PRICE VOLATILITY AND FUTURES MARGINS

GIKAS A. HARDOUVELIS
DONGCHEOL KIM

INTRODUCTION

The October, 1987 stock market crash renewed interest among regulators and economists in the role of margin requirements in futures contracts. Margin requirements became the focus of considerable debate following the January, 1988 recommendations of the Presidential Task Force on Market Mechanisms headed by Treasury Secretary, Nicholas Brady. The "Brady Report" argued that:

> One agency should coordinate the few, but critical, regulatory issues which have an impact across the related market segments and throughout the financial system. . . . Margins should be made consistent across marketplaces to control speculation and financial leverage. (p. 7, Executive Summary)

The Brady Report's call for making margins consistent across the different markets was perceived as a recommendation for drastically increasing the level of margin requirements in futures contracts. The maintenance margin requirement in the Standard & Poors 500 futures contract was around 3% before the crash of October, 1987; whereas, the

We would like to thank Benjamin Friedman and Alan Tucker who provided comments on earlier versions of the content of this article as well as two anonymous referees. Support for this research was provided by the Federal Reserve Bank of New York. The views expressed in this article, however, are our own and do not necessarily reflect the views of the Federal Reserve Bank of New York or the Federal Reserve System and its staff.

■ *Gikas A. Hardouvelis is a Professor of Finance, Rutgers University, and a Research Fellow at C.E.P.R.*

■ *Dongcheol Kim is an Assistant Professor of Finance, Rutgers University.*

The Journal of Futures Markets, Vol. 16, No. 1, 81–111 (1996)

CCC 0270-7314/96/010081-31

maintenance margin requirement for individual stocks has been 25% since the 1930s.[1]

The Brady Report has been criticized by many economists who argue that the exchanges, driven by the profit motive and the desire to prevent contractual defaults, are more capable of assessing the optimum level of margin requirements than regulators. Indeed, many earlier academic studies have concluded that historically, margin requirements in futures markets have performed well in preventing contractual defaults and may be, on average, conservatively high. [See Telser (1981); Figlewski (1984); Edwards and Neftci (1985); Kahl, Rutz, and Sinquefield (1985); Brennan (1986); Gay, Hunter, and Kolb (1986); Estrella (1988); and Craine (1992)]. Some also argue that any attempt to force a drastic increase in margin requirements in stock index futures contracts would drive trading volume overseas and hurt the liquidity and viability of U.S. futures markets [Miller (1990)].[2]

This article focuses on the relationship between futures margins and futures price volatility. Volatility is an important ingredient in an exchange committee's decision to alter the level of margin requirements. In an environment of higher volatility, the probability of large price changes and, hence, possible contractual defaults arising from large losses, is higher. Thus, to counteract the possibilities of greater defaults due to higher volatility, the exchanges have an incentive to increase margin requirements. [See the analysis of Figlewski (1984), or of Fenn and Kupiec (1993), among others.]

This article examines if, indeed, the exchanges respond to higher (lower) volatility by raising (reducing) margins. In addition, the article explores the possibility that the exchanges are not only reacting to past volatility changes; but are proactive as well, changing margins in anticipation of further future volatility changes. The latter anticipatory behavior of the exchanges is, of course, much harder to detect because data on the expectations of the exchanges are not available. Also, replacing the exchanges' expectations about future volatility with the actual future behavior of volatility may lead to biased estimates because the change in margin requirements itself could influence—perhaps

[1] For a more detailed exposition, see Sofianos (1988), or the recent books by Duffie (1989) and Kolb (1990). The difference between the 25% and, say, a 3% maintenance margin in the two markets is deceptively large. In cash markets, after a broker call, investors have five days to come up with the money. Futures markets investors usually have one day at most to deposit the funds.

[2] The Brady report's recommendations are applied now to the S&P 500 derivative contracts. In October, 1992, the authority to set margins was transferred to the Federal Reserve, the institution which is also responsible for cash market margins.

negatively [Hardouvelis (1990); Hardouvelis and Peristiani (1992); or Hardouvelis, Pericli, and Theodossiou (1995)]—the evolution of future volatility, or simply because volatility reverts toward its long-run mean. Despite this difficulty, this article examines the behavior of volatility both before and after a margin change. Moreover, to clarify the economic interpretation of the estimated lead and lag relationship between margins and volatility, the article compares the volatility behavior of contracts for which margins have changed with the simultaneous behavior of contracts for which no change in margins has occurred.

Many previous studies have analyzed the relationship between futures margins and futures price volatility, and are reviewed in the next section. The main conceptual innovation of this article is a decomposition of volatility into an ordinary and an extraordinary component through the use of a Poisson jump-diffusion model of futures prices. The ordinary component represents the normal vibration in prices caused by a temporary imbalance between supply and demand. This component of volatility is captured by a standard Wiener process and characterizes a continuous sample path of prices. The extraordinary component represents the abnormal vibration in prices and is due to the random arrival at discrete points in time of new important information about the commodity that has more than a marginal impact on prices. This component of volatility is captured by a Poisson-jump process and has a discontinuous sample price path reflecting the nonmarginal impact of information. For example, phenomena such as bubbles, fads, and the like, which can cause turmoil in asset markets and lead to crashes, would manifest themselves in the extraordinary volatility of asset returns [Friedman and Laibson (1989)]. It follows that the exchanges' concern about contractual defaults ought to be related primarily to the extraordinary component of volatility. Isolating the extraordinary component of volatility would provide a more precise measure of the variable of interest and, hence, would give considerable statistical power in estimating the behavior of the exchanges.

Eight metal futures contracts are examined: gold (two contracts), silver (two contracts), copper, aluminum, platinum, and palladium. These metals provide more than four hundred discrete margin changes. Metals are commodities not subject to strong seasonal and other idiosyncratic factors [Anderson (1985)], Kenyon, Kling, Jordan, Seale, and McCabe (1987)].[3] Metals, therefore, represent the first natural candi-

[3]An examination of the unconditional monthly variance of the daily returns of each of the metal futures shows no evidence of significant seasonality.

date for an examination of the relationship between margin requirements and volatility because they provide considerable statistical power.

PREVIOUS EMPIRICAL EVIDENCE

There is general agreement in the literature that higher futures margins slow market activity. Tomek (1985), Hartzmark (1986), Fishe and Goldberg (1986), Ma and Kao (1990), Moser (1990b), and Ma, Kao, and Frohlich (1993) find a negative impact on open interest. More recently, using the same eight metal futures contracts examined in this article, Hardouvelis and Kim (1995) find that there is a clear causal negative influence from margin requirements to open interest and trading volume. They compare the behavior of open interest and trading volume in the metal affected by a margin change with the behavior of open interest and trading volume in the remaining metals not affected by the margin change, and find strong differences. These differences lead to the interpretation of causality.

There is less agreement in the literature about the relationship between futures margins and futures price volatility. Nathan (1967) examines grain futures over a two-year period from 1947 to 1948, and finds that large changes in margin requirements curtail price fluctuations. Hartzmark (1986), on the other hand, finds an ambiguous relationship, but he only examines 13 instances of margin changes in four different markets (wheat, feeder cattle, pork bellies, and T-bonds). Breeden (1985) examines 11 Chicago Board of Trade (CBT) futures contracts from January, 1975 to January, 1982, and finds a positive relationship, which he interprets as evidence that Chicago Board of Trade officials are able to predict volatility very well.

More recently, Ma and Kao (1990), studying the CMX silver market from 1977 to 1984, find a strong negative impact of margin changes on volatility across various subperiods. Their volatility measure is one of price (detrended appropriately) rather than the more common return volatility that is used in this study. Ma and Kao also examine the evolution of silver prices, and find that margin changes counteract the previous growth in those prices. Both pieces of evidence lead them to conclude that margins stabilize the silver market. Moser (1990a) also finds a negative impact on volatility in the silver market using a time-series methodology, but claims that his result, unlike Ma and Kao's, is due to the late 1979–early 1980 period when the Hunt brothers caused a turmoil in the silver market. Moser (1990b) examines three additional contracts, the S&P 500, soybeans, and the deutschemark, and finds no effect on volatility. Kupiec (1993) performs a time-series analysis on the volatility of the S&P 500 contract, and finds a positive association. Kupiec uses the Garman–Klass (1980) daily volatility estimator, but associates it with a daily margin variable defined as the dollar margin level divided by the S&P 500 price index. This margin variable obscures somewhat the interpretation of his findings because, as he mentions, there is a positive relationship automatically built-in to his estimates by the well-known negative association between stock return volatility and the stock price level [Christie (1982)].

Fishe, Goldberg, Gosnell, and Sinha (1990) present a comprehensive study of ten CBT contracts. They measure volatility as the standard deviation of the daily high–low price spreads and examine the partial effect of margin requirements on volatility controlling for the change in open interest. They find an overall negative and insignificant effect that varies from contract to contract, concluding that the results are ambiguous. Finally, Hardouvelis and Kim (1995), who examine eight metal futures contracts, find a positive relationship between the change in margins and the change in volatility. They use two measures of volatility: the daily Garman–Klass volatility estimator, and the residual standard deviation of second-order autoregressive [AR(2)] processes of daily returns. This article extends their work by decomposing volatility into an ordinary and an extraordinary component, and by examining the volatility behavior over four separate monthly intervals around each margin change.

There is also an extensive literature on the relationship between initial margin requirements in the cash stock market and volatility. Cash margins are historically set by the Federal Reserve. An examination of the historical records shows that the Federal Reserve did not change margins anticipating a change in future price volatility [Hardouvelis (1990)]. Therefore, in cash markets, the relationship between margins and volatility can be interpreted as causal more easily than a similar relationship in futures markets. Yet, the literature on cash margins does not reach unanimous conclusions. Hardouvelis (1990) reports a negative association between margins and volatility, excess volatility, and deviations from fundamentals. Moreover, Hardouvelis and Peristiani (1992) show that margins have a clear price stabilizing influence in the post World War II Japanese stock market. On the other hand, Salinger (1989) and Hsieh and Miller (1990), among others, concentrate on one of the three measures Hardouvelis used, volatility, and argue that the negative association between margins and volatility in the U.S. is weak. More recently, Hardouvelis, Pericli, and Theodossiou (1995) use a more powerful statistical apparatus, daily data and the exponential GARCH-in-mean model of Nelson (1991), and counter the earlier claim that the negative association between margin requirements and volatility is weak. They report a strong and asymmetric relationship. Higher margins have a stronger negative association with subsequent volatility during bull markets than during bear markets. In this analysis, the presence of a negative causal association from margins to subsequent volatility is likely to bias the estimation on the proactive behavior of the exchanges towards finding no such proactive behavior.

