Original Article

Effects of full collateralization in commodity futures investments

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ABSTRACT **The study extends research on the impact of commodity futures investments on portfolio performance by incorporating levered futures directly into the optimization problem. Differences in portfolio performance between fully collateralized and levered futures arise primarily in the presence of investment constraints. The attractiveness of portfolios is also affected by differences in commodity investments, indicating that both more efficient collateral and investment management may improve performance.**

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INTRODUCTION

Investors and fund managers have long viewed commodities as investment alternatives. The dramatic growth of the hedge fund industry and the run-up in commodity prices in recent years has further fueled this interest. Commodity investments have several features that render them attractive additions to the traditional portfolio. Passive long-only portfolios of commodity futures – as well as certain individual futures – have displayed some risk premiums,[1–7] tend to have low correlations with other asset classes,[1,4,6,8–11] and may serve as a hedge against inflation and business cycles.[1,6,7,12–16] Further, commodity futures exhibit dynamic features that may be exploitable in tactical contexts,[17] including momentum,[4,7,18,19] seasonality,[7] and predictable responses to the shape of the term structure.[4,20,21]

A common assumption made in previous studies is that the futures investment is fully collateralized. Indeed, past researchers have ignored the possibility that imposing futures investments to be fully collateralized may affect optimal portfolio allocations, as it restricts the feasible set. One exception is Becker and Finnerty,[13] who incorporate levered futures by constructing 'levered indexes' that scale futures returns by a multiplier. They report that diversification benefits of commodity futures increase as the degree of leverage increases. However, their method of incorporating leverage has two potential shortcomings. First, their levered futures indexes do not incorporate margin calls, and second they do not optimize portfolio shares but rather assume that a fixed proportion (10 per cent) of the portfolio is allocated to commodity futures. Failure to allow for the proportion of commodity futures to be determined optimally (unconstrained) limits the ability to identify the effect of levered futures on portfolio allocations.

The effects of commodity futures' leverage – which provides investors with added flexibility to improve their portfolio returns and diversification benefits – are not well understood. In theory, added flexibility could allow managers to use 'freed up' funds to enhance their portfolios by investing more in attractive asset classes. In practice, however, investors and fund managers frequently impose upper bounds on the proportion of a portfolio that can be allocated to specific asset classes.[22] In the presence of these constraints, the degree to which futures' leverage allows investors to improve their portfolio is unclear.

This article extends previous work on commodity investments by incorporating levered futures in a more comprehensive framework and explicitly accounting for margin calls. Imposing full collateralization may have consequences when estimating 'optimal' portfolios under any optimization criterion. We also assess how the estimation of levered and collateralized allocations differs when portfolio weights (the share of investments) are constrained. In addition, we evaluate the investment performance of a variety of futures contracts *individually* as well as a general index to shed light on which markets provide the most benefits – a component absent in most previous studies.

A LEVERED FRAMEWORK FOR COMMODITY FUTURES INVESTMENTS

Most studies are based on the use of fully collateralized (unlevered) commodity futures investments. Collateralizing investments simplifies the analysis, as there is no need for daily marking-to-market; however, it ignores an essential characteristic of futures contracts – their potential to leverage investments – and is inconsistent with the practice of many fund managers. Holding fully collateralized commodity futures may constitute an opportunity cost because posting T-Bills in excess of the minimum performance bond may be an inefficient allocation of capital. Moreover, imposing full collateralization may affect the estimation of optimal allocations.

For example, if the margin requirement on a futures contract is 10 per cent of the underlying value, investment of the remaining 90 per cent in stocks and bonds rather than T-Bills only may be more efficient. The futures' leverage also allows investors to take positions that garner market exposure in excess of the total portfolio value. Although the levering of futures investments is conceptually similar to levering in a classical mean-variance framework, the performance of portfolios with levered and collateralized futures investments will differ if margin calls are incorporated, unless the returns on the collateralizing security (T-Bills) are perfectly correlated with the other portfolio elements (stocks and bonds). Further, if the costs of levering investments differ across asset classes, imposing full collateralization on futures investments may distort estimated optimal portfolio allocations.

An investment simulation is constructed that allows for both positions in futures and more 'traditional' assets. Futures positions are marked-to-market daily, and margin calls are accounted for directly. To assess the effect of futures leverage, two strategies are considered – a fully collateralized and a levered strategy. In the fully collateralized approach, the percentage of the portfolio allocated to futures simply earns the 3-month T-Bill rate on the full contract value. In the levered approach, the proportion of the portfolio funds assigned to commodity futures represents only the margin, not the full contract value. This implies that investors can assume market exposure in excess of the total portfolio value.

