Morgan Stanley

Journal of Applied Corporate Finance

SPRING 1995 VOLUME 8.1

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At the start of 1994 Metallgesellschaft A.G., the 14th largest corporation in Germany, stood on the brink of bankruptcy as a result of more than $1 billion in losses from trading in oil futures. The futures trades were part of a sophisticated strategy ostensibly conceived by its New York subsidiary to hedge against dangerous swings in the price of oil and oil-related products. How could a set of transactions that purportedly "locked in" profits, making the firm safer, in fact lead the firm to bankruptcy? Understanding the mistakes made by Metallgesellschaft is critical if other firms are to avoid a similar fate without forsaking the significant benefits available from a correctly planned hedging strategy.

The parent corporation Metallgesellschaft A.G. is a large conglomerate with interests in a wide variety of metal, mining, and engineering businesses, including 15 major subsidiaries. Total sales in 1993 topped DM 26 billion ($16 billion) on assets of DM 17.8 billion ($10 billion) and with total employment of 43,292. Metallgesellschaft is closely held with over 65% of its stock owned by seven institutional investors, including the Emir of Kuwait, Dresdner Bank, Deutsche Bank, Allianz, Daimler-Benz, the Australian Mutual Provident Society and M.I.M. Holdings Ltd. of Australia. Some of these are also important creditors to the firm.

Metallgesellschaft's U.S. subsidiary (MG Corp.) was reorganized in 1986 with equity capital of $50 million and net sales of $1.7 billion from trading in U.S. government bonds, foreign currency, emerging market instruments, and various commodities. The U.S. subsidiary's oil business, organized under MG Refining and Marketing (MGRM), grew significantly between 1989 and 1993. In 1989 the company obtained a 49% stake in Castle Energy, a U.S. oil exploration company, whose transformation into a refiner MGRM helped finance. MGRM contracted with Castle Energy to purchase their output of refined products—approximately 46 million bbl. per year—at guaranteed margins for up to 10 years, and assembled a large network of infrastructure necessary for the storage and transport of oil products. During 1992 and 1993, MGRM succeeded in signing a large number of long-term contracts for delivery of gasoline, heating oil, and jet fuel oil to independent retailers. By late 1993 MGRM had become an important supplier. In addition MGRM ran large trades in energy-related derivatives. Its portfolio included a wide variety of over-the-counter forwards, swaps, and puts, and it did large amounts of trading in futures contracts on crude oil, heating oil, and gasoline on a number of exchanges and markets.

MGRM AS A FINANCIAL INTERMEDIARY

MGRM had no competitive advantage in its cost of supply. It did not own significant amounts of oil in the ground and the refineries run by Castle were old and inefficient. Instead, MGRM's business plan laid out a marketing strategy based on long-term pricing.[1] MGRM's management believed that independent retailers required protection against temporarily high spot prices for their supplies. According to MGRM, spot price movements quickly impacted the wholesale price of refined oil products but not the retail price. While retailers attached to large integrated oil companies were able to ride out the temporary squeezes on margins, independent retailers often faced a severe liquidity crunch. And while retailers could buy products under contracts protecting them against these temporary price surges, MGRM believed these contract price terms were unnecessarily high given the recent history of spot prices.

This was the central premise of MGRM's strategy. MGRM believed it possible to arbitrage between the spot oil market and the long-term contract market. This arbitrage required skilled use of the futures markets in oil products, and this was to be MGRM's stock in trade.

MGRM developed several novel contract programs. First, MGRM offered a "firm-fixed" program, under which the customer would agree to a fixed monthly delivery of oil products at a set price. By September of 1993, MGRM was obligated for a total of 102 million barrels under this type of contract. About 95.5 million barrels were covered by contracts running for ten years, with most of the remainder covered by contracts running for five years.[2]

A second program, called "firm-flexible" contracts, included a set price and a specified total volume of deliveries over the life of the contract, but gave the customer extensive rights to set the delivery schedule—up to a maximum of 20% of its needs in any year—and with 45 days notice. By September of 1993, MGRM was obligated for a total of 52 million barrels under this type of contract. About 47.5 million barrels were covered by contracts running for ten years and 10.5 million barrels were covered by contracts running for five years.

MGRM also ran a third program of "guaranteed margin" contracts, under which it agreed to make deliveries at a price that would assure the independent operator a fixed margin relative to the retail price offered by its geographical competitors. The contract could be extended annually for a defined period and at MGRM's discretion. By September of 1993, MGRM was obligated for a total of 54 million barrels under this type of contract, although MGRM's renewal option meant that these volumes were not firm obligations. It is the first two programs involving 154 million barrels of obligations for periods up to ten years that constituted MGRM's designated short position in oil.

Although the contracts appear to deliver price protection in a straightforward manner, in fact the advantage to MGRM's customers was more roundabout. A familiar problem with long-term fixed-price contracts is that the protection offered on one side of the contract creates its own financial squeeze on the other side; that is, when the contract is deep in the money for the seller, the buyer may in fact be forced into default or at least a renegotiation of the terms. To minimize this danger, MGRM limited the annual volume supplied under contract to no more than 20% of the customer's needs. Of course, this also minimized the degree to which MGRM's contract would resolve the squeeze on a retailer during a period of high spot prices.

In order to both minimize the default risk in times of low spot prices and meet the customer's liquidity needs in times of high spot prices, MGRM included in its contracts a cash-out option. In times of high spot prices, customers could call for cash settlement on the full volume of outstanding deliveries over the life of the contract, thus receiving a cash infusion exactly when they were otherwise liquidity constrained. Under the *firm-fixed* contracts the customer would receive *one-half* the difference between the current nearby futures price and the contract price, multiplied by the entire remaining quantity of deliveries. Under the *firm-flexible* contracts the customer would receive the full difference between the second-nearest futures

1. *Business Plan for MG Refining and Marketing, Inc., December 1, 1991 to May 31, 1992.*

2. A comprehensive overview of MGRM's programs and positions is available in the report of the special auditor requested by the extraordinary shareholders meeting of February 24, 1994, *Bericht über die Sonderprüfung nach 142 Abs. 1 AktG bei der Metallgesellschaft Aktiengesellschaft, gemäß Beschluß der außerordentlichen Hauptversammlung am 24. Februar 1994*, by C&L Treuarbeit and Wollert-Elmendorff, January 20, 1995.

price and the contract price, multiplied by the portion of deliveries called.[3]

Through its pricing terms and these options, MGRM had assumed a good deal of its customers' oil price risk. To hedge this risk MGRM used a strategy known as the rolling stack. At the peril of some oversimplification, the strategy worked as follows. MGRM opened a long position in futures stacked in the near month contract. Each month MGRM would roll the stack over into the next near month contract, gradually decreasing the size of the position. Under this plan the total long position in the stack would always match the short position remaining due under the supply contracts. As of September 1993, the stack consisted of some 55 million barrels in futures on crude oil, heating oil, and gasoline, primarily in the near or next month contract, and a portfolio of similarly short-dated over-the-counter swap contracts bringing the total hedge to the full 154 million barrels of delivery obligated under the supply contracts. MGRM thus had a hedge ratio of one-to-one.[4]

MISMATCHED MATURITY IN THE HEDGE

The distinctive characteristic of this strategy is that MGRM was running a hedge with a maturity structure that did not match that of its delivery contracts. This had two critical consequences. First, it significantly *increased* the variance of the firm's cash flow at the outset of the strategy, making it vulnerable to an enormous liquidity crisis—exactly the opposite of what one would expect from a well designed hedging strategy. Second, it exposed the firm to an excessive amount of basis risk—variations in the value of the short-dated futures positions not compensated by equal and opposite variations in the value of the long-dated delivery obligations—so that the rolling stack had not actually succeeded in locking-in the value of the delivery contracts. We illustrate these two problems in turn.