THE BASIC MODEL: POISSON JUMP-DIFFUSION PROCESS

Volatility is decomposed into an ordinary and an extraordinary component and, subsequently, the relationship of margin changes to changes in each component of volatility is analyzed separately. As discussed in the introduction, it is the extraordinary component of volatility that can be responsible for large and abrupt price swings and, hence, for significant losses for exchange members. Indeed, Friedman and Laibson (1989) argue that phenomena such as bubbles, fads, and the like, which can cause turmoil in asset markets and lead to crashes, would manifest themselves in the extraordinary volatility of asset returns. The exchanges ought to be reacting primarily to changes in the extraordinary component volatility.

Asset returns are modeled as Poisson jump-diffusion processes. The model follows the work of Press (1967), Clark (1973), Ball and Torous (1983, 1985), Jarrow and Rosenfeld (1984), Akgiray and Booth (1987, 1988), Tucker and Pond (1988), and Friedman and Laibson (1989), who assume that asset returns are mixtures of normals, with the mixing variable being a Poisson random variable. These investigators claim that a mixture of normal distributions model provides a superior description of stock and foreign exchange returns than alternative time-independent statistical models. Hall, Brorsen, and Irwin (1989) specifically analyzed futures prices and showed that their distribution is described by a mixture of normals better than it would be described by a Paretian distribution.

The Poisson jump-diffusion process can be expressed as follows:

$$\log\left(\frac{S(t)}{S(t-1)}\right) = \mu t + \sigma Z(t) + \sum_{n=0}^{N(t)} J_n$$

where

$S(t) \equiv$ the security price at time t,

$Z(t) \equiv$ a standardized Wiener process,

$N(t) \equiv$ a Poisson counting process with intensity parameter $\lambda > 0$ (mean number of *abnormal* information arrivals per unit of time),

$J_n \equiv$ a normal random variate with mean zero and variance σ_J^2 representing the logarithm of one plus the percentage change in the security price caused by the nth jump,

$\mu \equiv$ the instantaneous expected rate of return per unit time for the Wiener process part,

$\sigma^2 \equiv$ the instantaneous variance of the security return, conditional on no arrivals of *abnormal* information.

The Poisson jump-diffusion process is equivalent to decomposing a security return, R_t, into an ordinary component, U_t, and an independent extraordinary component, V_t:

$$R_t \equiv U_t + V_t \tag{1}$$

where

$$U_t \sim N(\mu, \sigma^2)$$

$$V_t \equiv \sum_{n=0}^{N(t)} J_n$$

The extraordinary component, V_t, is the sum of $N(t)$ realizations, J_n, of white disturbances with mean zero and variance, σ_J^2. $N(t)$ is a Poisson random variable with mean parameter, λ, which indicates the number of new important information arrivals per unit of time. J_n is the random size of a discrete jump in asset prices caused by the random arrival of new important information. The extraordinary component allows for abrupt large price changes, which could potentially result in futures contract defaults. This is, therefore, exactly the characteristic of the return generating process that the exchanges ought to be concerned about. The jump volatility, σ_J^2, is the variance of each of the $N(t)$ independent abnormal vibrations in prices, i.e., J_n, while the total jump volatility of the extraordinary component is the variance of the total sum of $N(t)$ independent abnormal vibrations in prices that occurred during the unit period of time. Hence, the total jump volatility of the extraordinary component depends not only on the jump volatility σ_J^2, but also on the size of the frequency parameter, λ, i.e., the mean number of new information arrivals per unit of time, of the Poisson process:

$$\mathrm{Var}(V_t) \equiv \sigma_{TJ}^2 = \lambda \sigma_J^2$$

The empirical section examines the behavior of both σ_J^2 and σ_{TJ}^2. A concrete example based on the estimates of σ^2 and σ_{TJ}^2 is used to clarify further the interpretation of the volatility of the ordinary and extraordinary components of futures daily returns. During the month that precedes an increase in margin requirements, the average σ^2 is 6.005×10^{-4}. The average σ_{TJ}^2 is much higher, 15.925×10^{-4}. The parameter σ_{TJ}^2 is higher because the frequency parameter, λ, is greater than unity: the average λ is 1.881, which implies that abnormal information arrives every 0.53 days.[4] Naturally, a large price change may originate from the extraordinary component with a much higher probability than the ordinary component. For example, the probability of a price fall of 10% or more is calculated next. This probability is represented by the area under the standard normal probability distribution from minus infinity to $-0.01/\sigma$ in the case of the ordinary component, and from minus infinity to $-0.01/\sigma_{TJ}$ in the case of the extraordinary component. This probability is, therefore, equal to 2.24×10^{-5} and 6.11×10^{-3}, respectively. Put differently, a price crash of 10% or more during a single day would originate from the extraordinary component of volatility with a probability which is 273 times higher than the probability that the same crash would originate from the ordinary component of volatility.

The logarithm of the likelihood function of the vector of unknown parameters, $\Theta = (\mu, \sigma^2, \sigma_J^2, \lambda)$, can be described as follows:

$$\log L(\mathbf{R}|\Theta) = \sum_{t=1}^{T} \sum_{n=1}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \cdot f\left(R_t|\mu, \sigma^2 + n\sigma_J^2\right) \qquad (2)$$

where $f(R_t \mid a, b)$ denotes a normal density function with mean, a, and variance, b. To obtain the maximum likelihood estimator of Θ, one must truncate the infinite sum of discrete jumps in eq. (2). In the present

[4]Although, in principle, the estimate of λ should be invariant to the degree of time aggregation; in practice, it varies according to the choice of the return measurement interval. For example, Friedman and Laibson's (1989) estimate of λ using quarterly data is 0.0327 (every 30.6 quarters), Press's (1967) estimate (Allied Chemical Co.) using monthly data is 0.494 (every 2 months). This study's estimate using daily data is approximately 1.8 (every 0.6 days). The estimate of Ball and Torous (1985) using daily data is similar to this study's. The possible explanation for this discrepancy is that a substantial portion of valuable information is lost in the process of time aggregation from high-frequency (such as daily) data to low-frequency (such as quarterly) data, so that the Poisson-jump model does not satisfy the theoretical property of invariance to the return measurement interval.

article, as in Ball and Torous (1985), the truncation is at $N = 10$. For $N = 10$, the approximation error is very small.[5] To maximize the likelihood function, a modified Newton method is employed, which requires both the gradient and the Hessian matrix. To ensure quick convergence of the nonlinear maximization of the truncated log-likelihood function, the method of cumulants estimator of Θ proposed by Press (1967) and Beckers (1981) are used as starting values.[6]

To investigate the relationship between changes in ordinary and extraordinary (or jump) volatility and changes in margin requirements, the model of eq. (2) is estimated separately over four subperiods $[-43, -22]$, $[-21, -1]$, $[0, 21]$, $[22, 43]$ during each individual margin change, where day zero denotes the business day of a margin change. Thus, for N margin changes of a given metal, the model is estimated independently $4N$ times, and produces $4N$ independent estimates of each parameter. Each subperiod is approximately one month long and consists of 21 (or 22) daily returns. The length of the subperiods represents what is thought to be a reasonable compromise between two conflicting concerns. First, a subperiod ought to be sufficiently long to allow for precise estimates of the model parameters. Second, the subperiods must not be too long because very long subperiods result in significant overlapping—especially in contracts with frequent margin changes—between subperiods that belong to consecutive margin changes. Nevertheless, the results are not sensitive to the length of the subperiods. The analysis is repeated using three-week subintervals and the eventual cross-sectional regression estimates given in "Regression Results" remain qualitatively the same.

The estimated parameters in model (2) are subsequently used to form the dependent variables of regressions that include the percentage change in margin requirements as an independent variable. The sampling error of the parameter estimates of model (2) adds extra noise on the error term of the regressions of the following sections. This noise decreases the regression R^2's but does not affect the consistency of the

[5]Ball and Torous derived an approximation error bound when the infinite sum is truncated at N. The approximation error, $B(N)$, is

$$B(N) \leq (2\pi\sigma^2)^{-1/2} \frac{\lambda^{N+1}}{(N+1)!}$$

[6]The method of cumulants estimators provide relatively good starting values. In some cases, however, the method of cumulants give negative estimators of the variance parameters, σ^2, and σ_J^2. These negative estimates are not used as the starting values. For these cases, the sample variance is used for the starting value of σ^2 and σ_J^2.

regression estimates. Other measurement errors besides the sampling error would act in a similar fashion. These errors may originate from a possible price limit that has been hit or, perhaps, from the fact that the model does not allow for any systematic time dependence in the volatility estimates of model (2).[7] However, such errors would probably be overwhelmed by the size of the sampling error.

DATA, REGRESSION FRAMEWORK, AND VARIABLE DEFINITIONS

Description of the Data

The daily futures price, of eight metal futures contracts are provided by Technical Tools Inc.[8] The futures contracts used include: New York Commodity Exchange (CMX) gold, CMX silver, CMX copper, CMX aluminum, New York Mercantile Exchange (NYM) platinum, NYM palladium, Chicago Board of Trade (CBT) gold, and CBT silver. The CMX silver contract was a 10,000-ounce contract until September 26, 1974, and then it changed to a 5000-ounce contract. The dollar level of the margin requirement is standardized to reflect a 5000-ounce contract. The CMX copper data series switches from the old 25,000-pound contract to the new 25,000-pound high grade contract on November 27, 1989. Currently, only high grade copper is trading. Two contracts of the CBT gold are currently traded: a kilo and an 100-ounce contract. The data series of this study refer to the kilo contract. Margin levels are standardized to reflect an 100-ounce contract, the same-size contract traded at the CMX. Two contracts of the CBT silver are currently traded: the older 5000-ounce and the newer 1000-ounce. The data series of this study includes the 5000-ounce contract until 1/24/1982 and the 1000-ounce contract thereafter. The margin level is adjusted to reflect a 5000-ounce contract, the same-size contract traded at the CMX.

The oldest contract is the CMX silver contract which dates back to July, 1971. The newest contract is the CBT gold which began trading in April, 1984. The sample ends in November, 1990. The analysis excludes the sample observations of the two silver contracts from September,

[7]Currently, metal futures traded on the CMX, such as gold, silver, copper, and aluminum, have no price limits. Metal futures with price limits are: palladium (NYM), platinum (NYM), CBT gold, and CBT silver.

[8]Prices are for the first maturing contract, switching to the next maturing contract before the expiration date. The switching date for copper and CBT silver is the 25th calendar day of the month preceding the expiration month; and for all of the other metals, it is the 19th calendar day of the month preceding the expiration month.

1979 through April, 1980, a time when the Hunt brothers cornered the silver market. This avoids a possible contamination of evidence by the frequent intervention of the exchanges during that period.

The margin data are from the individual exchanges. The empirical analysis uses maintenance margins because their definition is similar across the different types of investors (hedgers and speculators) and contracts.[9] (An analysis using initial margins results in similar findings.)