Optimal portfolio weights are estimated by maximizing the Sharpe Ratio (SR) using a grid search. The SR is a common portfolio statistic that equals the portfolio return minus the risk-free rate, divided by the portfolio standard deviation. While the SR is admittedly simple, it is adopted here for its transparency and because of its prevalence in the industry and related work. The optimization is conducted separately for the fully collateralized and levered futures investment strategies. The optimization is *ex post*, and is thus a backward-looking estimate of the best-case scenario. This is the typical approach taken in studies with the aim of assessing the *strategic* value of different asset classes in the optimal portfolio.[23]

Over time the weights of stocks, bonds and futures in the portfolio may change because the returns to the individual assets differ. As a result, their allocations in the portfolio can deviate from the initial weights. Standard portfolio optimization techniques implicitly rebalance the portfolio at whatever interval the returns data are measured, typically monthly.

Here, it is necessary to account for this rebalancing explicitly. The portfolio is rebalanced on the first day of the month to adjust the weights back to their initial values. For example, if the initial asset weights are $w_{\text{Stocks}} = 30.0$ per cent, $w_{\text{Bonds}} = 60.0$ per cent and $w_{\text{Commodities}} = 10.0$ per cent, and price changes during the month cause the underlying values of the assets to shift these weights in portfolio to $w_{\text{Stocks}} = 40.0$ per cent, $w_{\text{Bonds}} = 55.0$ per cent and $w_{\text{Commodities}} = 5.0$ per cent, rebalancing adjusts the weights back to $w_{\text{Stocks}} = 30.0$ per cent, $w_{\text{Bonds}} = 60.0$ per cent and $w_{\text{Commodities}} = 10.0$ per cent. This involves selling a fraction of those assets that outperformed other assets in the portfolio during the previous month, and reallocating the proceeds to the assets that underperformed.

Daily margin calls from the levered futures positions are met by borrowing at the 3-month T-Bill rate, and excess funds beyond the minimum margin requirement earn interest at the same rate.[24] The analysis assumes the margin is 10 per cent of the contract value.[25,26] To maintain links to practice, we only allow for leverage in futures positions. *Prima facie*, it may appear that this could distort the analysis toward finding different results for levered futures. However, this may not be the case. First, if the presence of margin calls and the intermittent reallocation of investable funds have no effect on portfolio returns, then the relative weighting of each asset (in terms of total exposure) will remain unchanged when going between collateralized or levered investment scenarios.

Second, while traditional assets can be levered to some degree, futures are levered by design. Margin requirements are between 3 and 10 per cent for most futures contracts, and a futures position that is levered at 10–30 times the invested margin value is typical. In contrast, in real-world situations it would be less common for a portfolio of stocks and bonds to be levered to this degree. While futures exist for certain stock and bond indexes, we focus on the important *design* distinction between futures and traditional cash investments.

DATA

The analysis is conducted for the period from 2 January 1994 to 30 June 2006, using daily data. This sampling frequency is necessary to account for the possibility of margin calls. The stock and bond components of the portfolio are proxied using the S&P 500 index and the Lehman US Aggregate Bond Index. These indices represent a broad range of stocks as well as government and non-government bonds. The S&P 500 index data were obtained from DataStream, and the Lehman US Aggregate Bond Index was provided by Lehman Brothers, Inc.

To capture the returns of commodity investments we use daily closing futures prices of the nearby contract for the Goldman Sachs Commodity Index (GSCI), as well as for nine individual commodities (crude oil, copper, gold, silver, corn, soybeans, wheat, lean hogs and live cattle). The GSCI is a world production weighted index and represents a broad measure of commodity performance.

The individual contracts were selected because they represent some of the most liquidly traded contracts in each of the five commodity subclasses that comprise the GSCI (energy, precious metals, industrial metals, agriculture and livestock). The commodity futures data were supplied by the New York Mercantile Exchange, the Chicago Mercantile Exchange and the Chicago Board of Trade.

All futures are rolled to the next contract 1 month before the expiration of the futures contract that is nearest to expiration. Rolling to the next contract involves two transactions: (1) closing out the current futures position and (2) reinitiating the position in the subsequent contract. This method is representative of common investor strategies for rolling over contracts, avoids potential problems commonly associated with moving from the expiring to the consecutive contract (for example, owing to excessive volatility during the expiration month), and is consistent with the approach taken in previous studies and in practice.[6]

RESULTS AND DISCUSSION

Unconstrained fully collateralized versus levered portfolios

Portfolios containing fully collateralized commodity futures display the largest SRs when holding between 71.6 and 87.8 per cent in bonds (Table 1). Stocks are always part of the optimal portfolio, but constitute at most 12.2 per cent, whereas some of the individual commodities are not included. GSCI, crude oil, copper and live cattle futures occupy the largest portfolio shares with 18.4, 13.9, 14.5 and 12.1 per cent, and cause the SR to increase from 0.59 for the stock-and-bond-only portfolio to 0.87, 0.99, 0.87 and 0.66. The benefits of adding the GSCI during the period are driven primarily by the strong performance of energy markets (for example, oil futures), which are heavily weighted in the GSCI. Furthermore, a run-up in copper prices during 2004–2006 contributed significantly to the performance of copper futures.