Cash Flow Trouble with a Short-dated Hedge

A rolling stack of short-dated futures initially increases the variance of cash flow because movements in the price of oil within the month create losses or gains on the entire stack of contracts—losses or gains that must be settled by the end of the month—while compensating gains or losses on deliveries are realized only gradually over the remaining ten years of the delivery contract. We illustrate this danger with an example in Table 1.[5]

To see the effect of an oil price decrease on current cash flow, look at May, the second month of the contract. A $0.71/bbl. drop in the price of oil from $20.22 to $19.51/bbl. creates realized losses of $139 million on the more than 152 million barrels of futures contracts outstanding going into the month, while only raising realized gains on the month's deliveries of oil by $900,000, a 154-to-1 ratio of losses to gains.[6] In November and December, the eighth and ninth months of the contracts, the consecutive oil price drops create realized losses on the futures portfolio of $235 and $381 million, respectively, while raising realized gains on the monthly deliveries by only $2 and $3.1 million. The cash flow deficit grows monthly, so that at the end of the year it is just over $1.17 billion.[7]

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3. Attention to the customer's particular circumstances is key in valuing these options. To see why, notice that under the terms of the *firm-fixed* contracts the customer would forgo half the amount by which the contract was in the money. Therefore the customer has a significant disincentive to exercising the option except as their own liquidity needs outweigh the capital loss involved. The actual duration of MGRM's forward obligation is therefore highly variable and, due to its dependence on the customer's circumstances, difficult to anticipate. Note, moreover, that the duration may be either shorter or *longer* than that of an annuity since under the flexible contracts the customer had the right to delay taking deliveries until it believed spot prices put its option in the money.

In mid-1993 MGRM succeeded in renegotiating the terms of the option in a little more than half of the *firm-fixed* contracts so that cash settlement would occur automatically once the near-month futures price reached a certain level. The customers received a concession on the delivery price in exchange for losing this option.

4. The full details of MGRM's trading were more complicated than this simple characterization. For example, since some customers could alter the delivery schedule and since the options in the supply contracts allowed the buyer to advance maturity of the contract it was envisioned that the quantity of futures contracts rolled over might change to match the changing quantity of short positions retired. Moreover, MGRM maintained a long position in a variety of contract months, not only the near-month contract, and had flexibility to alter the exact maturity structure of its stack. Finally, MGRM shifted its position among different oil products independently of the products shorted under the delivery contracts. For full details of the actual positions see the special auditors report previously cited and court documents in *W. Arthur Benson v. Metallgesellschaft Corp. et al.*, Civ. Act. No. JFM-94-484, U.S. District Court for the District of Maryland, 1994. Also relevant is MGRM's own *Policy and Procedures Manual*, 1992, although its trades were not always faithful to these guidelines.

5. The example is a simplified version of what happened to MGRM since we have assumed that all of the contracts were signed in March of 1993 and that the rolling stack consists entirely of near month crude oil futures contracts. The actual losses as reported by the special auditors differ modestly in timing.

6. Of course it is not just the monthly variation in the spot price that determines MGRM's losses on its futures stack. What matters is the monthly realization of the spot price relative to the futures price at which the position was opened, i.e., how the entire term structure of oil prices moves from month to month. In 1993 this movement was characterized both by a marked fall in the spot price and a persistent contango. It is the combination that yields the exact cash flow consequences for MGRM.

7. The realized losses on the rolling stack detailed in Table 1 do not include the cash contributions necessary to meet margin calls and so significantly understate the cash flow deficit created by a rolling stack.

TABLE 1 ■ CASH FLOW DEFICIT CREATED BY A MATURITY MISMATCHED HEDGE

			Supply Contracts		Futures Stack		Net Position	
Month (A)	Near Month Futures Price ($/bbl) (B)	Next Month Futures Price ($/bbl) (C)	Deliveries (million bbl) (D)	Net Receipts ($ million) (E)	Size of Stack (million bbl) (F)	Monthly Settlement ($ million) (G)	Net Cash Flow ($ million) (H)	Accumulated Net Cash Flow ($ million) (I)
March	20.16	20.30	0.00	0.0	154.0	0.0	0.0	0.0
April	20.22	20.42	1.28	1.0	152.7	(12.3)	(11.3)	(11.3)
May	19.51	19.83	1.28	1.9	151.4	(139.0)	(137.1)	(148.4)
June	18.58	18.90	1.28	3.1	150.2	(189.3)	(186.2)	(334.6)
July	17.67	17.92	1.28	4.3	148.9	(184.7)	(180.4)	(515.0)
August	17.86	18.30	1.28	4.0	147.6	(8.9)	(4.9)	(519.9)
September	16.86	17.24	1.28	5.3	146.3	(212.5)	(207.2)	(727.1)
October	18.27	18.38	1.28	3.5	145.0	150.7	154.2	(572.9)
November	16.76	17.06	1.28	5.4	143.7	(234.9)	(229.5)	(802.4)
December	14.41	14.80	1.28	8.5	142.5	(380.9)	(372.4)	(1,174.8)

(B) As the maturity of the near month futures price approaches, this price becomes a proxy for the prevailing spot price. This is the price it will cost to supply monthly delivery requirements and the price at which the stack of futures will be closed out.
(C) This is the price at which the stack of futures contracts will be rolled over into the next month.
(D) Monthly deliveries equal the total initial position divided by 120 months, 154m.bbl./120 months.
(E) Monthly profit on the supply contract equals the difference between the contract delivery price—constant at $21/bbl—and the prevailing settlement price on the near month futures contract shown in column (B), multiplied by the volume of deliveries shown in column (D): E=[21–B]*D.
(F) The initial long position is 154 million barrels. It declines monthly by the volume of deliveries under the supply contract.
(G) Settlement on the futures position equals the price on the near month futures contract shown in column (B) less the price prevailing the month before when the position was opened and shown in column (C), multiplied by the number of contracts held at the start of the month shown in column F: $G=[B_t-C_{t-1}]*F_{t-1}$.
(H) Net cash flow is the sum of profits on the deliveries under the supply contract and settlement of the futures contracts: H=E+G.
(G) Accumulated net cash flow is the sum of all the net cash flow for prior months: $I_t=I_{t-1}+H_t$.

The danger of this type of cash flow problem is all too often overlooked. Recommendations for designing a good hedge too often focus exclusively on reducing variance in the total value of the firm's projects and underplay the consequences that different hedges have for variability and timing of cash flow. But often the firm's very reason for hedging is to assure a positive cash flow so that it can fund upcoming investments without turning to external sources for additional financing.[8] The strategic motivation for hedging should determine the choice of tactics, the choice of hedging instruments, but this simple fact is too often overlooked.[9] Even if a rolling stack of short-dated futures could help to lock in the total value of the long-term delivery contracts, the fact that it increases the initial variability of the firm's cash flow so significantly can make it a worse than useless hedging strategy.

