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Abstract

Demands for higher margins in stock index derivatives following the crash of 1987 have echoed the calls for higher stock margin which followed the crash of 1929. Yet empirical studies find little or no relationship between margin requirements (or the introduction of derivatives) and price volatility. And models of equilibrium prices with asymmetric information have not addressed these important policy issues.

We provide a simple extension of a rational expectations model to incorporate binding margin constraints and forced margin sales. We then analyze equilibrium price volatility as margin requirements change. If informed investors are initially constrained by high margin requirements, lower margins tend to increase market liquidity and price informativeness. This remains true if both informed and noise traders increase their positions with lower margins. Volatility tends to fall if there are no forced margin sales, or if all investors can observe such sales.

Volatility increases significantly only in the extreme case where all other investors are ignorant of forced margin selling, and instead believe they may be motivated by superior information. This leads to low market liquidity and the possibility of crashes.

Our analysis leads to a very strong policy recommendation: the introduction of low margins (or derivatives with low margins) should be accompanied by the best possible data on the potential amount of forced margin sales that could occur. If such information can be made widely available to investors, the liquidity benefits of low margins can be realized with minimal impact on market volatility.

(JEL 313)

I. Introduction

Prior to 1934, margin requirements for stock purchases were set by the exchanges on which the stocks traded. In response to the market gyrations surrounding the 1929 crash, however, Congress granted regulatory authority over stock margin requirements to the Federal Reserve Board. Margins on stock index futures, in contrast, continue to be set by the exchange on which the contract is traded. Yet following the October 1987 crash, there has been a prolonged and acrimonious debate about the need for government regulation of stock index futures margins.

Margins are held to serve two potential roles in stabilizing markets:

- (i) Assuring market integrity--that contractual obligations will be fulfilled.
- (ii) Reducing price volatility which results from the actions of leveraged investors.

The role of margins in assuring market integrity has been examined in several studies. With minor exceptions, most evidence suggests that futures and stock margins have ensured that contractual obligations will be met with a high probability.¹ Furthermore, the probabilities of default are comparable in the two markets.² More controversial, and the topic of this paper, is the role of margin requirements in affecting market volatility.

Critics have claimed that the low margins in stock index futures and other derivatives have added volatility, which has been passed through to the underlying stock market through index arbitrage. Some observers believe that the introduction of futures on the Nikkei 225 has added volatility to the Japanese market as well. These critics have called for futures margins to be "harmonized" with individual stock margins, by which they mean that futures margins should be raised to the level of stock margins, not vice-versa.

¹ Warshawsky [1989], for example, concludes that margins provided 98% coverage in the stock market and 95-98% coverage in the S&P 500 futures market. See also Figlewski [1984]; Gay, Kolb, and Hunter [1986]; Estrella [1988]. Schwert's [1989] and Hsieh and Miller's [1990] evidence that higher volatility has caused increases in margin requirements is consistent with the goal of preserving market integrity.

² Maintenance margins in stock index futures markets can be lower because (i) the price volatility of the stock index, a portfolio of many stocks, is considerably less than the price volatility of the average stock; and (ii) the grace period for investors to meet margin calls is considerably shorter with futures than with stocks.

The debate on the role of margins in market stability far predates the existence of low-margin stock derivatives. There seems to be two strands of criticism of low margins. First, they are said to encourage destabilizing speculation by leveraged investors. Second, they may be associated with "pyramiding and de-pyramiding," the fact that as prices rise, additional wealth permits further margined stock purchases; but when prices fall, margin requirements may force the sale of stock which was bought on credit. This in turn could lead to further sales, further margin calls, and an eventual "meltdown." Indeed, forced margin sales were widely believed to have played an important role in the crash of October 1929.³ And this belief was instrumental in the subsequent Security and Exchange Act which gave the Federal Reserve Board power to regulate margin requirements.

