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Opportunity Cost and Prudentiality: An Analysis of Collateral Decisions in Bilateral and Multilateral Settings

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by

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Abstract

This paper develops a model that explains how the creation of a futures clearinghouse allows traders to reduce default and economize on margin. We contrast the collateral necessary between bilateral partners with that required when multilateral netting occurs. Optimal margin levels balance the deadweight costs of default against the opportunity costs of holding additional margin. Once created, it may be optimal for the clearinghouse to monitor the financial condition of its members. If undertaken, monitoring will reduce the amount of margin required but need not affect the probability of default. Once created, it becomes optimal for the clearinghouse membership to expel defaulting members. This reduces the probability of default. Our empirical tests suggest that the opportunity cost of margin plays an important role in clearinghouse behavior particularly their determination of margin amounts. The relationship between volatility and margins suggests that participants face an upward-sloping opportunity cost of margin. This appears to dominate the effects of monitoring and expulsion might have on margin setting.

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The field of competition...consists of all the individuals who are willing and able to recontract about the articles under consideration.

F. Y Edgeworth

I. INTRODUCTION AND LITERATURE REVIEW

Contract terms that specify posting of collateral effect a limit on the exposure to loss from counterparty nonperformance. This outcome is obtained in two ways. First, seizure of deposited collateral inherently reduces losses resulting from contract nonperformance. Second, posting of collateral encourages contract performance. [1] This paper studies decision making for instances where collateral requirements are costly. We show that cost-avoidance within a competitive market reliably predicts certain outcomes.

Introduction

Brennan (1986) employs the Theory of Efficient Contract Design to model price limits. The theory explicitly recognizes the influence of cost-minimization incentives for the contract terms developed by exchanges. In that setting, he shows that price limits lessen contract nonperformance. Improvements in contract performance enable reductions in required collateral, lowering the costs of contracting.

This paper applies the Theory of Efficient Contract Design first to model the determination of collateral required from contracting counterparties. We then extend

this result to show how its cost-reducing potential influences the structural adaptation of exchanges. Futures exchanges specialize in providing facilities for designing and exchanging contracts. Their interest in successful trading of contracts makes these organizations a logical source for empirical examination of the hypotheses suggested by our model.

Our empirical analysis discriminates among competing representations of the margin decision by examining margin coverage ratios--required margin divided by a forward-looking measure of volatility. In the first, the marginal opportunity cost of margin requirements is constant. The second allows for increasing costs for margin funds.

Both time series and cross section evidence is developed. Our model predicts margin adjustments when margin coverage is too high (and too expensive) or too low (and too risky).[2] Time series evidence concludes that coverage ratios increase (decrease) when coverage ratios are lower (higher) than their unconditional means. Examining a cross section of margin-coverage ratios, we find that the opportunity cost of margin deposits significantly influences the levels required from members. Our regressions suggest a negative relationship between economy-wide shifts in the opportunity cost of margin deposits and levels of margin coverage. In addition, we find a negative relationship between margin coverage and participant-specific shifts in participants' borrowing needs as proxied by levels of implied standard deviation. These suggest that opportunity costs are important and that market participants face upward-sloping schedules of opportunity costs for their margin deposits.

Literature Review

We advance the theory of margins by explicitly incorporating the cost of margin deposits into the margin-setting decision. This establishes a tradeoff between these costs and prudential concerns. Further examination of this tradeoff gives insight into the effect of clearinghouse activities on its margin-setting decisions.

Craine (1997) models the clearinghouse as a profit-maximizing entity and describes the option to default. He contends that, since the clearinghouse charges no default premia, it must keep premium values at or close to zero. Our model, by contrast, argues that the values of default premia and counterparty risk offset across agents. Fenn and Kupiec (1993) also implicitly assume that the clearinghouse is an independent cost-minimizing entity. Their clearinghouse minimizes the sum of margin costs, settlement costs, and costs incurred when deficits arise in clearinghouse accounts. 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 volatility increases, increasing settlement frequency lowers this sum, and the margin-to-volatility ratio declines.

We model the clearinghouse as a club that minimizes the joint costs of its members. In our formulation, the clearinghouse need not make a profit, nor even recoup any deadweight losses incurred by its membership because members willingly subsidize the clearinghouse to avoid the greater cost of a bilateral arrangement.[3] Neither Craine nor Fenn and Kupiec provide motivation for clearinghouse development.

Our model results for expulsion and the value added by clearing activities match those of Bhasin and Brown (1997). They model the value of exchange seats as stemming from trading activity. Their model analyzes intra day default incentives. The values of exchange seats secure under-margined positions held during the day. Their model complements ours by explaining the dynamics of collateralizing against default during the trading day.

We develop the monitoring activities of exchanges as part of their intermediating role. In this respect, the model resembles the delegated monitoring described by Diamond (1984), and the modeling of risk management and financial guarantees by Merton and Bodie (1992) and Hsieh (1993). We extend the earlier work by explicitly incorporating certain institutional features of clearinghouses. These features include expulsion from the clearinghouse, clearinghouse monitoring of members' financial condition and the possibility that members face increasing costs for external funds. These have very different effects on optimal margin setting and the probability of default. Our model also parallels Gorton's (1985) modeling of bank clearinghouses, particularly concerning expulsion and risk mutualization.

II. DETERMINING COLLATERAL FOR BILATERAL CONTRACTS

We first model the setting of collateral requirements in a bilateral marketplace. Two parties j and h negotiate contracts for their own accounts but are unable to compel contract performance. Contract nonperformance, that is, failure to fulfill contractual terms always entails deadweight loss.[4] These deadweight losses include

costs of recontracting, higher borrowing costs that arise from liquidity problems, and costs arising from financial distress. Recovery against losses is limited to collateral deposited by the defaulting counterparty. We assume that a default-free trustee holds collateral deposits. Counterparties posting collateral with the trustee bond their contract performance.