Metallgesellschaft clearly needed to pay attention to cash flow. MGRM's parent corporation was facing a long-term liquidity crisis of its own and could not afford to finance cash shortfalls at its subsidiary. A series of expansions in the late 1980s and early 1990s had cost the company dearly and had not yet paid off as expected. Between 1989 and 1992, the company's fixed assets rose from DM 2.124 billion to DM 6.617 billion. During the same period, its reported return on capital fell from 13.1% to 6.7%, and its actual return had probably fallen further still. MG's accumulated cash flow deficit between 1988 and 1993 ran to DM 5.65 billion and was financed with a DM 4.44 billion increase in net debt and three equity issues yielding DM 1.21 billion. The U.S. subsidiary had also been forced to raise capital through a public sale of stock in Castle Energy. By 1993 the parent corporation was forced to turn to asset sales as a tool for continued financing of its central lines of business. Employment fell between 1992 and 1993 from 62,547 to 43,292. The company had already cut its dividend and was considering

8. See Kenneth Froot, David Scharfstein and Jeremy Stein, "Risk Management: Coordinating Corporate Investment and Financing Policies," *Journal of Finance*, December 1993.

9. We have made this point elsewhere in Antonio Mello, John Parsons and Alexander Triantis, "An Integrated Model of Multinational Flexibility and Financial Hedging," forthcoming in the *Journal of International Economics*.

TABLE 2
EX ANTE VALUATION OF CONTRACTS UNHEDGED AND HEDGED WITH A RUNNING STACK*

INPUTS TO SIMULATION MODEL:	
■ Duration of contract	10 years
■ Total delivery obligation	150 million bbl.
■ Monthly delivery	1.25 million bbl.
■ Fixed contract delivery price	$20/bbl
■ Cost of delivery	$2/bbl.
■ Initial spot price of oil	$17/bbl
■ Annual interest rate	7%
■ Annual convenience yield less cost of storage	7%
■ COST OF EXTERNAL FINANCING:	
$1 million/month	0 basis points
$10 million/month	0.2 basis points
$50 million/month	2.2 basis points
RESULTS:	
■ Present value of contract	$63.6 million
■ Cost of financing, unhedged	$ 4.4 million
■ Net value of contract, unhedged	$59.2 million
■ Cost of financing, rolling stack	$28.5 million
■ Net value of contract, rolling stack	$35.1 million

*Value estimates are derived using a standard contingent claims model to price commodity-related assets and related hedges: see M. Brennan and E. Schwartz, 1985, "Evaluating Natural Resource Investments," *Journal of Business*, 58:135-157.

omitting the next dividend entirely. In light of these circumstances, the parent corporation had recently announced that its subsidiaries were to be independent profit centers and could not expect to be easily financed by the parent company.

MGRM's foray into the oil trading business emerges, then, as a singularly bad fit for the parent corporation in its current circumstances. Just when the parent corporation was faced with low cash flow and a weak balance sheet, its U.S. subsidiary embarked on a business plan that involved functioning as a financial intermediary to independent oil retailers. MGRM's strategy was based upon its readiness to assume the oil price risk that independent operators would otherwise be forced to bear, but MG itself could not afford to shoulder the risk. MGRM might have tried to offload this risk in a number of ways—for example, by selling the contracts and taking its profit in the form of an origination fee. Or it might have managed the risk using a hedge that was the mirror image of its short obligation.[10] By choosing a hedge of short-dated futures contracts, however, MGRM actually exacerbated the problem, increasing the total risk of a large negative cash flow in the near term.

When cash flows matter, the rolling stack may be worse than no hedge at all, as we now illustrate. To evaluate the full effects of the rolling stack hedge under a wide variety of possible spot price paths, not just the extremely unfavorable one occurring in 1993, we constructed a simulation model of MGRM's financial condition for the life of the delivery contracts.

The inputs to the model are displayed in Table 2 along with the results. MGRM is assumed to have a contract obligation to deliver 150 million barrels of oil products over a period of 10 years, or 1.25 million barrels a month. The contract delivery price is $20/bbl, and MGRM has a cost of making delivery equal to $2/bbl, yielding a net price of $18/bbl. MGRM buys oil at the prevailing spot price, which starts at

10. Constructing a mirror-image hedge of a forward contract can be difficult. The mark-to-market feature of futures makes it difficult to use them to exactly match the maturity of a forward delivery obligation even when, as in the case of a strip, the nominal maturity is the same. Because settlement of the futures occurs continuously, cash flows resulting from price movements are paid out earlier than under a forward obligation with nominally identical maturity. In any case, due to the long maturity of MGRM's forward commitments an appropriate strip of exchange traded futures was not feasible. MGRM could have used the OTC market to construct an instrument with appropriate maturity. The OTC market makes it possible to custom design an instrument to mirror the maturity structure of the delivery obligations inclusive of the options.

$17/bbl and which for any horizon is expected to be 17/bbl, but which may vary from month to month with an annual variance of 12%. The rate of interest is 7%. Under these assumptions, the contract for long-term delivery of oil has a value of $10 million.

The contract is, however, very risky. For example, should the price of oil rise to $21, then MGRM would have a monthly cash flow deficit of $3.25 million.

Our assumption about the cost paid by MGRM if it has a sudden cash shortfall requiring external financing is also detailed in Table 2. The cost increases with the amount of financing required. Because of this cost, a constant low-risk cash flow is more beneficial to MGRM than the risky cash flow. Running our simulation model with this cost incorporated, we find that the value to MGRM of the unhedged contract declines to $9.86 million. The cost of external financing reduces the value of the contract by $0.74 million.

When a rolling stack with a one-to-one hedge ratio is included in our simulation model, the results are striking. The costs of external financing *increase* dramatically, to $4.75 million, so that the value of the contract hedged with a rolling stack is actually less than the value of the contract unhedged!

It was exactly a liquidity crisis like the one described in Table 1 that precipitated Metallgesellschaft's brush with bankruptcy. MGRM had been losing money on its futures position throughout 1993. The consequences had already been felt within the U.S. subsidiary by the end of the summer as the firm's credit lines were used up and, for example, traders in the emerging markets group were unable to find counterparties for some of their swap transactions. When the oil price fell yet more precipitously at the end of the year, the company did not have sufficient cash to continue rolling over its stack of oil futures contracts as planned and could not meet a large number of its other obligations until it received an emergency line of credit from its bankers.

Losses eventually totaled nearly $1.3 billion. By January the firm was close to declaring bankruptcy and its future was not clear. MG eventually negotiated a $1.9 billion bailout from its bankers in tandem with a plan to shed assets such as its auto parts manufacturing business, its tin mining operations, its recently acquired heating equipment, stainless steel, and boiler making lines, and others. MG was also forced to scale back a number of its central businesses, cutting employment in these businesses by more than 7,500 and reducing planned capital outlays by one-half, to a level below depreciation. The company has also since withdrawn from its lead position in the construction of a new copper smelter in Indonesia.

In short, the cumulative effect of the original trading losses and the firm's bankruptcy has been severe. The price of a share fell by half, from a high of DM 427 ($246) in November 1993, prior to news of the oil trading losses, to DM 216 ($125) in February 1994, after the rescue plan was organized.

Was the Firm Value-Hedged?