The language of sequential "meltdown" was subsequently revived by the Chairman of the New York Stock Exchange, John Phelan, both before and after the 1987 crash. The focus of criticism in 1987 was on hedging strategies such as portfolio insurance, as well as on low margins in the derivatives markets.⁴

Proponents of low margins argue that exchanges have proper incentives to set margin requirements without government interference. Many of their arguments are addressed to the question of market integrity, rather than market volatility per se. There is little empirical evidence to suggest that the introduction of derivatives raises the volatility in underlying markets.⁵ Nor is there significant evidence that lowering margins for stocks or futures has

³Garbade [1982] notes "the most famous example of forced liquidation in a declining market was the reduction in brokers' loans from \$8.5 billion to \$5.5 billion in 10 days, during the stock collapse that began in late October 1929." The \$3 billion of sales amounts to 3.45% of the \$87.1 billion value of NYSE issues in September, 1929. An equivalent forced liquidation in October 1987 would have equalled just over \$100 billion, more than ten times the estimated amount of portfolio insurance sales in that crash. See the Brady Report [1988], p. VIII-13.

⁴For example, the Brady Report [1988] focussed on portfolio insurance selling as a major contributor to the crash.

⁵ See, for example, Skinner [1989], Gemmill [1989] and Edwards [1988a,b].

caused volatility to increase, although more controversy exists on this point.⁶

Given the importance of the debate, the lack of conclusive empirical evidence and the statistical difficulties associated with the study of infrequent large fluctuations, theory takes on added importance.⁷ A final question can only be addressed by a theoretical model: Is increased volatility bad? If it reflects incremental risk, the answer is "yes." But if increased volatility simply reflects the earlier resolution of uncertainty, then current prices reveal information more fully and total risk does not increase. Yet few theoretical models have addressed the impact of margin requirements on volatility and the informational efficiency of prices.

Telser [1981], following an earlier argument by Friedman [1953], suggests that the increased speculation which results from lower margin requirements is stabilizing because it provides liquidity to hedgers. However, Telser's model does not explicitly recognize the information asymmetries which are central to the models of speculation and informational efficiency developed by Grossman and Stiglitz [1980], Hellwig [1980], Diamond and Verrecchia [1981], and Kyle [1985]. A recent contribution by DeLong, Shleifer, Summers and Waldmann [1990] utilizes this more appropriate framework, and concludes that increased "uninformed" speculation (noise trading) can be destabilizing. However, their paper does not explicitly consider the effect of reducing margins on informed trading, and the resultant impact on market volatility and informational

⁶ Chance [1990] and Hodges [1990] provide excellent summaries of empirical studies which examine the link between margin requirements (including the introduction of low-margin derivative instruments) and volatility. Contrary to other authors, Hardouvelis [1988] concludes that margin requirements and volatility are significantly and inversely related to the volatility of the S&P 500 index. His results were later criticized by Kupiec [1989b] and Hsieh and Miller [1990]. Furbush [1988] and Kupiec [1989a] reach conflicting results on the relationship between futures margins and stock market volatility.

⁷Kupiec [1989b] shows that Hardouvelis' [1988] results become statistically insignificant if the high volatility of the 1930s is excluded. Hsieh and Miller [1990], page 11, point out that the negative association between volatility and margins stems mainly from a single observation, the market break in 1937. (Their study excludes the 1929 crash, and the 1987 crash is relatively unimportant since there are no margin changes after 1974). This suggests that margins may have quite different effects during periods of extremely high volatility than during more normal periods, as our subsequent analysis indicates.

efficiency. And none of these papers considers the potentially destabilizing effects of forced margin sales.

Gennotte and Leland [1990], however, provide a framework for studying the pyramiding/de-pyramiding or "meltdown" effects which have so concerned practitioners. That research addresses the effect of portfolio insurance hedging (but not margin requirements) on market stability.