There are two periods. In the opening period, the two parties enter a contract with each other. The motivation for trading is exogenous to our model; however, our model does imply cost reductions that improve whatever benefits trading provides. Let N(j,h) denote the number of contracts outstanding between j and h. If N(j,h) is positive, j holds a long position in the contract. If N(j,h) is negative, then j's position in the contract is short. Contra-positions are held by h, so that N(h,j) = -N(j,h). The contract settles at the next-period price for the underlying good. The distribution of this price has a zero mean and finite standard deviation of s.[5]

Collateral posted by j with h is denoted M(j,h), and that posted by h with j is denoted M(h,j). Collateral are cash deposits held in interest-bearing accounts. Interest on deposits is paid to its respective depositor.[6] At the end of period two, the contract is settled. If x is positive and less than M(h,j), x is transferred from the account of the short to the account of the long. 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.

After contracts are settled, traders immediately restore their collateral-account balances to M(j,h) and M(h,j), by either depositing cash when they are on the losing

side or withdrawing excess balances on gains. These account adjustments restore equal values for the default options and counterparty risk of both counterparties.

Figlewski (1984) shows that contract counterparties implicitly give each other options to default. In the simplest case, contract default occurs whenever losses exceed margin-account balances. Thus, if x is positive and greater than M(h,j), the short rationally defaults on the contract and the long 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). Remaining losses include recontracting costs, higher borrowing costs arising from liquidity problems, and costs of financial distress. These are deadweight losses. Agent j's expectation of these losses is:

$$D(j,h) \quad = \quad \alpha N \int_{M(h,j)}^{\infty} (x - M(h,j) f(x,\sigma) dx) \qquad \textbf{(1)}$$

where N is the net number of contracts j has open with h; i.e., the absolute value of N(j,h).

Agents jointly minimize the cost of contracting as would be obtained in a perfectly competitive market. This is realistic provided agents freely choose among a large number of counterparties each willing to minimize joint contracting costs. Post-trade bargaining problems are included in the deadweight losses subsumed in α.

Proposition I: Collateral amounts are optimal when the default probability equals the ratio of the opportunity cost for posting additional collateral to the deadweight loss rate.

Contracting entails three costs: the total opportunity cost of margin deposits I(j); counterparty risk, that is, the expected difference between the promised and the actual payment when h defaults on j, L(j,h); and expected deadweight losses incurred when h defaults on j, D(j,h). Offsetting these costs, each party also receives an option to default O(j,h). The two parties jointly minimize the following costs:

$$\begin{array}{cc} I(j)+I(h) & \textit{Opportunity Costs} \\ D(j,h)+D(h,j) & \textit{Deadweight Losses} \\ L(j,h)+L(h,j) & \textit{Counterparty Risk} \\ O(j,h)+O(h,j) & \textit{Default Options} \end{array} \qquad \textbf{(2)}$$

We find it convenient to separate ignore the fact that default involves both a loss to one party and a corresponding gain to the other. In practice, Recognizing that one party's default option is another party's counterparty risk, that is, that L(j,h) = O(h,j), the expression for joint contracting costs reduces to:

$$I(j)+I(h)+D(j,h)+D(h,j) \qquad \textbf{(3)}$$

The first order conditions for minimization of (3) with respect to M(j,h) and M(h,j) are:

$$\left[1 - F\left(M^*(j,h),\sigma\right)\right] = \frac{i}{a} \quad and \quad F\left(M^*(j,h),\sigma\right) = \frac{i}{a} \qquad \textbf{(4)}$$

where i is the opportunity cost for an additional dollar of margin. Equation 4 implies that counterparties optimally collateralize when their default probabilities equal their ratios of opportunity cost of additional margin to their deadweight loss rate. The

higher this ratio, the lower is the optimal collateral level. Nonzero collateral requirements are optimal when $i/\alpha < 1$. Should i/α exceed unity, counterparties set margin at zero, the losing trader always defaults, and contracts are unenforceable.

Since the objective function is linear in the number of contracts, the opportunity cost of additional margin is constant. This implies that the collateral per unit of exposure is independent of the aggregate level of exposure, and that collateral amounts can be set on a per-contract basis. Further, if the distribution of price changes is symmetric, equal collateral amounts are required for both long and short positions.

Proposition II: when the distribution of price changes is uniquely invertible and the opportunity cost of collateral deposits is constant, optimal coverage ratios do not vary with volatility.

When a unique inverse exists for the price-change distribution depicted in equation 4, the coverage ratio giving the level of collateral to exposure to price changes is:

$$\frac{M^*}{\sigma} = F^{-1}\left(\frac{i}{\alpha},1\right) \tag{5}$$

Inspection of (5) confirms that margin increases proportionately with s. This implies that optimal coverage ratios do not vary with volatility. For instance, Proposition II holds if the distribution of price changes is normal.

III. DETERMINING COLLATERAL FOR A MULTILATERAL CLEARINGHOUSE

We next model of a clearinghouse acting solely as a netting facility.[7] We establish the benefits from clearinghouse arrangements within a framework that regards the clearinghouse as a club of its members, not as a separate, for-profit agency. We then model the margin-level choices made by clearinghouses as balancing the deadweight losses from counterparty defaults against opportunity costs incurred by posting margin. Although depositing interest-bearing assets can fulfill margin requirements, we argue that opportunity costs are nonzero when the firm's marginal borrowing cost exceeds the return on its marginable assets.[8]

The Intermediary Role of a Clearinghouse

Clearinghouses intermediate by substituting themselves as contract counterparties. This achieves certain economies by reducing both deadweight default costs and the opportunity costs of holding assets in margin accounts. We represent the clearinghouse acts as a club, that is, a voluntary organization that furthers the joint interests of its members by internalizing certain shared costs. This approach is more general than a more standard profit-maximizing framework, allowing us to represent the heterogeneous interests generally found within exchange organizations. Clearinghouse members minimize their joint contracting costs by committing to rules that allocate contract-default losses among themselves. Many loss-sharing rules are consistent with this objective function. Importantly, the model is consistent with the industry practice of paying for losses from a clearinghouse guarantee fund, in effect sharing losses *pro rata* among clearing members.[9]

Proposition III: If members have the same i and α, the clearinghouse sets margin at the same level as though contracts were cleared and settled bilaterally.

