would be as least as bad as the above crude oil futures' cumulative return (-52%) is 3.77%. Therefore, based on the data up to 1992, the chance of experiencing a similar margin call problem to the one MGRM faced in 1993, while not extremely unlikely, could be considered low. The second set of simulations uses the data from 1984 to 2000. The probability of getting similar or worse returns (than MGRM did) in the next 12 months is 7.32%. Therefore, based on 17 years of data, the risk that a stack-and-roll strategy would run into a similar margin call problem is no longer negligible.

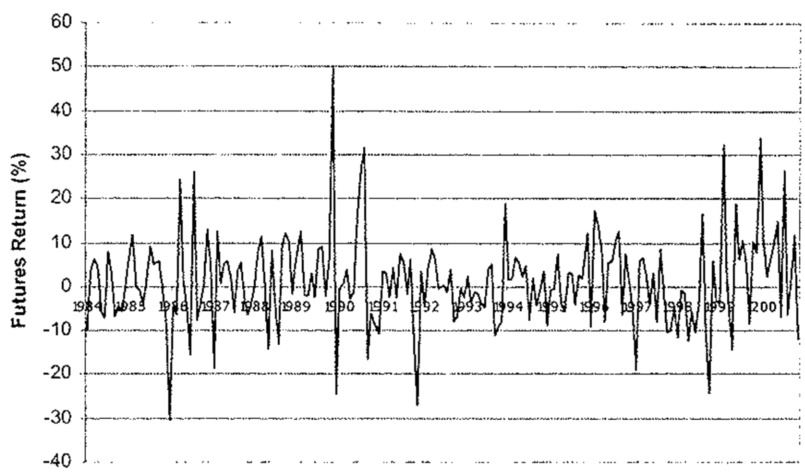

Figure 2(a): Crude Oil Monthly Futures Returns 1984 – 2000

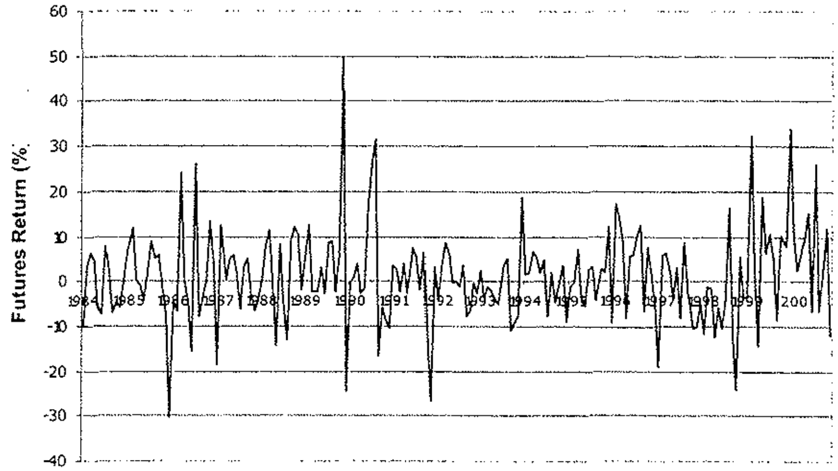

Figure 2(b): Heating Oil Monthly Futures Returns 1984 – 2000

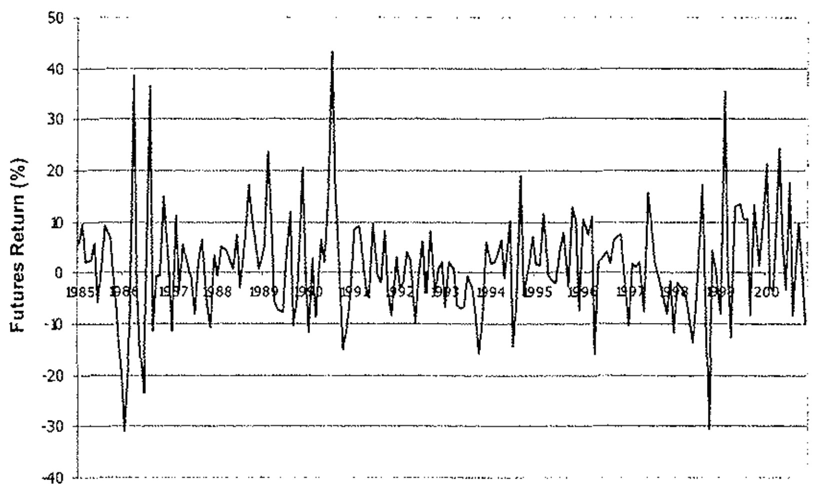

Figure 2(c): Gasoline Monthly Futures Returns 1984 – 2000

While a prolonged price decline can cause cash drains due to margin calls, it is the presence of backwardation/contango that determines whether a stack-and-roll hedging strategy will be profitable. In MGRM's case, the total rollovers per barrel in 1993 under such a strategy would have been -$3.37 (-19.28%) for crude oil, -$2.30 (-9.71%) for heating oil and -$5.60 (-26.87%) for gasoline.

How likely were the contango markets observed in 1993? From Figures 1 (a), (b) and (c), for all three commodities, the period of deep and/or prolonged rollover losses are not common. Besides 1993, the only other period of protracted rollover losses is 1998 – 1999 (and perhaps 1990 for crude oil). To obtain an idea about the likelihood of a similar rollover loss to one that occurred in 1993, we again run two sets of simulation (10,000 runs each) on crude oil prices – one based on the data up to 1992 and the other based on the data from the entire period. Based on the data up to 1992, the probability of a similar rollover loss occurring in the next 12 months is 4.79%. On the other hand, when the data up to 2000 are used, the probability is 10.04%, which is more than twice as high.

In summary, the results of our simulations show that both the margin call risk and the contango risk are quite low when evaluated using the data up to 1992 (which in fact were what was available to MGRM). However, when the data up to 2000 are considered, both risks become markedly higher. This suggests that, were one to construct a similar stack-and-roll strategy today, the risks that one would face would appear even greater than those MGRM faced in the early 1990's.

5. Conclusion

Using an updated energy price dataset, we revisit the MGRM debate. Our results show that based on the data from 1984 to 1992, a stack-and-roll hedging strategy using short-dated energy futures contracts to hedge long-term contracts might have appeared sensible. The expected rollover gains were sizable and significant, while the risks of rollover losses and of cash drains due to margin calls could be considered low. The same, however, cannot be said when we examine the data from the period from 1993 to 2000. The expected rollover gains during this latter period were generally not significant.

Still, when the entire sample period (1984 to 2000) is considered, the expected rollover gains are generally positive and significant. Nevertheless, their magnitude is not as high as that of their counterparts for the period up to 1992, and the risks are no longer negligible. Traders who are considering adopting a similar hedging strategy to the one MGRM employed should be wary.

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