Empirical Framework and Variable Definitions

The empirical analysis compares the two-month time interval before the margin change with the two-month time interval after the margin change. Letting day 0 denote the day of the margin change, the interval before the change is comprised of business days, -43 through -1, and the interval after the change is comprised of business days, 0 through 43.[10] These intervals are further divided into the following 4 one-month subintervals: $[-43, -22]$, $[-21, -1]$, $[0, 21]$, and $[22, 43]$. The parameters of the Poisson jump-diffusion process are estimated separately in each of the four subintervals. Only the cases in which the maximization algorithm converges in all four subintervals are reported. These are 415 of a total 500 margin changes.

The regression framework relates cross sectionally the percentage change in the various volatility measures with the percentage change in margins. Apart from the changes in volatility between subperiods 1, 2, 3, and 4, the time series properties of the dependent variables are ignored.[11] Since the volatility and margin series (when expressed as a percentage of the value of the underlying contract) are stationary variables (i.e., in the long run, they revert to a mean), a time-series study, for example, would probably associate the level of volatility with the level of margin requirements expressed as a percentage of the value

[9] Maintenance margins are set typically at 75% of the level of the initial margin and must always be satisfied. Speculators, who face higher initial margins than hedgers, usually face a maintenance margin equal to the initial margin of hedgers; and hedgers typically face a maintenance margin equal to their initial margin.

[10] The two-month intervals result in some overlapping between consecutive margin changes. This overlapping is more several in metals like CMX Silver with frequent margin changes. Regressions using only nonoverlapping subintervals produce results that are qualitatively the same.

[11] Consecutive margin changes frequently result in some overlapping between the time intervals, especially between interval [4] of the first margin change and interval [1] of the second margin change. This overlapping may induce some serial correlation in the volatility estimates which, however, would not affect the consistency of the cross-sectional ordinary least squares (OLS) parameter estimates.

of the underlying futures contract, and not the first difference in the logarithm of volatility with the first difference in the logarithm of margin requirements. See Hardouvelis (1990); Hsieh and Miller (1990); and Hardouvelis, Pericli, and Theodossiou (1995) for further discussion on this point. The technical issue of stationarity is important for the consistency of the estimated parameters of a time-series study. In a cross-sectional study, stationarity is important only in the interpretation of the evidence. The mean reversion of volatility implies, for example, that after an increase in volatility to which an exchange responds by raising margins, one may well observe a small decline in volatility, which is due entirely to mean reversion. One could erroneously conclude that the exchanges incorrectly raised margin requirements or that the higher margins caused the subsequent decline in volatility. In general, the interpretation of the behavior of volatility after—as opposed to before—a margin change requires special care.

The regression framework has the following specific form:

$$\Delta Y_k = \alpha + \beta \Delta \log M_k, \quad k = 1, \ldots N \tag{3}$$

where $\Delta \log M_k$ is the continuously compounded percentage change in the average margin level at the kth margin change, i.e., $\Delta \log M_k = \log(\overline{M}_{[22,43]}/\overline{M}_{[-43,-22]})$, ($\overline{M}_{[t_1,t_2]}$ is the average margin level over the period, $[t_1, t_2]$); ΔY_k is the continuously compounded percentage change in the level of a volatility variable at the kth margin change; and N is the number of margin changes.

Several measures of volatility are considered. For example, $\Delta \log \sigma_J^2 = \log(\sigma^2_{J[22,43]}/\sigma^2_{J[-43,-22]})$ is the continuously compounded percentage change in the level of jump (or extraordinary) volatility from the first to the fourth interval, where $\sigma^2_{J[22,43]}$ and $\sigma^2_{J[-43,-22]}$ are the jump volatilities estimated using data from the fourth interval [22, 43] and the first interval [−43, −22], respectively. The continuously compounded percentage changes in the level of jump volatility from the first to the second interval, from the second to the third, from the third to the fourth, or from the second to the fourth interval are defined in a similar manner. Thus, the percentage change from the first to the fourth interval is the sum of the percentage changes from the first to the second interval, the second to the third, and the third to the fourth interval. $\Delta \log \sigma^2_{TJ}$ (total jump volatility), $\Delta \log \sigma^2$ (ordinary volatility), and $\Delta \log \lambda$ (Poisson process parameter) are defined similarly.

THE EVIDENCE

Average Magnitudes

Table I presents the grand time-series and cross-commodity average of the different volatility estimates, separately for positive and negative margin changes at day 0, and separately for each interval [−43, −22], [−21, −1], [0, 21], and [22, 43]. These averages obscure the differences between contracts and give larger weight to contracts with higher average price volatility but, nevertheless, provide a useful preliminary summary of the more detailed evidence to come.

TABLE I

Average of Each Volatility Measure Across all Metal Futures in Each Time Interval

Variable	*Sample Size*	*Intervals* [−43, −22]	[−21, −1]	[0, 21]	[22, 43]
		Panel A: Positive day-zero changes in margin requirements			
σ_J^2 ($\times 10^4$)	180	4.681 (0.344)	6.914 (0.700)	7.275 (0.586)	5.905 (0.504)
Benchmark	220	4.066 (0.277)	5.030 (0.292)	4.400 (0.286)	4.265 (0.277)
σ_{TJ}^2 ($\times 10^4$)		9.070 (0.843)	15.925 (1.855)	17.601 (1.469)	13.730 (1.313)
Benchmark		7.907 (0.755)	8.372 (0.556)	8.175 (0.683)	7.575 (0.589)
σ^2 ($\times 10^4$)		3.758 (0.183)	6.005 (0.431)	6.469 (0.483)	5.860 (0.545)
Benchmark		3.249 (0.103)	3.958 (0.251)	3.789 (0.190)	3.522 (0.146)
λ		1.493 (0.067)	1.881 (0.095)	2.005 (0.084)	1.893 (0.085)
Benchmark		1.297 (0.037)	1.317 (0.036)	1.365 (0.040)	1.305 (0.060)
		Panel B: Negative day-zero changes in margin requirements			
σ_J^2 ($\times 10^4$)	235	7.016 (0.649)	5.744 (0.381)	6.283 (0.625)	5.703 (0.521)
Benchmark	357	4.066 (0.277)	5.030 (0.292)	4.400 (0.286)	4.265 (0.277)
σ_{TJ}^2 ($\times 10^4$)		16.666 (1.726)	12.675 (1.062)	13.700 (1.433)	12.435 (1.352)
Benchmark		7.907 (0.755)	8.372 (0.556)	8.175 (0.683)	7.575 (0.589)
σ^2 ($\times 10^4$)		5.596 (0.327)	5.033 (0.358)	4.652 (0.230)	4.309 (0.196)
Benchmark		3.249 (0.103)	3.958 (0.251)	3.789 (0.190)	3.522 (0.146)
λ		1.847 (0.071)	1.707 (0.070)	1.699 (0.073)	1.619 (0.073)
Benchmark		1.297 (0.037)	1.317 (0.036)	1.365 (0.040)	1.305 (0.060)

Notes: The table presents the sample mean of the variable in the left column with its standard error in parentheses. Each benchmark group consists of metals which do not undergo a margin change over the four-month interval [−43, 43] of a particular margin change of the target metal. Day −43 (+43) denotes the 43rd business day prior to (after) the day margin requirements change. σ_J^2 denotes jump volatility, σ_{TJ}^2 total jump volatility, σ^2 ordinary volatility, and λ the mean number of information arrivals. These four variables are parameters of a Poisson jump-diffusion model of metal prices, estimated separately for each margin change and for each of the four intervals.

Panel A shows that for positive margin changes, all four volatility measures increase from the first to the second and from the second to the third interval, but then decrease in the fourth interval. However, the volatility of the fourth interval remains higher than the volatility of the first interval. Thus, the increase in volatility to which the exchanges respond by increasing margins is not completely transitory. Part of the volatility increase is permanent. Observe that the volatility of the extra-ordinary component of daily returns, σ_{TJ}^2, behaves similarly as the volatility of the ordinary component, σ^2.

Panel B shows that after margins decrease, the earlier downward movement in jump volatility reverses to an upward movement. Margins may, therefore, curb an earlier downward movement in jump volatility.[12] However, in the fourth interval, jump volatility resumes its earlier decline reaching a level lower than its level during the first interval. Again, as in the earlier case of Panel A, the exchanges respond to a decrease in volatility by decreasing margins. They are justified in doing so because part of the volatility decline is relatively permanent.

Table II clarifies the evidence in Table I by presenting the percentage change in the various volatility measures and in the margin requirements. As in Table I, the numbers are averages both across time and across contracts. Unlike Table I, however, aggregation of volatility measures across different contracts presents no conceptual difficulties because the variables are aggregated after they are first transformed into percentage changes. Panel A emphasizes that volatility increases from the first to the fourth interval, but that this increase is due mainly to an increase from the first to the second interval and a slight increase from the second to the third interval. Volatility actually declines from the third to the fourth interval, but this decline is smaller than the earlier rise, generating a total increase in volatility from the first to the fourth interval. In Panel B, volatility shows a continuous decline from the first to the second, from the second to the third, and from the third to the fourth interval.

Comparison with a Benchmark Group

To assess more precisely the nature of the relationship between margins and volatility, a benchmark group of metals is constructed in a manner similar to that of Hardouvelis and Kim (1995). A benchmark group

[12]Alternatively, the increase in jump volatility from the second to the third interval could simply be the outcome of an earlier, (in the second interval) temporary, negative shock on volatility that disappears in the third interval.