The positive contributions of oil futures are further fueled by the process of rolling long futures positions forward over time. These returns capture a liquidity premium via increased convenience yields during periods of high volatility of the underlying commodity. Rolling long contracts forward may capture a risk premium over time if futures prices are a downwardly biased forecast of future spot prices. This relationship between spot volatility and roll return is not observed for all commodity groups, but is quite pronounced in the cases of energy and industrial metals. Earlier studies have found that the effect of spot price volatility on the mean roll return for agricultural, non-energy and precious metals is insignificant.[4] For crude oil futures, however, Litzenberger and Rabinowitz[27] argue that backwardation is a necessary condition for crude oil production, and that greater uncertainty regarding future crude oil prices will lead to stronger backwardation. This backwardation allows for positive roll returns as investments in expiring contracts are rolled over to cheaper outstanding contracts.

Silver, gold and soybeans comprise only marginal shares of the optimal portfolios (5.4, 3.8 and 4.8 per cent), increasing the SR relative to the stocks-and-bonds-only portfolio by 0.04, less than 0.01 and 0.02. Long positions in corn, wheat and hog futures were never part of the optimal portfolio. The results for hogs are in contrast to Fortenbery and Hauser,[9] who report an optimal portfolio weight of 0.18 for this commodity. The results for live cattle (optimal weight of 12.1 per cent for the whole sample) are similar to, but less significant than,

Table 1: Optimal asset allocations, returns and standard deviations of the portfolio with stocks, bonds and *fully collateralized* commodity futures,[a] 1994–2006 (portfolio shares, returns and standard deviations in per cent)

	Stocks[b]	*Bonds*[b]	*Commodities*[b]	*Annual return*	*Annual SD*	*Sharpe ratio*	*FCV/ TPV*[c]
Stock, Bond	12.2	87.8	—	6.32	4.13	0.59	—
Stock, Bond, GSCI	10.0	71.6	18.4	8.07	4.77	0.87	0.184
Stock, Bond, Crude	10.8	75.3	13.9	9.38	5.55	0.99	0.139
Stock, Bond, Copper	7.4	78.1	14.5	8.16	4.88	0.87	0.145
Stock, Bond, Silver	11.6	83.0	5.4	6.46	4.09	0.63	0.054
Stock, Bond, Gold	11.9	84.3	3.8	6.27	4.00	0.59	0.038
Stock, Bond, Corn	12.2	87.8	0.0	6.32	4.13	0.59	0.000
Stock, Bond, Soybeans	11.3	83.9	4.8	6.36	4.04	0.61	0.048
Stock, Bond, Wheat	12.2	87.8	0.0	6.32	4.13	0.59	0.000
Stock, Bond, Cattle	10.1	77.7	12.1	6.50	3.93	0.66	0.121
Stock, Bond, Hogs	12.2	87.8	0.0	6.32	4.13	0.59	0.000

[a]Stocks=S&P 500, Bonds=Lehman US Aggregate Bond Index, Commodities=GSCI, Crude Oil, Copper, Silver, Gold, Corn, Soybeans, Wheat, Cattle, Hogs.
[b]May not add up to 100 per cent owing to rounding.
[c]Futures contract value/total portfolio value.

those of Fortenbery and Hauser,[9] who report an optimal weight of 0.26.

Contrasting levered with fully collateralized futures, the amount of capital that is invested into levered commodities decreases for all contracts (Table 2). However, total commodity exposure (that is, the contract value of the futures position relative to the total portfolio value) increases modestly for levered investments. This increase is a result of a greater degree of diversification provided by commodities in portfolios with larger stock and bond exposures. Portfolios containing levered futures exhibit slightly higher returns and risk than portfolios containing collateralized futures, but nearly identical SRs (differences are always less than 0.005), indicating similar unconstrained risk-adjusted returns.