MGRM's management tried to downplay the significance of the liquidity crisis, arguing that it was *merely* a liquidity crisis and that the cash losses on the stack of futures were matched by an increase in the value of the supply contracts: the drop in oil prices that created losses on the stack of futures would mean a lower cost of meeting future delivery requirements under the long-term supply contracts. Summed over the life of the contract, the extra profits earned on future deliveries would exactly match the initial losses on the stack of futures. So although the firm faced a short-run liquidity crisis like the one illustrated in Table 1, the value of its total assets, they claimed, had not actually declined and so the firm was solvent.[11] MG's financial crisis, however, was more than just a liquidity crisis. The losses on its future contracts were real; it is simply not true that these losses were matched by an equivalent increase in the value of the supply contracts.

MGRM hedged its long-run delivery commitments with an equal number of futures contracts. While this one-to-one hedge portfolio appears sensible, it was not. This brings us to the second problem with a hedge portfolio of mismatched maturity structure: basis risk. One barrel of oil for delivery in

11. MG's liquidity crisis was never *merely* a liquidity crisis. Even if the firm were solvent and merely needed a cash infusion, a liquidity crisis itself can create real costs. MG had a large number of bankers, and while this may seem advantageous, the question of who shall provide the extra financing and with what seniority relative to the preexisting debt obligations opens up a Pandora's box of maneuvering and negotiation, all of which may impose dead weight losses on the firm. And while one may be critical of the bankers for engaging in such conduct, one should also be critical of the management for not anticipating these kinds of problems in its design of the hedge. It is no use complaining about the costs that arise in going to the market for external funds when the very purpose of the hedge should be to avoid this necessity in the first place!

TABLE 3
RELATIONSHIP BETWEEN THE CHANGING OIL PRICE AND THE VALUE OF FORWARD DELIVERY COMMITMENTS

Time Forward to Delivery	First Derivative of Present Value with Respect to Spot Price	Time Forward to Delivery	First Derivative of Present Value with Respect to Spot Price
1 month	0.991	5 years	0.520
6 months	0.941	6 years	0.454
12 months	0.884	7 years	0.398
2 years	0.776	8 years	0.348
3 years	0.678	9 years	0.304
4 years	0.594	10 years	0.266

Based on data in Rajna Gibson and Eduardo Schwartz, 1990, "Stochastic Convenience Yield and the Pricing of Oil Contingent Claims," *Journal of Finance*, 45:959-976.

one month is simply not equal in present value to one barrel of oil for delivery in ten years, and the value of the two differently dated obligations do not move in lock step. In general, spot prices are more variable than futures prices, and a one dollar fall in the current spot price of oil implies a smaller change in the expected price of oil anytime in the future. As a result, it is unlikely that a drop in the current price of oil creates gains on the delivery contracts that match in present value terms the losses incurred on the stack of short-dated futures.[12]

To illustrate the effect that this has on MGRM's net position, we have provided in Table 3 some reasonable estimates for the present value factors relating a $1 movement in the prevailing spot price of oil with the change in expected value of forward contracts for oil at different dates. While a $1 increase in the spot price of oil would increase the expected value of a 6-month forward contract by $0.941, it would increase the expected value of a 5-year forward obligation by only $0.520 or approximately one-half. A ten-year forward obligation would increase by only $0.266. These estimates make clear that there may be variation in the spot price that changes the value of the stack of short-dated futures without a comparable offsetting movement in the expected value of the long-dated delivery contracts.[13]

In Table 4 we calculate how the value of the outstanding contracts may have changed as the spot price fell during 1993: calculations are based on the factor estimates given in Table 3. In May, with 151.4 million barrels of oil to be delivered over a little less than ten years, and with a $0.71 drop in the price of oil, the present value of the outstanding delivery obligation increases by 56% of the changed cost of supply—that is, by $60.24 million, an amount far less than the $139 million loss on the futures portfolio in the same month. The cumulative increase in the value of the delivery contracts during 1993 was $479 million, less than one-half the losses on the futures portfolio.

A comparison of the monthly losses on the futures portfolio in 1993 against the monthly realized and unrealized income on the delivery contracts is shown in Figure 1. The cumulative loss for 1993, net of unrealized increases in the value of the delivery contracts, is more than $695 million.

The situation described in these tables is a generous picture of what actually befell MGRM. Oil prices dropped in late 1993 due to conflicts within OPEC that temporarily added supplies onto the market. The expectation of the long-term spot price 3, 4 and 5 years out was largely unchanged so that the losses on the stack of futures were actually matched by little if any change in the capitalized value of the supply contracts.

Because of basis risk, if one is committed to using a stack of short-dated futures contracts, then it is necessary to use a hedge ratio much smaller than MGRM's one-to-one hedge. A comparison of the

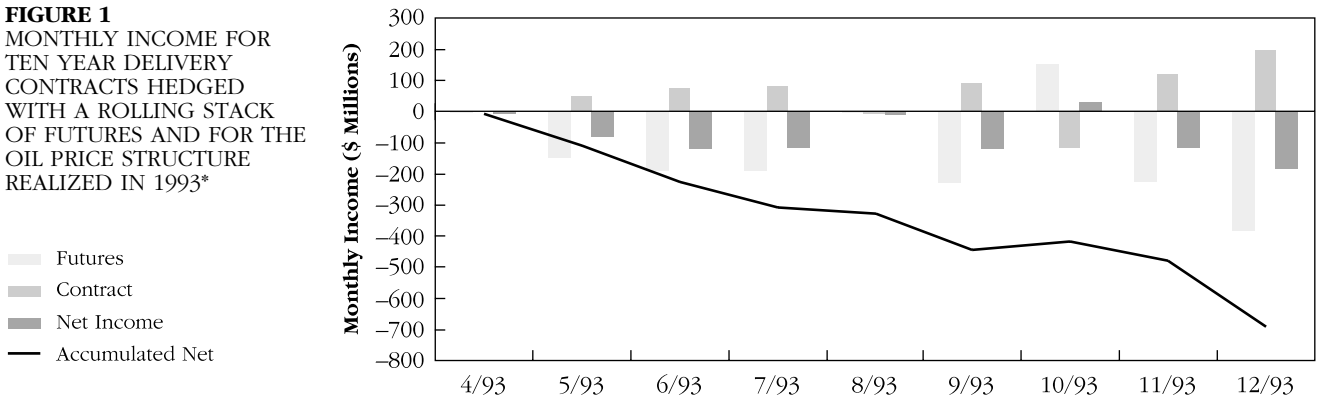
12. For data on oil see Rajna Gibson and Eduardo Schwartz, 1990, "Stochastic Convenience Yield and the Pricing of Oil Contingent Claims," *Journal of Finance*, 45:959-976, and Rajna Gibson and Eduardo Schwartz, "Valuation of Long Term Oil-Linked Assets," in *Stochastic Models and Option Values*, D. Lund and B. Kendal, eds., Amsterdam:North-Holland, 1991, 73-101, and also Franklin Edwards and Michael Canter, "The Collapse of Metallgesellschaft: Unhedgeable Risks, Poor Hedging Strategy, or Just Bad Luck?," forthcoming in *The Journal of Futures Markets*, 15(3), May 1995. For data on other commodities see E. Fama and K. French, "Business Cycles and the Behavior of Metals Prices," *Journal of Finance*, 43:1075-1094.