TABLE II
Average of Percentage Change in Margin Requirements and Volatility Measures Across all Metal Futures

	Sample Size		Δ log M	Δ log σ_J^2	Δ log σ_{TJ}^2	Δ log σ^2	Δ log λ
		Panel A: Positive day-zero changes in margin requirements					
All metals	180	[1] → [2]		35.59 (6.64)	57.84 (10.82)	46.16 (5.91)	22.25 (5.68)
		[2] → [3]		5.15 (6.03)	14.86 (10.36)	0.84 (6.69)	9.71 (5.93)
		[3] → [4]		−14.98 (6.29)	−21.31 (9.64)	−11.70 (6.29)	−6.33 (4.86)
		[2] → [4]		−9.83 (6.49)	−6.45 (10.86)	−10.86 (6.67)	3.38 (6.01)
		[1] → [4]	28.58 (3.95)	25.76 (6.64)	51.39 (6.48)	35.31 (10.54)	25.63 (5.33)
Benchmark	220	[1] → [2]		32.04 (8.06)	50.39 (11.43)	31.71 (6.25)	18.34 (5.27)
		[2] → [3]		−15.17 (7.40)	−17.94 (10.77)	−5.99 (6.16)	−2.77 (5.56)
		[3] → [4]		−3.65 (6.71)	−4.71 (10.56)	−0.77 (6.11)	−1.06 (5.57)
		[2] → [4]		−18.82 (7.89)	−22.64 (11.39)	−6.75 (6.10)	−3.83 (5.64)
		[1] → [4]	0.00 (N.A.)	13.22 (7.50)	27.74 (11.54)	24.96 (5.85)	14.52 (5.76)
		Panel B: Negative day-zero changes in margin requirements					
All metals	235	[1] → [2]		−10.75 (5.25)	−21.04 (8.56)	−11.86 (5.52)	−10.30 (4.62)
		[2] → [3]		−3.30 (5.64)	−6.46 (8.86)	−2.23 (5.10)	−3.27 (4.66)
		[3] → [4]		−5.11 (5.86)	−9.36 (9.38)	−6.87 (4.85)	−4.18 (5.28)
		[2] → [4]		−8.31 (5.38)	−15.76 (8.89)	−9.09 (5.16)	−7.45 (4.86)
		[1] → [4]	−21.44 (2.52)	−19.05 (5.83)	−36.80 (9.34)	−20.95 (5.18)	−17.75 (4.82)
Benchmark	357	[1] → [2]		5.30 (4.81)	−0.67 (7.91)	−6.16 (4.86)	−5.98 (4.23)
		[2] → [3]		−8.30 (5.23)	−3.32 (7.75)	−1.64 (4.49)	4.97 (4.03)
		[3] → [4]		−3.71 (4.93)	−14.55 (7.49)	−2.94 (4.70)	−10.84 (3.94)
		[2] → [4]		−12.01 (5.08)	−17.88 (8.00)	−4.58 (4.45)	−5.87 (4.03)
		[1] → [4]	0.00 (N.A.)	−6.71 (4.82)	−18.55 (7.65)	−10.74 (4.90)	−11.84 (3.92)

Notes: The table presents the sample mean of the variable in the top row with its standard error in parentheses. [*i*] → [*j*] indicates the change from the *i*th interval to the *j*th interval; intervals [1], [2], [3], and [4] are [−43, −22], [−21, −1], [0, 21], and [22, 43], respectively. ΔX denotes the continuously compounded percentage in variable *X*. *M* denotes the average margin requirement in each interval. See Table I for the remaining variable definitions.

includes the metals which do not undergo a margin change over the four-month interval [−43, 43] of a particular margin change of the target metal. Thus, for a given margin change in the target metal, the number of commodities in the benchmark group can vary from zero to seven. Some margin changes are associated with more than one benchmark commodity and some are not associated with any commodity. The counterpart market of a particular commodity is excluded from a benchmark group. For example, when the CMX gold (silver) is in the target group, then CBT gold (silver) is not included in the benchmark group. The reason for the exclusion is that there is an arbitrage relationship that links the prices between CMX and CBT gold.

Table III presents the bivariate correlation coefficient between the unconditional variances of the eight metal contracts estimated in each calendar month by using the daily futures returns of the month. The sample period used to calculate each bivariate correlation is common to both contracts. Most correlations are positive. Months with high volatility in one contract are likely to be months with relatively high volatility in another contract. This positive correlation may induce some similarities in the behavior of the volatility of a target metal with the volatility of its benchmark group. In particular, the correlation between CBT and CMX gold, as well as between CBT and CMX silver, is very high and justifies the exclusion of the counterpart gold and silver contract from the benchmark group. The remaining correlations are, however, small. The small size of the correlation coefficients suggests that the methodology of distinguishing between a target metal and its benchmark group has considerable statistical power.

Tables I and II also present the grand average statistics for the benchmark group of metals. There are important differences between metals that incur margin changes and metals without any simultaneous margin changes. The major difference is in the volatility behavior from the first to the second interval. Panels A of Tables I and II show that target metal volatility rises more drastically; whereas, Panels B of Tables I and II show that target metal volatility falls more drastically than benchmark metal volatility. The exchanges apparently increase (decrease) the margin requirements of those metals that have recently shown the most increase (decrease) in volatility.

TABLE III

Correlation Coefficients of Unconditional Variances of Daily Futures Returns

	Gold (CMX) 1	*Gold (CBT)* 2	*Silver (CMX)* 3	*Silver (CBT)* 4	*Copper (CMX)* 5	*Aluminum (CMX)* 6	*Palladium (NYM)* 7	*Platinum (NYM)* 8
1	.	0.945	0.568	0.528	0.374	−0.144	0.512	0.743
2	0.945	.	0.392	0.393	−0.149	−0.142	0.338	0.657
3	0.568	0.392	.	0.971	0.240	0.208	0.477	0.598
4	0.528	0.393	0.971	.	0.208	0.179	0.473	0.597
5	0.374	−0.149	0.240	0.208	.	0.320	−0.032	0.256
6	−0.144	−0.142	0.208	0.179	0.320	.	−0.020	−0.150
7	0.512	0.338	0.477	0.473	−0.032	−0.020	.	0.621
8	0.743	0.657	0.598	0.597	0.256	−0.150	0.621	.

Notes: The table presents the bivariate correlation coefficients between the unconditional variances of daily futures returns of the eight metal contracts. The unconditional variances are estimated in each calendar month. In calculating each bivariate correlation, the sample period common to both contracts is utilized.

Panels A and B of Tables I and II also show that the total change in volatility from the first interval to the fourth is much more drastic in the target metals than the benchmark group. This behavior can be interpreted as evidence that the exchanges change the margins of those metals which undergo a *more permanent* change in volatility.

Regression Results

Table IV presents the detailed regression results. The table first presents a pooled (stacked) regression of all contracts, and then the individual commodity regressions. There is an overall positive and statistically significant association between the change in margins and the change from the first to the fourth interval in all considered measures of volatility (jump volatility, σ_J^2, total jump volatility, σ_{TJ}^2, ordinary volatility, σ^2, and the mean number of information arrivals, λ). In the stacked regression, an increase in margins by 10% from the first to the fourth interval is associated with an increase in jump volatility of 6.09%, in ordinary volatility of 6.44%, in the mean number of information arrivals of 4.91%, and in total jump volatility of 11%. For each individual commodity, an increase in margins is associated with an increase in all volatilities. Except for a few cases, this positive association is statistically significant.

Table IV also shows that there are statistically significant differences between the behavior of a target metal and its benchmark group (observe the t-statistics inside the brackets). The change in the level of volatility of the benchmark group from the first to the fourth interval is associated positively with the change in margins. However, the magnitude and the statistical significance of the regression coefficients are much smaller than those of the target metals. Also, the regression R^2's are always much smaller in the benchmark group.

The positive association between the change in margins and the change in volatility from the first to the fourth interval is primarily due to the volatility behavior from the first to the second interval. The exchanges apparently react to past increases (decreases) in volatility by raising (reducing) margins. Moreover, the differences with the benchmark group show that the exchanges increase (decrease) margins in metal contracts that undergo the largest increase (decrease) in volatility

The behavior of volatility following a margin change is less clearcut and varies somewhat from commodity to commodity. In gold (CMX and CBT) and silver (CBT), the association between the change in margins and the change in volatility from the second to the third

TABLE IV
Volatility and Futures Margins: Regression Results

$\Delta Y_k = \alpha + \beta \Delta\ log\ M_k + \epsilon_k$

Market	Sample Size		$\Delta\ log\ \sigma_J^2$	$\Delta\ log\ \sigma_{TJ}^2$	$\Delta\ log\ \sigma^2$	$\Delta\ log\ \lambda$
All metals	415	[1] → [2]	4.89 (6.15)	7.89 (6.06)	5.58 (7.13)	3.00 (4.31)
			0.084	0.082	0.110	0.043
		[2] → [3]	1.86 (2.33)	4.09 (3.16)	1.47 (1.86)	2.23 (3.15)
			0.013	0.024	0.008	0.023
		[3] → [4]	−0.66 (−0.79)	−0.98 (−0.75)	−0.61 (−0.82)	−0.32 (−0.45)
			0.002	0.001	0.002	0.000
		[2] → [4]	1.20 (1.50)	3.11 (2.34)	0.86 (1.08)	1.91 (2.61)
			0.005	0.013	0.003	0.016
		[1] → [4]	6.09 (7.41)	11.00 (8.40)	6.44 (8.38)	4.91 (7.22)
			0.117	0.146	0.145	0.112
Benchmark	577	[1] → [2]	3.07 (2.80)	4.74 (2.81)	3.76 (3.80)	1.66 (1.95)
			0.013	0.014	0.025	0.007
			[1.33]	[1.47]	[1.43]	[1.21]
		[2] → [3]	−0.21 (−0.19)	−0.18 (−0.11)	0.22 (0.24)	0.03 (0.03)
			0.000	0.000	0.000	0.000
			[1.51]	[2.05]	[1.02]	[2.00]
		[3] → [4]	−0.66 (−0.65)	−0.71 (−0.45)	−1.34 (−1.41)	−0.05 (−0.06)
			0.001	0.000	0.003	0.000
			[0.00]	[−0.13]	[0.60]	[−0.25]
		[2] → [4]	−0.87 (−0.78)	−0.89 (−0.53)	−1.12 (−1.21)	−0.02 (−0.03)
			0.001	0.000	0.003	0.000
			[1.50]	[1.86]	[1.62]	[1.73]
		[1] → [4]	2.20 (2.08)	3.85 (2.31)	2.64 (2.71)	1.64 (1.94)
			0.007	0.009	0.013	0.006
			[2.89]	[3.37]	[3.04]	[3.00]
Gold (CMX)	82	[1] → [2]	5.77 (3.12)	8.08 (2.75)	3.87 (2.07)	2.31 (1.49)
(741231–			0.109	0.086	0.051	0.027
901031)		[2] → [3]	−1.42 (−0.85)	0.49 (0.16)	3.39 (1.80)	1.91 (1.02)
			0.009	0.000	0.039	0.013
		[3] → [4]	0.33 (0.17)	−0.71 (−0.21)	−0.28 (−0.17)	−1.04 (−0.52)
			0.000	0.001	0.000	0.003
		[2] → [4]	−1.08 (−0.68)	−0.22 (−0.08)	3.11 (1.79)	0.86 (0.48)
			0.006	0.000	0.039	0.003
		[1] → [4]	4.69 (2.87)	7.86 (2.93)	6.98 (4.15)	3.17 (1.98)
			0.094	0.097	0.177	0.047
Benchmark	147	[1] → [2]	−1.75 (−0.86)	−2.12 (−0.67)	0.59 (0.30)	−0.37 (−0.24)
			0.005	0.003	0.001	0.000
			[2.74]	[2.37]	[1.21]	[1.23]
		[2] → [3]	2.83 (1.42)	4.09 (1.27)	2.31 (1.17)	1.26 (0.70)
			0.014	0.011	0.009	0.003
			[−1.63]	[−0.81]	[0.40]	[0.25]
		[3] → [4]	0.85 (0.40)	0.73 (0.22)	−0.72 (−0.38)	−0.12 (−0.07)
			0.001	0.000	0.001	0.000
			[−0.18]	[−0.31]	[0.17]	[−0.36]

continued

TABLE IV (Continued)

