

# Opportunity Cost and Prudentiality: An Analysis of Futures Clearinghouse Behavior

Herbert L. Baer, Virginia G. France, and James T. Moser

Herbert L. Baer  
Policy Research Department  
The World Bank

Virginia G. France  
Department of Finance  
University of Illinois at Urbana-Champaign

James T. Moser  
Research Department  
Federal Reserve Bank of Chicago

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by

Herbert L. Baer

Virginia G. France

and

James T. Moser

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The authors are Financial Economist at the World Bank Policy Research Department; Assistant Professor at the University of Illinois at Urbana-Champaign; and Senior Economist at the Federal Reserve Bank of Chicago, respectively. Much of this paper was completed while France was visiting at the Chicago Mercantile Exchange and the University of Chicago. Susanne Malek and Jan Napoli provided valuable research assistance. The authors thank John Conley, Ramon DeGennaro, Mark Flannery, Gary Koppenhaver, Todd Petzel, Will Roberds, Jerry Roberts, an anonymous referee, and seminar participants at the University of Illinois at Urbana-Champaign, the Federal Reserve Bank of Chicago, and the Chicago Risk Management Workshop. Opinions expressed are entirely those of the authors and do not reflect concurrence by the Federal Reserve, the Chicago Mercantile Exchange, or the World Bank. Comments may be addressed to the third author at 312-322-5769; or the middle author at [V-FRANCE@UIUC.EDU](mailto:V-FRANCE@UIUC.EDU).

## **Opportunity Cost and Prudentiality:**

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#### Abstract

This paper develops a model which 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 are determined by the need to balance the deadweight costs of default against the opportunity costs of holding additional margin. Once created, it may (but need not) 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 have any effect on 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 margin determination. The relationship between volatility and margins indicates that participants face an upward sloping opportunity cost of margin. This appears to more than offset the effects that monitoring and expulsion would be expected to have on margin setting.

## **Opportunity Cost and Prudentiality:**

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#### **INTRODUCTION**

A futures clearinghouse reduces the risk of default by netting all a trader's positions with other clearinghouse members, in turn allowing its members to economize on margin. In this paper, we show that clearinghouse netting systems are *Pareto superior* to bilateral margin setting, and characterize the cost savings involved. We show this by contrasting the necessary collateral when trading partners net bilaterally (as in the OTC market) with that needed when multilateral netting is possible (as when a clearinghouse acts as intermediary). Margin deposits are typically the most important tool in the clearinghouse's risk management efforts. Margin deposits serve as collateral<sup>1</sup> to protect the clearinghouse. The opportunity cost of margin deposits constrains the level of protection which the members will regard as optimal. Margins are optimal when the marginal opportunity cost of margin is proportional to the incremental protection obtained from additional margin.

However, the creation of a clearinghouse will have additional risk reducing effects. Since membership is valuable, it is credible and effective for the clearinghouse to threaten defaulting members with expulsion. At a minimum, this further reduces default risk by causing potential defaulters to perform when the amount owed exceeds the margin on deposit. It may also enable members to further economize on margin. The clearinghouse may also find it optimal to undertake monitoring that would not otherwise occur.

Four alternative models are provided: one in which the marginal opportunity cost of margin requirements is constant, one in which the marginal opportunity cost of margin increases as margin

requirements increase, one in which the threat of expulsion acts as a partial substitute for margin, and one in which senior claims on the firm's pool of unencumbered assets act as a substitute for margin. 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 elasticity of margin with respect to changes in volatility is less than one. If the clearinghouse can credibly threaten expulsion or can monitor the member's financial condition, our model predicts that the elasticity of margin with respect to changes in volatility will be greater than one.

Our empirical work tests these hypotheses using time series for eighteen futures contracts having associated futures options. The protection afforded by margin is characterized using implied coverage ratios -- required margin divided by the implied price volatility extracted from futures options. A coverage ratio of three, for instance, implies that margin deposits are exhausted when the magnitude of a price change exceeds three standard deviations.

Our first test examines the time series of daily coverage ratios for four contracts to determine how coverage ratios are adjusted in response to shocks. We present evidence that coverage ratios are increased when coverage ratios are lower than their unconditional means and lowered when the coverage ratio is excessive. This latter result is not predicted by the previous literature, but is predicted by our model.<sup>ii</sup> We also find evidence that clearinghouses respond less quickly to excessive margin than to inadequate margin.

We then present empirical evidence that margin levels are strongly influenced by the opportunity cost of margin deposits using the cross section of contracts pooled over the sample period. 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. These suggest that opportunity costs are important and that market participants face an upward-sloping opportunity cost of margin. Sensitivity tests are conducted for the possibility that margin is being set according to some alternative exogenous rules. The results of these tests favor our model over these alternatives. Our findings suggest that the increasing opportunity cost of margin dominates any effects that monitoring and expulsion may have on margin setting.