While margin calls between rebalancing periods allow for possible differences between these two approaches, the results suggest that the impact on the optimal SR is modest. This is likely owing to the relatively small number of margin calls that emerged with levered futures investments. For example, there were only 17 margin calls for levered GSCI futures during the period.[28] Thus, the results do not appear to support Becker and Finnerty's[13] conclusion that levered futures can be superior. However, the portfolio composition (that is, the relative portfolio weightings) and the resultant magnitudes of risk

Table 2: Optimal asset allocations, returns and standard deviations of the portfolio with stocks, bonds and *levered* commodity futures,[a] 1994–2006 (portfolio shares, returns and standard deviations in per cent)

	Stocks[b]	*Bonds*[b]	*Commodities*[b]	*Annual return*	*Annual SD*	*Sharpe ratio*	*FCV/ TPV*[c]
Stock, Bond	12.2	87.8	—	6.32	4.13	0.59	—
Stock, Bond, GSCI	11.9	85.9	2.2	8.81	5.64	0.87	0.215
Stock, Bond, Crude	12.3	86.1	1.6	10.07	6.26	0.99	0.155
Stock, Bond, Copper	8.6	89.9	1.6	8.73	5.55	0.87	0.163
Stock, Bond, Silver	12.2	87.2	0.6	6.58	4.30	0.63	0.056
Stock, Bond, Gold	12.5	87.2	0.4	6.35	4.15	0.59	0.037
Stock, Bond, Corn	12.2	87.8	0.0	6.32	4.13	0.59	0.000
Stock, Bond, Soybeans	11.8	87.7	0.5	6.47	4.22	0.61	0.049
Stock, Bond, Wheat	12.2	87.8	0.0	6.32	4.13	0.59	0.000
Stock, Bond, Cattle	11.4	87.3	1.3	6.80	4.40	0.66	0.133
Stock, Bond, Hogs	12.2	87.8	0.0	6.32	4.13	0.59	0.000

[a]Stocks=S&P 500, Bonds=Lehman US Aggregate Bond Index, Commodities=GSCI, Crude Oil, Copper, Silver, Gold, Corn, Soybeans, Wheat, Cattle, Hogs.
[b]May not add up to 100 per cent owing to rounding.
[c]Futures contract value/total portfolio value.

and return do differ when investors hold T-Bills for the whole value of the commodity position rather than allocate their capital to other profitable investments.

Unconstrained versus constrained portfolios

In the unconstrained portfolios with fully collateralized futures investments, the optimal weights for the Lehman US Aggregate Bond Index were between 87.8 and 71.6 per cent, which is quite high. Further, collateralized futures require the full contract value to be placed in T-Bills as performance bonds. Thus, the share of interest-bearing instruments (bonds + performance T-Bills) in the portfolio increased substantially as a result of collateralizing. In practice, this may lead to risk and return profiles that are not reasonable and possess low out-of-sample investment efficiency. To investigate the performance of levered and collateralized futures investments with portfolio constraints, we limit the weight of interest-bearing instruments (US Aggregate Lehman Bond Index + excess T-Bills over initial margin) to 0.80, 0.60 and 0.40.[29]

The bond constraints are binding for all three weight levels (Tables 3 and 4). In the fully collateralized case, the constraints are binding when commodities fail to enter the optimal portfolio. In the levered case, the constraints are always binding. For the fully collateralized case this translates into an increase in the optimal portfolio weights of commodities. For the levered case, the actual share of commodities is smaller for the levered investments, but the portfolio's commodity exposure (that is, the futures contract value (FCV) relative to the total portfolio value (TPV)) is greater than for collateralized investments. Portfolios containing levered futures also display greater risk-adjusted returns than those with fully collateralized futures. For example, a portfolio with a bond constraint of 0.40 that includes GSCI futures has an optimal SR of 0.70 and an optimal commodity exposure (that is, full FCV/TPV) of 0.638 in the levered case (Table 4), but only 0.61 and 0.444 in the collateralized case (Table 3). Further, the superiority of the levered over the collateralized investments increases as the constraints on the interest-bearing instruments become stricter. For example, when investing in GSCI futures, the difference between the levered

Table 3: Optimal asset allocations, returns and standard deviations of the portfolio with stocks, bonds and *fully collateralized* commodity futures[a] and constrained bond weights, 1994–2006 (portfolio shares, returns and standard deviations in percent)