Volatility and Futures Margins: Regression Results

$\Delta Y_k = \alpha + \beta\Delta\, log\, M_k + \epsilon_k$

Market	Sample *Size*		$\Delta\ log\ \sigma_J^2$	$\Delta\ log\ \sigma_{TJ}^2$	$\Delta\ log\ \sigma^2$	$\Delta\ log\ \lambda$
		[2] → [4]	3.68 (1.79) 0.022 [1.81]	4.82 (1.47) 0.015 [−1.16]	1.59 (0.84) 0.005 [0.59]	1.13 (0.66) 0.003 [−0.11]
		[1] → [4]	1.93 (0.85) 0.005 [0.97]	2.70 (0.76) 0.015 [1.15]	2.18 (1.07) 0.013 [1.80]	0.76 (0.49) 0.002 [1.10]
Gold (CBT) (840412–901113)	8	[1] → [2]	10.26 (1.19) 0.191	22.48 (1.40) 0.247	19.35 (1.96) 0.389	12.22 (1.55) 0.287
		[2] → [3]	−4.65 (−0.81) 0.099	−8.68 (−0.98) 0.138	−1.24 (−1.34) 0.231	−4.03 (−0.52) 0.043
		[3] → [4]	−0.47 (−0.04) 0.000	−2.11 (−0.18) 0.005	−1.52 (−0.21) 0.007	−1.64 (−0.24) 0.010
		[2] → [4]	−5.12 (−0.67) 0.069	−10.79 (−1.01) 0.146	−13.90 (−1.92) 0.380	−5.67 (−1.51) 0.275
		[1] → [4]	5.14 (0.79) 0.094	11.69 (0.94) 0.128	5.45 (0.88) 0.115	6.55 (1.02) 0.148
Benchmark	13	[1] → [2]	7.35 (0.72) 0.045 [0.19]	18.51 (1.26) 0.127 [0.17]	17.94 (2.60) 0.381 [0.12]	11.15 (1.91) 0.249 [0.11]
		[2] → [3]	2.91 (0.23) 0.005 [−0.44]	−1.90 (−0.13) 0.001 [−0.33]	−6.69 (−1.08) 0.096 [−0.53]	−4.80 (−0.86) 0.063 [0.08]
		[3] → [4]	−12.19 (−1.45) 0.160 [0.84]	−19.30 (−1.58) 0.186 [0.94]	−14.55 (−1.91) 0.250 [1.14]	−7.09 (−1.00) 0.084 [0.51]
		[2] → [4]	−9.29 (−0.87) 0.065 [0.27]	−21.20 (−1.60) 0.189 [0.54]	−21.25 (−4.29) 0.626 [0.86]	−11.90 (−2.82) 0.420 [1.00]
		[1] → [4]	−1.94 (−0.25) 0.006 [0.62]	−2.68 (−0.21) 0.004 [0.74]	−3.31 (−0.51) 0.022 [0.89]	−0.74 (−0.12) 0.001 [0.75]
Silver (CMX) (710729–901031)	160	[1] → [2]	5.06 (4.86) 0.130	8.98 (4.67) 0.121	6.93 (6.38) 0.205	3.91 (3.37) 0.067
		[2] → [3]	2.26 (2.02) 0.025	3.77 (2.00) 0.025	−0.24 (−0.20) 0.000	1.51 (1.43) 0.013
		[3] → [4]	−1.44 (−1.27) 0.010	−1.84 (−0.99) 0.006	−1.22 (−1.15) 0.008	−0.40 (−0.38) 0.001
		[2] → [4]	0.83 (0.69) 0.003	1.93 (0.93) 0.005	−1.45 (−1.26) 0.010	1.10 (0.96) 0.006
		[1] → [4]	5.89 (4.65) 0.120	10.91 (5.03) 0.138	5.48 (5.13) 0.143	5.01 (4.36) 0.108

continued

TABLE IV (Continued)

Volatility and Futures Margins: Regression Results

$$\Delta Y_k = \alpha + \beta \Delta \log M_k + \epsilon_k$$

Market	*Sample Size*		$\Delta \log \sigma_J^2$	$\Delta \log \sigma_{TJ}^2$	$\Delta \log \sigma^2$	$\Delta \log \lambda$
Benchmark	185	[1] → [2]	4.74 (2.55)	7.40 (2.61)	6.21 (3.99)	2.67 (1.95)
			0.034	0.036	0.080	0.020
			[0.16]	[0.46]	[0.38]	[0.70]
		[2] → [3]	1.55 (0.85)	2.77 (1.08)	0.21 (0.15)	1.22 (1.01)
			0.004	0.006	0.000	0.006
			[0.33]	[0.31]	[−0.25]	[0.18]
		[3] → [4]	−0.61 (−0.37)	−0.30 (−0.12)	−0.51 (−0.34)	0.31 (0.24)
			0.001	0.000	0.001	0.000
			[−0.41]	[−0.50]	[−0.39]	[−0.43]
		[2] → [4]	0.94 (0.52)	2.47 (0.91)	−0.29 (−0.21)	1.53 (1.18)
			0.001	0.005	0.000	0.007
			[−0.05]	[−0.16]	[−0.64]	[−0.25]
		[1] → [4]	5.68 (3.45)	9.87 (3.71)	5.92 (3.60)	4.20 (3.00)
			0.061	0.070	0.066	0.047
			[0.10]	[0.30]	[−0.23]	[0.45]
Silver (CBT)	20	[1] → [2]	14.24 (3.82)	22.92 (3.73)	8.03 (2.94)	8.68 (3.02)
(740907–			0.448	0.436	0.324	0.336
901031)		[2] → [3]	−2.11 (−0.46)	−2.48 (−0.37)	−2.72 (−0.83)	−0.37 (−0.15)
			0.012	0.008	0.037	0.001
		[3] → [4]	−3.24 (−0.79)	−7.78 (−1.30)	−1.49 (−0.51)	−4.55 (−2.01)
			0.033	0.086	0.014	0.183
		[2] → [4]	−5.34 (−1.57)	−10.26 (−1.90)	−4.21 (−1.28)	−4.92 (−2.04)
			0.121	0.167	0.083	0.188
		[1] → [4]	8.90 (2.38)	12.66 (2.04)	3.82 (0.93)	3.77 (1.32)
			0.240	0.188	0.046	0.088
Benchmark	23	[1] → [2]	6.50 (1.09)	8.94 (1.02)	7.76 (1.77)	2.44 (0.61)
			0.054	0.048	0.129	0.017
			[−1.07]	[1.30]	[0.05]	[1.26]
		[2] → [3]	−1.46 (−0.23)	−4.98 (−0.54)	−4.24 (−0.90)	−3.52 (−0.81)
			0.002	0.014	0.037	0.030
			[−0.08]	[0.22]	[0.26]	[0.62]
		[3] → [4]	−7.25 (−1.21)	−8.66 (−1.30)	−2.36 (−0.52)	−1.41 (−0.49)
			0.065	0.075	0.013	0.011
			[0.55]	[0.10]	[0.16]	[−0.86]
		[2] → [4]	−8.71 (−1.42)	−13.63 (−1.87)	−6.60 (−1.47)	−4.93 (−1.37)
			0.088	0.142	0.093	0.082
			[0.48]	[0.37]	[0.43]	[0.00]
		[1] → [4]	−2.21 (−0.39)	−4.69 (−0.63)	1.16 (0.24)	−2.49 (−0.69)
			0.007	0.019	0.003	0.001
			[1.62]	[1.79]	[0.42]	[1.36]
Copper	82	[1] → [2]	3.26 (1.86)	4.20 (1.70)	4.53 (2.74)	0.94 (0.74)
(CMX)			0.042	0.035	0.086	0.007
(720822–		[2] → [3]	5.83 (2.98)	10.64 (3.75)	3.25 (1.83)	4.82 (3.30)
901118)			0.100	0.150	0.040	0.120

continued

TABLE IV (Continued)

Volatility and Futures Margins: Regression Results

Market	Sample Size		$\Delta Y_k = \alpha + \beta\Delta\ log\ M_k + \epsilon_k$ $\Delta\ log\ \sigma_J^2$	$\Delta\ log\ \sigma_{TJ}^2$	$\Delta\ log\ \sigma^2$	$\Delta\ log\ \lambda$
		[3] → [4]	−1.92 (−1.00)	−2.53 (−0.93)	−1.64 (−1.03)	−0.60 (−0.48)
			0.012	0.011	0.013	0.172
		[2] → [4]	3.91 (1.98)	8.12 (2.81)	1.61 (0.89)	4.21 (2.91)
			0.047	0.090	0.010	0.095
		[1] → [4]	7.16 (4.21)	12.32 (4.81)	6.14 (3.56)	5.16 (4.07)
			0.181	0.225	0.137	0.172
Benchmark	108	[1] → [2]	3.29 (1.00)	9.09 (1.67)	5.43 (1.53)	5.81 (1.87)
			0.009	0.026	0.022	0.032
			[−0.01]	[−0.85]	[−0.24]	[−1.53]
		[2] → [3]	0.84 (0.26)	1.30 (0.25)	0.93 (0.28)	0.46 (0.16)
			0.001	0.001	0.001	0.000
			[1.30]	[1.60]	[0.62]	[1.37]
		[3] → [4]	−6.04 (−1.82)	−8.60 (−1.58)	−3.37 (−1.02)	−2.56 (−0.85)
			0.030	0.023	0.010	0.007
			[1.07]	[1.02]	[0.49]	[0.63]
		[2] → [4]	−5.20 (−1.57)	−7.30 (−1.35)	−2.44 (−0.76)	−2.10 (−0.67)
			0.023	0.017	0.005	0.004
			[2.36]	[2.56]	[1.10]	[1.89]
		[1] → [4]	−1.91 (−0.55)	1.79 (0.31)	2.99 (0.89)	3.70 (1.08)
			0.003	0.001	0.007	0.011
			[2.41]	[1.73]	[0.85]	[0.43]
Aluminum	24	[1] → [2]	5.50 (1.57)	8.09 (1.51)	5.28 (1.39)	2.59 (1.16)
(CMX)			0.100	0.094	0.081	0.057
(831208–		[2] → [3]	−0.29 (−0.09)	1.30 (0.23)	1.27 (0.31)	1.59 (0.57)
901113)			0.000	0.002	0.004	0.014
		[3] → [4]	6.16 (1.48)	11.26 (1.63)	8.34 (1.45)	5.10 (1.52)
			0.090	0.108	0.087	0.095
		[2] → [4]	5.87 (1.74)	12.56 (2.07)	9.60 (1.94)	6.69 (2.12)
			0.121	0.163	0.146	0.170
		[1] → [4]	11.37 (2.82)	20.66 (2.98)	14.88 (2.75)	9.28 (2.62)
			0.265	0.287	0.256	0.238
Benchmark	55	[1] → [2]	−2.83 (−0.76)	−5.86 (−1.01)	−3.52 (−1.05)	−3.03 (−1.03)
			0.011	0.019	0.020	0.020
			[1.53]	[1.65]	[1.71]	[1.35]
		[2] → [3]	−5.17 (−1.20)	−9.06 (−1.50)	−4.48 (−1.45)	−3.89 (−1.52)
			0.027	0.041	0.038	0.042
			[0.80]	[1.17]	[1.15]	[1.40]
		[3] → [4]	7.50 (2.37)	12.29 (2.59)	5.61 (1.90)	4.79 (1.95)
			0.096	0.113	0.063	0.013
			[−0.26]	[−0.13]	[0.49]	[0.08]
		[2] → [4]	2.33 (0.65)	3.23 (0.61)	1.14 (0.36)	0.90 (0.38)
			0.008	0.007	0.002	0.003
			[0.67]	[1.14]	[1.57]	[1.52]