Though this paper deals with clearinghouses as they exist at organized futures exchanges, it has implications for the over-the-counter (OTC) derivatives markets. It suggests that the default risk in these markets could be decreased, and cost savings attained, by the development of an over-the-counter clearinghouse. Baer, France, and Moser (1995a) describes recent innovations whose benefits are modeled in this paper. Multinet, the foreign exchange clearinghouse, is currently allowing only bilateral netting, but proposes to extend itself to multilateral netting as soon as regulatory and legal obstacles are resolved. In addition, our model suggests that clearinghouses add value which is entirely separate from trade execution and could be sold separately. Both the Chicago Board of Trade and the Chicago Mercantile Exchange have recently proposed collateral management systems which share many of the features of a full futures clearinghouse, but would not necessarily require that trade execution be done on the exchange.

## **I. LITERATURE REVIEW**

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 has implications for the second strand, usually referred to as

prudential margin setting. A number of earlier researchers have analyzed prudential margin setting, most notably Telser (1981); Figlewski (1984); Hunter (1986); and Gay, Hunter, and Kolb (1986). A comprehensive survey of this literature can be found in France (1990). Our model advances the theory of margins by explicitly incorporating the cost of margin deposits into the margin-setting decision, demonstrating the tradeoff between these costs and prudential concerns, and showing how margin setting is affected by other clearinghouse activities.

Craine (1992) models the clearinghouse as a profit-maximizing entity and describes 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 these agents. Fenn and Kupiec (1993) also implicitly assume that the clearinghouse is an independent entity, minimizing its costs. In contrast, we model the clearinghouse as a club which minimizes the joint costs of its members. In our formulation, the clearinghouse does not have to make a profit: our clearinghouse need not actually recover the deadweight losses incurred by the membership, because 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 a motivation for the development of a clearinghouse.

The main contribution of Fenn and Kupiec is to examine the role of frequency of settlement in setting margin size. They model cases where the clearinghouse sets the frequency of regular settlements, and when it will call for special settlement. Their 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 volatility

increases, 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 always in addition to regular settlement. With the exception of the model in 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.

Our model of expulsion from the clearinghouse and of the effect of value of clearing is related to concurrent work being done by Bhasin and Brown (1994). They model the value of exchange seats by analyzing the benefits stemming from trading. Their model analyzes the incentive to default intraday. Since positions may in some cases be held during the day without the posting of margin, intraday default is primarily secured by the value of the exchange seat itself. Their model is complementary to ours, in explaining the dynamics of default during the trading period. Another complementary literature deals with the role of price limits in risk management. Brennan (1986) shows how they can act as a partial substitute for margin during intraday trading.

Our model of capital monitoring by the clearinghouse is related to more general models of delegated monitoring by financial intermediaries by Diamond (1984), and to models of risk management and financial guarantees by Merton and Bodie (1992) and Hsieh (1993). Our models of clearinghouse behavior extend this earlier work by showing that expulsion from the clearinghouse, monitoring of the financial condition of the membership by the clearinghouse, and a recognition that members face an upward sloping supply of external funds have very different effects on optimal margin setting and the probability of default. Our model also has interesting parallels with models of bank clearinghouses, as discussed in Gorton (1985), particularly in the



role of expulsion and the mutualization of risk.

## **II. A MODEL OF BILATERAL AND MULTILATERAL CLEARING**

We first present a model of a clearinghouse acting solely as a netting facility.<sup>iii</sup> We demonstrate the benefits of clearinghouse arrangements when the clearinghouse is treated as a club of its members, not a separate, for-profit 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 the exchange membership, not to enforce a brokerage cartel.<sup>iv</sup>

We develop a model in which margin setting and the formation of clearinghouses 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.<sup>v</sup> In the simplest case, the marginal opportunity cost of a margin deposit is assumed to be a constant differential rate denoted as  $i$ . We later generalize this to the case where the opportunity cost is an increasing function of the amount of margin demanded.

### A. Bilateral Margin Setting:

We first model the setting of margin in a bilateral marketplace. There are two parties  $j$  and  $h$ . We assume that the judicial and extrajudicial enforcement of contracts is costly or impossible so that there exists no means by which a participant can be compelled to perform on a contract against her will.<sup>vi</sup> This assumption introduces the important distinction between a counterparty's ability to

perform (which is tied to its liquidity and solvency) and its willingness to perform. A counterparty may have the capacity to perform yet not find it in her interests to do so. The result will be what we term opportunistic default.<sup>vii</sup>

While we assume that there is no mechanism to compel performance on a contract, we do assume the existence of trusted collateral agents that will not abscond with collateral posted with it. This permits counterparties to post collateral with the trustee as bond against contract nonperformance. In the event of default it is assumed that participants are only able to attach collateral that has previously been posted with the trustee.

There are two periods. In the opening period, the two parties trade with each other, each entering into a contract with the other. The motivation for trading is exogenous to our model; however, our model does imply that a clearinghouse system reduces the cost of obtaining whatever benefits trading may provide. 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  $N(h,j) = -N(j,h)$ .

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 distributed with a finite variance such that the change in the contract price,  $x$ , is a random variable with mean zero and standard deviation  $s$ .<sup>viii</sup>

Margin posted by  $j$  with  $h$  is denoted  $M(j,h)$ , and the margin posted by  $h$  with  $j$  is denoted  $M(h,j)$ . Since our model applies to clearing members, we assume that initial and maintenance margins are identical; this is standard practice on most clearinghouses. Margin payments are made in cash and placed into interest-bearing accounts. Interest on these deposits is paid to the party posting the margin.<sup>ix</sup> 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.