Let party j's open interest $\sum_{h=1}^{n} N(j,h)$ be denoted by N(j). If we assume that f(), the distribution of price changes, is symmetric then the clearinghouse chooses M(j,h) to minimize joint contracting costs of:

$$\sum_{j=1}^{n}\left[\left|N(j)\right|\left\{iM(j)+\alpha\int_{M(j)}^{\infty}(x-M(j))f(x,\sigma)dx\right\}\right] \tag{6}$$

When i and α are the same for all members the solution to this problem is given by equation 4. Thus, per contract, margin will be the same whether contracts are cleared and settled bilaterally by counterparty pairs or multilaterally through a clearinghouse.

Because a clearinghouse will set the same margin rate that these agents willingly negotiate between themselves, analyzing the benefits derived from forming a clearinghouse is straightforward. In our model, the essential benefit of the clearinghouse is that it permits its members to economize on margin while also reducing expected deadweight losses. Clearinghouses economize on margins and deadweight loss because, for the same set of contracts, participants' net positions are less (weakly) risky. Consequently, total margin deposits required by the clearinghouse are smaller than totals required for a comparable set of bilateral

transactions. In addition, *pro rata* expected deadweight losses are also smaller.

Proposition IV: Total margin deposits posted by each member will be the same or lower under a clearinghouse system than under a system of bilateral collateral deposits.

Under a clearinghouse system, j posts margin against the net of his position with the rest of the market, that is $M/N(j)/$. In effect, a multilateral clearinghouse secures the losing positions of a potential defaulter with his winning positions. That is, members cannot "cherry pick" gains while defaulting on losses. The margin posted by each member will be the same or lower under a clearinghouse system.

Proposition V: Under an appropriate loss-sharing arrangement, total expected deadweight losses are lower under a clearinghouse system than under a system of bilateral collateral deposits.

Similarly, no counterparty's expected deadweight loss is greater under a clearinghouse system and for some, it will be smaller.[10] In a bilateral system, j's expected loss from counterparty default is proportional to the number of her open contracts; that is $\sum_{h=1}^{n} /N(j,h)/$. Member j benefits by joining a multilateral clearinghouse that keeps her default-loss exposure proportional to her net open contracts; that is, proportional to $/N(j)/$. Other loss-sharing arrangements also achieve this result.

Increasing opportunity cost of funds

The cost of funds function may be increasing as the amount of required margin increases. Thus, an increase in margins drives up the marginal cost of funds.

Proposition VI: Where the marginal cost of funds is increasing, the optimal coverage ratios decrease with volatility when prices are normally distributed and the opportunity cost of margin assets is increasing.

If marginal costs of margin are increasing in M then:

$$i = \rho(M);\ \rho'(M) > 0 \tag{7}$$

and the clearinghouse sets margin to meet the condition:

$$\frac{\rho'(M)}{\alpha} = [1 - F(M,\sigma)] \tag{8}$$

An increase in s now causes the clearinghouse to increase margin less than proportionately with s. As the standard deviation increases, the clearinghouse increases margin levels to keep the probability of default constant. However, doing so drives up the marginal financing costs of its members. The members of the clearinghouse therefore choose to bear greater deadweight losses to economize on their financing costs. Thus, coverage ratios should decrease with volatility.

Note that, even if their cost functions are identical, individuals holding different numbers of contracts may have different marginal costs of funds. In addition, unlike the agents of the previous section, the slope and level of member cost functions may differ. This will result in disagreement among members as to appropriate margin levels, though each will have only one preferred margin level. The club literature suggests that in decisions made by diverse interests, majority rule reflects median voter preferences provided individuals have single-peaked preferences.[11] For such preference structures, relevant marginal costs are those of median voting members. Severe disagreement about appropriate margin levels will lead some traders to reject

clearinghouse membership, of these some may seek economies through other arrangements.

IV. Tests of the model

The modeling of the previous sections suggests three hypotheses for clearinghouse determination of required margin. The first of these is a positive relationship between margin levels and risks stemming from the contracts. Baer, France, and Moser (1995b) provide supporting evidence for this result. The second is that clearinghouses incorporate the cost of maintaining margin balances into their margin-level decisions. Thus, we can expect a negative correlation between margin levels and the opportunity costs of clearinghouse members. Our remaining hypothesis relates to coverage ratios, predicting that coverage ratios are invariant to risk levels when members have constant costs while increasing costs imply a negative correlation between coverage ratio and risk level.

Description of the Sample Data Set

Margin data are 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. These eighteen contracts are the most heavily traded contracts having options on the underlying futures contract.

During the sample period, with the exception of contracts listed by the New York Mercantile Exchange, exchange affiliation was the basis for determining margin requirements. The speculative positions of non-clearing members are assessed the

highest levels of margin.[12] The initial margin requirement for clearing members is usually the same as the initial margin amount for the hedge positions of non-clearing members. Finally, the maintenance margin requirements of clearing members are the same as their initial requirements. Thus, our assumption that periodic settlement restores the account to the level M gives a lower bound for a clearing member's margin account. Members 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 summarizes our sample. Listed under each exchange are the contracts trading on that exchange. The start date is the first date used in the sample; generally, this is 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. We report mean margin levels for positions classed as initial nonmember speculative and for clearing members (or nonmember hedgers) on the above-indicated sample dates.

For each sample date, we impute volatilities for the respective contracts. The needed data are from various issues of the *Wall Street Journal.* 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. The Barone-Adesi and Whaley (1987) model was used to

impute volatilities for each of the option contracts. For each contract, we calculate a time series of representative implied standard deviations (ISDs) on each sample date using a Taylor-series approximation based on iterated regressions as described by Whaley (1982). The table reports mean ISDs. These range from a low of .01 for the Eurodollar contract to .53 for the sugar contract.[13]

Margin coverage ratios divide the respective margin amounts by dollar-price volatility. Dollar-price volatility is the product of the ISD and the notional value of the contract—futures prices times number of deliverable units—after adjusting the annualized volatility for the length of the holding period. This gives a market-based forecast of holding period volatility. Dividing initial speculative and member margin requirements by their respective dollar volatilities gives coverage ratios. Columns 6 and 8 list mean coverage ratios for the member and nonmember categories. The peak of the frequency distribution for mean nonmember speculative margin coverage ratios is about five. This implies that margin levels most often cover five times the expected single-day price deviation. Comparison of the means of nonmember speculative and member margin requirements reveals that clearing members' margin is about 80% of that 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 well exceeds the typical level obtained for nonmember speculative positions, averaging 10.17 during the sample period. In contrast to the coverage obtained by nonmember margin levels, the S&P 500 members' margin, generally around four, is within the range obtained for

other contracts. The difference between coverage ratios for the S&P and other nonmember speculative margins probably reflects considerations unique to the sample period. Market breaks in 1987 and 1989 increased debate over the need for regulatory intervention in the determination of stock-index margin requirements may have resulted in higher margins than the clearinghouse would have set for purely prudential reasons.