	Stocks[b]	*Bonds*[b]	*Commodities*[b]	*Annual return*	*Annual SD*	*Sharpe ratio*	*FCV/TPV*[c]
Bond constraint (Excess T-Bills + Lehman Index)=0.80							
Stock, Bond	20.0	80.0	—	6.53	4.68	0.56	—
Stock, Bond, GSCI	17.8	60.1	21.1	8.56	5.50	0.85	0.211
Stock, Bond, Crude	18.4	65.6	16.0	10.05	6.37	0.97	0.160
Stock, Bond, Copper	18.3	65.0	16.7	8.74	5.89	0.82	0.167
Stock, Bond, Silver	19.4	74.5	6.1	6.69	4.65	0.60	0.061
Stock, Bond, Gold	19.6	76.6	4.3	6.47	4.53	0.57	0.043
Stock, Bond, Corn	20.0	80.0	0.0	6.53	4.68	0.56	0.000
Stock, Bond, Soybeans	19.5	75.5	5.0	6.58	4.62	0.58	0.050
Stock, Bond, Wheat	20.0	80.0	0.0	6.53	4.68	0.56	0.000
Stock, Bond, Cattle	18.7	68.3	13.0	6.75	4.55	0.63	0.130
Stock, Bond, Hogs	20.0	80.0	0.0	6.53	4.68	0.56	0.000
Bond constraint (Excess T-Bills + Lehman Index)=0.60							
Stock, Bond	40.0	60.0	—	7.02	7.14	0.44	—
Stock, Bond, GSCI	36.8	30.8	32.4	10.06	8.67	0.71	0.324
Stock, Bond, Crude	37.3	35.3	27.4	12.90	10.55	0.85	0.274
Stock, Bond, Copper	37.2	34.5	28.3	10.58	9.85	0.67	0.283
Stock, Bond, Silver	39.1	51.9	8.9	7.22	7.16	0.47	0.089
Stock, Bond, Gold	39.7	57.5	2.8	6.98	7.04	0.44	0.028
Stock, Bond, Corn	40.0	60.0	0.0	7.02	7.14	0.44	0.000

Table 3 *continued*

	Stocks[b]	*Bonds*[b]	*Commodities*[b]	*Annual return*	*Annual SD*	*Sharpe ratio*	*FCV/ TPV*[c]
Stock, Bond, Soybeans	39.4	54.5	6.1	7.07	7.12	0.45	0.061
Stock, Bond, Wheat	40.0	60.0	0.0	7.02	7.14	0.44	0.000
Stock, Bond, Cattle	38.3	44.2	17.5	7.29	7.14	0.48	0.175
Stock, Bond, Hogs	40.0	60.0	0.0	7.02	7.14	0.44	0.000
Bond constraint (Excess T-Bills + Lehman Index)=0.40							
Stock, Bond	60.0	40.0	—	7.41	10.21	0.34	—
Stock, Bond, GSCI	55.6	0.0	44.4	11.49	12.41	0.61	0.444
Stock, Bond, Crude	55.8	2.4	41.7	16.10	15.86	0.77	0.417
Stock, Bond, Copper	55.7	1.2	43.1	12.53	14.84	0.58	0.431
Stock, Bond, Silver	58.7	28.9	12.3	7.67	10.30	0.37	0.123
Stock, Bond, Gold	60.0	40.0	0.0	7.41	10.21	0.35	0.000
Stock, Bond, Corn	60.0	40.0	0.0	7.41	10.21	0.34	0.000
Stock, Bond, Soybeans	59.3	33.4	7.4	7.47	10.21	0.35	0.074
Stock, Bond, Wheat	60.0	40.0	0.0	7.41	10.21	0.34	0.000
Stock, Bond, Cattle	57.7	18.9	23.5	7.76	10.34	0.37	0.235
Stock, Bond, Hogs	60.0	40.0	0.0	7.41	10.21	0.34	0.000

[a]Stocks=S&P 500, Bonds=Lehman US Aggregate Bond Index, Commodities=GSCI, Crude Oil, Copper, Silver, Gold, Corn, Soybeans, Wheat, Cattle, Hogs.
[b]May not add up to 100 per cent owing to rounding.
[c]Futures contract value/total portfolio value.

and collateralized SRs is only 0.06 (that is, $0.77-0.71=0.06$), or an increase of 8 per cent (that is, $0.06/0.71=0.08$), when the bond constraint is 0.60. However, the difference increases substantially when the constraint is tightened. For example, the difference increases to 0.21 when the bond constraint is 0.20 (results not presented). This relationship between levered and collateralized portfolios regarding bond constraints is consistent across all constraint levels.

These results illustrate that under binding investment constraints, the full collateralization assumption can have a significant impact on the estimated portfolio allocations and resultant portfolio performance. This finding suggests that efficient collateral management may become increasingly important as constraints on investment behavior are tightened. Notice that the analysis does not imply that other assets could not be levered. However, typical costs associated with levering traditional assets – which are not applicable to futures investments – may render this option less attractive.