After contracts are settled, 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 when gains are realized. Because participants do not carry 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 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 (Figlewski, 1984). 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  $M(j,h)$ . We assume that default imposes a deadweight loss on the counterparty that is a constant proportion, denoted  $\alpha$ , of the amount of the difference between the promised payment and the actual payment. This is in addition to the direct monetary losses, which are a wealth transfer between parties. 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:

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

We assume agents jointly minimize the cost of contracting. One way of reaching this result is to assume perfect competition. We think this is realistic because the parties have a wide choice of

partners at the inception of each trade. This situation ensures the absence of bargaining power so that parties to the contract will seek to jointly minimize the costs of contracting. With a small number of agents, the *Pareto optimal* outcome may not be reached. The bargaining problems which may arise between the two parties after the trade are regarded as included in the deadweight losses subsumed in  $\alpha$ . Contracting entails three costs: the opportunity cost of margin deposits  $I(j)$ ; the credit risk, that is, the expected difference between the promised and the actual payment when  $h$  defaults on  $j$ ,  $L(j,h)$ ; and the 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 seek to jointly minimize:

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

which is the sum of the interest costs and deadweight losses for  $h$  and  $j$ . Thus, substituting into (3) from (1), the total cost to be minimized is

The first order conditions for minimization of (4) with respect to  $M(j,h)$  and  $M(h,j)$  are as follows:

For a normal distribution this can be expressed as the ratio  $M/s$ , which is referred to in the futures literature as a coverage ratio:

Thus margin amounts 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. Positive margin requirements are optimal when  $i/\alpha < 1$ . If  $i/\alpha$  exceeds unity firms set margin at zero, the losing trader always defaults, and the contract is unenforceable.

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, and margin can be set on a per-contract basis. Further, if the distribution of price changes is symmetric, margins will be equal on long and short positions. Note that when prices are normally distributed, margin increases proportionately with  $s$ . The above first-order conditions imply that when the distribution is normal and the opportunity cost of margin assets is constant, the coverage ratio in a bilateral transaction should not vary with volatility.

#### B. The Clearinghouse:

Clearinghouses offer market participants the possibility of reducing both deadweight default costs and the opportunity costs associated with holding assets in margin accounts, even in the absence of other externalities such as failure of the payments system or reputation. 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. Thus, members of the clearinghouse seek to minimize their joint contracting costs. They do this by netting positions multilaterally to limit cherrypicking by allocating any losses among themselves according to a pre-agreed rule. Our model is consistent with the normal practice of paying for losses out of a clearinghouse guarantee fund, in effect sharing losses *pro rata* among clearing members.<sup>x</sup> The exact distribution of losses is not derived since we assume the clearinghouse seeks

only to minimize its joint contracting costs: many loss sharing rules are consistent with this objective function.<sup>xi</sup>

Let party  $j$ 's open interestst be denoted by  $N(j)$ . If we assume that  $f(\bullet)$  is symmetric then the clearinghouse will choose  $M(j,h)$  to minimize joint contracting costs of:

When  $i$  and  $\alpha$  are the same for all members of the clearinghouse, the solution to this problem is the same as that given by equation (5). Thus, per contract, margin will be the same whether contracts are cleared and settled bilaterally by pairs of counterparties or multilaterally through a clearinghouse. Because a clearinghouse will set the same margin rate that these 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 with the clearinghouse is smaller than the total amount posted in a world of bilateral transactions and the expected deadweight loss to each party is also smaller.

Under a clearinghouse system,  $j$  posts margin only against the net of his position with the rest of the market which is . In effect, the clearinghouse gives participants a vehicle for securing a potential defaulter's losing positions with one counterparty with the potential defaulter's winning positions from another counterparty. For each individual, posted margin will be the same or lower under a clearinghouse system.

Similarly, no counterparty's expected deadweight loss is greater under a clearinghouse system and for some it will be smaller.<sup>xii</sup> In a bilateral system,  $j$ 's expected loss from counterparty default is

proportional to the number of his open contracts; that is,  $\lambda_i$ . In a multilateral clearinghouse in which  $\lambda_j$ 's expected loss from defaults is proportional to the net number of her open contracts; that is,  $\lambda_j$ , it pays for each individual to join the clearinghouse. This may not be the case for all loss sharing arrangements, but several simple rules will generate this result.

The creation of a clearinghouse leaves no participant worse off and, if there are offsetting positions, lowers margin requirements and deadweight default costs for some participants. Thus, the creation of a clearinghouse is *Pareto improving*. In our model, these improvements are achieved because the clearinghouse is able to make the proceeds from a party's winning positions available to offset losing positions. This makes it difficult for members to cherrypick each other by honoring advantageous contracts while at the same time defaulting on disadvantageous contracts.

