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Abstract

This paper develops a model which explains how combining into a futures clearinghouse allows traders to economize on margin, and how such a combination will set margin levels for the benefit of the traders as a whole. We also provide evidence which supports the predictions of this model. Our theory implies that the clearinghouse will set margins as a function of the volatility of the futures price and the opportunity cost associated with holding margin assets. Previous studies focus on the impact of volatility. Most of these studies use historical measures of volatility. In this paper we use the implied volatility derived from futures option prices to measure the volatility which the market anticipates in the futures price.

I. INTRODUCTION

The literature on margin has two strands: the usefulness of margin levels as a public policy tool to control excess volatility; and the private interest in setting margin levels to provide adequate protection against default. This paper addresses the second strand, usually referred to as prudential margin setting. We demonstrate empirically that margin levels reflect both prudential concerns and the opportunity cost of margin deposits. Our model contributes to the literature by explicitly incorporating the cost of margin deposits and demonstrating the tradeoff between these costs and prudential concerns.

By providing a contract guarantee, the clearinghouse pools default risk among members. Levels of margin and other deposits serve as collateral to protect the clearinghouse: the higher the deposits, the greater the protection. The opportunity cost of margin deposits constrains the level of protection which the members will regard as optimal. This optimality condition is met when the opportunity cost of margin is equal to the increment of protection obtained from the deposit of additional margin.

Two alternative models are provided: one with constant and one with increasing opportunity costs. If the marginal cost of margin is constant, our model predicts that the level of margin protection chosen by the clearinghouse is determined by opportunity costs but is independent of volatility. With increasing costs of margin, the clearinghouse is motivated to increase its share of risk as volatility increases.

Our empirical work tests these hypotheses at three levels. Our sample consists of a series of cross sections of eighteen futures contracts having associated futures options. We construct coverage ratios by dividing required margin by the futures price volatility (in dollar terms). A coverage ratio of three, for instance, indicates that a price change must be three standard deviations from the mean to exhaust margin. The estimates of volatility are based on option prices, and thus reflect a market-consensus forecast of volatility. The coverage ratio expresses the level of loss protection provided by a given level of margin, in a form which can be compared over time and across contracts.

We first examine the hypothesis that margin levels are positively associated with the level of expected volatility using cross-section regressions at each date in the sample. This re-examines previous tests of prudentiality by Gay, Hunter and Kolb (1986). Our evidence confirms their finding that margin levels increase with volatility, as is consistent with prudentiality. Our next test examines the time series of daily coverage ratios for four contracts to determine how coverage ratios are adjusted in response to shocks. The evidence of this section confirms GHK's finding that coverages are increased when coverage ratios are lower than their unconditional means. These tests also demonstrate that clearinghouses lower coverage when margin coverage is excessive. This result was not predicted by the previous literature, but is predicted by our model.

Our third series of tests examines the cross section pooled over the sample period. Our results are consistent with the clearinghouse adjusting margin levels to allow for the opportunity cost of margin. Our regressions indicate that margin coverage is negatively related to economy-wide shifts in the opportunity cost of margin deposits and also negatively related to participant-specific shifts in participants' borrowing needs as proxied by the levels of implied standard deviation. The results are consistent with margin levels having increasing costs for market participants. Sensitivity tests are conducted for the possibility that margins are a fixed proportion of the futures price, or a fixed value. The results favor our model over these alternatives.

II. A MODEL OF PRUDENTIAL MARGINS

In this model, the clearinghouse acts as a club, that is, a voluntary organization which furthers the joint interests of its members by internalizing some of the externalities which would otherwise exist between members. The role of the club in the provision of club goods is similar to that of a local government in the provision of local public goods, but membership in clubs is strictly voluntary, and non-members can be costlessly excluded from the benefits of club membership.

A futures clearinghouse allows its members to exploit a variety of economies of scale accessible only by acting as a group. A centralized clearinghouse simplifies recordkeeping, since members need only keep track of their net position with the clearinghouse. Credit monitoring and control is simplified, since a member's financial standing need only be assessed once by the clearinghouse, rather than separately by each trading partner. A central clearinghouse can take margin on the net position of a member, rather than on each separate trade. There are economies of scope between record keeping and credit control, since knowledge of a member's net position is necessary to assess his exposure. In addition, because exchange members precommit to binding arbitration, disputes are no longer a matter for bilateral bargaining, and are thus settled at lower average cost to members as a group (see Moser, 1993).

Most models which incorporate the exchange or the clearinghouse as an economic agent assume that the organization is profit maximizing. Frequently, profits are assumed to be positively associated with volume of trading. By contrast, our model treats the clearinghouse as a club of its members, not a separate agency. We ignore any *ex ante* conflicts of interest among members. We assume that all members are clearing members. We also ignore the presence of customers served by members in their broker capacity; the clearinghouse exists to provide local public goods to exchange membership, not to enforce a brokerage cartel.[1]

Margin setting with a single commodity

In the course of modelling the determinants of contract margin, we demonstrate that margin setting and the formation of clearing houses are both motivated by the need of market participants to balance deadweight losses due to counterparty defaults against the opportunity cost of margin deposits. Despite the fact that interest-bearing assets may be posted, we assume margin requirements have a positive opportunity cost because a firm's marginal borrowing cost exceeds the return on its marginable assets. In the simplest case, the marginal opportunity cost of a margin deposit is assumed to be a constant which we call i. We later generalize this to the case where the opportunity cost is an increasing function of the amount of margin demanded.

We first model the setting of margin in a bilateral marketplace. There are two parties j and h. Assume that in the event of default, participants are only able to attach collateral that has previously been posted.[2] There are two periods. In the opening period, the two parties trade with each other; one party buys the contracts from the other party. We do not model the motivation for trading; it is exogenous to this model. Let N(j,h) denote the

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[1]Violations of these assumptions can lead to economically important and interesting complications of our model. For instance, when some members act as brokers for non-member traders and some do not, members will disagree about regulations governing dual trading (see Sarkar, 1993).

[2]In practice, clearinghouses may have additional collateral on clearing members: required deposits in an exchange guarantee fund, required purchases of minimum numbers of exchange memberships, etc. In addition, clearinghouses require that clearing firms maintain a certain minimum level of capital. The system of requiring the actual posting of margin may imply two things: 1) attaching additional collateral is very costly; or 2) counterparties cannot verify the existence of other liabilities or assets. In either case, this additional collateral can be ignored.

number of contracts outstanding between j and h. If N(j,h) is positive, j is long the contract. If N(j,h) is negative, then j is short the contract so that N(j,h) = -N(h,j).

In the second period, the contract is settled based on a random final price for the underlying good. The final price is assumed to be symmetrically distributed with a finite variance such that the change in the value of the contract, x, is a random variable with mean zero and standard deviation s.

We assume that the two parties set the margin posted by j with h, m(j,h), and the margin posted by h with j, m(h,j). Initial and maintenance margins are assumed to be identical. Margin payments are made in cash and placed into an interest-bearing account. The interest paid on the account is paid to the party posting the margin. At the end of period 2, the contract is settled. If x is positive and less than m(h,j), x is transferred from the short's account to the long's account. Thus the short now has m(h,j)-x; the long now has m(j,h) + x. If x is negative and $|x|$ is less than m(j,h) then x is transferred from the long to the short.

