Marginal influence

Whatever the hopes of futures market regulators, increasing margin deposits doesn't dampen volatility, say ***Ted Day*** *and* ***Craig Lewis***

CAN MARGIN requirements be used to control the volatility of crude oil futures prices? Despite the accumulation of empirical evidence suggesting that margin requirements have little impact on futures market volatility, this question continues to be debated by regulators, exchange members, and futures traders.

From an economic perspective, it would be surprising if margin requirements could be used as the risk management tool often envisioned by regulators. Since futures prices are closely linked to the price of the underlying commodity by arbitrage, the volatility of futures prices must reflect the volatility of the underlying cash market. Therefore, to the extent that the volatility of the cash market reflects the flow of information concerning the fundamentals of supply and demand, it is hard to imagine how changes in margin requirements might insulate the futures market from the forces that determine volatility in the spot market. But because of its regulatory significance, the extent to which changes in margin requirements can be used to control the volatility of the futures market remains an open empirical question.

To examine the impact of changes in margin requirements on the volatility of the crude oil futures market, we estimate a daily time series of implied volatilities from the prices of crude oil futures options. Our estimation approach, which is discussed in more detail in Day and Lewis (1997)[1], explicitly recognises that volatility is stochastic and perhaps mean-reverting. Note that in contrast to previous research, which has been limited by the need to use time series data as a proxy for changes in the underlying volatility of the futures market, implied volatilities represent *ex-ante* consensus forecasts of future volatility. Since option prices should respond instantaneously to changes in volatility, inferring volatility from option prices permits us to match changes in the volatility of the futures market with the corresponding changes in margin requirements. It also permits us to examine whether margin policy has any feedback effects on volatility. Further, to the extent the increases in the volatility of a particular market are transitory or mean-reverting, the parameters of the stochastic process can provide an estimate of the time required for the volatility of the market to return to more normal levels.

To model the stochastic volatility of the crude oil futures market, we begin with the standard assumption that changes in the futures price, F, over an infinitesimal unit of time, dt, are given by:

$$dF = \mu F\,dt + \sqrt{v}\,F\,dz_1(t)$$

where μ and v are respectively the instantaneous mean and variance of changes in the futures price, and $z_1(t)$ is a standard Wiener process. The instantaneous (or spot) variance is assumed to follow a mean-reverting square root diffusion process:

$$dv = \alpha(\beta - v)\,dt + \xi\sqrt{v}\,dz_2(t),$$

where α determines the speed at which the instantaneous variance reverts to its long-run mean of β and $z_2(t)$ is a standard Wiener process such that the instantaneous correlation between increments in $z_1(t)$ and $z_2(t)$ is ρ. This process is consistent with Day and Lewis (1993)[3], who show that shocks to the volatility of the crude oil futures market are persistent and mean-reverting.

The stochastic processes assumed above permit the formulation of a stochastic differential equation describing the evolution of the price of a call option on a futures contract. By applying the appropriate boundary conditions, this partial differential equation can be solved numerically to determine the price of an option on a futures contract as a function of the spot volatility and the five parameters that define the stochastic movements of the futures price and the underlying futures market volatility. We then estimate the parameters of the stochastic volatility model, along with the spot volatility of the crude oil futures market, from the prices of options on crude oil futures contracts using Hansen's (1982)[5] Generalised Methods of Moments (GMM) technique. Apart from the fact that the stochastic nature of futures market volatility necessitates the estimation of additional parameters, our implementation of this procedure is conceptually similar to the estimation of an implied volatility using the Black-Scholes model.

The period we examine begins with the initiation of trading in West Texas Intermediate (WTI) crude oil futures options on November 14, 1986 and ends March 18, 1991. This period is of interest since it includes the August 1, 1990 invasion of Kuwait by Iraq. The New York Mercantile Exchange (Nymex) supplied the dates and margin levels for all adjustments of initial margin requirements in the nearby (spot month) futures contract. The sample includes 19 changes in margin requirements prior to the invasion of Kuwait and 11 changes in margin requirements in the subsequent period.