13. The present value factors shown in Table 3 provide only a rough order of magnitude for the relationship being estimated. The values shown were derived at a particular historical period and are only the local change in value for a small change in price. A detailed calculation is beyond the scope of this paper.

TABLE 4
UNREALIZED GAINS ON THE DELIVERY CONTRACTS BASED ON MONTHLY PRICE CHANGES IN 1993

Month	Outstanding Delivery Obligation (million bbl.)	Monthly Price Change ($/bbl.)	Present Value Factor for Remaining Deliveries	Total Change in Contract Value ($ million)
March	154.0	0.00	0.56	0.00
April	152.7	0.06	0.56	(5.11)
May	151.4	(0.71)	0.56	60.24
June	150.2	(0.93)	0.56	78.59
July	148.9	(0.91)	0.57	76.57
August	147.6	0.19	0.57	(15.92)
September	146.3	(1.00)	0.57	83.43
October	145.0	1.41	0.57	(117.12)
November	143.7	(1.51)	0.58	124.87
December	142.5	(2.35)	0.58	193.45
TOTAL				478.99

FIGURE 1
MONTHLY INCOME FOR TEN YEAR DELIVERY CONTRACTS HEDGED WITH A ROLLING STACK OF FUTURES AND FOR THE OIL PRICE STRUCTURE REALIZED IN 1993*



*Income on the futures portfolio is realized profits or losses. Income on the contracts is the sum of realized income on deliveries plus unrealized capital gains on outstanding deliveries as calculated in Table 4.

minimum variance hedge against the one-to-one hedge run by MGRM over the ten-years of the program is presented in Table 5. Two alternative minimum variance hedge calculations are shown, corresponding to alternative assumptions about the underlying delivery contracts being hedged. Using the present value factors shown in Table 3, the minimum variance hedge ratio (A) for a ten-year monthly annuity of oil deliveries is about .56; and, so, to cover 154 million barrels in delivery over 10 years would initially require a stack of only about 86 million barrels.

Revising the minimum variance hedge ratio to incorporate the effect of the cash-out options is technically quite difficult, but we have made an illustrative calculation based on the assumption that the contracts were all to be cashed out at the end of the third year, the horizon assumed by MGRM's management. This calculation yields the second minimum variance hedge ratio, ratio B, in which the firm's optimal stack is still only 87.3 million bbl at the outset.[14]

There are additional reasons to believe that the long-term contracts had not increased in value

14. These two simple hedge ratio calculations have been made for ease of exposition. The proper ratio incorporating the options can be calculated using the appropriate differential equations as shown in Gibson and Schwartz (1990), previously cited. In recognizing the cash out option it is important to remember that customers holding the firm-fixed contracts would forego half of the profit on the contract should they call. MGRM's exposure, therefore, to the volume called is only one-half the nominal volume and it should hold maximally a one-to-two ratio of futures to deliveries to cover this exposure.

TABLE 5 ■ A COMPARISON OF THE ONE-FOR-ONE HEDGE WITH THE MINIMUM VARIANCE HEDGE UNDER ALTERNATIVE ASSUMPTIONS

Year	One-for-one Hedge (million bbl)	Minimum Variance Hedge of a Ten-year Annuity of Forward Deliveries (million bbl)	Hedge Ratio	Minimum Variance Hedge Assuming Option Exercise at Year 3 (million bbl)	Hedge Ratio
0	154.0	85.5	0.56	87.3	0.57
1	138.6	81.2	0.59	83.1	0.60
2	123.2	76.2	0.62	78.2	0.63
3	107.8	70.5	0.65	72.2	0.67
4	92.4	64.0	0.69		
5	77.0	56.5	0.73		
6	61.6	48.0	0.78		
7	46.2	38.3	0.83		
8	30.8	27.1	0.88		
9	15.4	14.4	0.94		
10	0.0	0.0	1.00		

as much as the stack of futures had lost value. The risk of default by some of the independent operators was great and naturally increasing as the price of oil fell. In valuing the supply contracts it is necessary to take into account the high probability of default or renegotiation in the shadow of possible future defaults. Renegotiation is a very common event for fixed-price delivery contracts, as distinguished from the sort of financial forward contracts financial economists are used to valuing and as opposed to the futures contracts used to hedge the supply obligation.

MGRM's management was aware of the danger that fixed-price terms designed to benefit the retailers on one side of spot price movements could hurt those same retailers on the other side, and it had placed limits on the quantity of oil products provided to each retailer under the contract specifically to minimize the danger of just this sort of default or renegotiation problem. But however intelligently the program was designed, some significant risk of renegotiation or non-performance remained, and it is essential to factor this in when estimating the true value of MGRM's short exposure.[15] This extra default risk on the supply contracts means that a drop in oil prices does not create a one-to-one increase in the value of the contracts to match the drop in the value of the futures.

MGRM's choice of maturity structure for its hedge produced enormous deadweight costs on the firm. These costs could have been avoided with a smaller hedge ratio or using a hedge with a better matched maturity structure. But is the issue here really the right hedge for the delivery contracts? In fact, analyzing the stack of futures as a hedge has been a little misleading as we shall now see.

HEDGING OR SPECULATION

If our preceding analysis is correct, it leaves us with some puzzling questions. Why did management choose a hedge with a mismatched maturity structure? And why did management run such a large stack? The answers are revealing of the depth of the problems at MGRM, and they give us some insight to the questions raised above about the valuation of the delivery contracts themselves.

Far from being simply a hedge meant to lock in profits generated by the long-term delivery contracts, the rolling stack itself was intended by MGRM management to be a source of profits. The company's business plan reads:

As is well documented in standard textbooks, a hedge is said to be perfect when the gain (or loss) in the cash market is totally offset by the loss (or gain) in

15. MGRM's accountants, Arthur Andersen, had always recognized the possibility of defaults, adding to reserves against this possibility. After the adverse price movements in 1993 KPMG suggested that this reserve might need to be increased. See "Draft Report on Handelsbilanz II Financial Statements," KPMG, January 14, 1994.

the futures market. However, it is important to recognize that if a hedge program is carefully designed to "lock in" a favorable basis between spot and futures prices at the most advantageous time, hedging can generate trading profits which can substantially enhance the operating margin. Our proposed risk management program, discussed below, not only protects the pump profit margins with a minimum amount of risk from the spot market, but also offers us an opportunity for extraordinary upside profit with no additional risk. (2, p.2)

Locking in return was clearly only one part of MGRM's motivation for buying the futures contracts. The second part was speculation. Management believed that prices on a wide variety of oil-related derivatives often deviated from fundamentals and that profits could be made with the right trades. MGRM's management had identified a long list of mispricings, and a large part of their time was spent analyzing market data in order to quickly recognize others as they might arise. Far from being simply a subordinate element of MGRM's general business strategy, we believe that MGRM's overall position in oil-related derivatives was driven more by its own belief that these financial instruments were mispriced than by a need for hedging its underlying activity in the cash markets—the tail wagging the dog, so to speak.

In evaluating a portfolio of futures contracts as a hedge, one should generally assume that the prevailing price structure is "fair," so that the contracts themselves have zero net present value. The benefit of the contracts should not be in the value they yield directly to the company, but in whether they succeed in locking in the value of the company's underlying business. One hedge is better than another, not because the particular instruments used are priced more favorably, but because the instruments provide a better lock on profits being earned elsewhere.