Traders are assumed to immediately bring their margin-account balances back to m(j,h) and m(h,j) by making new cash deposits when they are on the losing side and by withdrawing any excess balances. Because recoveries in the event of a default are limited to the margin account balance and participants do not carry any excess balances, we preclude the possibility that traders who have previously realized gains are better able to weather adverse price movements. This means that a simple two-period futures contract resembles in important respects an n-period contract which is marked to market at the close of each period.

By entering into a contract, the counterparties implicitly give each other an option to default (see Figlewski, 1984). When will a default occur? In the simplest case, a trader would default whenever his losses exceed the balance in his margin account. Thus, if x is positive and greater than m(h,j), the short rationally defaults on the contract and takes possession of the margin assets m(h,j). Similarly, if x is negative and |x| is greater than m(j,h), the long rationally defaults and the short takes possession of the margin assets m(j,h). We assume that default imposes a deadweight loss on the counterparty that is a constant proportion, denoted α, of the amount of the difference between the promised payment and the actual payment. These deadweight losses include the cost of recontracting, higher borrowing costs which arise from liquidity problems, and costs arising from financial distress. The expected deadweight loss from default born by agent j is:

$$D(j,h) = \alpha N \int_{m(j,h)}^{\infty} (x - m(j,h)) f(x,s) dx \tag{1}$$

where N is the net number of contracts j has open with h.

We assume that the parties to the contract will seek to jointly minimize the costs of contracting. We make this assumption because traders have a wide choice of partners when first opening a trade, a situation which approximates perfect competition; it is only after the initial contract has been made that a bargaining problem arises between the two parties. Contracting entails three costs: the opportunity cost of margin deposits I(j,h), the credit risk (the expected difference between the promised payment and the actual payment) L(j,h), and the expected deadweight losses incurred in the event of default D(j,h). Offsetting these costs, each party also receives an option to default O(j,h). The two parties seek to minimize these costs; that is, they minimize:

$I(j,h) + I(h,j)$	*Opportunity Costs*
$+ D(j,h) + D(h,j)$	*Deadweight Losses*
$+ L(j,h) + L(h,j)$	*Credit Risk*
$- O(j,h) - O(H,j)$	*Default Options*

Because one party's default option is another party's credit risk, that is $L(j,h) = -O(h,j)$, the expression for contracting costs reduces to

$$I(j,h) + I(h,j) + D(j,h) + D(h,j) \tag{2}$$

which is the sum of the interest costs and deadweight losses for h and j. Thus, substituting into (2) from (1) the total cost to be minimized is

$$N\{i(m(j,h)+m(h,j)) + \alpha\left[\int_{m(j,h)}^{\infty}(x-m(j,h))f(x,s)dx + \int_{-\infty}^{-m(j,h)}(m(j,h)-x)f(x,s)dx\right]\} \tag{3}$$

Minimizing (3) with respect to m(j,h) and m(h,j) yields the following first order conditions:

$$1 - F(m(j,h),s) = \frac{i}{\alpha}$$

$$F(-m(h,j),s) = \frac{i}{\alpha}$$

Thus margins are optimal when the probability of default is equated to the ratio of opportunity cost of an additional dollar of margin to the deadweight loss rate. The higher this ratio, the lower the optimal level of margin. Note that the objective function is linear in the number of contracts. Hence, in the case of constant marginal opportunity cost, the level of margin per unit of exposure is independent of the aggregate level of exposure. In other words, there are constant returns to scale in risk management. If the distribution of price changes is symmetric, margins will be equal on long and short positions. Finally, note that when prices are normally distributed, a mean preserving spread in x causes the margin to increase proportionately with s. We define the coverage ratio as:

$$COV = \frac{m}{s} \tag{4}$$

The first-order conditions above imply that when the opportunity cost of margin assets is constant, the coverage ratio should not vary with volatility. A similar result is derived in Fenn and Kupiec (1993) and Craine (1992).

Clearinghouses offer market participants the possibility of reducing both deadweight default costs and the opportunity costs created by holding assets in margin accounts, even in the absence of other externalities such as failure of the payments system or reputation. Absent these other externalities, the previous results ensure that, per contract, margin will be the same whether contracts are cleared and settled bilaterally by pairs of counterparties or multilaterally through a clearing house. Because a clearinghouse will set the same margin rate that our representative agents willingly negotiate between themselves, it becomes relatively straightforward to analyze the benefits derived from forming a clearinghouse. In our model, the key benefit of the clearinghouse is that it permits its members to economize on margin while at the same time reducing their expected deadweight losses. Clearinghouses economize on margins and deadweight loss because, for the same set of contracts, each participant's net exposure is smaller. As a result, the total amount of margin posted at the clearinghouse is smaller than the total amount posted in a world of bilateral transactions and the expected deadweight loss to each party is smaller.

Under a bilateral system j posts margin of $m|N(j,h)|$ with each of n counterparties. Summing over all of j's counterparties, j posts total margin of $m\sum_n |N(j,h)|$. Summing over all participants j, total margin posted by all participants is $m\sum_j\sum_n |N(j,h)|$.

Under a clearinghouse system, j must post margin only against the net of his position with the rest of the market which is $m|\sum_n N(j,h)|$. In effect, the clearinghouse gives participants a vehicle for securing a potential defaulter's long losing positions with one counterparty with a potential defaulter's winning positions from another counterparty. Summing over all parties j, the total margin posted on all contracts is $m\sum_j |\sum_n N(j,h)|$.

Since $\sum_j\sum_n |N(j,h)| \geq \sum_j |\sum_n N(j,h)|$ total margin and total opportunity cost will never be greater under a clearinghouse framework and will generally be smaller.

Similarly, no counterparty's expected deadweight loss is greater under a clearinghouse system and some will be smaller. In a bilateral system, j's expected loss from counterparty default is proportional to the number of open contracts; that is, $\sum_n |N(j,h)|$. In a multilateral clearinghouse, j's expected loss from defaults is proportional to the net number of open contracts; that is, $|\sum_n N(j,h)|$.

Because the creation of a clearinghouse leaves no participant worse off and lowers margin requirements and deadweight default costs for some participants, then the creation of a clearinghouse is pareto optimal. In our model, these improvements are achieved because the clearinghouse is able to register trades and make the proceeds from a party's winning positions available to offset losing positions.

Increasing opportunity cost of funds

The cost of funds function may be increasing in the amount of margin required. Many results in corporate finance suggest that interest costs increase with the level of total borrowing. In the one-contract case, an increase in margins would thus drive up the marginal cost of funds. Thus, if marginal costs of margin are increasing in m:

$$c=c(m); \quad c'(m)>0 \tag{5}$$

Note that, even if their cost functions are identical, individuals who hold different numbers of contracts will have different marginal costs of funds. In addition, the slope and level of the cost functions may differ across individuals. This will result in disagreement among members as to appropriate margin levels, though each will have only one preferred margin level. Under majority rule, if individuals have single-peaked preferences, the club goods literature shows that an equilibrium will be reached which reflects median voter preferences.[3] In this case, the marginal cost involved in equation (6) is that of the median voting member.