The long-run mean volatility of the crude oil futures market, β, has an estimated value of 0.0811, which corresponds to an annualised standard deviation of approximately 28.5%. The time series of implied spot volatilities derived from our estimation procedure has a mean value of 0.1704 and a median value of 0.0811. These mean and median values of the spot variance respectively correspond to annualised standard deviations of 41.28% and 28.48%. Our results indicate that the distribution of estimates of spot volatility is highly skewed and has fat tails. This is attributable to several dramatic increases in the volatility of the crude oil futures market during the sample period. For example, during the period following the invasion of Kuwait by Iraq, the increase in the volatility of the crude oil futures market is both more dramatic and more prolonged than the volatility observed following the stock market crash of 1987. The first-order auto-correlation of the daily spot volatility series is

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Margins are the cash deposits required by futures market clearinghouses as guarantees against default by buyers and sellers of futures contracts.

Can changes in margin requirements be used to control the volatility of crude oil prices by, for instance, increasing margin deposits to dampen volatility by making it more expensive to trade futures?

At an economic level, it's difficult to see how manipulating margin levels in a particular futures market can affect price volatility generated by supply and demand factors applying to the underlying physical commodity.

However, Ted Day and Craig Lewis (see main feature) have tested two theories about the impact of changes in margin requirements on the volatility of oil futures prices. They use a mathematical technique which assumes volatility is a stochastic, or random, process which reverts over time to a mean level.

The first theory says margin requirements can be varied to control volatility by, for instance, increasing margin deposits to dampen volatility by making it more expensive to trade futures. The second theory says margins are used as a risk management tool by clearinghouses to control the impact of volatility on the credit risk presented by the futures market trading members who are a clearinghouse's counterparties.

Overall, the tests show that changes in initial margin requirements have very little short-term impact on the forecasts of future volatility.

0.95. This auto-correlation reflects the persistence in volatility that has been characterised by auto-regressive conditional heteroscedasticity-type models of conditional volatility.

The estimated value of the parameter which controls the speed of mean-reversion, α, is 1.931. An intuitive measure of the speed at which the estimated mean-reversion parameter causes volatility to revert to the long-run mean is the 'half-life' for the current spot volatility, which is the time required for the expected future spot volatility to revert halfway to the long-run mean. It is straightforward to show that the half-life can be determined by setting $e^{-\alpha\tau}$ equal to one half and solving for τ. Given an estimated value for α of 1.931, the expected time for an arbitrary volatility of v to revert halfway to the long-run mean is 90 trading days.

The empirical tests that we use are designed to distinguish between two alternative hypotheses concerning the impact of margin requirements on volatility. According to the first hypothesis, the required margin is a control variable that can be increased to dampen excessive volatility in the futures market. Alternatively, as argued by Fenn and Kupiec (1993)[2] and Day and Lewis (1996)[4], changes in margin requirements are used as a risk management tool by the futures clearinghouse to control the impact of volatility on the counterparty risk implicit in futures trading. Each of these hypotheses suggests that increases (decreases) in margin requirements should tend to occur following increases (decreases) in volatility. Under the first hypothesis, the increase (decrease) in margin requirements should reduce (increase) volatility in the period subsequent to the change in margin requirements while under the second hypothesis volatility may be independent of the prevailing margin requirement.

To distinguish between these alternative hypotheses, we examine changes in the volatility of the crude oil futures market during an event window beginning 10 days prior to a change in margin requirements and ending 10 days following the change in margin requirements. Each change in volatility is measured relative to the volatility at the beginning of the event window. If increases in initial margin requirements reduce volatility, we should on average expect to see volatility fall to a lower level during the 10-day period following increases in the initial margin requirement. However, it is important to adjust for the fact that, when the volatility of the futures market follows a mean-reverting stochastic process, volatility would be expected to fall as a result of the usual reversion to the mean, even though volatility may be independent of margin requirements. To distinguish between the impact of changes in margin requirements and the natural decay in volatility attributable to mean-reversion, we compare the spot volatility for each day following a change in margin requirements with the spot volatility that would have been expected given the volatility on the day that margin requirements were changed.