Table 4: Optimal asset allocations, returns and standard deviations of the portfolio with stocks, bonds and *levered* commodity futures[a] and constrained bond weights, 1994–2006 (portfolio shares, returns and standard deviations in per cent)

	Stocks[b]	*Bonds*[b]	*Commodities*[b]	*Annual return*	*Annual SD*	*Sharpe ratio*	*FCV/ TPV*[c]
Bond constraint (Excess T-Bills + Lehman Index)=0.80							
Stock, Bond	20.0	80.0	—	6.53	4.68	0.56	—
Stock, Bond, GSCI	17.6	80.0	2.4	9.29	6.27	0.86	0.243
Stock, Bond, Crude	18.3	80.0	1.8	10.70	6.98	0.98	0.175
Stock, Bond, Copper	18.1	80.0	1.9	9.39	6.55	0.83	0.191
Stock, Bond, Silver	19.3	80.0	0.7	6.82	4.84	0.61	0.067
Stock, Bond, Gold	19.4	80.0	0.6	6.56	4.64	0.57	0.056
Stock, Bond, Corn	20.0	80.0	0.0	6.53	4.68	0.56	0.000
Stock, Bond, Soybeans	19.4	80.0	5.8	6.70	4.78	0.58	0.058
Stock, Bond, Wheat	20.0	80.0	0.0	6.53	4.68	0.56	0.000
Stock, Bond, Cattle	18.5	80.0	1.6	7.07	4.96	0.64	0.155
Stock, Bond, Hogs	20.0	80.0	0.0	6.53	4.68	0.56	0.000
Bond constraint (Excess T-Bills + Lehman Index)=0.60							
Stock, Bond	40.0	60.0	—	7.02	7.14	0.44	—
Stock, Bond, GSCI	35.6	60.0	4.4	11.91	10.43	0.77	0.444
Stock, Bond, Crude	37.0	60.0	3.0	13.93	11.29	0.89	0.298
Stock, Bond, Copper	36.7	60.0	3.3	11.78	10.88	0.72	0.332
Stock, Bond, Silver	38.8	60.0	1.2	7.50	7.45	0.48	0.118
Stock, Bond, Gold	38.9	60.0	1.2	7.07	7.02	0.45	0.115
Stock, Bond, Corn	40.0	60.0	0.0	7.02	7.14	0.44	0.000
Stock, Bond, Soybeans	39.0	60.0	1.0	7.29	7.35	0.43	0.101
Stock, Bond, Wheat	40.0	60.0	0.0	7.02	7.14	0.44	0.000
Stock, Bond, Cattle	37.3	60.0	2.7	7.91	7.74	0.52	0.267
Stock, Bond, Hogs	40.0	60.0	0.0	7.02	7.14	0.44	0.000
Bond constraint (Excess T-Bills + Lehman Index)=0.40							
Stock, Bond	60.0	40.0	—	7.41	10.21	0.34	—
Stock, Bond, GSCI	53.6	40.0	6.4	14.25	14.93	0.70	0.638
Stock, Bond, Crude	55.5	40.0	4.5	17.52	16.68	0.82	0.448
Stock, Bond, Copper	52.3	40.0	7.7	17.32	21.69	0.62	0.774
Stock, Bond, Silver	58.2	40.0	1.8	8.11	10.75	0.39	0.181

Table 4 *continued*

	Stocks[b]	*Bonds*[b]	*Commodities*[b]	*Annual return*	*Annual SD*	*Sharpe ratio*	*FCV/ TPV*[c]
Stock, Bond, Gold	58.2	40.0	1.8	7.49	10.01	0.36	0.178
Stock, Bond, Corn	60.0	40.0	0.0	7.41	10.21	0.34	0.000
Stock, Bond, Soybeans	58.5	40.0	1.5	7.79	10.56	0.37	0.153
Stock, Bond, Wheat	60.0	40.0	0.0	7.41	10.21	0.34	0.000
Stock, Bond, Cattle	55.9	40.0	4.1	8.72	11.27	0.43	0.408
Stock, Bond, Hogs	60.0	40.0	0.0	7.41	10.21	0.34	0.000

[a]Stocks=S&P 500, Bonds=Lehman US Aggregate Bond Index, Commodities=GSCI, Crude Oil, Copper, Silver, Gold, Corn, Soybeans, Wheat, Cattle, Hogs.
[b]May not add up to 100 per cent owing to rounding.
[c]Futures contract value/total portfolio value.

Sensitivity analyses

The results presented to this point are based on the assumption that managers rebalance their portfolios monthly. Yet, leverage increases the relative magnitude of the returns from the futures position between rebalancing periods. Hence, the opportunity cost of not withdrawing excess funds from futures' margin accounts (in the levered case) during time periods between portfolio rebalancing may be significant in terms of overall portfolio performance. Using levered GSCI futures – the contract that is most representative of aggregate commodity performance – we find that altering the frequency of portfolio rebalancing changes the optimal SR from 0.872 (monthly) to 0.877 (bi-monthly), 0.863 (semiannually), 0.902 (annually) and 0.872 (bi-annually). The optimal SRs for the levered and collateralized strategies, however, are highly consistent for all rebalancing frequencies. Our findings regarding constrained and unconstrained portfolios are hence robust to alternative rebalancing intervals. Further, the optimal asset allocations are virtually unchanged across all rebalancing intervals. Thus, although the frequency with which the portfolios are rebalanced affects performance measures to a small degree, it does not appear to influence the differences between the levered and collateralized approaches or the optimal asset allocations.