### **C. Increasing opportunity cost of funds**

The cost of funds function may be increasing in the amount of margin required. Thus, an increase in margins would drive up the marginal cost of funds. If marginal costs of margin are increasing in  $M$ :

the clearinghouse sets margin to meet the condition:

An increase in  $s$  now causes the clearinghouse to increase 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, doing so 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. Note that, even if their cost functions are identical, individuals who hold 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 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. To represent diverse interests, we rely on a result from the club literature: Majority rule reflects median voter preferences provided individuals have single-peaked preferences.<sup>xiii</sup> Thus, assuming this preference structure, the relevant marginal cost is that of the median voting member. Note that disagreement about the appropriate level of margin gives clearinghouse members an incentive to split off into a rival clearinghouse if disagreement becomes too severe. It is also possible that some traders may choose not to join the clearinghouse.

### III. Other Clearinghouse Risk Control Mechanisms

The preceding section describes a clearinghouse whose actions have been fairly limited in scope -- registering trades, netting trades, and controlling margin deposits. The twin goals of these activities are to reduce opportunistic default and economize on margin by making a party's winning positions available to offset its losing positions. This simple clearinghouse does 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. The question is whether the behaviors we have modelled are indeed the *raison d'etre* of modern derivatives clearinghouses. To gain a better understanding of this issue we begin by examining clearinghouse policy toward members that default on their contracts. We show that because membership is valuable it will be credible to threaten expulsion and that such a threat will cause members to perform when the change in the



value of their position exceeds their margin deposit. We then examine one model in which the clearinghouse monitors the value of membership and another in which it monitors the financial condition of the membership.

### **A. The Threat of Expulsion**

Because clearinghouses reduce the deadweight welfare losses associated with opportunistic default while at the same time allowing participants to economize on margin, each member of the clearinghouse finds membership valuable. The presence of a member may also be beneficial to the rest of the membership. These joint benefits raise questions about the credibility of the threat to expel. We will show that when traders expect to trade in more than one period, the threat of expulsion from the clearinghouse allows traders to achieve additional reductions in opportunistic default. In the 19th century, expulsion from the exchange was the principal mechanism for ensuring contract performance. Defaulters were barred from trading with any exchange member until they had settled with their creditors. If the value of membership is verifiable by the clearinghouse it may also be possible to further reduce the amount of margin posted. These gains are possible because the threat of expulsion will cause potential defaulters to honor their contracts even when the price change  $x$  exceeds the posted margin  $m$ . This section lays out conditions under which it is credible to expel a defaulting member. The next section examines the impact of credible expulsion on margin requirements and the probability of default.

Let  $C$  denote the present value of the total gains, present and future, derived if the potential defaulting party  $d$  remains a member in good standing of the clearinghouse. These gains have two sources, the reduced deadweight losses associated with default and the reduced margin requirements. Some of these gains accrue to  $d$  and are denoted by  $C(d,d)$ . The remainder of the

gains from  $d$ 's membership accrue to the clearinghouse and are denoted by  $C(d, CH)$ .

It would be rational for a potential short defaulter  $d$  to respond to an expulsion threat by performing if the cost of performing on the contract is less than the value of remaining a member:

A similar condition would apply to a long trader. It is rational for the rest of the clearinghouse to decide to vote to expel a defaulting party if the total costs of the default, including both the contractual shortfall and the deadweight loss, exceed the future costs incurred by expelling the defaulting firm.

It will be credible for the clearinghouse to threaten expulsion *and* for the potential defaulter to respond by performing on the contract when

If the potential defaulter  $d$  is small relative to the membership of the clearinghouse so that members suffer virtually no loss from refusing to trade with  $d$ , then the entire cost of the expulsion are born by  $d$  and  $C(d, CH) = 0$ . We will assume that  $C(d, CH) = 0$  and  $C(d, d) = C$ . When  $C(d, CH)$  is zero, the membership needs no information to implement this policy: it simply expels any defaulters. Moreover, it is *Pareto improving* for all members of the clearinghouse to precommit to expel a defaulter. Agreeing to a policy of expulsion allows members to precommit to behavior that reduces opportunistic default without raising margin levels. In the next section we discuss the interactions between margin setting rules and expulsion.

A clearinghouse should also take expulsion into account when setting margin. The decrease in opportunistic default caused by the threat of expulsion implies that the clearinghouse is no longer at the optimum margin level. The introduction of expulsion does not greatly alter the clearinghouse's basic maximizing problem. The only difference is that  $|x| > M$  is the optimal

default rule only when the value of future clearing privileges is zero. The general default rule for the short position is given by equation (11). This has three implications. First, firms perform in more states of the world. Second, the value of clearing membership  $C$  is a perfect substitute for margin deposits  $M$  in preventing default. Third, the value of membership is an imperfect substitute for margin deposits when default occurs. This occurs because each dollar increase in required margin increases the amount received in default states while increases in the value of membership generate no return because the value of membership to the defaulting firm is not transferable. This presumes that the value of an exchange seat reflects trading rather than clearing privileges. A related paper by Bhasin and Brown (1994) attributes the value of exchange seats to the value of trading on the exchange.