The clearinghouse sets:

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[3]Exchanges usually set margins, not on the basis of a direct vote, but by a committee designed to be representative of the membership. It should also be noted that some firms, having more than one seat, have more than one vote.

$$\frac{c'(m)}{\alpha} = 1-F(m,s) \qquad (6)$$

A mean-preserving spread now causes the clearinghouse to increase the margin less than proportionately with s. As the standard deviation increases, the clearinghouse would increase the margin level to keep the probability of default constant. However, this drives up the marginal financing costs of its members. The members of the clearinghouse therefore choose to bear greater deadweight losses in order to economize on their financing costs. Thus, coverage ratios should decrease with volatility.

In equilibrium, clearinghouses will set margin levels such that the opportunity cost is strictly positive, since additional margin increases coverage ratios. Empirically, marginal opportunity costs are not directly observable. However, the model does still have empirical implications provided suitable proxies for shifts in the marginal opportunity cost are available.

If the participants in some markets tend to have higher financing costs than others, clientele effects might observed. If coverage ratios are systematically higher for financial than for the agricultural futures, this might reflect the lower financing costs of financial firms. In addition, markets with smaller firm participants are likely to have steeper opportunity cost of funds functions. If marginal interest costs increase with borrowing levels, then coverage ratios will decrease less as volatility increases for contracts that are a smaller part of the total portfolio.

Margin setting on a multi-contract exchange

In generalizing the model to a multi-contract exchange, the clearinghouse can set margin on a per-contract basis because losses are linearly related to the size of the position. We assume that the clearinghouse knows each trader's position at all times. Since all positions are cleared through the clearinghouse, this assumption is reasonable. We also assume that the clearinghouse has complete control of a trader's margin; if the member has a gain on one leg of a spread and a loss on the other, the clearinghouse can use the gain to help offset the loss. Thus, all that concerns the clearinghouse is the total loss and the total margin.

The traders each deposit margin m with the clearinghouse, where the clearinghouse specifies the function $m = m(n_1, n_2, \ldots n_q)$, where q contracts are listed on the clearinghouse. The function m(.,.) is determined endogenously by the clearinghouse. At the end of period one, the position is marked to market. The changes in the value of the contracts, x_1, x_2,... are assumed to be jointly normally distributed, with means zero, and covariance matrix $S = \{s_{i,j}\}$.

The net gains or losses of a trader are:

$$g = \sum_{i=1}^{q} n_i x_i \qquad (7)$$

If g is positive, the clearinghouse transfers g to the trader's account from the clearinghouse account. If g is negative and less than m, the clearinghouse transfers g from the trader's account to the clearinghouse account. In either case, the trader then has g + m. Since contracts sold equal contracts bought, and the gain to the short equals the loss to the long on each contract, the clearinghouse's account will net out at zero, except for contract defaults. Traders are assumed to bring their margin account balances back to m immediately. As above, initial and maintenance margins are assumed to be identical and excess balances are assumed to be withdrawn.

If g is negative and greater than m, the trader is assumed to default on the contract. The clearinghouse transfers m from the trader's account to the clearinghouse account and adds (g-m) from its own funds. The trader's position is automatically closed out at the settlement price (as above, with no additional loss to the clearinghouse). The clearinghouse loses one-for-one as g exceeds m.

Since linear combinations of normal variables are themselves normal, g is distributed normally with mean zero and variance given by:

$$Var(g) = \sum_{i=1}^{q} \sum_{j=1}^{q} n_i n_j s_{ij} \tag{8}$$

The clearinghouse's expected loss is still:

$$\int_{m}^{\infty} (g-m) f(g,\sigma) \, dg \tag{9}$$

Therefore, the clearinghouse sets:

$$\frac{c'(m)}{\alpha} = \frac{d}{dm} \int_{m}^{\infty} (g-m) f(g) \, dg \tag{10}$$

or:

$$\frac{c'(m)}{\alpha} = 1-F(m) \tag{11}$$

Note that, since we are now relating the loss on a portfolio of contracts to a sum of margin deposits, results should resemble standard CAPM formulations, i.e., the contribution of a contract to portfolio variance should be related to its covariance with the rest of the portfolio. However, it is not reasonable to assume that diversification is complete, since most members will not be holding a large number of different futures contracts. Since the expected value of the portfolio is always zero at settlement, the main difference that multiple contracts makes is to redefine the coverage ratio to be:

$$\frac{m}{\frac{d\sigma}{dn_i}} \tag{12}$$

There are two immediate implications of this formula. First, a clearinghouse setting a margin requirement for a single-contract position would set the same margin as a single-contract clearinghouse, given the same opportunity cost of margin. Second, due to the diversification effects of imperfectly covarying contract prices, the margin requirement for a multi-contract position will generally be less than the sum of the margins for the individual single-contract positions. Both of these implications are qualitatively supported by what we know about current and past exchange margin-setting policies. The first of these implications is explicitly tested in our empirical work.

III. LITERATURE REVIEW

A number of researchers have analyzed margin setting. In Telser (1981) margin must be adequate to cover expected broker losses from defaults, but is driven down to an equilibrium level by competition among brokers. Exchanges may impose a minimum margin above this level due to the reputational externalities of a contract default.[4] Figlewski (1984) calculates the percentage of price moves which would be covered by the margin deposit, and

[4]Telser also demonstrates how commission restraints might be avoided through adjustments to required margin.

concludes that the protection provided by margin deposits is actually quite good.[5] Hunter (1986) derives the optimal margin as a function of the risk aversion of the members; he argues that optimal clearinghouse minimums should be set as a function of the weighted average of the risk aversions of members.

A model similar to Figlewski's is provided in Gay, Hunter, and Kolb (1986). They argue that the probability of non-coverage for a given time until settlement should be equal across contracts which are closely related economically, and across time for any one commodity. This hypothesis is tested by comparing non-coverage probabilities across contracts. They conclude that non-coverage probabilities differ across commodities. However, individual commodities seem to have constant probabilities across time. They also find that revisions in margin levels are made in a direction consistent with their model. One possible interpretation of their empirical results is that revising margin requirements is a costly process, done only intermittently, or that the cost of an inappropriate margin level is negligible.

Craine (1992) models the clearinghouse as a profit-maximizing entity and explicitly characterizes the option to default. He contends that, since the clearinghouse does not explicitly charge a default premium to either long or short, it must keep the value of this premium at or close to zero. Our model, by contrast, implies that the value of the default premium equals the credit risk for the representative agent. Fenn and Kupiec (1993) also assume that the clearinghouse is profit-maximizing. In contrast, we model the

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[5]Warshawsky (1989) analyses equity futures, cash, and options margin systems, using a more robust procedure to assess the adequacy of futures, options, and stock margining systems. Kofman (1992) finds that the probability of default calculated in previous work significantly understates the true probabilities. His empirical work suggests that the distributions of futures prices are leptokurtic.

clearinghouse as a joint agent of exchange members. In our formulation, the clearinghouse does not have to make a profit: members would be willing to subsidize the clearinghouse to avoid the greater cost of a bilateral arrangement. In neither Craine's nor Fenn and Kupiec's model is there an explicit economic rationale for the existence of the clearinghouse.