The contrast between margin for the S&P contract and the others is more noticeable on recognizing that 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 we calculate coverage ratios with daily standard deviations, the coverage ratio for the S&P 500 should be smaller, not larger. Other things equal Fenn and Kupiec's (1993) analysis suggests coverage ratios should be approximately half as large.

Assuming price changes are normally distributed, the coverage ratios for clearing members imply that the probability of a price change exceeding required margin from one settlement period to the next is much less than 1%. The "excess" of coverage suggests that actual distributions are kurtotic, a result that is consistent with the findings of Kofman (1993).

Time-series Evidence

We use daily data for four of the eighteen contracts to gain further insight into the margin-setting process. These contracts are: Deutschemark, S&P 500, Soybean and Treasury Bond. Daily implied volatilities, computed as previously described,

were matched with required margin levels on these dates and margin coverage ratios computed. We examine the time series of these quantities.

The first test considers whether the coverage ratio for a contract tends to revert to its long-run, unconditional mean. Denoting coverage ratios CR_t, our model implies that shocks to these ratios initiate intervention that restores them to desired levels. Specifically, prudential concerns dictate that coverage ratios regarded as too small should lead to increasing margin coverage and opportunity cost concerns dictate that excessively large ratios lead to reducing margin coverage. Our model equilibrates these pressures, and predicts a mean-reverting time series of coverage ratios.

We employ the augmented Dickey-Fuller (ADF) procedure 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:

$$\Delta CR_{i,t} = \alpha_{i,0} + \alpha_{i,1} CR_{i,t-1} + \sum_{j=1}^{K} \alpha_{i,1+j} \Delta CR_{i,t-j} + u_{i,t} \qquad \textbf{(9)}$$

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

The test examines the coefficient on the lag level, employing Fuller's (1976) critical values: -1.95 at the 5% level and -2.58 at the1% level. Table 2 reports the results of these tests. Coefficient t statistics below these critical values suggest mean reversion in the series. We find evidence of mean reversion at the 1% level or better in every case.

Evidence of mean reversion in coverage ratios can be the result of mean reversion in volatilities. Although substantial research finds evidence that the volatility of returns on financial assets is nonstationary,[14] in our sample volatility appears to be stationary. We examine the possibility that the mean reversion in coverage ratios is caused by mean reversion in volatility by comparing the mean half lives from coverage-ratio shocks to the half lives for volatility shocks. From equation (9), the mean half-life from a coverage-ratio shock is given by $1 - \log(2)/\log(a_{i,1})$. Substituting for the CR variables in (9) with the respective volatilities--these are the denominators of the coverage ratios--gives the half-life for a shock to volatility. Half-lives are computed for two standard errors above and below the coefficient estimates from the volatility specification and for the coverage-ratio specification. In no case do these ranges overlap. Hence, we reject the alternative hypothesis that adjustments to coverage ratios stem from volatility reverting to its long-run mean rather than from exchange action.[15] We can be confident at the 5% level that exchanges actively adjust margin levels in response to coverage-ratio shocks.

We extend these tests to detect if reversion to the mean is more rapid when coverage ratios are above or below their long-run averages. The prudential hypothesis of previous authors such as Gay, Hunter, and Kolb (1986) predicts that clearinghouses respond to low coverage ratios by raising margin requirements. Previous models of prudentiality do not predict clearinghouse response to shocks resulting in excess margin coverage. In contrast, the model of this paper predicts that a high cost of margin coverage induces clearinghouses to lower margin coverage

with the provision that they meet prudentiality objectives. 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 indicator variables, denoted Q^l, used to classify observations into quartiles.

Lagged coverage ratios are interacted with quartile-indicator variables to measure differential responses by the clearinghouses. This specification is:

$$\Delta CR_t = \alpha_0 + \sum_{l=1}^{4} \alpha_1^l Q^l CR_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta CR_{t-i} + u_t \qquad \textbf{(10)}$$

We report these results in the lower panel of Table 2. Most coefficients 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 statistically significant. However, in every case, coefficients on the highest quartile classification differ reliably from zero. This is consistent with clearinghouse policies that lower margin requirements when margin coverage ratios exceed their long-run averages and implies an internalization of the costs of high margins born by the exchange membership. Fenn and Kupiec (1993) predict a similar cost internalization.

Comparing the coefficients on the low and high coverage quartiles adds evidence for the presence of tradeoffs between prudentiality and margin costs. Coefficients that 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 clearinghouses respond more quickly to surety lost when coverage ratios decline than to the increase in costs borne by clearinghouse members when coverage ratios rise.[16]

Pooled cross-section time series analysis

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 margin deposits were non-interest-bearing cash, movements in firms' short-term borrowing costs would suitably measure changes in the opportunity cost of margin. However, members most often fulfill margin requirements with securities or standby letters of credit. For securities, the appropriate measure of opportunity cost is the risk-adjusted difference between the yield on the margin assets and an additional dollar of credit. During our sample period, the sampled exchanges accepted government and agency-debt securities as margin, Treasury bills being the most widely posted form of margin.[17]

Ideally, we need a time series on the spread between the risk-adjusted borrowing costs of market participants and rates on Treasury bills. Lacking this, we adopt a proxy for the cost of borrowing. The proxy should capture economy-wide shifts in the borrowing costs. In addition, borrowing-cost changes should be correlated across borrowers even though members may be at different points on their respective credit supply curves.

Commercial banks are a significant source of credit to futures market participants. Consequently, the prime rate measures credit costs. When the prime

rate rises, firms with prime-based loan agreements experience a change in borrowing costs. To isolate credit premia we use differences between the prime rate and the Treasury bill rate to represent changes in the opportunity cost of margin.