Examining the optimal portfolio allocations for collateralized and levered strategies in two subperiods, January 1994 – December 1999 and January 2000 – June 2006 (not displayed), also does not change the nature of our results with respect to constrained and unconstrained portfolios. However, as expected the compositions of the optimal portfolios do change. During the first half of the data period both bonds and stocks displayed strong returns, while bonds dominated stocks in the second half. In the first half, only GSCI and crude oil futures contributed significantly to the optimal portfolios, increasing the SR relative to the stock-and-bond-only portfolio by 5.87 per cent and 24.82 per cent. In the second half, however, seven of ten commodities are significant components of the optimal portfolios. The average value of the weights for the individual commodities (excluding the GSCI) is 3.3 per cent during the first half of the sample, versus 8.3 per cent during the second half. Further, the average increase in the SR for portfolios with individual commodities was 3 per cent during the first half, versus 22 per cent for the second half relative to the stock-and-bond-only portfolio. Corn, wheat and lean hogs are not part of the optimal portfolios during either subperiod.

Partitioning the data according to restrictive/expansive monetary policy has little impact on our findings with respect to the distorting effects of the full collateralization assumption. However, the results are consistent with the findings of Jensen *et al*[30] that restrictive monetary policy was correlated with increased performance of commodity investments. For example (results not reported), a portfolio with a collateralized investment in the GSCI yields an optimal weight of 0.22 (0.06) during restrictive (expansive) monetary policy environments, where restrictive/expansive is defined similarly to Jensen *et al*.[30] Further, the investment benefits of including the GSCI are significant during restrictive monetary environments, as the SR increases from 0.77 for the stock-and-bond-only portfolio to 1.34 with the inclusion of GSCI futures (74 per cent). In contrast, during periods of expansive monetary policy, the inclusion of GSCI futures only had modest effects on the portfolio, increasing the SR of the stock-and-bond-only portfolio relative to the portfolio including the GSCI from 0.42 to 0.44.

Our findings appeared to be relatively insensitive to including transactions costs. In addition, altering the method of incorporating margin calls (that is, assuming borrowing/lending at the T-Bill rate versus liquidating/reinvesting in stocks and bonds) did not have a qualitative impact on our findings. Again, the limited number of margin calls may have influenced this result. Finally, our results appeared insensitive to whether the SR was calculated using daily or monthly returns.

CONCLUSION

This study revisits the issue of commodity investment performance and assesses the possible distorting impacts of imposing the full collateralization assumption when estimating optimal futures investments. Comparing the levered estimation framework to the collateralized, the results suggest that the differences resulting from the effects of margin calls and the intermittent reinvestment of surplus margin funds are minimal. Differences do arise, however, in the presence of investment constraints. This result implies that when the cost of levering is not 'free', more efficient collateral management may improve portfolio performance. It is important to emphasize that while the relative attractiveness of specific investments can change with market dynamics, the differences between levered and fully collateralized futures positions and their effects on portfolio performance are most likely to appear when constraints on investment behavior exist.

The results also indicate that crude oil is the single most important commodity, as it contributed significantly to portfolio performance in all cases. If not to the same degree, long investments in copper, cattle and silver also consistently improve portfolios. However, investments in other individual commodity futures are not part of optimal portfolios or do not significantly increase portfolio performance. These results are consistent with research that has found risk premiums for individual commodities to be elusive, but identifies that selective use of commodities can provide significant portfolio improvements.

This study investigated the leverage aspect of the commodity investment problem in a *strategic* context. Future research could extend the analysis to investigate the performance of levered futures investments in *tactical* frameworks. Future work could also focus on more accurately modeling the costs associated with levering different types of assets, and the effect that these costs might have on investment performance.