The main contribution of Fenn and Kupiec is to explain the role of frequency of settlement in setting margin size. They model cases where the clearinghouse sets the frequency of regular settlements, and where it calls for special settlement whenever necessary. The clearinghouse minimizes total costs, where costs involve margin costs, settlement costs, and the cost of allowing a deficit to arise in a clearinghouse's account. The clearinghouse sets the probability of a deficit equal to the ratio of opportunity costs per settlement period to the marginal cost of an account deficit. As in our constant interest-cost model, the ratio of margin to volatility should be constant for given opportunity costs and settlement frequency; as volatility increases, however, more frequent settlement may be cost-minimizing, and the margin-to-volatility ratio may decline. In practice, changes in settlement frequency are not very common. Most clearinghouses settle once a day; some have instituted twice-daily settlements between clearing members. Only in extremely rare circumstances do clearinghouses call for special settlement; when they do, it is normally in addition to regular settlement.

The contribution of our model is to give an expression for the optimal value of the default option. As such, it is closely related to Gay, Hunter and Kolb, and especially to Fenn and Kupiec. With the exception of the model of this paper, only Fenn and Kupiec take explicit account of the opportunity cost of margin, though it is implicit in some of the earlier work.

The theoretical work cited above implies that higher anticipated volatility should lead to higher margin requirements. Another strand of literature, however, argues that higher margin requirements will supress excess speculation, leading to lower volatility in the future. Since volatility is a persistent series, it is hard to distinguish empirically between these two effects in a single time series.[6]

IV. Tests of the model

A. Data

Margin data were obtained from the clearing organizations for eighteen contracts trading on the following futures exchanges: the Chicago Board of Trade, the Chicago Mercantile Exchange, the Coffee, Sugar and Cocoa Exchange, the Commodity Exchange, and the New York Mercantile Exchange. The eighteen contracts selected are the most heavily traded contracts having options on the underlying futures contract.

With the exception of the New York Mercantile Exchange, margin requirements are differentially assessed based on affiliation with the exchange. The speculative positions of nonclearing members are assessed the highest levels of margin.[7] The initial margin requirement for clearing members is generally the same as the initial margin amount for the hedge positions of nonclearing members. Finally, the maintenance margin

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[6]Recent attempts include Fishe, Goldberg, Gosnell, and Sinha (1990), Hsieh and Miller (1991), Kupiec (1990), and Moser (1991, 1992, 1993). Surveys of earlier contributions may be found in Chance (1990), France (1991), and France, Kodres, Kupiec, and Moser (1992). Approaches vary; several of these studies use GARCH or ARIMA models based on the historical time series of volatility to remove the persistence in the series. Only one other study of which we are aware uses implied standard deviations to estimate volatility. Day and Lewis (1992) use a technique similar to ours to study the relationship of volatility and margin levels in the oil futures market.

[7]Margin amounts collected when these accounts are opened are referred to as initial margin. Should the amount of margin fall below a specified maintenance level, the margin balance must be restored to the current initial level. Maintenance margin requirements in US stock markets differ. In stock markets, should a deficiency occur, margin must be restored to the maintenance level.

requirements of clearing members are the same as their initial requirements. Thus, our assumption that accounts are brought back to m after each settlement period gives a lower bound for the amount of margin in a clearing member's account: they must always have at least the amount of the current initial margin, and may choose to allow excess balances to remain in the account.

Table 1 provides summary information on these contracts. Listed under each exchange are the contracts trading on that exchange which were used in the analysis. The start date is the first date used in the sample; generally, this date is determined by the beginning of options trading on the respective futures contracts. In each case, the sample extends through June 1991. Sample dates are the last Thursday of every contract month. The number of available observations ranges from 29 for the Treasury Bond and Deutschemark contracts to 15 for the Heating Oil contract. Mean margin levels reported are for initial positions classified as nonmember speculative and for clearing members (or nonmember hedgers) on the above-indicated sample dates.

For each of the sample dates, data were collected to impute volatilities for the respective contracts. These data are: prices for call options expiring in the next delivery month at each strike price traded on that date, futures settlement prices for corresponding delivery months, and Treasury bill rates with maturities most closely matching the time until expiration of the option contracts. These data were obtained from the *Wall Street Journal*. The Barone-Adesi and Whaley (1987) model was used to impute volatilities for each of the option contracts. A time series of representative implied standard deviations (ISDs) for each contract was calculated on each sample date using a Taylor-series approximation based on iterated regressions as described by Whaley (1982). The method employs a nonlinear regression to obtain a representative ISD incorporating the information available from each of the options traded. Mean ISDs are reported. These range from a low of .01 for the Eurodollar contract to .53 for the Sugar contract.[8]

Margin coverage ratios divide the respective margin amounts by dollar-price volatility. To obtain dollar-price volatility, ISDs are multiplied by the dollar value of the contract--futures prices times number of deliverable units--and divided by the square root of 365. This gives a market-based estimate of dollar volatility for one day. Initial speculative and member margin requirements are divided by the dollar volatilities previously described. Means of these coverage ratios are reported in Table 1. Margin coverage ratios appear to be grouped according to their classification as member or nonmember. Nonmember speculative margin coverages seem to be roughly distributed around five. Comparison of nonmember speculative and member margin requirements indicates that clearing member margins are about 80% of the level required for speculative positions. The exception is the New York Mercantile Exchange where they are equal.

Notably, the coverage ratio for the S&P 500 contract is well above the typical level obtained for nonmember speculative positions, averaging 10.17 during the sample period. Member margin coverages are generally around four. In this case, the S&P 500 margin does not fall outside the range obtained for other contracts. The discrepancy between these coverage ratios suggests that determination of nonmember speculative margins for the S&P contract may have reflected additional requirements during the sample period.

This contrast becomes even more extreme when allowance is made for the length of the settlement period. During part of this period, the S&P 500 contract settled twice per day. Other contracts settled only once per day throughout the period. Since the daily standard deviation is used in

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[8]Implied standard deviations for short-term interest rate contracts are generally expressed in terms of yield variation. For consistency with our other contracts, they are here reported in terms of variation of rates of return.

calculating the coverage ratio, one would expect the coverage ratio to be smaller, not larger, for the S&P 500, other things equal (see Fenn and Kupiec, 1993).

Assuming price changes are normally distributed, this coverage ratio for clearing members implies that the probability of a price change exceeding required margin from one settlement period to the next is much less than 1%. Thus, exchanges seem to set margin such that the probability of losses exceeding margin levels is extremely small. A subsequent subsection examines the relationship between coverage ratios and our proxies for the opportunity cost of placing margin deposits.