Our model implies a negative correlation between coverage ratios and volatility levels when members face inelastic supplies of external finance. Holding constant the coverage ratio, open interest, and the other assets of clearing members, a volatility increase implies higher margin deposits and greater reliance on external finance. With an upward-sloping supply of external funds, a higher margin requirement raises the opportunity cost for margin deposits. A clearinghouse which is optimizing as our model suggests will respond to this higher opportunity cost by reducing its coverage ratios. Thus, a constant cost for borrowing implies a positive correlation between volatility and individual member borrowing costs. Hence, our model implies a negative correlation between volatility and coverage ratio.

This discussion suggests the following test specification:

$$CR_{it} = \alpha_i 0 + \alpha_1 R_t + \alpha_{i2} ISD_{it} + \mu_{it} \qquad \textbf{(11)}$$

where i denotes the ith contract, R_t is a proxy variable capturing variation in the opportunity cost of borrowing from economy-wide changes in bank financing, and ISD_{it} is the implied standard deviation for the particular contract. Including these implied standard deviations incorporates both intertemporal and cross-sectional differences in market participants' opportunity cost that might result from differences

in the demand for credit to finance margin positions. The increasing opportunity cost model implies the following coefficient restrictions: $a_1 \leq 0$ and $a_{i2} \leq 0$.

Table 3 presents estimation results for equation (11). The first three columns of data in Table 3 present the results from OLS estimation of equation (11) for the eighteen contracts included in our sample. With the exception of the British pound, gold and silver, the coefficients on ISD are negative and differ reliably from zero. The coefficient on the interest-rate-spread variable differs significantly from zero only for the contracts on the British pound and wheat. From these results we conclude that after controlling for the opportunity costs imposed by margin deposits, the coefficients on ISD generally (17 of 18 contracts) support the hypothesis of increasing cost. Thus, volatility increases lead to lower coverage; that is, margin coverage increases but by a smaller percentage than the accompanying volatility increase.

We also estimate equation (11) as a system of 18 equations using the method of iterated seemingly unrelated regressions. To represent better the fact that exchange decisions on margin requirements reflect the opportunity costs and risk tolerances of their memberships irrespective of their preferred trading venues, we impose coefficient restrictions. Specifically, we require equal coefficients on the opportunity costs for all contracts trading within a single exchange. Likewise, we impose the restriction that the ISD coefficients on contracts trading within an exchange also be equal. The effect of these restrictions is to represent exchange members as, at the margin, indifferent as to the margin requirements for the various contracts they may trade on the exchange.

Columns 4 through 7 of table 3 report the SUR results. With the exception of the opportunity cost at COMEX, all coefficients are negative and differ significantly from zero at usual confidence levels. This result concurs with the increasing-cost conclusion obtained from the OLS coefficients on ISD. The significantly negative coefficients on opportunity cost bolster this conclusion. This implies that with risk exposure held constant, an increase in the opportunity cost of margin deposits prompts exchanges to choose lower margin and, therefore, less risk coverage.

We also compare the margin coverages for gross- and net-margin exchanges. The two gross-margin exchanges--the CME and the NYMEX-- require clearing members to post with their respective clearinghouses, the full amount of margin due on all the positions carried by each clearing member. In contrast, the net-margin exchanges--the CBOT, the CSCE and the COMEX--allow clearing members to post margin on the net of their long and short positions. The ability to net contracts can substantially lessen aggregate margins deposited with the exchange. Hence, increasing costs implies that the coefficients on opportunity cost and on ISD for gross-margin exchanges should be larger in absolute value than those for net-margin exchanges.

Four F tests generally support this view. Comparing ISD results, the coefficient for the CME is substantially larger in absolute value than for the CBOT. Likewise, the equal-weighted average of ISD coefficients for the CME and the NYMEX is larger than the equal-weighted average of ISD coefficients for the CBOT, CSCE and the COMEX. The F tests for these comparisons conclude that the

differences are significant. Comparing opportunity cost results, the coefficient for the CME is substantially larger in absolute value than that for the CBOT. This difference is statistically significant. Comparing the weighted-average coefficients for the CME and NYMEX with those for the CBOT, CSCE and COMEX also obtains a larger effect, but the comparison is not statistically significant at the usual levels.

V. EXTENSIONS: OTHER CLEARINGHOUSE RISK CONTROL MECHANISMS

The preceding sections model a clearinghouse using margin deposits to manage default losses and provide evidence supporting the model. This simple clearinghouse need not monitor the financial condition of its participants, link margin deposits to the riskiness of its participants, expel nonperforming members or otherwise seek to control risk. Yet, these ancillary activities are likely sources for additional economies. Exploring these issues adds to our understanding of present-day institutional arrangements. This section begins by examining clearinghouse policy toward defaulting members. We then model the monitoring activities of the clearinghouse with respect to the value of membership and to the financial condition of its members.

The Threat of Expulsion

Because clearinghouses reduce deadweight losses from opportunistic default and allow participants to economize on margin costs, membership is valuable. When traders expect to trade in more than one period, the threat of expulsion reduces opportunistic default. Verifiable membership value reduces the amounts of required

margin because the expulsion threat induces contract performance beyond that obtainable from margin deposits. A member's presence may also be beneficial to other members. Such joint benefits raise questions about the credibility of an expulsion threat. This subsection lays out conditions for a credible expulsion policy.

Let C() denote the capitalized value derived by members from continued membership. This value has two sources: expectations of lower loss rates resulting from contract default and lower margin requirements. We denote gains accruing to member d as C(d,d) and the aggregate of benefits accruing to other members as C(d,CH). A short contract position rationally responds to an expulsion threat by performing if contract-performance costs are less than membership value:

$$/\sum_{j=1}^{n} N(d,j) \,//\, x - M / \quad < \quad C(d,d) \tag{12}$$

A similar condition applies to long positions. A clearinghouse rationally expels its defaulting members if default costs, including both the contractual shortfall and the deadweight loss, exceed the value losses other members incur by expelling d, that is, when:

$$(1+\alpha) / \sum_{j=1}^{n} N(d,j) \,//\, x - M / \quad > \quad C(d,CH) \tag{13}$$

Combining these conditions, a credible expulsion threat exists and a potential defaulter rationally performs on the contract when

$$\frac{C(d,CH)}{(1+\alpha)} \quad < \quad / \sum_{j=1}^{n} N(d,j) \,//\, x - M / \quad < \quad C(d,d) \tag{14}$$