In Section II, we provide a simple extension of the Gennotte and Leland [1990] model to study the effects of changing margin requirements in a market with asymmetric information. Our results support some of the arguments of both sides:

- (i) Low margins will render markets more informationally efficient if speculators are informed. Even if low margins encourage increased trading by both informed and noise traders, they will result in price having greater informational content.
- (ii) Low margins will increase market liquidity.
- (iii) In the absence of pyramiding/de-pyramiding behavior, low margins will slightly reduce total volatility if speculators are informed. Equal numbers of informed and noise traders result in little change in total volatility.
- (iv) When low margins lead to the possibility of margin calls and forced liquidation of positions (pyramiding/de-pyramiding), low margins will have little effect on price volatility if all investors are cognizant of the extent of margin sales. Volatility will increase by small amounts, even when a minute fraction (0.5%) of investors are aware of the extent of margin selling.
- (v) In the extreme case where no investors are cognizant of the magnitude of forced margin sales, low margins can lead to greater volatility and to the possibility of crashes. There is some evidence that this may have been the case in 1929, but not in 1987.

II. A Model of Financial Markets

A satisfactory model for studying the impact of margin requirements on volatility must possess the following elements:

- (i) An investor portfolio selection process which allows margin requirements to affect investor demand.
- (ii) A means to study the effects of forced margin calls (i.e., the "pyramiding and de-pyramiding" resulting from low margins).
- (iii) An environment in which market volatility and liquidity are endogenously determined.
- (iv) A rational expectations equilibrium in which investors recognize that speculators possess superior information.
- (v) An environment in which market makers (but perhaps not other investors) may observe the selling generated by margin calls.

Models of the type examined by Grossman and Stiglitz [1980], Hellwig [1980], and Kyle [1985] satisfy requirements (iii) and (iv). The model of Gennotte and Leland [1990] (GL hereafter) further incorporates portfolio insurance selling. Portfolio insurance bears some resemblance to margin selling. But to fully satisfy requirements (i), (ii) and (v) the GL model must be suitably adapted to study the effects of margin constraints on speculators' demands. We consider a simple extension below which will enable us to examine the impact of lower margins (or low-margin derivatives) on investor demands and on stock market volatility.

The Basic Framework

The GL model examines single-period equilibrium in a market with a single risky asset ("the market") and a risk-free asset. Thus it is suited to examine the impact of margins on the market price and volatility, but not the prices or volatilities of individual securities.⁸

⁸Admati [1985] and Gennotte [1985] introduce a model with multiple securities which might (with considerable effort) be adapted to examine our questions. Note that one would not necessarily expect different margins across similar securities (i.e., stocks) to have the same impact on price and volatility as changing margins for the market as a whole, since information spill-overs between individual securities may importantly affect behavior and prices. Seguin and Jarrell (1991) suggest that the difference in performance of margined versus unmargined OTC securities was negligible during the 1987 crash. This observation does not preclude the possibility that market-wide

The market is composed of four classes of investors:

- (a) Informed speculators, who receive (imperfect) information about future market prices.
- (b) Uninformed investors, who receive no information but correctly recognize that current prices reflect speculators' information.
- (c) Liquidity or "noise" traders, whose demand reflects exogenous needs or speculation (erroneously) based on pure noise.
- (d) Traders who receive (imperfect) information about the extent of liquidity traders' demand. We call these traders "market makers."

All investors (except liquidity traders, whose demands are exogenous) choose portfolios to maximize expected utility, given identical exponential utility functions. Expectations are conditional upon the information observed by each investor class.

A linear rational expectations equilibrium price function can be derived which relates the current price p_0 to the future price p , and to liquidity demand S observed by market makers as well as to the unobserved liquidity demand L :

$$p_0 = F[(p - \bar{p}) + HL + IS],$$

where \bar{p} is the ex ante expected future price, and $F > 0$, $H < I < 0$ are constants determined by the model's exogenous parameters.⁹ For realistic values of these parameters¹⁰ the price function is given by equation (3) of Gennotte and Leland [1990]:

Base Case: Informed Investors = 2%.

changes in margin will have important effects on the overall level of volatility.