B. Examination of individual cross-sections

The arguments of Figlewski (1984) and others state that margin levels should rise as volatility in the underlying contract rises. To examine this hypothesis, regressions were run for contract cross sections at each of the thirty sample dates. Dependent variables in these regressions were the initial margin levels for the open futures positions of members and nonmembers. These were regressed on the dollar volatilities imputed from the corresponding futures options. The specification is:

$$MARGIN_i = \alpha_0 + \alpha_1 DOLVOL_i + e_i \quad \textit{for each contract } i \qquad (13)$$

Results for speculative margin levels are reported in Table 2a and for member margin levels in Table 2b. Results are very similar regardless of margin classifications. These results are in the main consistent with the hypothesis that price volatility is an important determinant of exchange margin policy. Coefficients are positive as predicted and generally differ reliably from zero. Two exceptions are apparent in Table 2a. The first is for the sample date of 6/84 where the number of observations is smallest--3. The second is 12/88 which is positive but insignificant. In Table 2b, the 12/88 coefficient differs reliably from zero. The discrepancy between the 12/88 results in Table 2a and 2b is consistent with exchanges adjusting member margins more rapidly than nonmember margins. The R^2 figures obtained from these regressions add support for the conclusion that margins are set in accord with price volatility--considerable portions of the cross-sectional variations are explained by price volatility.

C. Time-series Evidence

To obtain further insight into the margin-setting process, daily data were obtained for four of the eighteen contracts. These contracts are: Deutschemark, S&P 500, Soybean and Treasury Bond. Implied volatilities were computed using the procedures previously described. These were matched with required margin levels on these dates and margin coverage ratios were computed. The time series of these quantities were examined.

The first test considers whether coverage ratios for a contract tend to revert to its long-run, unconditional mean. Denoting coverage ratios COV_t, our model implies that shocks to these ratios result in pressures to bring them back to acceptable levels. Such a test does depend on the time path of volatility. Substantial research finds evidence that the volatility of returns on financial assets is nonstationary.[9] Thus, adjustments to coverage ratios are appropriately ascribed to changes in margin as opposed to mean reversion in volatility: prudential concerns that coverage ratios have become too small lead to increased margin coverage and the cost concerns inherent in excessively large ratios lead to reduced margin coverage. Our model implies

[9]For an extensive review of this literature see Bollerslev, Chou, Jayaraman, and Kroner (1992).

that in the absence of either of these pressures, coverage ratios would not be adjusted to equilibrium levels, resulting in a non-stationary time series of coverage ratios (our alternative hypothesis). Evidence of stationarity is consistent with our model.

The augmented Dickey-Fuller (ADF) procedure is employed to consider this hypothesis. Changes in coverage ratios are regressed on the first lag of their levels and lags of changes in the coverage ratio. The specification is:

$$\Delta COV_{i,t} = \alpha_{i,0} + \alpha_{i,1} COV_{i,t-1} + \sum_{j=1}^{K} \alpha_{i,1+j} \Delta COV_{i,t-j} + u_{i,t} \tag{14}$$

The number of lags--K--is determined by comparing Akaike's Information Criterion (AIC) at various lag lengths, choosing the lag length which obtains maximum AIC values.

The test examines the coefficient on the lag level. This test employs the critical values provided by Fuller (1976): -1.95 at the 5% level and -2.58 at the 1% level. Coefficient t statistics below these critical values are indicative of mean reversion in the series. In each case, evidence of mean reversion is found at the 1% level or better regardless of the margin category.

This test is then extended to determine if reversion to the mean is more rapid when coverage ratios are above or below their long-run averages. The prudential hypothesis of the previous authors such as Gay, Hunter, and Kolb predicts that exchanges will respond to low coverage ratios by raising margin requirements, but prudentiality does not explain how exchanges will respond to shocks which result in high coverage ratios. In contrast, the model of this paper predicts that the cost of margin coverage will induce exchanges to lower margin coverage provided their prudentiality objectives are met. The ADF test is modified to test for differential slopes on the lagged level of the coverage ratio. Quartiles are determined for the sample of coverage ratios and dummy variables, denoted Q^1, computed to classify observations according to these quartiles. Lagged coverage ratios are multiplied by these dummy variables to obtain a specification which can capture differential responses by the exchanges based on levels of lagged coverage ratios. This specification is:

$$\Delta COV_t = \alpha_0 + \sum_{l=1}^{4} \alpha_1^l Q^l COV_{t-1} + \sum_{i=1}^{K} \alpha_i \Delta COV_{t-i} + u_t \tag{15}$$

Coefficients generally differ reliably from zero. The exception is the speculative margin requirement of the Soybean contract where response to low coverage ratios has the correct sign, but is not significant. However, in every case coefficients on the highest quartile classification differ reliably from zero. This is consistent with an exchange policy to lower margin requirements when margin coverages exceed their long-run averages. This result implies an internalization of the costs of high margins born by the exchange membership. The internalization of these costs, although generally implicit in the literature, is explicitly predicted only by Fenn and Kupiec (1993) and the model in this paper.

Further evidence of the tradeoff between prudentiality and margin costs can be obtained from a comparison of the coefficients on the low and high coverage quartiles. Coefficients which are larger (in absolute value) imply quicker responses to shocks to the coverage ratio. In every case, the coefficients on the low-coverage quartiles are larger in absolute value than those on the high-coverage quartiles. This implies that these exchanges respond more quickly to surety lost when coverage ratios decline than to the increase in costs borne by exchange members when coverage ratios rise.[10]

D. Pooled cross-section time series analysis

Our theoretical analysis suggests that margin setting by clearinghouses is influenced by the opportunity costs incurred by posting margin assets. In addition, with increasing costs, the higher the volatility, the lower the coverage ratio.

The opportunity cost of margin is the difference between the cost of financing an additional dollar of margin assets and the return on those assets. If participants were required to post margin in the form of non-interest-bearing cash, movements in firms' short-term borrowing costs would provide a good proxy for the impact of money-market conditions on changes in the opportunity cost of margin. However, most margin deposits are in the form of securities or standby letters of credit rather than cash.

In the case of securities, the appropriate measure of opportunity cost is the difference between the yield on the margin assets and an additional dollar of credit with a comparable duration. During the period covered in this paper, the five clearinghouses included in our sample accepted government and agency-debt securities as margin; Treasury bills being the most widely posted form of margin.[11]

Ideally, we would like to have a time series on the spread between the risk-adjusted borrowing costs of market participants and rates on Treasury bills. However, such a series is unavailable. This forces us to proxy for

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[10] An F test indicates that the difference between the coefficients on the high and low quartiles of the S&P and Deutschemark contracts is significant at better than the 95% level.

[11] Other clearinghouses, for instance the Options Clearing Corporation, have long accepted equity as margin. This practice is increasingly being adopted by other clearinghouses.

the cost of borrowing. The borrowing costs of market participants could vary over time because of economy-wide shifts in the cost of borrowing. However, if individual borrowers face upward-sloping supply curves for credit, borrowing costs for market participants could also vary over time because of changes in the credit demands of market participants.