MGRM did not make the key assumption of fair market prices in choosing its hedge. As the previous quote indicates, MGRM's management believed that a good hedge can create value because the prevailing market prices are not fair. The prevailing prices for long-dated oil instruments, they believed, were too high relative to the prevailing pattern of prices for short-dated oil. According to their estimates, the second component of the business as described above, the speculation on the basis, had a positive value. Moreover, MGRM chose not to hedge the delivery contracts with long-dated instruments precisely because management felt that the prevailing price structure for those instruments was too high: i.e., the first component of the business as described above, the delivery contracts cum long-dated hedge, had a negative net present value.

In sum, MGRM's management wanted to sell the long-dated instruments and buy the short-dated ones. Thinking of the short-dated contracts as MGRM's hedge of its delivery contracts has the situation turned on its head. In fact, it was the favorable returns MGRM imagined to be available on short-dated futures that gave a value to a business of signing up customers for long-term delivery contracts. The following passage from its business plan illustrates how this way of thinking worked at MGRM:

Even if we do not have a 10-year forward product in place, *we still should take advantage of the pricing inefficiency between the spot crude market and the crude oil reserves market. Using the data from the previous section, when the spot crude oil prices rose to $44, the 18-month forward was only at $28, and the reserves were valued at $6.25. With this kind of price scenario, we should look into buying crude oil reserves and selling crude oil swaps.* (1, p. 7, emphasis added)

Backwardation and Profiting from the Roll

What was the source of the favorable returns on short-dated oil futures? The rolling stack was a bet placed by MGRM management on the persistent backwardation that arises in the oil market. Buying a near-month futures contract when the market is in backwardation means buying at a price low relative to the prevailing spot. Assuming that the prevailing spot price remains constant, then as the contract matures and the futures price increases to the spot the position makes a profit.

MGRM's front-to-back hedging strategy was designed to reap this anticipated "roll return". It is because MGRM viewed this anticipated monthly return as an extra profit, unrelated to the need to hedge its delivery commitments, that it was not reluctant to run an excessively large stack. MGRM planned to maximize the return from backwardation by timing the placement of its hedges in different months and commodities. During the winter months, approximately November through March, the fu-

tures price for heating oil is generally below the spot price and the market exhibits backwardation, moving closer to a cost-of-carry relationship during the summer months. The opposite seasonal pattern arises for gasoline. MGRM believed it could make extra profit by exploiting the cyclical nature of the backwardation:

It is during these off-seasons or weak periods that we have to secure this negative refinery economics. With the existence of the energy futures market, we can create a "paper refinery" which can produce oil products from $1.25 to $1.50 per barrel cheaper than a standard $800 million oil company refinery, by taking advantage of the inefficiencies *created in the illiquid distant contract months in the futures market.* (2, pp. 2-3, emphasis added) *This profit is made possible as the 12-month spreads are established at the most advantageous level (i.e., taking advantage of the narrow backwardation when the gasoline market is weak) and continuously rolling forward to capture the market inefficiency whenever it occurs.* (2, p. 19)

It needs to be emphasized at this point that there may be good reasons why markets for oil products move into backwardation and of course why they do so in a cyclical fashion. If the seasonal swing in gasoline and heating oil prices is an equilibrium reflective of the underlying fundamentals of supply and demand in the heating oil and gasoline markets, then it offers no special profit opportunities and no reason to run a front-to-back hedging strategy. The same is true for backwardation in oil in general.[16]

Although MGRM's management never did any appropriate estimations of the size of the basis risk, MGRM's management implicitly believed that the amount of backwardation was often too much to be accounted for by fundamentals and that a strategy of purchasing the near-month futures contract and rolling them over in each market during its period of backwardation would produce a profit on average. They based this belief on a simple simulation of the returns to a strategy of purchasing a one-month oil futures contract and rolling it over. Using the recent historical data, they found, the strategy would have made money.[17]

But such data has very little to do with identifying a good hedge and everything to do with identifying a good speculative investment strategy. The two are not at all the same thing! The fact that this strategy is open to any and all investors only serves to reinforce the point that it is an essentially speculative bet, not an argument for a hedging strategy being driven by MGRM's business in supplying the long-term market. In fact, a good number of Wall Street houses market their own commodity investment vehicles using return data on just such a strategy run over the same period of time.[18]

The profitability of the rolling stack of near-month contracts was central to MGRM's entire set of profit calculations. Had the long-term contracts been evaluated based upon a hedge with a longer maturity structure, their profitability would have disappeared. This fact helps to highlight the extent to which MGRM's very choice of business line was essentially a bet on the basis.

A rolling stack of near-month futures can be run for either hedging or for speculative purposes. Unravelling these two distinct motives is the key to drawing the right lessons from MG's financial crisis. We do not wish to argue with the speculative motive for rolling oil futures—although the mere fact that the strategy was good in the past is for us a rather weak argument. We are not taking a stand that this speculative investment was a bad one for any investor. MGRM's management took a position that the prevailing price structure in oil was not an equilibrium structure. There is clearly room for disagreement. Differences of opinion make a horse race and there will always be some investors willing to take either side of such a bet.

But while there is room for one to argue that a rolling stack of short-dated contracts is a good speculative investment, we think it is important to make a clear distinction between a good specula-

16. For an equilibrium model producing persistent backwardation, see Robert Litzenberger and Nir Rabinowitz, "Backwardation in Oil Futures Markets: Theory and Empirical Evidence," working paper, Wharton School, University of Pennsylvania, April 11, 1994. Of course, if futures prices are backwardated according to the predictions of this model, then a strategy of buying the futures contract does not yield a positive net present value when properly discounted to recognize its risk.

17. See especially the paper "MG Refining and Marketing Inc: Hedging Strategies Revisited" in *W. Arthur Benson v. Metallgesellschaft Corp. et al.*, Civ. Act. No. JFM-94-484, U.S. District Court for the District of Maryland, 1994.

18. See, for example, *The JPMCI—A Commodity Benchmark*, J.P. Morgan, September 20, 1994.

tive investment and a sound hedge. The short-dated contracts were not a sound hedge. In a very important sense they were not meant to be. The very fact that MGRM's management believed the short-dated stack was a good speculative investment undermines the argument that it was a good hedge. A speculative investment is a risky undertaking. But the hedge is supposed to reduce the corporation's risk. MG cannot be both hedging and speculating in the oil futures business. As MGRM added to its stack of near-month futures it was not trying to decrease its risk, contract by contract; it was trying to multiply its bet on backwardation, it was increasing the corporation's capital at risk, a different matter entirely.

MGRM's strategy document makes clear that the mechanical rolling stack described earlier is a stark oversimplification of MGRM's trading in the futures markets. MGRM planned from the beginning to shift its position among contract months for a given commodity as well as from commodity to commodity—gasoline to heating oil to crude—according to management's own beliefs about where profits were to be had. It was MGRM's readiness to speculate on a variety of perceived mispricings in oil derivatives that explains the many variations in their positions. MGRM's management had identified a long list of mispricings, and a large part of their time was spent analyzing market data in order to quickly recognize others as they might arise. MGRM was to operate as any other speculator in the financial markets, buying low and selling high.