Assuming for the moment that  $C$  is constant across individuals, the threat of expulsion alters the problem by changing the lower limit of integration in equation (4) from  $M$  to  $M+C/|N^*(j)|$ , where  $N^*$  is the median trader's exposure. The problem of the clearinghouse now becomes minimizing

The first order condition for minimization of (14) with respect to  $M(j,h)$  and  $M(h,j)$  is:

Whenever membership in the clearinghouse is valuable ( $C > 0$ ) the final term on the left hand side is strictly positive. This means that a policy of expelling a defaulting member reduces the probability of default  $F(\bullet)$  to less than  $i/\alpha$ , the level that would prevail if expulsion did not occur. Differentiating equation (15) with respect to  $M^{**}$  and  $C/|N(j)|$ , it is straightforward to show that where margin is taken  $dM^{**}/d(C/|N(j)|) < 0$ . Thus the greater the value of the membership to the potential defaulting party, the greater the reduction in the required margin deposits. If the value of clearing  $C$  is not positively correlated with volatility, the optimal margin coverage ratio  $M^{**}/s$

increases as volatility increases. Thus margin must increase more rapidly than volatility in order to supply the same overall level of protection. This result contrasts sharply with our basic model which predicts that the coverage ratio is constant. It also is at odds with the increasing opportunity cost model which predicts that coverage ratios should fall as volatility rises.

These results suggest that the benefits of creating a clearinghouse extend beyond economizing on margin and deadweight default costs by eliminating cherrypicking. In addition, the creation of a clearinghouse also makes it possible to compel firms to perform even when price movements exceed the margin on deposit. This benefit can be achieved without the clearinghouse expending resources to monitor the financial condition of members.

## **B. The clearinghouse as monitor**

We now relax the assumption that only collateral can be attached in the event of default and allow counterparties to grant senior claims on a general pool of unencumbered assets  $k(j)$ .<sup>xiv</sup> Each party knows its own  $k(j)$ , however we assume that a counterparty can only determine  $k(j)$  by incurring an examination cost which is denoted  $e$ . A trader will choose to be monitored if the savings from being able to grant a senior claim against its pool of unencumbered assets  $k(j)$  exceeds the cost of examination. The most the firm can save by being examined is  $ik(j)$ . If the quantity  $ik(j)$  is less than the cost of inspecting  $e$ , then inspection clearly does not pay. However, failure of this condition is not sufficient for inspection to occur. If the optimal margin  $M^*|N(j)|$  in the absence of inspection is less than  $k(j)$ , the opportunity cost savings from granting a senior claim to a part of  $k(j)$  would be  $iM^*|N(j)|$ .<sup>xv</sup>

If a firm is inspected one of two conditions will hold. If the firm's unencumbered assets  $k(j)$  exceed  $e$ , then no margin is posted. If  $e$  exceeds the firm's unencumbered assets, then the

clearinghouse's problem is of the same form as equation (4) with  $M+k(j)/|N(j)|$  substituted for  $M$ .

In this case the optimal margin rule is

Because  $k(j)$  is less than  $M$ , parties must still post some margin. Thus, if the opportunity cost of margin is assumed constant, the optimal default probability is identical to the case where no examination occurs. Firms merely substitute claims against unencumbered assets  $k(j)$  for more costly margin. This contrasts sharply with our model of margin setting with expulsion. In that model, increases in the value of membership always decrease the probability of default. Equation (14) tells us that when the clearinghouse monitors firms, the coverage ratio  $M/s$  increases as volatility increases, as the firm's unencumbered assets  $k(j)$  decrease, and as the firm's open interest increases.

The prediction that the coverage ratio will decline as a firm's supply of unencumbered assets increases contrasts sharply with predictions of the basic netting model laid out in equation (5) and the increasing opportunity cost model of equation (10). It also seems at odds with the observed uniformity of margin requirements across clearing members of organized clearinghouses. This uniformity arises for several reasons. First, delays in payment could be the principal reason default generates a deadweight loss for members of the clearinghouse. When time is of the essence, the existence of unencumbered assets which cannot be immediately liquidated would be relatively unimportant. Second, it is possible that the clearinghouse cannot verify the existence of  $k$  in a timely fashion. Third, netting may reduce each party's net exposure to such low levels that intensive monitoring is not cost effective. In any event, the uniformity of margins across clearinghouse members suggests that if clearinghouses do engage in extensive monitoring, it must be for a purpose other than the control of risk between members of the clearinghouse.

The prediction of a positive correlation between volatility and the coverage ratio also contrasts sharply with the independence of the coverage ratio and volatility predicted by the simple netting model of equation (5) and the negative correlation generated by the increasing opportunity cost of funds model of equation (10). The goal of the empirical work presented in this paper will be to use data on coverage ratios and volatility to draw inferences about the relevance of these alternative models of clearinghouse behavior.

### **III. Tests of the model**

#### Hypotheses to be examined

The model developed in the previous sections of this paper suggest five hypotheses for clearinghouse determination of its levels of required margin. The first of these is a positive relationship between margin levels and risks stemming from the contracts. This is examined in Baer, France, and Moser (1995b). The second is that clearinghouses incorporate the costs of maintaining margin balances into the decisions on margin levels. Thus, margin levels should be negatively correlated with the opportunity costs of the members of a clearinghouse.