As the membership of a clearinghouse increases, the cost to the group as a whole of expelling any one member will decline, but the cost to an individual of losing clearing privileges will, if anything, increase. When members suffer virtually no loss from refusing to trade with d, then C(d,CH) = 0. If C(d,CH) = 0 and C(d,d) > 0, then an expulsion threat is always credible. Moreover, it is *Pareto improving* for clearinghouse members to pre-commit to expelling any member defaulting on a contract because the threat of membership loss reduces opportunistic default without raising margin levels.[18]

The expulsion threat alters the clearinghouse's basic maximizing problem in that |x|>M is the optimal default rule only when the value of future clearing privileges is ignored. Equation (14) gives a more general default rule for the short position. This has three implications. First, due to the threat of expulsion, firms default in fewer states of the world. Second, the value of clearing membership C() perfectly substitutes for margin deposits M in preventing default but third, the value of membership imperfectly substitutes for margin deposits when default occurs. This is because increases in required margin increase the amount received in default states but the benefits of membership are not transferable.[19]

Proposition VII: When the clearinghouse can make a credible expulsion threat, the optimal margin coverage ratio increases as volatility increases.

When C() is identical across individuals, a credible expulsion threat increases the lower limit of integration in equation (6) from M to M+C/|N*(j)|, where N* is the

median trader's exposure. The clearinghouse now minimizes:

$$\sum_{j=1}^{n}\left[|N(j)|\left\{\mathrm{iM(j)}+\alpha\int_{M(j)+\frac{C}{|N(j)|}}^{\infty}\langle x-M(j)\rangle f(x,\sigma)dx\right\}\right] \tag{15}$$

The first order condition for minimization of (15) with respect to M(j,h) and M(h,j) is:

$$\left[1 \quad - \quad F\left(M^{**}+\frac{C}{|N(j)|},\sigma\right)+\frac{C}{|N(j)|}f\left(M^{**}+\frac{C}{|N(j)|},\sigma\right)\right] \quad = \quad \frac{i}{\alpha} \tag{16}$$

Whenever clearinghouse membership is valuable, then C() > 0 and the final term on the left-hand side of (16) is strictly positive. This means that a policy of expelling a defaulting member reduces the probability of default F(•) to less than i/a, the level prevailing absent expulsion. Since a credible expulsion threat acts as a substitute for costly margin, the clearinghouse will choose a higher level of protection than it otherwise would.

Differentiating equation (16) with respect to M^{**} and C/|N(j)|, implies that when margin is taken $dM^{**}/d(C/|N(j)|) < 0$. Thus, increasing the value placed on membership decreases the amount of margin required to obtain a given level of safety. Intuitively, as membership and the volume cleared expands over time, the threat of expulsion becomes more serious because clearing privileges are more valuable, and the clearinghouse can place greater reliance on the expulsion threat as

a deterrent to default, thus decreasing the optimal level of margin.

If the threat of expulsion is an important part of the guarantee system, how would coverage rations change when volatility changes? On the one hand, if we hold the value of clearing C constant, then optimal margin coverage ratio M^{**}/s increases as volatility increases. Thus, margin must increase more rapidly than volatility to supply the same level of protection. This result contrasts sharply with our analytic results for constant or increasing costs of margin deposits.

On the other hand, it may be that the value of clearing C changes systematically with changes in volatility. The most likely conjecture is that the value of clearing increases as volatility increases, because increased volatility is likely to be associated with increased volume of trading. This could reverse the result cited in the previous paragraph: if clearing becomes more valuable in volatile markets, it is possible that optimal margin could drop.

The above suggests the benefits of clearinghouse creation can go beyond margin economies and avoiding deadweight default costs. Creation of a clearinghouse assures contract performance at levels beyond that obtained by margin deposits. Further, it can be the case that reliance on membership value is more cost effective than relying simply on margin deposits.

The clearinghouse as monitor

Relaxing the assumption that only collateral can be attached in case of default, we allow counterparties to grant senior claims on unencumbered assets k(j).[20] Each

party knows its own k(j), however we assume counterparties incur an examination cost to learn k(j). This cost is denoted e. Traders choose to be monitored when the savings from these senior claims against k(j) exceed examination costs.

Examination, at most, saves the firm the opportunity cost of holding k(j), that is, the maximum savings is ik(j). If the quantity ik(j) is less than e, then inspection does not pay. However, failure of this condition is not sufficient for inspection to occur. If the optimal margin $M^*|N(j)|$ without inspection is less than k(j), the opportunity cost savings from granting a senior claim against k(j) is $iM^*|N(j)|$.[21]

Proposition VIII: When the clearinghouse acts as monitor to verify the existence of unencumbered assets, coverage ratios increase as volatility increases.

Inspecting a member firm reveals one of two conditions. Members post no margin when unencumbered assets k(j) exceed $M^*|N(j)|$. Alternately, if k(j) is less than $M^*|N(j)|$, then the clearinghouse's problem is of the same form as equation (6) with M+k(j)/|N(j)| substituted for M.

If k(j) is less than $M^*|N(j)|$, the optimal margin rule is:

$$M^{***} + \frac{k(j)}{|N(j)|} = F^{-1}\left(\frac{i}{\alpha}, s\right) \tag{16}$$

Because k(j) is less than $M^*|N(j)|$, parties still post margin. Thus, for a constant opportunity cost of margin, the optimal default probability is identical to the no-

examination case because firms substitute claims against unencumbered assets for more costly forms of margin. Unlike the case where expulsion acts as a deterrent to default, if default occurs, the other assets can be seized, making them a perfect substitute for margin deposits.

However, when opportunity costs are increasing in total required margin, examination decreases the optimal default rate. When other assets are substituted for margin, the cost of additional margin decreases, and the optimal level of protection can thus be increased.

Equation (16) implies that with monitoring, coverage ratios increase as volatility increases, as unencumbered assets k(j) decrease, and as the number of open contracts increases. The result that the optimal coverage ratio declines as firms become less able to substitute unencumbered assets for collateral deposits differs from the predictions of the constant opportunity cost model (equation 4) and the increasing opportunity cost model (equation 8).