Commercial banks are a significant source of credit to futures market participants. As a result, the prime rate is a useful indicator of economy-wide shifts in the cost of credit obtained through the banking system. Indeed, the majority of floating-rate loans made to commercial borrowers are tied to the prime rate.[12] When the prime rate rises, firms with prime-based loan agreements experience a change in borrowing costs irrespective of changes in open market rates. Differences between the prime rate and the Treasury bill rate provide one indicator of changes in the opportunity cost of margin.[13]

Proxies for shifts in the market participant's borrowing costs

If the borrower does not face a perfectly elastic supply of external financing, borrowing costs also vary over time and across borrowers as the quantity borrowed increases. The assumption that borrowers do not face a perfectly elastic supply of external financing is supported by a growing body of literature which indicates that firms--both financial and

[12] For example, see the Terms of Lending at Commercial Banks Survey for November 2-6, 1992 published in the February 1993 Federal Reserve Bulletin.

[13] It is less obvious that the opportunity costs associated with obtaining standby letters of credit (SLOC) should vary with monetary policy since they create no funding obligation for the bank. However, clearinghouses generally limit the SLOC portion of total margin posted. In the case of the Board of Trade Clearing Corporation, the SLOC share of margin deposits cannot exceed 25 percent of a member's adjusted net capital. In the case of the Chicago Mercantile Exchange Clearinghouse, clearing members with margin requirements in excess of $5 million, standbys can be no more than 50 percent of margin requirements in excess of $5 million.

nonfinancial--find it costly to raise additional debt or equity from external sources.[14]

If clearinghouse members do not face a perfectly elastic supply of external finance, we would expect to observe a negative correlation between coverage ratios and volatility levels. Holding the coverage ratio, open interest, and the clearing member's other assets constant, an increase in volatility implies higher margin deposits and greater external financing. With an upward-sloping supply of external funds, this higher margin requirement will result in higher borrowing costs and a higher opportunity cost for deposited margin. An optimizing clearinghouse will respond to this higher opportunity cost by reducing its coverage ratios. Thus, we would expect that, holding constant economy-wide borrowing costs, volatility and borrowing cost will be positively correlated while volatility and the coverage ratio would be negatively correlated.

The specification

The foregoing discussion suggests the following specification:

$$COV_{it} = \alpha_{i0} + \alpha_1 R_t + \alpha_{i2} ISD_{it} + \mu_{it} \qquad (16)$$

where i denotes the ith contract, R_t is a proxy variable designed to capture intertemporal variation in the opportunity cost of borrowing that are the result of economy-wide changes in the cost of borrowing from the banking system, and ISD_{it} is the implied standard deviation for the particular contract. These implied standard deviations are included to capture

[14] Calomiris and Hubbard (1992), Fazzari, Hubbard, and Petersen (1987); Himmelberg and Petersen (1989); Fazzari and Petersen (1990); Hubbard and Kashyap (1992) all provide evidence that nonfinancial firms behave as if they find it extremely expensive to finance growth through external financing. Baer and McElravey (1993) report similar results for U.S. banking corporations.

intertemporal and cross-sectional differences in market participants' opportunity cost that are the result of differences in the demand for credit to finance margin positions. Our model offers the following restrictions:

$$\alpha_{io} > 0, \ \alpha_1 \leq 0, \ \alpha_{i2} \leq 0$$

We estimate equation (16) by pooling data on 18 contracts for the time periods reported in Table 1. Table 4 presents the pooled estimation results for equation (16) using both the prime rate (RPR) and the spread between the prime rate and the Treasury bill rate (SPREAD) as the measures of changes in the opportunity cost of margin. Columns (1) and (2) of Table 4 present the results for a pooled regression where the coefficients on ISD are constrained to be the same across contracts.[15] In both cases the coefficient on ISD is negative and reliably different from zero. The coefficient on RPR is negative but insignificant while the coefficient on SPREAD is negative and significant at the 5% level. Columns (3) and (4) of Table 4 present estimates of equation (16) where we constrain the coefficients α_{i0} and α_{i2} to be constant across time periods but permit them to vary across commodities. We find that the coefficients on RPR and SPREAD are significantly less than zero at the 5 percent level. In both specifications, we also find that the coefficients on implied volatility are negative for all contracts and significantly less than zero in 12 of 18 contracts. In addition, an F test rejects the joint hypothesis that all coefficients on ISD equal zero; that is, consistent with our model we reject $\alpha_{1,2} = \ldots = \alpha_{i,2} = \ldots = \alpha_{18,2} = 0$ at the .0001 level.

Contracts for which the implied standard deviation has no explanatory

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[15]Note that our model does not require that the coefficients on ISD be equal across contracts. Indeed, if different individuals hold different numbers of contracts, the opportunity cost of a per-contract increase in margin would differ among members, and therefore might differ across contracts. All our model requires is that this coefficient be negative.

power include the British Pound, cattle, copper, gold, silver, and Treasury bonds. The heavy volume of the Treasury bond contract makes this exception especially interesting. Notably, margin requirements for the participants in this market are likely to be least onerous since their ordinary course of business makes available to them a ready supply of marginable assets. It is interesting to note that margin requirements for three of the remaining exceptions are determined by a single organization, COMEX.

Consideration of Alternative Specifications

There is the possibility that estimating equation (16) may yield a negative correlation between volatility and the coverage ratio even if our model were incorrect. Suppose that instead of being set on a cost-minimizing basis, clearinghouses set margin at fixed percentages of current prices for futures contracts, that is

$$M_{it} = \beta_{1i} P_{it} \tag{17}$$

where $P_{i,t}$ is the price of the ith futures contract at time t. If we divide both sides of equation (17) by $DOLVOL_{i,t}$, then

$$COV_{it} = \frac{\beta_{1i} P_{it}}{DOLVOL_{it}} = \frac{\beta_{1i}}{ISD_{it}} \tag{18}$$

In this case we would find that ISD and the coverage ratio would be negatively correlated even though (17) is the true model. However, this alternative model implies that coefficients on our proxies for the opportunity cost of margin, α_1 should be zero. Thus, our estimates of equation (16) reject this alternative in favor of our model.

Another possibility is that exchanges set margin at constant levels independent of either price or volatility, that is

$$M_{it} = \overline{\beta}_{0i} \qquad (19)$$

In this instance, the coverage ratio becomes

$$COV_{it} = \frac{\overline{\beta}_{0i}}{DOLVOL_{it}} \qquad (20)$$

The positive correlation of DOLVOL and ISD thereby implies a negative correlation between ISD and our coverage ratio even though, in this instance, equation (19) is the true model. This possibility is not strictly nested within the specification given in equation (16), requiring an alternative procedure. We estimate a specification based on (20), obtaining predicted values for coverage ratios. We augment equation (16) by including these predicted values and re-estimate. Under the alternative null the coefficients on our implied standard deviations and opportunity-cost proxies should be zero. The F statistic for these coefficients jointly equaling zero is 8.6. This result strongly favors our model over the alternative.

V. Summary

Our model recognizes that determination of margin requirements is driven by the cost of external funds and the deadweight losses associated with counterparty default. The opportunity cost of posting margins both creates the need for a clearing house and governs the setting of margins. As a voluntary association, the exchange internalizes these costs into its margin decisions. Thus, exchange pursuit of prudentiality through margin is constrained by the costs that members incur by carrying these balances.