Our remaining hypotheses relate to coverage ratios. Thus our third hypothesis is that when members have constant costs, coverage ratios will be invariant to levels of risk. However, when costs are increasing coverage ratios will be negatively related to risk levels. Fourth, when members of a clearing association face a credible threat of expulsion, coverage ratios will be lower than otherwise. Fifth, monitoring lowers coverage ratios.

#### 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 non-clearing members are assessed the highest levels of margin.<sup>xvii</sup> 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 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 I 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.<sup>xviii</sup>

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 I. Margin coverage ratios appear to be grouped according to their classification as member or nonmember. Nonmember speculative margin coverage ratios 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 coverage ratios are generally around four; the S&P 500 member 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. The political firestorms accompanying the market breaks in 1987 and 1989, and the resulting debate over whether the federal government should assume responsibility for the regulation of margin requirements, may have resulted in margins which were higher than the



clearinghouse would have set for purely prudential reasons. It should be noted that a great deal of empirical work on margins and volatility has been devoted to the study of the S&P 500, which our data suggests is atypical.

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 calculating the coverage ratio, one would expect the coverage ratio to be smaller, not larger, for the S&P 500, other things equal (Fenn and Kupiec's analysis suggests it should be approximately half as large: see Fenn and Kupiec, 1993).

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%. Thus, clearinghouses 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. 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 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 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.<sup>xix</sup> 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 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 (the alternative hypothesis). Thus, 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:

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. Results of the test are reported in Table II. 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 previous authors such as

Gay, Hunter, and Kolb predicts that clearinghouses will respond to low coverage ratios by raising margin requirements, but prudence does not predict how clearinghouses 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 clearinghouses to lower margin coverage provided their prudence 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  $Q^l$ , 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 clearinghouses based on levels of lagged coverage ratios. This specification is:

Results are reported in Table II. 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 a clearinghouse policy to lower margin requirements when margin coverage ratios 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 is explicitly predicted only by Fenn and Kupiec (1993) and the model in this paper.

Further evidence of the tradeoff between prudence 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 clearinghouses respond more quickly to surety loss when coverage ratios decline than to the increase in costs borne by clearinghouse members when coverage ratios rise.<sup>xx</sup>

### C. 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. When the opportunity cost of margin increases with the total margin requirement, the higher the volatility, the lower the coverage ratio. Models where the clearinghouse monitors either the financial condition of its members or the value its members attach to membership predict the opposite relationship.

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.<sup>xxi</sup>

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 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.<sup>xxii</sup> 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.<sup>xxiii</sup>

### ***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 nonfinancial--find it costly to raise additional debt or equity from external sources.

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:

where  $i$  denotes the  $i$ th 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 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. The increasing opportunity cost model offers the following restrictions:

We estimate equation (20) by pooling data on 18 contracts for the time periods reported in Table I. Table III presents the pooled estimation results for equation (20) 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 III present the results for a pooled regression where the coefficients on  $ISD$  are constrained to be the same across contracts.<sup>xxiv</sup> 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 III present estimates of equation (20) where we constrain the coefficients  $\alpha_{i0}$  and  $\alpha_{i2}$  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  $\alpha_{1,2} = \dots = \alpha_{i,2} = \dots = \alpha_{18,2} = 0$  at the .0001 level.

Contracts for which the implied standard deviation has no explanatory power are 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 (20) 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

where  $P_{i,t}$  is the price of the  $i$ th futures contract at time  $t$ . If we divide both sides of equation (21)

by  $DOLVOL_{i,t}$ , then

In this case we would find that ISD and the coverage ratio would be negatively correlated even though (21) is the true model. However, this alternative model implies that coefficients on our proxies for the opportunity cost of margin,  $\alpha_1$  should be zero. Thus, our estimates of equation (20) reject this alternative in favor of our model.

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

In this instance, the coverage ratio becomes

The positive correlation of  $DOLVOL$  and ISD thereby implies a negative correlation between ISD and our coverage ratio even though, in this instance, equation (23) is the true model. This possibility is not strictly nested within the specification given in equation (20), requiring an alternative procedure. We estimate a specification based on (24), obtaining predicted values for coverage ratios. We augment equation (20) 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 this alternative.

#### **IV. Summary**

Our models of clearinghouse behavior recognize 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 clearinghouse and governs the setting of margins. As a voluntary association, the clearinghouse internalizes these costs into its margin decisions. Thus, clearinghouse pursuit of prudence 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. Our models also emphasize that when a clearinghouse actively monitors its members for the purposes of managing risk between members of the clearinghouse, the coverage ratio will be positively correlated with volatility. Finally, the emphasis on the foundations of the clearinghouse, make clear that membership is valuable to all members. Because membership is valuable, it is credible and effective for the clearinghouse to expel defaulting members. This means that members will perform on their contracts even when price moves exceed the value of margin on deposit.