⁹Because there are a very large number of traders, the average signal of informed investors will converge to the true future price p . Thus p also reflects the informed investors' mean signal about future price.

¹⁰See Appendix A for details. Reflecting relative market importance, it is assumed that informed traders represent 2% of investor capital; market makers represent 0.5% of investor capital; and uninformed ("long term") investors represent the remaining 97.5%. Informed investors have relatively poor information, with a signal-to-noise ratio of 0.2. Other parameters are scaled so the market portfolio has an annual mean return of 6% above the risk-free rate, and a standard deviation of 20%. Section VI shows that our conclusions are largely insensitive to changes in these parameter values.

$$\begin{aligned}
p_0 &= 1.000 + .500[(p - \bar{p}) - 19.952L - 8.140S], \\
&= 1.000 + .500(p - \bar{p}) - 9.976L - 4.070S
\end{aligned}$$

$$\text{Std}(p_0) = .2000; \text{Std}(p|p_0) = .2000$$

Note that the coefficient of $(p - \bar{p})$ can be interpreted as the responsiveness of current price to future price; it is one measure of the "informational efficiency" of the market.¹¹ The coefficients of L and S indicate the sensitivity of current price to unobserved and observed liquidity demand, respectively. These coefficients therefore are an inverse measure of market liquidity.

Appendix B shows that, with suitable modifications, the original GL model can be adapted to include the effect of margin requirements on market equilibrium. A fall in margin requirements will lead to an increase in the size of risky asset positions held by speculative traders. An increase in speculative positions has the effect of increasing the relative importance (i.e., fraction) of speculative traders in the original GL model.

We examine the case where speculative traders are either "informed"--the usual perception of speculators--or naive. A relaxation of margin requirements from a level m_0 to a level m_1 will increase speculators' risky asset positions by a maximum factor of m_0/m_1 . For example, if a speculator could take a position x when (stock) margins were 50%, s/he could take a (maximal) position of $4x$ in stock index futures if futures margins were 12.5%.¹²

III. Case A: Informed Speculators

We first examine the case when speculators are informed investors; that is, they receive information about the future price which is superior to that

¹¹Given the relatively low volatility of liquidity demand $S+L$, it can be shown that the coefficient F will closely approximate R^2 of a regression of p on p_0 , another measure of the informational efficiency of the market.

¹²Of course this assumes all speculators would shift from stock to futures markets, and use leverage to a maximum (see Appendix B). This would clearly represent a maximal possible impact from introducing lower-margined futures.

obtained by other types of investors.¹³ If all informed investors were constrained by margins both before and after the introduction of futures, their positions would (at maximum) quadruple as argued above. Informed investors would now constitute 8% of investor "capital," or average positions, rather than 2%. If only half of the informed investors took full advantage of the increased margin, they would constitute 4% of investor capital, or double their earlier presence. In this subsection, we ignore the possible pyramiding/de-pyramiding or hedging strategies which margined investors may follow.

Using the same initial parameters as GL, but expanding informed traders' actions by factors of two and four gives the following rational expectations equilibrium price functions:

A.1. Doubling Informed Speculation:

$$\begin{aligned} p_0 &= 1.037 + .814[(p - \bar{p}) - 9.976L - 2.557S], \\ &= 1.037 + .814(p - \bar{p}) - 7.945L - 2.081S \end{aligned}$$

$$\text{Std}(p_0) = .2549; \text{Std}(p|p_0) = .1221; \text{Avg.Std.} = .19985$$

A.2. Quadrupling Informed Speculation:

$$\begin{aligned} p_0 &= 1.054 + .948[(p - \bar{p}) - 4.988L - 0.733S], \\ &= 1.054 + .948(p - \bar{p}) - 4.729L - 0.695S \end{aligned}$$

$$\text{Std}(p_0) = .2751; \text{Std}(p|p_0) = .0645; \text{Avg.Std.} = .19976$$

Comparing these numbers with those of the base case, we see that the informativeness of prices--the coefficient of $(p - \bar{p})$ --has increased. The liquidity of the market--inversely related to the coefficients of L and S --has dramatically increased for both observed and unobserved liquidity trades.