How would management know which prices were "low" and which were "high"? MGRM developed what amounted to a traditional technician's trading system. For a first approximation, they modeled the historical experience in each of the markets and operated on the standard assumption that the price patterns of the past would mechanically extend into the future. Then, for improved profit performance they developed some mathematical signals to anticipate the peaks of cyclical price movements:

If we can take advantage of the market weakness in establishing the hedges, we should also make use of the strength of the market in taking off the hedges. For example, the maximum values for the inter-month spread are, respectively, 19.36, 21.84, 25.35 and 21.58 cents per gallon in 1986, 1987, 1988 and 1989. Therefore, instead of taking off the hedges ratably, it may be possible to take off the hedges at a much higher level, thus improving the profit margins. ...By liquidating the spreads at their peak or close to the peak, we are capturing the positive refinery economics in lifting our hedges without giving back any of the profit margin that a normal refinery would lose during its off-season low-demand period. Therefore, we need some reliable exit indicators to suggest an optimal time to take off the hedges. (2, p. 19)

The exit indicators chosen are embarrasingly old fashioned: they are the standard computational techniques for identifying a local maximum in a function and therefore rely heavily upon very questionable assumptions about the smoothly cyclical structure of commodity futures prices. In addition to modifying its basic running stack, MGRM's management conducted a number of so-called "arbitrages" otherwise completely unrelated to its basic delivery contracts. Members of the management team claimed that at least $25 million a month were made exploiting such transient arbitrage opportunities in addition to the longer-term mispricings that formed the core of MGRM's speculative strategy.

Once one investigates MGRM's actual transactions in futures and takes note of management's very clearly articulated belief that there were speculative profits to be had, the decision of the creditors to bring the operation under control is thrown into a different light. A speculation with one's own money is one thing, a speculation with the creditors' several billion dollars is another thing entirely. And while a speculation may properly be put onto the balance sheet of an appropriately capitalized investment house, the very same speculation does real damage on the balance sheet of an industrial corporation, especially one with a weak balance sheet. Adding a speculative financial investment to the balance sheet is the simplest, most obvious example of what is politely known as "the risk shifting game." Creditors quite wisely make great efforts to prevent such actions by the management.[19]

19. The agency problems to which we are referring here arise both between the shareholders and the creditors and between the subsidiary management and the shareholders. A good introduction to the problems of shareholder-creditor relations in general and the risk shifting game in particular is given in Brealey and Myers, *Principles of Corporate Finance*, Chapter 18, 4th edition, New York: McGraw Hill, 1991.

CONCLUSION

The case of Metallgesellschaft provides a wide array of lessons for businesses interested in properly hedging their exposure to various risks.

Taking MGRM's decision to provide long-term contracts for granted and focusing instead on the design of the hedge used to manage the risk of the business, one can use the Metallgesellschaft case to elucidate the importance of maturity structure in hedging as in every other product line of finance. A hedge with a mismatched maturity structure can create enormous funding risks. The case of Metallgesellschaft only reinforces the recommendations of the Group of Thirty that a corporation's position needs to be stress tested and evaluated against worst case scenarios. It is folly to put in place a seemingly innocuous hedge without careful regard for the possibly temporary but nevertheless large amount of financing it may require in the event of unfavorable price movements. If, as is often the case, the original reason for hedging is to avoid funding problems arising in the course of the firm's normal operations, then cash flow patterns ought to be the starting point and not an afterthought in the choice of hedging instruments. The maturity structure of a hedge is also central to the degree to which the firm's value is actually hedged; a mismatch in maturity structure means that the firm has assumed important risks.

The Metallgesellschaft case also illuminates the fine line that sometimes exists between hedging and speculating. The lingo of the derivatives industry and its relative novelty has allowed a number of speculative activities to be passed off as "risk management." MGRM's losses in late 1993 made this pretense no longer possible, and Metallgesellschaft's shareholders and creditors took the necessary remedial actions to limit the sorry consequences. MGRM's use of a one-for-one hedge of near-month futures looks superficially to be a straightforward purchase of insurance against capital gains and losses on its delivery contracts. In reality, the entire line of business was a bet on the basis, a bet on the roll return earned by the futures contracts in a backwardated market. Adding this bet onto the balance sheet of a major industrial corporation was a disastrous mistake. Recognizing the bets implicit in a variety of hedging strategies requires careful attention. As the Metallgesellschaft case illustrates, the stakes can be high.

REPLY TO CULP AND MILLER

MGRM's strategy has received support in a recent paper by Christopher Culp and Merton Miller, "Metallgesellschaft and the Economics of Synthetic Storage," which appeared in the previous issue of this journal (Winter 1995). Since our analysis of Metallgesellschaft's debacle differs significantly from theirs, we sketch here the main points of agreement and differences between the two papers. The areas of agreement are much greater than might be supposed, given the large degree of public controversy surrounding the case.

First, there is agreement that using a rolling stack to hedge a flow of deliveries may produce temporarily large negative cash flows. The warnings of the Group of Thirty regarding potential funding risks and the need for thorough stress tests of any derivative strategy should be kept in mind when considering the rolling stack. There is also agreement that the cash flow losses in the case of Metallgesellschaft were quite large. Culp and Miller estimate $650 million from price declines and another $250 million due to rollover costs, for a total cash flow loss on the futures leg of the transaction of $900 million. In our Table 1 we estimated $1.17 billion. The special auditors calculated losses on the futures and OTC swaps portfolios at $413 million by the end of September 1993 and at over $1.276 billion by the end of December. MGRM's original management had estimated losses on the rolling stack of $434 million through September, prior to the spectacular price drop in November and December. The differences among all of these estimates is small relative to the range in which all of the estimates lie and given the assumptions buried in each of the calculations. $900 million is a large cash flow deficit to finance in a single calendar year.

Second, there is agreement that the rolling stack with a one-to-one hedge ratio leaves a firm exposed to basis risk. This shows up in Culp and Miller's Table 1 as an increase in the net cost of carry (the rollover costs) and therefore a divergence between the anticipated contract income and the realized cash flow or income. Culp and Miller break the firm's risks down into two components, spot price risk and rollover risk, and they emphasize that the rolling stack fully hedges the firm against the spot price risk. We, on the other hand, emphasize that in hedging the firm fully against spot price risk, the rolling stack leaves the firm very exposed to rollover risk.

There also appears to be growing agreement that this basis risk was large for MGRM. Elsewhere Culp and Miller recently estimated that oil price movements in 1993 increased rollover costs by $620 million—an increase of $250 million in realized rollover costs in 1993 and of $370 million in expected future rollover costs.[20] This $620 million figure is very close to our own estimate of a $695 net loss on MGRM's contract and futures positions.[21]

Both the firm's exposure to funding risk and its exposure to basis risk are a result of its choice of a hedge with a mismatched maturity structure. In another paper we have used Culp and Miller's own illustrative example of "synthetic storage" and shown that a firm that had hedged using a maturity matched strip of futures instead of a stack would have been exposed to less variation in the timing of its cash flows, and would have completely hedged the basis risk.[22] The contrast between the strip and the stack makes clear that it was MGRM's use of a stack of short-dated futures contracts to hedge a set of long-dated delivery obligations that opened the door to the losses incurred in 1993.