The time series of coverage ratios also supports the conclusion that clearinghouse determination of margin incorporates prudential concerns, but suggests that clearinghouses respond to high levels of margin by adjusting coverage ratios downward. This behavior cannot be explained by prudence alone.

Our pooled-regression results indicate that futures clearinghouses 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 emphasis on opportunity cost is in contrast to the emphasis of Fenn and Kupiec (1993) on the transactions costs of frequent mark-to-market settlements. It also contrasts sharply with the view that the clearinghouse primarily acts as a delegated monitor by examining its members' financial condition.

If examination does not play an important role in controlling risk between members of the clearinghouse, what role does it play? We posit two alternative roles for examination. First, examination may be undertaken for the purpose of informing the customers of a clearing member about the clearing member's condition, not for controlling risk between clearing members. Second, examination may be undertaken to support the clearinghouse's expulsion policy rather than to economize on margin. The threat of expulsion can only be effective if the firm contemplating default has the financial capacity to honor its contracts and has a long time horizon. Insolvent firms violate both criteria and examination serves to identify them. For these firms, the threat of expulsion will not be effective.

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## Footnotes:

1. Margin is a deposit to ensure contract performance, just as collateral is a deposit to ensure loan performance. Like loan collateral, margin is seized in the event of default. However, in the case of margin on futures contracts, no loan is involved. Exchanges and clearinghouses have other policy tools at their disposal: clearing fees, required deposits in a clearinghouse guarantee fund, daily price change limits, speculative position limits, tick size, minimum capital requirements, settlement interval, and the required minimum number of seats for clearing members, for example. Most of these are changed infrequently if at all.
2. A re-examination of previous tests of prudentiality are presented in Baer, France and Moser (1995b).
3. A futures clearinghouse also allows its members to exploit a variety of other economies of scale accessible only by acting as a group. A centralized clearinghouse also simplifies recordkeeping, since members need only keep track of their net positions 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. There are economies of scope between record keeping and credit control, since knowledge of a member's net position is necessary to assess exposure. In addition, because exchange members precommit to binding arbitration, disputes are no longer a matter for bilateral bargaining.
4. 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).
5. Calomiris and Hubbard (1992), Fazzari, Hubbard, and Petersen (1987); and Hubbard and Kashyap (1992) all provide evidence that nonfinancial firms behave as if they find it relatively expensive to finance growth through external financing. Baer and McElravey (1993) report similar results for U.S. banking corporations.
6. This could be justified on one of two grounds. First, courts may lack the capacity to force the transfer of collateral. Second, courts may not be able to force the transfer of collateral quickly enough to allow the other party to avoid the cost of deadweight default costs.
7. Opportunistic default is an important feature of both organized and over-the-counter derivatives markets. Examples include the Brent crude market, the natural gas market, and the tin market among others. The Hunt Brothers' silver crisis in 1980 is an especially interesting example of this problem. The Hunts had the financial capacity to meet their obligations to the COMEX clearinghouse, however, many of their assets were sheltered in trusts which were beyond the legal reach of the clearinghouse (see Koppenhaver, 1987 for a description).
8. A 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 resemble a standard Markowitz model with incomplete diversification, since most members will not be holding a large number of different futures contracts. Due primarily to notional complexity, this model has not been included, but is available in earlier working papers (Baer France Moser, 1993).

9. Most margin on US exchanges is actually deposited in interest-bearing forms, for instance in Treasury bills. In this case, the actual bill would be returned to the depositor when the account is closed, while any gains or losses (variation margin) would be handled by cash payments. By this arrangement, the depositor in effect gets interest on his deposit. The London Clearinghouse actually pays interest on cash deposits. Our formulation covers both cases. If cash is deposited, the opportunity cost is driven by the levels of market rates. Most clearinghouses allow standby letters of credit (SLOCs) as margin, but 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, for 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.

10. In practice, clearinghouses may have additional collateral on clearing members. In addition, clearinghouses require that clearing firms maintain a certain minimum level of capital. We consider the existence of this additional capital in a later section.

11. The use of margin as collateral, the netting, and the attendant loss sharing rules effectively redefine the legal priority of claims. The ability of a clearinghouse to take possession of margin assets in the event of a default cannot be obstructed by law. When we say a "pre-agreed rule," we assume that the priority of claims in the event of default is clear. Without this clarity, a clearinghouse cannot operate. Historically, the rise of clearinghouses resulted in a clarification and streamlining of bankruptcy law as it applied to futures claims.

12. Certain loss sharing rules could potentially undo this result, by allocating a disproportionate share of losses to an individual member. Futures exchange generally use a common fund to pay for defaults. By contrast, the prospectus for explicitly recognizing the moral hazard involved, states that "to the greatest extent possible, Multinet International will allocate any losses to those that traded with the failed participant." Both of these rules are consistent with a reduction in default losses for all individuals.

13. 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.

14. By relaxing this assumption we are implicitly assuming 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.

15. We assume that part of the process of inspection involves assessing the probable value of  $k$  in

the default state. Clearinghouses record all non-cash assets at less than current market value (they "haircut" them).