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REFERENCES AND NOTES

1 Bodie, Z. and Rosansky, V.I. (1980) Risk and return in commodity futures. *Financial Analysts Journal* 36(3): 27–39.
2 Carter, C.A., Rausser, G.C. and Schmitz, A. (1983) Efficient asset portfolios and the theory of normal backwardation. *Journal of Political Economy* 91(2): 319–331.
3 Chang, E.C. (1985) Returns to speculators and the theory of normal backwardation. *Journal of Finance* 40(1): 193–208.
4 Erb, C. and Harvey, C. (2006) The strategic and tactical value of commodity futures. *Financial Analyst Journal* 62(2): 69–97.
5 Fama, E.F. and French, K.R. (1987) Commodity futures prices: Some evidence of forecast power, premiums, and the theory of storage. *Journal of Business* 60(1): 55–73.
6 Gorton, G. and Rouwenhorst, K.G. (2006) Facts and fantasies about commodity futures. *Financial Analysts Journal* 62(2): 47–68.
7 Woodard, J.D. (2008) Commodity futures investments: A review of strategic benefits and tactical opportunities. In: F. Fabozzi, R. Fuess and D. Kaiser (eds.) *The Handbook of Commodity Investing*. New York: John Wiley & Sons, pp. 56–86.
8 Anson, M.J.P. (2006) *Handbook of Alternative Investments*. Hoboken, NJ: John Wiley & Sons.
9 Fortenbery, T.R. and Hauser, R.J. (1990) Investment potential of agricultural futures contracts. *American Journal of Agricultural Economics* 72(3): 721–726.
10 Jaffe, J.F. (1989) Gold and gold stocks as investments for institutional portfolios. *Financial Analysts Journal* 45(2): 53–60.
11 Kaplan, P.D. and Lummer, S.L. (1993) GSCI collateralized futures as a hedging and diversification tool for institutional portfolios: An update. *Journal of Investing* 2(2): 75–82.
12 Ankrim, E.M. and Hensel, C.R. (1993) Commodities in asset allocation: A real-asset alternative to real estate. *Financial Analysts Journal* 49(3): 20–29.
13 Becker, K.G. and Finnerty, J.E. (1997) Indexed commodity futures and the risk and return of institutional portfolios. *Advances in Investment Analysis and Portfolio Management* 4: 1–14.
14 Gay, G.D. and Manaster, S. (1982) Hedging against commodity price inflation: Stocks and bills as substitutes for futures contracts. *Journal of Business* 55(3): 317–343.
15 Greer, R.J. (1978) Conservative commodities: A key inflation hedge. *Journal of Portfolio Management* 4(4): 26–29.
16 Kat, H.M. and Oomen, R.C.A. (2007) What every investor should know about commodities, Part II: Multivariate return analysis. *Journal of Investment Management* 5(3).
17 Vrugt, E.B., Bauer, R., Molenaar, R. and Steenkamp, T. (2004) Dynamic Commodity Timing Strategies. Working Paper, July.
18 Georgiev, G. (2004) Active long-only investment in energy futures. *Journal of Alternative Investments* 7(2): 32–43.
19 Miffre, J. and Rallis, G. (2007) Momentum strategies in commodity futures markets. *Journal of Banking and Finance* 31(6): 1863–1886.
20 Chong, J. and Miffre, J. (2006) Conditional risk premia, volatilities and correlations in commodity futures markets. Paper presented at the Academy of Financial

Services and the Financial Management Association Conferences; April, University of Essex, UK.

21 We refer the reader to Woodard[7] for an extensive review of the commodity investment literature.

22 Research has shown that investment constraints can improve out-of-sample portfolio performance.[31,32] Here, we focus on the effects of added flexibility of levered futures when these constraints exist.

23 While the analysis can be extended to include *ex ante* criteria, investigation of this *tactical* dimension is beyond our scope. Woodard[7] provides an extensive review of commodity investment research dealing with *strategic* and *tactical* approaches.

24 When stocks and bonds are sold to meet margin calls instead of borrowing at the T-Bill rate, the results were not materially different.

25 Lee, C. and Leuthold, R.M. (1983) Investment horizon, risk, and markets: An empirical analysis with daily data. *Quarterly Review of Economics and Business* 23: 6–18.

26 This approach is adopted because data on the actual margins were not available for all commodities. Preliminary investigations suggested that the results of the analysis differed little when using initial and maintenance margins of 10 and 5 per cent of the contract value.

27 Litzenberger, R.H. and Rabinowitz, N. (1995) Backwardation in oil futures markets: Theory and empirical evidence. *Journal of Finance* 50(5): 1517–1545.

28 Note the margin account is reset monthly when the portfolio is rebalanced. It is also reset whenever a roll occurs, but these are not classified as margin calls.

29 Imposition of constraints for stocks and commodities is not necessary as their optimal unconstrained weights are small compared to bonds.

30 Jensen, G.R., Johnson, R.R. and Mercer, J.M. (2000) Efficient use of commodity futures in diversified portfolios. *Journal of Futures Markets* 20(5): 489–506.

31 Cohen, K.J. and Pogue, J.A. (1967) An empirical evaluation of alternative portfolio selection models. *Journal of Business* 40(2): 166–189.

32 Frost, P.A. and Savarino, J.E. (1986) An empirical Bayes approach to efficient portfolio selection. *Journal of Financial and Quantitative Analysis* 21(3): 293–305.