¹³Note that the quality of information received, even by "informed" traders, is not very precise. It has a "signal to noise" ratio of 0.2, implying that conditional on this information the volatility of future prices (given current price) is 19.1% rather than the 20% for uninformed investors.

Average current price also rises, since the greater information efficiency of current price reduces future risks to investors.¹⁴

Has market volatility increased? The answer is both "yes" and "no." In our two-period model, current volatility (the standard deviation of p_0) increases, reflecting two things: the increased informativeness of prices, but the decreased impact of liquidity trading. On the other hand, because current prices are now more informative, the future price uncertainty (given p_0) is reduced.

The average volatility, $[[\text{Var}(p_0) + \text{Var}(p|p_0)]/2]^{1/2}$, has fallen from .20000 to .19985 in the 4% case and to .19976 in the 8% case.¹⁵ The (unconditional) variance of future price p has not changed, but a larger fraction of that randomness is now revealed earlier, due to the greater informational content of the current price. The reduction of total variance results from random liquidity trades having less current price impact due to the greater liquidity of markets.¹⁶ Trading volume increases as speculators (receiving different information signals) trade larger amounts amongst themselves.

We consider now the case where margined investors must follow hedging strategies to protect margin lenders from the possibility of default. Such strategies might simply involve a stop-loss sale when a margined investor's equity falls beneath the maintenance margin requirement, the classic "forced margin sale." Alternatively, an investor might follow a dynamic hedging

¹⁴We assume that the (unconditional) volatility of the future price p is fixed. In a multi-period model, the volatility of all future prices prior to the final period may rise, and the price increase in the initial period may be less.

¹⁵ $\text{Var}(p_0)$ is the risk to an investor who purchases the risky asset prior to time 0 and resells at the price p_0 which prevails in equilibrium at time 0. $\text{Var}(p|p_0)$ is the risk faced by an investor who purchases the asset at time 0 and holds it until the future date. The average variance reflects the average risk of the two investors. We take the square root of the average variance in order to compare with the original standard deviation of .20.

¹⁶The small magnitude of variance reduction follows from the fact that liquidity trades create a small amount of current price uncertainty relative to information arrival. Note our model presumes that all investors are aware of the increased positions undertaken by margined speculators. The interested reader can verify that volatility will rise rather than fall if other investors are ignorant of the increased level of speculation resulting from the relaxation of margin requirements.

strategy which replicates a put option, providing protection against wealth falling beneath the minimum required level.¹⁷

This dynamic hedging strategy, known as "portfolio insurance," requires that investors progressively sell their stock holdings as stock prices decline, but permits them to become more aggressive as prices rise.¹⁸ Thus it captures quite exactly the notion of "pyramiding/de-pyramiding" or "cascading" which has been claimed to reflect the behavior of leveraged investors facing low margin requirements. In the analysis which follows, we shall assume that investors on margin follow such a hedging strategy, and shall refer to the sales necessitated by such a strategy as "forced margin sales."

The GL model allows for the existence of possible hedging strategies, including portfolio insurance. The supply of shares or futures generated by hedging strategies is given by an arbitrary function $\pi(p_0)$, with $\pi'(p_0) < 0$. The actual function π will depend on the level of protection against loss, the time horizon, and the fraction of investors following such a protection strategy.

With hedging, the rational expectations equilibrium price function becomes a nonlinear correspondence:

$$p_0 = f((p - \bar{p}) + HS + IL).$$

GL show that the argument of f is identical to the linear rational expectations equilibrium price function when there is no hedging: the coefficients H and I are unaffected by the degree of hedging. The sensitivity of f to changes in its argument, and the possibility of discontinuities ("crashes"), will depend upon (i) the amount of hedge selling π , and (ii) the extent to which hedging activity is observed by various market participants. We consider these two aspects below.