Our examination of the cross-section evidence confirms the results of previous research indicating that exchange determination of margin incorporates prudential concerns. The time series of coverage ratios also supports this conclusion, but suggests that exchanges respond to high levels of margin by adjusting coverage ratios downward. This behavior cannot be explained by prudentiality alone.

Our pooled-regression results indicate that futures exchanges set margin in a cost-minimizing fashion, balancing the risk of loss against the greater opportunity costs associated with higher margins. Our results suggest that at least a portion of these opportunity costs arise because market participants have imperfect access to capital markets for their general financing. This is in contrast to the emphasis of Fenn and Kupiec (1993) on the transactions costs of frequent mark-to-market settlements.

Researchers have long argued whether margin requirements have significant impacts on market participation. However, efforts to demonstrate the significance of opportunity costs by studying the impact of margin changes on volume and open interest have met with little success, perhaps because the null hypotheses is so poorly posed. By developing a model of clearinghouse behavior we are able to generate testable hypotheses about margin setting. The data are consistent with the hypothesis that opportunity cost is important. Having established how and why opportunity costs affect margin setting, it may now be easier to establish how and why they affect volume and open interest.

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Table 1
Margins and implied volatilities

Contract	Sample Start Date	N	Mean ISD	Mean Initial Speculative Margin	Mean Speculative Coverage	Mean Initial Member Margin	Mean Member Coverage
Chicago Board of Trade							
Corn	3/85	26	.21	520.58	5.10	353.85	3.38
Soybeans	12/84	26	.16	1396.38	5.61	1067.31	4.20
Treasury Bond	3/84	29	.11	2618.97	5.32	2120.69	4.27
Wheat	3/87	16	.21	725.31	4.38	543.75	3.24
Chicago Mercantile Exchange							
British Pound	3/85	26	.12	2197.23	5.44	1938.46	5.02
Deutschemark	3/84	29	.12	1864.17	5.45	1689.66	5.01
Eurodollar	3/85	17	.01	925.00	7.06	823.53	6.07
Japanese Yen	6/86	21	.10	2069.67	4.90	1788.10	4.24
Live Cattle	12/84	23	.14	756.78	4.02	619.57	3.29
Swiss Franc	3/85	26	.12	2111.38	4.81	1875.00	4.25
S&P 500	3/84	26	.17	11134.62	10.17	4865.38	4.56
Coffee, Sugar and Cocoa Exchange							
Coffee	12/87	15	.30	2733.33	5.25	1366.67	2.62
Sugar	3/85	26	.53	1209.62	5.46	604.81	2.73
Commodity Exchange							
Copper	6/86	20	.30	1734.50	4.81	1355.00	3.66
Gold	3/84	28	.16	1692.46	5.34	1253.57	3.95
Silver	12/84	27	.24	2004.52	5.55	1585.00	4.10
New York Mercantile Exchange							
Crude Oil	12/86	19	.36	2284.21	7.53	2284.21	7.53
Heating Oil	9/87	15	.37	2293.33	6.79	2293.33	6.79

Note: Start date is the first sample date. Mean margin is the average of initial speculative or initial member margin required on the sample dates. Mean ISD is the average implied standard deviation for options trading on the sample dates. The Barone-Adesi and Whaley (1987) model is used to impute volatilities. The Whaley (1982) method is used to combine volatilities at each sample date. Margin coverage is respective level of margin divided by the dollar volatility of the contract. Dollar volatilities are ISD multiplied by the dollar value of the contract and divided by the square root of 365

Table 2a

Cross-section regressions of initial speculative-margin on dollar volatility

$$MARGIN_t = \alpha_0 + \alpha_1 DOLVOL_t + e_t$$

Date	N	α_0	$t(\alpha_0)$	α_1	$t(\alpha_1)$	R^2
3/84	4	-1886.4	-5.56	10.82	14.25	.99
6/84	3	-1415.6	-0.25	11.39	0.88	.44
9/84	4	-3461.2	-2.99	14.71	5.74	.94
12/84	7	-47.6	-0.04	7.55	2.37	.53
3/85	11	-820.2	-1.11	9.10	4.62	.70
6/85	12	-733.0	-1.19	8.48	4.63	.68
9/85	11	-560.6	-0.62	7.47	2.93	.49
12/85	12	-416.0	-1.64	7.76	10.25	.91
3/86	12	177.2	0.56	4.11	6.81	.82
6/86	13	268.2	0.89	4.22	6.75	.81
9/86	13	-75.7	-0.35	4.68	10.84	.91
12/86	14	203.5	1.81	5.41	18.93	.97
3/87	14	79.6	0.56	6.09	21.26	.97
6/87	13	-275.1	-0.66	6.98	8.38	.86
9/87	17	-162.4	-0.79	5.73	14.55	.93
12/87	16	-636.0	-0.64	5.96	4.20	.56
3/88	18	-1665.1	-0.94	11.41	2.73	.32
6/88	18	424.1	0.35	5.01	2.89	.34
9/88	18	-2271.5	-1.89	12.31	5.02	.61
12/88	16	1673.1	1.11	2.46	1.36	.12
3/89	18	-2034.4	-3.78	12.25	10.22	.87
6/89	17	454.0	2.68	3.49	12.18	.91
9/89	18	-169.8	-0.84	5.39	13.97	.92
12/89	14	393.1	1.02	4.35	3.79	.55
3/90	16	290.2	1.19	4.44	6.62	.76
6/90	18	-886.6	-2.49	8.13	15.81	.94
9/90	18	1601.2	1.29	2.42	2.33	.25
12/90	16	1017.4	3.06	1.91	4.68	.61
3/91	18	-2747.3	-3.16	13.42	7.84	.79
6/91	16	295.0	1.34	3.64	6.01	.72

Note: $Margin_t$ is the initial amount of margin required for speculative positions of the sample contracts. $DOLVOL_t$ is the volatility expressed in dollars implied by futures options trading on the sample date. Implied standard deviations are computed using the Barone-Adesi and Whaley pricing procedure. The Whaley (1982) method is used to combine volatilities at each sample date. Margin coverage is initial speculative margin divided by the dollar volatility of the contract. Dollar volatilities are ISD multiplied by the dollar value of the contract and divided by the square root of 365.