Since firm asset holdings are dissimilar, reliance on unencumbered assets entails scrutiny of member positions, with margin setting on a member-by-member basis. Instead, margin requirements are uniform across the memberships of organized clearinghouses. This uniformity arises for several reasons. First, payment delays may be the principal cause of deadweight losses for members of the clearinghouse. The presence of unencumbered-but-illiquid assets may not be useful for time-critical settlement requirements. Second, timely verification of the existence of k may significantly raise clearinghouse costs, making is uneconomical to monitor at

all. Third, netting may reduce each party's net exposure to such low levels that intensive monitoring can not be cost-effective. In any event, the uniformity of margins across members suggests that if clearinghouses do engage in extensive monitoring, it must be for purposes other than controlling risk between members.

The prediction of a positive correlation between volatility and the coverage ratio also contrasts sharply with the independence of the coverage ratio and volatility. Thus, this result is distinct from the simple netting model of equation (5) and the negative correlation generated by the increasing opportunity cost of funds model of equation (10).

VI. Summary

We incorporate the cost of external funds and the deadweight losses associated with counterparty default into collateral decisions. Given their scale of activities, it is not surprising that clearinghouses internalize these costs into their margin decisions. Thus, clearinghouse pursuit of prudentiality through margin is constrained by the costs that members incur by carrying these balances. When margin is set without regard to additional information about the condition of the clearinghouse members, the coverage ratio is either uncorrelated or negatively correlated with volatility.

The time series of coverage ratios supports the conclusion that clearinghouse determination of margin incorporates prudential concerns. Our empirical results demonstrate that clearinghouses respond to high levels of margin by adjusting

coverage ratios downward. This behavior is not consistent with prudentiality alone, but is consistent with exchanges optimizing across the costs of placing margin deposits and the costs from incurring deadweight losses.

Our pooled-regression results show that futures clearinghouses set margin in a cost-minimizing fashion, balancing the risk of loss against the greater opportunity costs associated with higher margins. Those results suggest that at least part of these opportunity costs arise because market participants have imperfect access to capital markets for their general financing.

We extend our model to capture other institutional features. We expect positive correlations between coverage ratios and volatility when clearinghouses actively monitor their members for risk-management purposes. Our emphasis on the foundations of the clearinghouse makes clear that membership is valuable. Because membership is valuable, expelling defaulting members is credible and effective for the clearinghouse. This means that members will perform on their contracts even when price moves exceed the value of margin on deposit.

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Table 1 Margins and implied volatilities

Table reports summary statistics for a sample of futures contracts. 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. Margin coverage is respective mean level of margin divided by the dollar volatility of the contract.

Contract	Sample Start Date	Number Obser-vations	Sample Means				
				Speculative Margin		Member Margin	
			ISD	Margin	Coverage	Margin	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

Table 2 Estimates of margin coverage adjustment

Table reports results for the two time series specifications listed below. CR_t is the time-t ratio of initial member margin to the option-implied volatility stated in dollars. Q^l is the coverage quartile for margin coverage during the sample period. K, the number of lagged changes in coverage ratio included in the specification, is determined by AIC. 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., rejects the null of no mean reversion.

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

Initial Member Margin

Contract	a_1	$t(a_1)$
Deutschemark	-0.004579	-3.52
S&P 500	-0.004704	-2.88
Soybean	-0.012160	-4.04
Treasury Bond	-0.017178	-6.84

$$\Delta CR_t = \alpha_0 + \sum_{l=1}^{4} \alpha_l^l Q^l CR_{t-1} + \sum_{i=1}^{K} \alpha_{4+i} \Delta CR_{t-i} + u_t$$

Quartile Rankings of Margin Coverage at Time t-1

Contract	Lowest Quartile		Second Quartile		Third Quartile		Highest Quartile	
	a_1	$t(a_1)$	a_1	$t(a_1)$	a_1	$t(a_1)$	a_1	$t(a_1)$
Deutschemark	-0.0135	-3.18	-0.0084	-2.58	-0.0097	-3.43	-0.0090	-3.78
S&P 500	-0.0438	-4.47	-0.0417	-5.25	-0.0239	-4.44	-0.0233	-5.35
Soybean	-0.0277	-2.12	-0.0265	-2.88	-0.0200	-2.91	-0.0180	-3.49
Treasury Bond	-0.0408	-5.96	-0.0389	-6.48	-0.0356	-6.55	-0.0321	-6.83

Table 3 Estimates for the opportunity cost specifications

Table reports results for two methods of estimating the following time-series and cross-sectional specification: $CR_{ijt} = \alpha_{ij0} + \alpha_{ij1} R_t + \alpha_{ij2} ISD_{it} + \mu_{ijt}$. Variable definitions are: CR_{ijt} is the coverage ratio for contract i traded at exchange j on date t, R_t is the excess of the prime rate over the 3-month treasury bill rate, and ISD_{it} is the implied standard deviation for options trading on contract i at date t. Unrestricted coefficients are from separate OLS regressions for each contract. The within-exchange restricted coefficients are from estimating those equations as a system of seemingly unrelated regressions. Regressions include equality restrictions on the two right-hand side variables. Within the five exchanges, the coefficients on R are restricted to equality and the coefficients on ISD are restricted to equality. See table 1 for contracts traded on the five exchanges.