continued

TABLE IV (Continued)
Volatility and Futures Margins: Regression Results

Market	Sample Size		$\Delta Y_k = \alpha + \beta\Delta\ log\ M_k + \epsilon_k$ $\Delta\ log\ \sigma_J^2$	$\Delta\ log\ \sigma_{TJ}^2$	$\Delta\ log\ \sigma^2$	$\Delta\ log\ \lambda$
		[1] → [4]	−0.50 (−0.17)	−2.63 (−0.57)	−2.38 (−0.79)	−2.13 (−0.83)
			0.001	0.006	0.012	0.013
			[2.46]	[2.99]	[3.14]	[2.72]
Platinum (NYM)	24	[1] → [2]	−4.93 (−1.22)	−3.76 (−0.58)	1.41 (0.43)	1.17 (0.36)
			0.063	0.015	0.008	0.006
		[2] → [3]	5.65 (1.85)	8.25 (1.76)	2.47 (0.89)	2.60 (1.02)
			0.135	0.124	0.035	0.045
		[3] → [4]	−1.66 (−0.64)	0.42 (0.10)	−1.78 (−0.63)	2.07 (0.79)
			0.018	0.000	0.018	0.027
		[2] → [4]	4.00 (1.16)	8.67 (1.55)	0.69 (0.24)	4.67 (1.56)
			0.057	0.099	0.003	0.100
		[1] → [4]	−0.93 (−0.36)	4.91 (1.25)	2.10 (0.89)	5.84 (2.62)
			0.006	0.066	0.035	0.238
Benchmark	28	[1] → [2]	8.54 (2.57)	10.60 (2.16)	2.16 (0.80)	2.07 (0.72)
			0.203	0.152	0.024	0.020
			[−2.48]	[−1.74]	[−0.17]	[−0.19]
		[2] → [3]	−6.89 (−2.05)	−8.86 (−1.96)	0.14 (0.05)	−1.97 (−0.75)
			0.140	0.128	0.000	0.021
			[2.51]	[2.45]	[0.55]	[1.14]
		[3] → [4]	−0.46 (−0.18)	−0.68 (−0.17)	−3.33 (−1.33)	−0.23 (−0.10)
			0.001	0.001	0.064	0.000
			[−0.31]	[0.18]	[0.39]	[0.63]
		[2] → [4]	−7.34 (−1.74)	−9.54 (−1.54)	−3.19 (−1.20)	−2.20 (−0.85)
			0.104	0.084	0.052	0.027
			[1.84]	[1.98]	[0.93]	[1.66]
		[1] → [4]	1.20 (0.36)	1.06 (0.25)	−1.03 (−0.50)	−0.13 (−0.08)
			0.005	0.002	0.009	0.000
			[−0.45]	[0.60]	[0.94]	[2.07]
Palladium (NYM) (821101–901113)	15	[1] → [2]	24.30 (1.93)	41.32 (1.83)	29.96 (2.64)	17.01 (1.58)
			0.222	0.205	0.348	0.161
		[2] → [3]	−6.01 (−0.65)	−3.60 (−0.27)	−8.05 (−1.64)	2.41 (0.35)
			0.032	0.006	0.172	0.009
		[3] → [4]	11.46 (0.86)	13.74 (0.82)	4.89 (0.53)	2.28 (0.31)
			0.054	0.049	0.021	0.007
		[2] → [4]	5.45 (0.44)	10.13 (0.59)	−3.15 (−0.38)	4.69 (0.52)
			0.014	0.026	0.011	0.021
		[1] → [4]	29.75 (1.67)	51.45 (2.52)	26.81 (3.69)	21.70 (3.58)
			0.177	0.329	0.511	0.496
Benchmark	18	[1] → [2]	19.40 (1.75)	24.99 (1.69)	12.33 (1.70)	5.59 (0.89)
			0.160	0.152	0.152	0.048
			[0.28]	[0.62]	[1.34]	[0.96]

continued

TABLE IV (Continued)
Volatility and Futures Margins: Regression Results

$\Delta Y_k = \alpha + \beta\Delta\ log\ M_k + \epsilon_k$

Market	*Sample Size*	$\Delta\ log\ \sigma_J^2$	$\Delta\ log\ \sigma_{TJ}^2$	$\Delta\ log\ \sigma^2$	$\Delta\ log\ \lambda$
	[2] → [3]	−6.80 (−0.79)	5.25 (0.39)	13.75 (2.12)	12.05 (1.46)
		0.037	0.009	0.219	0.118
		[0.06]	[−0.44]	[−2.39]	[−0.82]
	[3] → [4]	−0.71 (−0.10)	−8.62 (−0.71)	−10.56 (−1.66)	−7.91 (−1.20)
		0.001	0.030	0.148	0.082
		[0.86]	[1.08]	[1.39]	[0.99]
	[2] → [4]	−7.52 (−0.62)	−3.37 (−0.19)	3.19 (0.50)	4.14 (0.55)
		0.024	0.002	0.016	0.019
		[0.71]	[0.51]	[−0.61]	[0.05]
	[1] → [4]	11.88 (1.16)	21.62 (1.46)	15.52 (2.97)	9.73 (1.55)
		0.077	0.117	0.355	0.130
		[0.91]	[1.19]	[1.27]	[1.28]

Notes: The table presents coefficient estimate β multiplied by a factor of 10 with its t-statistic in parentheses and the regression R^2 below the t-statistic. The benchmark regressions are similar to the target regressions but, for each target metal margin change, they utilize the remaining metals for which no margin change occurs during the internal [−43, +43] of the target metal. Numbers in brackets are t-statistics of the hypothesis that the coefficient β is the same in the target commodity and its benchmark group. [i] → [j] indicates the change from the ith interval to the jth interval; intervals [1], [2], [3], and [4] are [−43, −22], [−21, −1], [0, 21], and [22, 43], respectively. In all regressions, Δ log M_k is the continuously compounded percentage change in the average margin from interval [−43, −22] to interval [22, 43]; hence the three regression coefficients [1] → [2], [2] → [3], and [3] → [4] sum up to the regression coefficient [1] → [4].

interval is negative. Such a negative association could either be due to a causal negative influence of margins on volatility, or it could be due to the presence of mean reversion in volatility. In all the remaining contracts, namely in silver (CMX), copper, aluminum, platinum, and palladium, the same association is positive. In the pooled regressions at the beginning of Table IV, the positive association dominates and is significantly different from the corresponding association of the benchmark group.[13]

Volatility shows a slight decline from interval [3] to interval [4], although the relationship is not statistically significant and varies from contract to contract. The absence of a positive relationship from interval [3] to interval [4] casts some doubt on the hypothesis that margins are raised well in advance of an increase in volatility. Nevertheless, the overall positive association from interval [2] to interval [4] is consistent with the hypothesis that the exchanges raise margins when they perceive that the earlier increase in volatility is more permanent.

[13]This positive association coupled with the positive association of margins with the past behavior of volatility results in an even stronger positive association of margins with the total change in volatility from the first to the third or fourth interval.

Consistent with the evidence of Tables I and II, Table IV shows that the behavior of extraordinary volatility, σ^2_{TJ}, across the intervals [1], [2], [3], and [4] is similar to the behavior of ordinary volatility, σ^2. This result is not surprising, given a positive cross-sectional correlation between the parameters σ^2_{TJ} and σ^2.[14] The interesting evidence in Table IV is the fact that the sizes of the regression coefficients of σ^2_{TJ} are larger than the sizes of the regression coefficients of σ^2. For example, in the stacked results of Table IV, the regression coefficient in the $\Delta \log \sigma^2_{TJ}$ regression for the overall change from interval [1] to interval [4] has a size almost twice the size of the regression coefficient in the $\Delta \log \sigma^2$ regression. The difference between the two regression coefficients is particularly striking immediately after a margin change, namely, from interval [2] to interval [3]. Thus, a more descriptive interpretation of the evidence is that while the exchanges respond to a past change in overall volatility, they tend to respond more strongly when they perceive that the extraordinary component of volatility is likely to increase further in the immediate future.

Positive Versus Negative Margin Changes

To gain further insight on the effect of margin changes, margin changes on day 0 are classified into positive and negative changes, and are analyzed separately. The results for the stacked regressions are presented in Table V. The results for positive and negative margin changes are generally similar to those of the combined changes in Table IV, although some very interesting differences do exist. The positive association between the change in margins and the overall change in volatility from the first to the fourth period is similar across positive and negative margin changes and is statistically significant in all cases. In the case of positive changes, however, the regression fits, as evidenced by the size of the R^2 coefficients, are considerably better. Moreover, in the case of positive margin changes, this positive association is also significantly different from the behavior of the benchmark group. The smallest among the four t-statistics (for the cases of σ^2, σ^2_J, σ^2_{TJ}, and λ) that test the equality of the regression coefficients of the two groups (and are inside the brackets) is 2.23. On the other hand, in the case of negative margin changes, the largest of the corresponding four t-statistics has a value of only 1.85.

[14]In the stacked results, these correlations with their standard errors in parentheses are as follows: 0.495 (0.043) in interval [1], 0.364 (0.046) in interval [2], 0.471 (0.043) in interval [3], and 0.365 (0.046) in interval [4].