16. More generally, when the opportunity cost of margin is an increasing function of the total required margin, examination will lead to a decrease in the optimal default rate.
17. 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 U.S. stock markets differ. In stock markets, should a deficiency occur, margin must be restored to the maintenance level.
18. Implied standard deviations for short-term interest rate contracts are generally expressed in terms of yield variation. For consistency with other contracts, they are reported in terms of variation of rates of return.
19. For an extensive review of the literature see Bollerslev, Chou, Jayaraman, and Kroner (1992).
20. 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.
21. Other clearinghouses, for instance the Options Clearing Corporation, have long accepted equity as margin. This practice is increasingly being adopted by futures clearinghouses.
22. For example, see Federal Reserve Board (1993).
23. 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, as discussed above, clearinghouses generally limit the SLOC portion of total margin posted.
24. Note that our model does not require that the coefficients of 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.



iMargin is a deposit to ensure contract performance, just as collateral is a deposit to ensure loan performance. Like loan collateral, margin is seized in the event of default. However, in the case of margin on futures contracts, no loan is involved. Exchanges and clearinghouses have other policy tools at their disposal: clearing fees, required deposits in a clearinghouse guarantee fund, daily price change limits, speculative position limits, tick size, minimum capital requirements, settlement interval, and the required minimum number of seats for clearing members, for example. Most of these are changed infrequently if at all.

iiA re-examination of previous tests of prudentiality are presented in Baer, France and Moser (1995b).

iiiA futures clearinghouse also allows its members to exploit a variety of other economies of scale accessible only by acting as a group. A centralized clearinghouse also simplifies recordkeeping, since members need only keep track of their net positions 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. There are economies of scope between record keeping and credit control, since knowledge of a member's net position is necessary to assess exposure. In addition, because exchange members precommit to binding arbitration, disputes are no longer a matter for bilateral bargaining.

ivViolations 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).

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

viThis could be justified on one of two grounds. First, courts may lack the capacity to force the transfer of collateral. Second, courts may not be able to force the transfer of collateral quickly enough to allow the other party to avoid the costs of deadweight default costs.

viiOpportunistic default is an important feature of both organized and over-the-counter derivatives markets. Examples include the Brent crude market, the natural gas market, and the tin market among others. The Hunt Brothers' silver crisis in 1980 is an especially interesting example of this problem. The Hunts had the financial capacity to meet their obligations to the COMEX clearinghouse, however, many of their assets were sheltered in trusts which were beyond the legal reach of the clearinghouse (see Koppenhaver, 1987 for a description).

viiiA 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 resemble a standard Markowitz model with incomplete diversification, since most members will not be holding a large number of different futures contracts. Due primarily to notational complexity, this model has not been included, but is available in earlier working papers (Baer France Moser, 1993)

ix Most margin on US exchanges is actually deposited in interest-bearing forms, for instance in Treasury bills. In this case, the actual bill would be returned to the depositor when the account is closed, while any gains or losses (variation margin) would be handled by cash payments. By this arrangement, the depositor in effect gets interest on his deposit. The London Clearinghouse actually pays interest on cash deposits. Our formulation covers both cases. If cash is deposited, the opportunity cost is driven by the levels of market rates. Most clearinghouses allow standby letters of credit (SLOCs) as margin, but 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, for 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.

x In practice, clearinghouses may have additional collateral on clearing members. In addition, clearinghouses require that clearing firms maintain a certain minimum level of capital. We consider the existence of this additional capital in a later section.

xi The use of margin as collateral, the netting, and the attendant loss sharing rules effectively redefine the legal priority of claims. The ability of a clearinghouse to take possession of margin assets in the event of a default cannot be obstructed by law. When we say a "pre-agreed rule," we assume that the priority of claims in the event of default is clear. Without this clarity, a clearinghouse cannot operate. Historically, the rise of clearinghouses resulted in a clarification and streamlining of bankruptcy law as it applied to futures claims.

xii Certain loss sharing rules could potentially undo this result, by allocating a disproportionate share of losses to an individual member. Futures exchanges generally use a common fund to pay for defaults. By contrast, the prospectus for Multinet International, a over-the-counter foreign exchange clearinghouse, explicitly recognizing the moral hazard involved, states that "to the greatest extent possible, Multinet International will allocate any losses to those that traded with the failed participant." Both of these rules are consistent with a reduction in default losses for all individuals.

xiii 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.

xiv By relaxing this assumption we are implicitly assuming 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.

xv We assume that part of the process of inspection involves assessing the probable value of  $k$  in the default state. Clearinghouses record all non-cash assets at less than current market value (they "haircut" them).

xvi More generally, when the opportunity cost of margin is an increasing function of the total required margin, examination will lead to a decrease in the optimal default rate.

xvii 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 U.S. stock markets differ. In stock markets, should a deficiency occur, margin must be restored to the maintenance level.

xviii 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.

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

xx 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.

xxi Other clearinghouses, for instance the Options Clearing Corporation, have long accepted equity as margin. This practice is increasingly being adopted by futures clearinghouses.

xxii For example, see Federal Reserve Board (1993).

xxiii 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, as discussed above, clearinghouses generally limit the SLOC portion of total margin posted.

xxiv 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.