Although both sides seem to agree that MGRM was exposed to significant funding and basis risk, there is disagreement about whether these risks undermined the business plan from the start. Naturally this disagreement carries over to a different assessment about how the parent corporation responded when these risks became apparent at the end of 1993. We believe that the business plan and hedging strategy were essentially and significantly flawed. Culp and Miller, on the other hand, believe the delivery contracts were valuable and that the funding risk and basis risk mentioned above were worth the bet. Correspondingly, we believe it was appropriate to try and close down as much of MGRM's activities as possible in December 1993, even at certain costs, while Culp and Miller believe it was still valuable and closing it down merely dissipated this value. Since we have already made our case, we turn to a few particulars of this dispute.

We think Culp and Miller play down the funding risk too much and lean far too much on the idea that MG's creditors and shareholders should have readily coughed up extra cash. Culp and Miller have argued in the abstract that MG *could not* have really faced a liquidity constraint, except as Deutsche Bank and others foolishly chose not to continue financing the oil business. But we have documented in fact that Metallgesellschaft faced a liquidity crunch *prior* to MGRM's huge losses at the end of 1993, and that it took a variety of actions consistent with this fact both before the futures trading crisis and afterwards: for example, it was forced both times to sell other assets in order to improve liquidity. Speaking of Deutsche Bank as if it had unlimited pockets is simply not facing up to the real-world constraints that had already been evidenced. We believe that cash flow mattered for Metallgesellscaft and MGRM management should have paid attention to funding risks in its choice of maturity structure of its hedge or, alternatively, in its decision to pursue the entire strategy of operating as a financial intermediary.

Culp and Miller believe that MG's pre-existing relationships with many banks should have made it possible to survive a brief liquidity crisis had the company remained behind the basic strategy. We note, on the other hand, that a plethora of creditors, each with a different stake in the firm and different circumstances of its own, can in some cases ensure deadlock should the firm have to negotiate additional financing or a restructuring of debt. It is management's job to design a hedge precisely to avoid the dangers inherent in such a process.

Culp and Miller believe that the funding risks at hand were obvious, that "you don't have to be a rocket scientist" to see the possible cash drains. But if one assumes away the possibility that management made a mistake—as this argument does—then one can never learn from the mistakes management actually makes. We think that the possible cash flow drains were ignored, rocket scientists or not. We have seen nothing in the documentary record at

20. Christopher Culp and Merton Miller, "Auditing the MG Shareholders' Audit," *Risk*, v. 8, n. 4 (April 1995).

21. Curiously, in their paper that appeared in the *Journal of Applied Corporate Finance*, Culp and Miller give the impression that basis risk is a relatively minor issue, referencing their own estimates of the high correlation between spot and front month futures prices. Despite the impression raised that these correlation figures are high, in fact, they are consistent with the data we referenced and used to construct Table 3, 4 and 5. For example, Culp and Miller focus on the basis risk within one month and find R2 values of 0.99 for crude oil, 0.96 for heating oil, and 0.95 for gasoline, while the factor we used to relate a $1 change in the prevailing spot price to the change in the expected value of a one-month forward delivery obligation was 0.991, relatively close. And as the time to maturity of the forward obligation increases, the effect of imperfect correlation within any single month is compounded, yielding the other factors shown in Table 3 of our paper. The one month correlation data in Culp and Miller's paper therefore appear perfectly consistent with our estimates of $650 million net loss due to basis risk. This fact seems to be borne out by Culp and Miller's own later estimate of the total change in rollover costs, which appeared in their *Risk* magazine article.

22. Antonio Mello and John Parsons, "Hedging a Flow of Commodity Deliveries with Futures: Problems with a Rolling Stack," forthcoming in *Derivatives Quarterly*, Fall 1995.

MGRM to suggest that they had done any "worst case" simulation. On the contrary, only after experiencing large losses partway through 1993 did they consider the use of put options to place a floor on the possible cash losses from their hedging. The opportunity of using puts had always been available but had never been considered until *after* enormous losses had been incurred. As Culp and Miller themselves note, there were a large variety of alternative corporate and financial structures that could have been used, including spinning off a subsidiary with the delivery contracts and the hedge: many of these might have been viable had they been pursued *before* the firm faced its liquidity crisis. That they were only entertained in the midst of a crisis highlights the failure of forethought at MGRM.

Our own review of MGRM's strategy documents and other materials suggests that they were fixated on the historical record of regular profits from their proposed strategy: they made the classic mistake of devising a technical trading strategy based on past data without testing it out of sample. And they made another classic mistake of not "stress testing" their derivative trading strategy. MGRM's business plan includes a few scenario analyses of projected profits, but the worst outcomes displayed are "minimum profit" scenarios and do not reveal the possibility of any cash drain.

A good illustration of how easy it is to underestimate the problem of possibly negative cash flow is Culp and Miller's own suggestion for a pure synthetic strategy, a suggestion made with no number attached. Under this strategy MGRM deposits with the clearinghouse collateral in the form of T-bills equal to the initial face value of its total futures position, "thus ensuring that no further cash outlays would be required over the life of the hedge, regardless of price movements." Just how much in T-bills would have been required given MGRM's position? Assuming no basis risk, we estimate more than $3 billion, a hefty sum indeed! A calculation recognizing possible losses due to basis risk would raise the number higher still. Culp and Miller say that the notion of a pure synthetic strategy puts to rest once and for all the view that maturity mismatch gave rise to financial distress. We think, on the contrary, that the $3 billion figure illustrates perfectly the significance of the maturity mismatch problem: when that number is compared against the rest of the parent corporation's balance sheet, the idea that MGRM would have received funding becomes dubious to say the least.

A final point of difference we have with Culp and Miller is our claim that MGRM was actively speculating in oil derivatives. Although Culp and Miller downplay this possibility, we think their representation of MGRM's strategy as "synthetic storage" makes *our* point. The firm was not hedging any real storage activity. Rather it was constructing storage using the financial markets, betting that the prevailing cost of long-term deliveries relative to the implicit cost of storage reflected in the history of short-term oil futures prices. We have already pointed out above that this strategy is essentially a speculation on the basis risk. There seems to be agreement on the formal mathematical facts describing MGRM's strategy but some difference in how we each judge these facts.

We claim, moreover, that a careful examination of MGRM's actual business plan as well as the history of its trading activities and most especially the exaggerated size of its stack all lead one to the conclusion the MGRM's management was speculating. It was MGRM's management who justified the rolling stack using calculations of the historic profit an arbitrary investor would have made rolling over a one-month crude oil futures contract: these calculations did not include any careful analysis of the net present value of synthetic storage. The calculations in the business plan regarding synthetic storage are riddled with assumptions about mispriced contracts and the opportunity available to profit by buying in at highs and selling at lows. Nowhere in the business plan does MGRM's management do any accounting for basis risk and the appropriate discount to charge for it. Not only was MGRM's strategy speculative, but it exhibited all the features of classically mistaken speculations. MGRM's decision to run a "front-to-back" strategy is just the oil market equivalent of riding the yield curve in the bond market, with all the dangerous consequences that entails.

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Journal of Applied Corporate Finance (ISSN 1078-1196 [print], ISSN 1745-6622 [online]) is published quarterly on behalf of Morgan Stanley by Blackwell Publishing, with offices at 350 Main Street, Malden, MA 02148, USA, and PO Box 1354, 9600 Garsington Road, Oxford OX4 2XG, UK. Call US: (800) 835-6770, UK: +44 1865 778315; fax US: (781) 388-8232, UK: +44 1865 471775, or e-mail: subscrip@bos.blackwellpublishing.com.

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