TABLE V
Aggregate Results of Positive and Negative Changes in Margin Requirements in Metal Futures

$$\Delta Y_k = \alpha_j + \beta_j \Delta \, log \, M_k + \epsilon_k, \qquad j = POS, NEG$$

Target Variable		*Positive Change* α_{POS}	β_{POS}	R^2	*Negative Change* α_{NEG}	β_{NEG}	R^2
Δ log σ_J^2	[1] → [2]	2.64 (3.55)	3.21 (2.59)	0.036	−0.18 (−0.32)	4.14 (3.09)	0.039
	[2] → [3]	−0.38 (−0.56)	3.12 (2.79)	0.042	−0.29 (−0.44)	0.16 (0.11)	0.000
	[3] → [4]	−1.25 (−1.74)	−0.87 (−0.73)	0.003	−0.38 (−0.57)	0.61 (0.40)	0.001
	[2] → [4]	−1.63 (−2.22)	2.26 (1.85)	0.019	−0.67 (−1.08)	0.77 (0.55)	0.001
	[1] → [4]	1.01 (1.42)	5.47 (4.59)	0.106	−0.85 (−1.30)	4.91 (3.31)	0.045
Benchmark	[1] → [2]	2.26 (2.41)	3.80 (1.96)	0.017	0.46 (0.85)	−0.51 (−0.30)	0.000
		[0.31]	[−0.25]		[−0.78]	[2.14]	
	[2] → [3]	−0.98 (−1.13)	−2.15 (−1.20)	0.007	−0.35 (−0.60)	3.40 (1.87)	0.010
		[0.54]	[2.52]		[0.07]	[−1.38]	
	[3] → [4]	−0.12 (−0.15)	−0.98 (−0.61)	0.002	−0.47 (−0.86)	−0.72 (−0.42)	0.000
		[−1.10]	[0.06]		[0.11]	[0.58]	
	[2] → [4]	−1.10 (−1.20)	−3.13 (−1.65)	0.012	−0.82 (−1.45)	2.68 (1.51)	0.006
		[−0.44]	[2.40]		[0.18]	[−0.84]	
	[1] → [4]	1.16 (1.32)	0.67 (0.36)	0.001	−0.36 (−0.68)	2.17 (1.29)	0.005
		[−0.12]	[2.23]		[−0.57]	[1.22]	
Δ log σ_{TJ}^2	[1] → [2]	4.35 (3.58)	5.01 (2.49)	0.034	−0.75 (−0.78)	6.32 (2.89)	0.035
	[2] → [3]	−0.04 (−0.03)	5.33 (2.77)	0.041	0.55 (0.64)	6.25 (2.32)	0.015
	[3] → [4]	−1.92 (−1.74)	−0.75 (−0.41)	0.001	−1.55 (−1.86)	−0.70 (−0.27)	0.000
	[2] → [4]	−1.95 (−1.60)	4.58 (2.26)	0.028	−1.00 (−1.33)	5.55 (2.11)	0.013
	[1] → [4]	2.40 (2.13)	9.59 (5.15)	0.130	−1.92 (−1.84)	8.20 (3.46)	0.049
Benchmark	[1] → [2]	3.40 (2.57)	6.55 (2.40)	0.026	−0.57 (−0.64)	−3.52 (−1.28)	0.005
		[0.52]	[−0.45]		[−0.14]	[2.77]	
	[2] → [3]	−0.99 (−0.79)	−3.19 (−1.23)	0.007	0.56 (0.64)	6.25 (2.32)	0.015
		[0.55]	[2.65]		[−0.55]	[−1.15]	
	[3] → [4]	0.15 (0.12)	−2.49 (−0.98)	0.004	−1.55 (−1.86)	−0.70 (−0.27)	0.000
		[−1.23]	[0.56]		[0.42]	[0.12]	
	[2] → [4]	−0.84 (−0.64)	−5.68 (−2.09)	0.020	−1.00 (−1.13)	5.56 (2.00)	0.020
		[−0.61]	[3.03]		[−0.12]	[−1.01]	
	[1] → [4]	2.56 (1.89)	0.87 (0.31)	0.000	−1.57 (−1.83)	2.04 (0.76)	0.002
		[−0.09]	[2.62]		[−0.26]	[1.72]	
Δ log σ^2	[1] → [2]	3.64 (5.54)	3.41 (3.13)	0.052	−0.26 (−0.42)	4.33 (3.07)	0.039
	[2] → [3]	−0.66 (−0.87)	2.60 (2.08)	0.024	−0.13 (−0.21)	0.45 (0.34)	0.001
	[3] → [4]	−0.96 (−1.34)	−0.72 (−0.61)	0.002	−0.73 (−1.31)	−0.20 (−0.15)	0.000
	[2] → [4]	−1.62 (−2.14)	1.88 (1.50)	0.012	−0.85 (−1.44)	0.26 (0.19)	0.000
	[1] → [4]	2.02 (2.88)	5.29 (4.55)	0.104	−1.11 (−1.91)	4.59 (3.49)	0.050
Benchmark	[1] → [2]	2.14 (2.97)	4.13 (2.79)	0.034	−0.75 (−1.37)	−0.92 (−0.54)	0.001
		[1.52]	[−0.39]		[0.58]	[2.36]	
	[2] → [3]	−0.62 (−0.86)	0.10 (0.07)	0.000	0.02 (0.05)	1.33 (0.85)	0.002
		[−0.03]	[1.28]		[−0.19]	[−0.42]	
	[3] → [4]	0.81 (1.15)	−3.56 (−2.44)	0.027	−0.27 (−0.51)	0.19 (0.21)	0.000
		[−1.75]	[1.51]		[−0.58]	[−0.18]	
	[2] → [4]	0.19 (0.27)	−3.45 (−2.37)	0.025	−0.24 (−0.49)	1.52 (0.98)	0.003

TABLE V (Continued)

Aggregate Results of Positive and Negative Changes in Margin Requirements in Metal Futures

Target		$\Delta Y_k = \alpha_j + \beta_j \Delta\ log\ M_k + \epsilon_k,\quad j = \text{POS, NEG}$					
		Positive Change			*Negative Change*		
Variable		α_{POS}	β_{POS}	R^2	α_{NEG}	β_{NEG}	R^2
		[−1.75]	[2.77]		[−0.78]	[−0.61]	
	[1] → [4]	2.33 (3.39)	0.68 (0.48)	0.001	−0.99 (−1.81)	0.60 (0.35)	0.000
		[−0.31]	[2.52]		[−0.15]	[1.83]	
Δ log λ	[1] → [2]	1.71 (2.65)	1.81 (1.69)	0.016	−0.56 (−1.07)	2.18 (1.83)	0.014
	[2] → [3]	0.34 (0.51)	2.21 (1.99)	0.022	0.10 (0.19)	1.99 (1.65)	0.011
	[3] → [4]	−0.67 (−1.20)	0.12 (0.13)	0.000	−0.61 (−1.00)	−0.88 (−0.64)	0.002
	[2] → [4]	−0.33 (−0.48)	2.33 (2.07)	0.023	−0.51 (−0.91)	1.11 (0.88)	0.003
	[1] → [4]	1.38 (2.39)	4.14 (4.30)	0.094	−1.07 (−1.96)	3.29 (2.67)	0.030
	[1] → [2]	1.14 (1.87)	2.77 (2.20)	0.022	−1.02 (−2.17)	−3.01 (−2.04)	0.012
		[0.64]	[−0.58]		[0.64]	[2.72]	
	[2] → [3]	−0.01 (−0.02)	−1.05 (−0.78)	0.003	0.90 (2.01)	2.85 (2.03)	0.012
		[0.38]	[1.87]		[−1.14]	[−0.46]	
	[3] → [4]	0.27 (0.42)	−1.51 (−1.12)	0.006	−1.08 (−2.45)	0.03 (0.02)	0.000
		[−1.08]	[1.00]		[0.64]	[0.47]	
	[2] → [4]	0.26 (0.39)	−2.56 (−1.89)	0.016	−0.18 (−0.40)	2.88 (2.05)	0.012
		[−0.62]	[2.78]		[−0.46]	[−0.93]	
	[1] → [4]	1.40 (2.07)	0.21 (0.15)	0.000	−1.20 (−2.74)	−0.13 (−0.10)	0.000
		[−0.02]	[2.33]		[0.19]	[1.85]	

Notes: The table presents coefficient estimates $\hat{\alpha}$ and $\hat{\beta}$ of the stacked regressions multiplied by a factor of 10 with their *t*-statistics in parentheses. Numbers in brackets are *t*-statistics of the hypothesis that a coefficient is equal across the target and its benchmark group. [*i*] → [*j*] indicates the change from the *i*th interval to the *j*th interval; intervals [1], [2], [3], and [4] are [−43, −22], [−21, −1], [0, 21], and [22, 43], respectively. There are 180 positive and 235 negative margin changes in metal futures contracts; the corresponding sample sizes in the benchmark group are 220 and 357. In all regressions, Δ log M_k is the continuously compounded percentage change in the average margin from interval [−43, −22] to interval [22, 43].

When the percentage change in volatility from the first to the fourth interval is partitioned into two components, the percentage change from the first to the second interval, and the percentage change from the second to the fourth interval, a similar behavior across positive and negative margin changes is observed in the first component, but quite different behavior in the second component. That is, the strength of the response of the exchanges to past changes in volatility is similar whether the change in margins is positive or negative. However, the subsequent behavior of volatility differs across positive and negative margin changes. Indeed, although the association between the change in volatility and the earlier change in margins is positive in all eight regressions (cases [2] → [4]), the statistically significant associations characterize positive margin changes only. In particular, statistically significant regression coefficients at the 10% level are observed (the *t*-statistics are inside the parentheses) in the regressions of the three parameters that characterize the extraordinary component of volatility (σ_J^2, σ_{TJ}^2, and λ). These regression coefficients are also significantly different from their benchmark counterparts (the *t*-statistics are inside the brackets). This evidence suggests that the exchanges are concerned about a future increase in extraordinary volatility and take precautionary steps by raising margins.

The results in Table V are consistent with the average magnitudes presented in Table II. Observe, for example, the −6.45% change in total jump volatility from the second to the fourth period in Panel A of Table II. This negative change is consistent with the corresponding positive slope coefficient in Table V because the corresponding regression intercept in Table V is −19.5%. More precisely, from the regression estimates of Table V and the average percentage change of margins in Table II, one can calculate the average percentage change in volatility as follows: $-0.195 + (0.458) \times (0.2858) = -0.0641$, or −6.421 percent, a number only slightly different—due to rounding error—from the one tabulated in Panel A of Table II. The negative intercept suggests the presence of mean reversion in jump volatility. The positive slope coefficient is then interpreted as evidence that the exchanges raise margins more at times when the mean reversion is expected to be relatively small, i.e., at times when the exchanges perceive that the earlier increase in volatility carries a stronger permanent component.[15]

There is no evidence of mean reversion in volatility when the exchanges decrease margins. In this case, the regression intercepts are negative and suggest that the earlier decline in volatility, to which the exchanges responded by decreasing margins, continues its autonomous downward trend. The positive (but statistically insignificant) slope coefficients is interpreted as evidence that the exchanges lower margins by a greater amount at times when volatility subsequently falls by a greater amount. One interpretation of the absence of mean reversion in the case of reductions in margin requirements is that the exchanges are anxious to reduce margins—and thus increase trading activity and profits—before the level of volatility in the market has bottomed out. In other words, the decision to reduce margins may not be necessarily symmetric to the decision to increase margins. It is possible that by reducing margins, the exchanges simply reverse an earlier increase in margins once they

[15]This interpretation is strengthened by the fact that the positive slope coefficient is observed from interval [2] to interval [3]; whereas, the negative intercept is observed from interval [3] to interval [4].

perceive that the earlier environment of very high volatility, which had caused them to raise margins, is over.