Table 2b
Cross-section regressions of initial member-margin on dollar volatility

$$MARGIN_t = \alpha_0 + \alpha_1 DOLVOL_t + \varepsilon_t$$

Date	N	α_0	$t(\alpha_0)$	α_1	$t(\alpha_1)$	R^2
3/84	4	-93.4	-0.23	4.23	4.61	.91
6/84	3	433.3	0.27	4.16	1.12	.56
9/84	4	-351.5	-5.29	5.34	36.28	.99
12/84	7	577.3	1.22	3.28	2.35	.53
3/85	11	-318.1	-1.07	5.76	7.30	.86
6/85	12	-177.9	-0.71	5.20	6.95	.83
9/85	11	-340.7	-1.08	5.35	6.01	.80
12/85	12	252.4	1.03	3.90	5.35	.74
3/86	12	558.1	1.94	2.17	3.96	.61
6/86	13	417.1	2.29	2.68	7.07	.82
9/86	13	293.2	1.53	2.82	7.40	.83
12/86	14	573.4	2.61	2.94	5.26	.70
3/87	14	585.8	3.13	2.86	7.57	.83
6/87	13	498.0	1.49	3.30	4.98	.69
9/87	17	468.9	2.67	2.73	8.14	.82
12/87	16	-156.3	-0.24	4.12	4.51	.59
3/88	18	-854.6	-0.95	7.49	3.55	.44
6/88	18	1038.6	1.53	2.31	2.40	.26
9/88	18	733.3	2.63	2.12	3.72	.46
12/88	16	1205.0	4.51	0.64	2.00	.22
3/89	18	332.6	1.65	3.08	6.87	.75
6/89	17	593.9	3.32	1.89	6.26	.73
9/89	18	486.8	2.87	2.28	7.09	.76
12/89	13	261.7	0.64	3.24	2.69	.40
3/90	15	476.9	1.64	2.48	3.17	.44
6/90	17	359.1	1.94	2.68	10.29	.88
9/90	18	1044.9	2.32	1.50	4.07	.52
12/90	16	604.9	1.67	2.00	4.58	.62
3/91	17	-861.8	-2.35	6.10	8.64	.83
6/91	15	281.9	1.28	2.53	4.21	.58

Note: $Margin_t$ is the initial amount of margin required for member positions of the sample contracts. $DOLVOL_t$ is the volatility expressed in dollars implied by futures options trading on the sample date. Implied standard deviations are computed using the Barone-Adesi and Whaley pricing procedure. The Whaley (1982) method is used to combine volatilities obtained for the contracts at each sample date. Margin coverage is initial speculative margin divided by the dollar volatility of the contract. Dollar volatilities are ISD multiplied by the dollar value of the contract and divided by the square root of 365.

Table 3
Margin coverage adjustments

$$\Delta COV_t = \alpha_0 + \alpha_1 COV_{t-1} + \sum_{i=1}^{K} \alpha_{1+i} \Delta COV_{t-i} + u_t$$

Contract	Initial Speculative Margin α_1	$t(\alpha_1)$	Initial Member Margin α_1	$t(\alpha_1)$
Deutschemark	-.008044	-4.73	-.004579	-3.52
S&P 500	-.001950	-2.88	-.004704	-2.88
Soybean	-.006525	-3.40	-.012160	-4.04
Treasury Bond	-.013175	-6.48	-.017178	-6.84

$$\Delta COV_t = \alpha_0 + \sum_{l=1}^{4} \alpha_1^l Q^l COV_{t-1} + \sum_{i=1}^{K} \alpha_{4+i} \Delta COV_{t-i} + u_t$$

	Level of margin coverage at time t-1							
	Lowest Quartile		Second Quartile		Third Quartile		Highest Quartile	
Contract/Position	α_1	$t(\alpha_1)$	α_1	$t(\alpha_1)$	α_1	$t(\alpha_1)$	α_1	$t(\alpha_1)$
Deutschemark								
Initial Speculative	-.0234	-4.20	-.0200	-4.18	-.0190	-4.54	-.0167	-4.77
Initial Member	-.0135	-3.18	-.0084	-2.58	-.0097	-3.43	-.0090	-3.78
S&P 500								
Initial Speculative	-.0126	-3.34	-.0099	-3.49	-.0062	-3.17	-.0060	-4.06
Initial Member	-.0438	-4.47	-.0417	-5.25	-.0239	-4.44	-.0233	-5.35
Soybean								
Initial Speculative	-.0088	-0.85	-.0125	-1.71	-.0092	-1.87	-.0078	-2.18
Initial Member	-.0277	-2.12	-.0265	-2.88	-.0200	-2.91	-.0180	-3.49
Treasury Bond								
Initial Speculative	-.0374	-6.74	-.0333	-6.90	-.0305	-7.04	-.0282	-7.48
Initial Member	-.0408	-5.96	-.0389	-6.48	-.0356	-6.55	-.0321	-6.83

COV_t is the time-t ratio of initial speculative margin to the option-implied volatility stated in dollars. Q^l is the coverage quartile for margin coverage during the sample period. Critical values are from Fuller (1976): -1.95 at the 5% level and -2.58 at the 1% level. Lower values of t are indicative of reversion to the mean; i.e., the null of no mean reversion is rejected.

Table 4
Pooled Time-Series Regressions

$$COV_{it} = \alpha_0 + \alpha_1 R_t + \alpha_2 ISD_{it} + \sum_{j=2}^{18} \beta_j D_j + \sum_{k=1}^{18} \delta_k D_k ISD_{kt} + \mu_{it}$$

Opportunity Cost Proxy:		Coefficient Restriction: $\delta_k=0$ RPR	SPREAD	Coefficient Restriction: $\alpha_2=0$ RPR	SPREAD
Parameter	Contract				
α_0		6.5227	6.6044	7.2173	6.8447
		(0.736)	(0.640)	(1.450)	(1.373)
α_1		-0.1187	-0.4645	-0.1335	-0.4453
		(0.070)	(0.215)	(0.065)	(0.201)
α_2		-3.2065	-3.1468		
		(0.458)	(0.458)		
δ_1	British Pound			-7.7889	-5.5372
				(10.584)	(10.626)
δ_2	Cattle			-11.4340	-10.6305
				(6.677)	(6.627)
δ_3	Coffee			-3.0370	-3.5746
				(2.032)	(2.027)
δ_4	Copper			-3.5078	-3.3578
				(2.164)	(2.167)
δ_5	Corn			-5.6660	-5.8975
				(2.118)	(2.118)
δ_6	Crude Oil			-3.4674	-3.2741
				(0.862)	(0.868)
δ_7	Deutschemark			-29.4419	-29.3113
				(7.365)	(7.358)
δ_8	Eurodollar			-1873.62	-1911.14
				(261.08)	(261.16)
δ_9	Gold			-4.9219	-4.9800
				(7.936)	(7.927)
δ_{10}	Heating Oil			-3.9239	-3.8797
				(0.935)	(0.934)
δ_{11}	Japanese Yen			-47.4932	-43.6372
				(17.218)	(17.294)
δ_{12}	Swiss Franc			-23.5832	-23.0859
				(11.202)	(11.191)
δ_{13}	Sugar			-1.5328	-1.5380
				(0.647)	(0.647)
δ_{14}	Silver			-1.3621	-0.1981
				(6.347)	(6.345)
δ_{15}	Soy Bean			-17.1179	-16.6645
				(6.182)	(6.187)
δ_{16}	S&P 500			-22.3409	-21.1606
				(6.223)	(6.184)
δ_{17}	Treasury Bond			-14.5535	-12.7488
				(10.367)	(10.352)
δ_{18}	Wheat			-6.5590	-6.1514
				(3.710)	(3.703)
Tests of coefficient restrictions:					
$\beta_2 = \ldots = \beta_j = \beta_{18} = 0$		12.22	12.26	17.33	17.07
$\delta_1 = \ldots = \delta_k = \delta_{18} = 0$		NA	NA	8.93	8.73

(Standard errors in parentheses.)