	Unrestricted Coefficients			Within-Exchange Coefficient Restrictions: $\alpha_{ij1} = \alpha_{j1} \ \exists \ j$, $\alpha_{ij2} = \alpha_{j2} \ \exists \ j$		
	Intercept	Opportunity Cost	ISD	Intercept	Opportunity Cost	ISD
British Pound	14.35 (1.89)	-3.57 (0.76)	3.36 (10.32)	11.23 (0.38)	-0.91 (0.08)	-27.71 (0.77)
Cattle	7.47 (0.91)	-0.32 (0.28)	-17.33 (2.41)	10.50 (0.27)		
Deutschemark	8.83 (2.33)	0.18 (0.82)	-32.72 (8.70)	11.06 (0.40)		
Eurodollar	13.56 (4.78)	1.07 (1.64)	-2807.12 (291.75)	10.62 (0.84)		
Japanese Yen	10.77 (0.62)	-0.38 (0.24)	-51.34 (5.20)	9.89 (0.24)		
Swiss Franc	9.65 (1.86)	-0.00 (0.61)	-40.41 (8.79)	10.54 (0.32)		
S&P 500	7.86 (7.14)	4.25 (2.41)	-51.23 (18.45)	17.38 (1.00)		
Corn	9.26 (2.56)	-0.80 (0.93)	-9.66 (2.52)	9.35 (0.47)	-0.19 (0.16)	-3.47 (0.34)
Soy Bean	10.57 (2.47)	-0.20 (0.96)	-27.38 (6.99)	6.50 (0.57)		
Treasury Bond	7.60 (0.80)	0.21 (0.28)	-25.22 (4.28)	6.25 (0.44)		
Wheat	12.18 (1.77)	-2.18 (0.65)	-9.12 (2.82)	5.86 (0.49)		
Heating Oil	8.60 (2.51)	-0.19 (0.92)	-3.81 (0.85)	11.25 (1.18)	-0.88 (0.42)	-6.01 (0.39)
Crude Oil	9.89 (1.84)	-0.41 (0.74)	-3.35 (0.79)	8.71 (1.14)		
Coffee	10.47 (2.46)	-1.22 (0.83)	-6.71 (1.56)	9.31 (1.20)	-1.02 (0.42)	-4.62 (0.44)
Sugar	8.05 (2.32)	-0.40 (0.86)	-3.01 (0.71)	10.51 (1.19)		
Gold	7.90 (1.56)	-0.65 (0.52)	-6.14 (5.97)	7.45 (0.74)	-0.50 (0.28)	-5.70 (0.86)
Silver	8.80 (2.39)	-1.15 (1.05)	-1.30 (6.87)	8.15 (0.80)		
Copper	7.95 (1.63)	-0.57 (0.67)	-5.32 (1.81)	7.89 (0.77)		

(standard errors in parentheses)

Footnotes

[1] The term collateral is used for all instances where a deposit is required to reduce exposure to credit risk. The term "margin" when used here is the special case applying when collateral deposits are uniform within broad categories of counterparties.

[2] Baer, France and Moser (1995b) re-examine some previous tests of prudentiality.

[3] For-profit exchanges operating in a competitive market can also be expected to cost minimize. Hence, our model also applies to for-profit organizations.

[4] For example, courts may be unable to force the transfer of collateral quickly enough to avoid deadweight default costs and will involve significant legal costs.

[5] Generalization to a multi-contract exchange results in a relation between the loss on a portfolio of contracts and the sum of margin deposits. The results depend on the extent of members' diversification. See Baer, France and Moser (1993).

[6] Most margin deposits at US exchanges are in interest-bearing forms though marked-to-market gains or losses (variation margin) require cash payments. For example, a US Treasury Bill deposited as margin would be returned to the depositor when the account is closed. This arrangement effectively gives the depositor interest on deposit. The London Clearinghouse pays interest on cash deposits. Our model covers both cases. If cash is deposited, the opportunity cost is driven by the levels of market rates. Clearinghouses also allow limited use of standby letters of credit (SLOCs) for margin.

[7] A futures clearinghouse also allows its members to exploit a variety of other scale economies accessible only by acting as a group. Centralization simplifies record keeping since members need only keep track of their positions with the clearinghouse. Credit monitoring and control is simplified, since members' financial standing need only be assessed once by the clearinghouse, rather than by every counterparty. Economies of scope exist between record keeping and credit control, since knowledge of a member's net position is needed to assess exposure. Finally, precommiting to binding arbitration lowers cost because disputes are no longer a matter for bilateral bargaining. See Baer, France, and Moser 1995a.

[8] Calomiris and Hubbard (1995), Fazzari, Hubbard, and Petersen (1988); and Hubbard and Kashyap (1992) provide evidence that nonfinancial firms behave as if financing growth through external financing is relatively expensive. Baer and McElravey (1994) report similar results for U.S. banking corporations.

[9] The use of margin as collateral, the netting, and the attendant loss-sharing rules effectively redefine the legal priority of claims. We assume the ability of a clearinghouse to take possession of margin assets in the event of default is not obstructed by law. When we say a "pre-agreed rule," we assume that the priority of claims in the event of default is clear. Historically, the rise of clearinghouses resulted in a clarification and streamlining of bankruptcy law as it applied to futures claims.

[10] Certain loss-sharing rules can undo this result by allocating a disproportionate share of losses to an individual member. Since loss-sharing rules are agreed upon in advance and since clearinghouse membership is voluntary, it can be shown that such rules will not be adopted. Futures exchanges generally use a common fund to pay for defaults.

[11] See Laffont, 1988, pp. 51-53, or Cornes and Sandler, 1986. Exchanges usually set margins, not on the basis of a direct vote, but by a committee designed to be representative of the membership.

[12] Margin amounts collected when these accounts are opened are called initial margin. Should deposited

amounts fall below a specified maintenance level, the margin balance must be restored to the current initial level. Maintenance margin requirements in U.S. stock markets differ. In stock markets, should a deficiency occur, margin must be restored to the maintenance level.

[13] 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 reported here in terms of variation of rates of return.

[14] See Bollerslev, Chou, Jayaraman, and Kroner (1991).

[15] Another possibility not considered here is that the margin responses of exchanges induce subsequent changes in volatility. The evidence does not generally support this claim, however for an alternative view, see Hardouvelis (1988).

[16] 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.

[17] Other clearinghouses, for instance the Options Clearing Corporation, have long accepted equity as margin. Futures clearinghouses are increasingly adopting this practice.

[18] A minimal number of clearing members may be necessary to insure that none are too valuable to expel.

[19] This presumes that the value of an exchange seat reflects trading rather than clearing privileges, as suggested by Bhasin and Brown (1997). If clearing memberships were a separately traded asset, their value would reflect the value of C(d,d) for the marginal member, and that amount could be recouped by the other members in a default. The model would then closely resemble that in the next section, where counterparties grant senior claims on assets.

[20] Relaxing this assumption implicitly assumes that courts are effective in seizing collateral and that the speed of payment is not an issue. If payment delay is the principal reason that default imposes a deadweight loss on the membership, then the existence of unencumbered assets may be irrelevant.

[21] We assume that the inspection process includes assessing the probable value of k in the default state. Clearinghouses "haircut" non-cash assets by valuing them at less than current market value.