Our empirical findings are consistent with the argument that margin requirements are increased and decreased in response to increases and decreases in the volatility of the futures market. For example, we find that increases in volatility during the period prior to the increase in margin requirements seem to reverse themselves in the subsequent 10-day period. Similarly, we find that decreases in margin requirements are preceded by a decline in futures market volatility, but that the decline in volatility does not continue into the second half of the event window. The interpretation of these results is unclear. Since the average volatility during the period surrounding an increase in margins is at its highest on the announcement date, the decrease in average volatility following the increases in margin requirements can be attributed to either the effect of the increase in margins or the tendency for transitory shocks to the volatility of the futures market to decay over time. For decreases in margin requirements, the fact the average volatility on the announcement date is well above the long-run volatility implies that the spot volatility should on average be expected to decay following the reduction in margin requirements.

To distinguish the impact of changes in margin requirements from mean-reversion in futures market volatility, we compare the spot volatility with an estimate of the volatility that would be expected to prevail had conditions not changed over the 10-day period following alterations in margin requirements. For increases in margin requirements, we find that although the average spot volatility declines by more than would be expected given the expected mean reversion in the volatility on the announcement date, the difference is not statistically significant for any of the 10 days following the change in margin requirements. This result is confirmed by performing a non-parametric test for the difference between actual and the conditional expected volatility as of 10 days following the change in margin requirements. The test results indicate that the actual volatility at the end of the event window is not significantly different from the volatility that would be expected based on mean reversion in the spot volatility observed on the announcement date. For decreases in margin requirements, a similar non-parametric test statistic rejects the null hypothesis that the average spot volatility 10 days following the change in margin requirements is less than the conditional expected spot volatility. Although the rejection of the null hypothesis implies that decreases in margin requirements may have slowed the forces causing volatility to decay to its long-run mean, the limited size of the sample suggests that this result should be interpreted with caution.

There is some evidence that *ex-ante* volatility increases temporarily during the period immediately prior to increases in margin requirements. However, we are unable to reject the null hypothesis that on average futures market volatility 10 days after a change in margin requirements is equal to the volatility 10 days prior to the change in margin requirements. Further, while decreases in initial margin requirements are associated with decreases in *ex-ante* volatility, the results suggest that decreases in volatility lead (in a statistical sense) to decreases in initial margin requirements. Taken together, these results indicate that changes in initial margin requirements have very little short-term impact on the forecasts of future volatility embedded in the prices of crude oil futures options. ■

TABLE 1

Summary data for estimates of spot volatility from Nymex WTI crude oil futures call options for the period November 14, 1986 to March 18, 1991.

Statistic	Estimated Value
Mean	0.1704
Median	0.0811
Standard error	0.2980
Minimum value	0.0117
Maximum value	3.1925
Skewness	5.01
Kurtosis	34.17

The sample period includes 1086 trading days
Source: Day and Lewis, 1997[1]

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Note

1. Day, Theodore E and Craig M Lewis, 1997, Initial Margin Policy and Stochastic Volatility in the Crude Oil Futures Market, forthcoming Review of Financial Studies, volume 10, issue 2.

2. Fenn, George W and P Kupiec, 1993, Prudential Margin Policy in a Futures-style Settlement System, Journal of Futures Markets, 13, 389–408.

3. Day, Theodore E and Craig M Lewis, 1993, Forecasting Futures Market Volatility Using Alternative Models of Conditional Volatility, Journal of Derivatives 1, 33–50.

4. Day, Theodore E and Craig M Lewis, 1996, Margin Adequacy in the Crude Oil Futures Market, working paper, Vanderbilt University.

5. Hansen, LP and KJ Singleton, 1982, Generalised Instrumental Variables Estimation of Non-Linear Rational Expectations Models, Econometrica, 50, 1269–1268; Errata, 52, 267–268.