The evidence in Table I supports the view that the decision rule of the exchanges is asymmetric. As expected, at times when the exchanges raise margin requirements, target metal volatility is, on average, higher than benchmark metal volatility (see Panel A). Surprisingly, however, target metal volatility is also higher than benchmark metal volatility at times when the exchanges lower margin requirements (Panel B). This asymmetry is an interesting empirical phenomenon on its own and deserves further exploration.

CONCLUSIONS

Historically, margin requirements in metal futures contracts increase (decrease) in those metals which recently undergo a drastic increase (decrease) in volatility. The positive association between margins and past volatility is present both in the extraordinary (total jump) and in the ordinary component of volatility. These two components are derived from a Poisson Jump-diffusion process of futures returns. This positive association is significantly stronger than a similar, simultaneous, positive association with the volatility of metals whose margin levels remain unchanged. Thus, the data show that while the exchanges raise (lower) margins in an overall environment of increased (reduced) volatility, they do choose to raise (lower) margins in those metals that show the largest increase (decrease).

There is also evidence that the exchanges do respond more to the more persistent changes in volatility. In the majority of contracts examined, as well as in the pooled regressions, there is a positive association between the change in margin requirements and the subsequent change in volatility. This positive association is present mainly in total jump volatility. However, the positive association originates primarily from the cases where margins increase and much less from the cases where margins decrease. A regression of the percentage changes in volatility on the positive percentage changes in margins results in a large negative intercept and a positive and statistically significant slope coefficient. In other words, after margins increase, volatility actually declines somewhat from its very high earlier level, namely, there is a mean reversion in volatility. However, this mean reversion is smaller when the earlier increase in margins is greater. Put differently, the exchanges raise the margin requirements by a larger amount exactly during those times that the increase in volatility, and especially jump volatility, is more permanent.

Finally, it appears that the decision to change margin requirements is not symmetric across positive and negative margin changes. The exchanges do increase margins at times when volatility is unusually high. However, they decrease margins well before the level of the volatility has bottomed out. The asymmetry in the behavior of the exchanges is an interesting topic for future research.

BIBLIOGRAPHY

Akgiray, V., and Booth, G.G. (1987): "Compound Distribution Models of Stock Return: An Empirical Comparison," *Journal of Financial Research*, 10:269–280.

Akgiray, V. and Booth, G.G. (1988): "Mixed Diffusion-Jump Process Modeling of Exchange Rate Movements," *The Review of Economics and Statistics*, 70:631–637.

Anderson, R.W. (1985): "Some Determinants of the Volatility of Futures Prices," *The Journal of Futures Markets*, 5:331–348.

Ball, C.A. and Torous, W.N. (1983): "A Simplified Jump Process for Common Stock Returns," *Journal of Financial and Quantitative Analysis*, 19:53–65.

Ball, C.A. and Torous, W.N. (1985): "On Jumps in Common Stock Prices and Their Impact on Call Option Pricing," *Journal of Finance*, 40:155–173.

Bear, R.M. (1972): "Margin Levels and the Behavior of Futures Prices," *Journal of Financial and Quantitative Analysis*, 7:1907–1930.

Beckers, S. (1981): "A Note on Estimating the Parameters of the Diffusion-Jump Model of Stock Returns," *Journal of Financial and Quantitative Analysis*, 16:127–140.

Brady, N.F. (1988): *Report of the Presidential Task Force on Market Mechanisms*, Washington, D.C.: U.S. Government Printing Office.

Breeden, D.T. (1985): "Futures Margins as Predictors of Price Volatility," Unpublished Working Paper No. CSFM-115, Columbia University Graduate School of Business.

Brennan, M.J. (1986): "A Theory of Price Limits in Futures Markets," *Journal of Financial Economics*, 16:213–233.

Christie, A.A. (1982): "The Stochastic Behavior of Common Stock Variances: Value, Leverage and Interest Rate Effects," *Journal of Financial Economics*, 10:407–432.

Clark, P.K. (1973): "A Subordinated Stochastic Process Model with Finite Variance for Speculative Prices," *Econometrica*, 41:135–155.

Craine, R. (1992): "Are Futures Margins Adequate?" Working Paper, Department of Economics, University of California, Berkeley.

Duffie, D. (1989): *Futures Markets*. Englewood Cliffs, NJ: Prentice-Hall.

Edwards, F. and Neftci, S.N. (1988): "Extreme Movements in Futures Prices: Implications for Setting Margins," *The Journal of Futures Markets*, 8:639–656.

Estrella, A. (1988): "Consistent Margin Requirements: Are They Feasible?" *Quarterly Review,* Federal Reserve Bank of New York, 13(2):61–79.

Fenn, G. and Kupiec, P. (1993): "Prudential Margin Policy in a Futures-Style Settlement System," *The Journal of Futures Markets,* 13:389–408.

Figlewski, S. (1986): "Margins and Market Integrity: Margin Setting for Stock Index Futures and Options," *The Journal of Futures Market,* 4:639–656.

Fishe, R. P. H., and Goldberg, L. G. (1986): "The Effect of Margins on Trading in Futures Markets," *The Journal of Futures Markets,* 6:261–271.

Fishe, R. P. H., Goldberg, L. G., Gosnell, T. F., and Sinha, J. (1990): "Margin Requirements in Futures Markets: Their Relationship to Price Volatility," *The Journal of Futures Markets,* 10:541–554.

Friedman, B. M., and Laibson, D. I. (1989): "Economic Implications of Explanatory Movements in Stock Prices," *Brookings Papers on Economic Activity,* 2:137–172.

Garman, M. B., and Klass, M. J. (1990): "On the Estimation of Security Price Volatilities from Historical Data," *Journal of Business,* 53:67–78.

Gay, G. D., Hunter, W. C., and Kolb, R. W. (1986): "A Comparative Analysis of Futures Contracts Margins," *The Journal of Futures Markets,* 6:307–324.

Hall, J. A., Brorsen, B. W., and Irwin, S. H. (1989): "The Distribution of Futures Prices: A Test of the Stable Paretian and Mixture of Normal Hypotheses," *Journal of Financial and Quantitative Analysis,* 24:105–116.

Hardouvelis, G. A. (1990): "Margin Requirements, Volatility, and the Transitory Component of Stock Prices," *American Economic Review,* 80:736–762.

Hardouvelis, G. A., and Kim, D. (1995): "Margin Requirements, Price Fluctuations and Market Participation in Metal Futures," *Journal of Money, Credit, and Banking,* 27:659–671.

Hardouvelis, G. A., Pericli, A., and Theodossiou, P. (1995): "The Asymmetric Relation between Margin Requirements and Stock Market Volatility across Bull and Bear Markets," Unpublished Working Paper, Rutgers University.

Hardouvelis, G. A., and Peristiani, S. (1992): "Margin Requirements, Speculative Trading and Stock Price Fluctuations: The Case of Japan," *Quarterly Journal of Economics,* 107:1333–1370.

Hartzmark, M. L. (1986): "The Effects of Changing Margin Levels on Futures Market Activity, the Composition of Traders in the Market, and Price Performance," *Journal of Business,* 59 (part 2):S147–80.

Hsieh, D. A., and Miller, M. H. (1990): "Margin Regulation and Stock Market Volatility," *Journal of Finance,* 45:3–29.

Jarrow, R. A., and Rosenfeld, E. R. (1984): "Jump Risks and the Intertemporal Capital Asset Pricing Model," *Journal of Business,* 57:337–351.

Kahl, K. H., Rutz, R. D., and Sinquefield, J. C. (1985): "The Economics of Performance Margins in Futures Markets," *The Journal of Futures Markets,* 5:103–112.

Kenyon, D., Kling, K., Jordan, J., Seale, W., and McCabe, N. (1987): "Factors Affecting Agricultural Futures Price Variance," *The Journal of Futures Markets,* 7:73–91.

Kolb, R. W. (1991): *Understanding Futures Markets,* Miami, FL: Kolb Publishing.

Kupiec, P. H. (1993): "Futures Margins and Stock Price Volatility: Is There Any Link?" *The Journal of Futures Markets,* 13:677–691.

Ma, C. K., and Kao, G. W. (1990): "Margin Requirements and the Behavior of Silver Futures Prices," Unpublished Working Paper, Texas Tech University.

Ma, C. K., Kao, G. W., and Frohlich, C. J. (1993): "Margin Requirements and the Behavior of Silver Futures Prices," *Journal of Business Finance & Accounting,* 20:41–60.

Miller, M. H. (1990): "International Competitiveness of U.S. Futures Exchanges," *Journal of Financial Services Research,* 4:387–408.

Moser, J. T. (1990a): "Evidence on the Impact of Futures Margin Specification on the Performance of Futures and Cash Markets," Unpublished Working Paper No. 90-20, Federal Reserve Bank of Chicago.

Moser, J. T. (1990b): "Evidence on the Impact of Futures Margin Changes on Futures and Cash Markets," Unpublished Working Paper, Federal Reserve Bank of Chicago.

Nathan, R. R. (1967): *Margins Speculation and Prices in Grain Futures Markets,* Washington D.C.: U.S. Department of Agriculture.

Nelson, D. B. (1991): "Conditional Heteroscedsticity in Asset Returns: A New Approach," *Econometrica,* 59:347–370.

Press, S. J. (1967): "A Compound Events Model for Security Prices," *Journal of Business,* 40:317–335.

Salinger, M. A. (1989): "Stock Market Margin Requirements and Volatility: Implications for Regulation of Stock Index Futures," *Journal of Financial Services Research,* 3:121–138.

Sofianos, G. (1988): "Margin Requirements on Equity Instruments," *Quarterly Review,* Federal Reserve Bank of New York, 13(2):47–60.

Telser, L. G. (1981): "Margins and Futures Contracts," *The Journal of Futures Markets,* 1:225–153.

Tomek, W. G. (1985): "Margins on Futures Contracts: Their Economic Roles and Regulations," in *Futures Markets: Regulatory Issues,* Anne Peck (ed.), Washington, D.C.: American Enterprise Institute, pp. 143–209.

Tucker, A. L., and Pond. L. (1988): "The Probability Distribution of Foreign Exchange Price Changes: Tests of Candidate Processes," *The Review of Economics and Statistics,* 70:638–647.