For any level of observability, greater hedging activity will increase the sensitivity of $f(\cdot)$ to changes in its argument, relative to the case when there

¹⁷For an illustration of how a simple dynamic strategy can replicate a put option, see Rubinstein and Leland [1981]. Also, Cox and Huang [1988] suggest that following such a strategy is appropriate for a wealth-constrained investor.

¹⁸Note that a group of investors, each following a stop-loss strategy with different stop-loss price levels, would behave similarly as the price falls to a group of investors, each following an identical portfolio insurance strategy.

is no hedging and the sensitivity is the coefficient F . Comparing $f'(\bullet)$ with F will show the impact of hedging. Locally, the volatility (standard deviation) of current price p_0 will increase by the factor $f'(\bullet)/F$, relative to the volatility of p_0 when there is no hedging activity.¹⁹

Observability also affects market volatility. If investors are unaware of the amount of hedging activity, the sensitivity of f to changes in its argument will be large. Hedging sales can substantially raise price volatility and even cause crashes in realistic environments.

If, however, the extent of hedge selling is observed by even a small subset of investors (e.g., by "market makers" who can observe the origin of orders), the impact of such selling will be considerably less. This is because market makers will be willing to take the other side of such transactions, recognizing that the fall in prices was not the result of unfavorable information. The impact of hedging on volatility is even smaller if all investors are aware of its magnitude.

At the initial margin level of 50%, hedging strategies are assumed to protect the 2% of total market capitalization of speculators against losses exceeding 50%. In this base case, the hedging strategies have a minimal effect on both current volatility ($\text{Std}(p_0)$) and average volatility regardless of the degree to which margin-related hedging can be observed.

<u>A.3. 2% Speculators; 50% Margin</u>	<u>Slope $f'(\bullet)$</u>	<u>(Local) $\text{std}(p_0)$</u>	<u>Avg. Std.</u>
Base (no hedging)	.50000	.20000	.20000
Hedging; observed by all	.50000	.20000	.20000
Hedging; observed by market makers	.50010	.20004	.20002
Hedging; not observed	.50024	.20010	.20005

The small effect of hedging on current and average volatility results from the minimal amount of hedging--even if every speculator has purchased on full margin--since the level of protection is so far beneath the current price

¹⁹Since $f'(\bullet)$ changes as its argument changes, we shall focus on the situation where all variables equal their expected values.

p_0 .²⁰ However, if prices were to fall 40%, the dynamic strategy would require larger trades, and the effect on market volatility would be more pronounced.

We now consider the effects of hedging on the equilibrium where effective margins have been reduced to 12.5% through the introduction of stock index futures. Again we examine two cases, one where the speculative demand doubles (with associated hedging), and the other where the speculative demand quadruples (with associated hedging). The former is modeled by a rise in speculative capital from 2% to 4%, with the 4% of margined investors protecting themselves against losses exceeding 12.5%. The second case is modeled by a rise in speculative capital to 8%, with all these investors protecting themselves against losses exceeding 12.5%.

Hedging will now be more aggressive for two reasons. One reason is that the equivalent of more investor capital is being hedged; and the second is that the desired level of protection is higher, necessitating more aggressive trading at the current price p_0 .²¹

<u>A.4. 4% Speculators; 12.5% Margin</u>	<u>Slope $f'(\cdot)$</u>	<u>(Local) $\text{std}(p_0)$</u>	<u>Avg. Std.</u>
Base (no hedging)	.81366	.25488	.19982
Hedging; observed by all	.81420	.25504	.19993
Hedging; observed by market makers	.89604	.28068	.21642
Hedging; not observed	1.26886	.39746	.29400

²⁰The volume of hedging as prices fall depends upon the "gamma" (at the current price) of the option being replicated. This gamma is small for a put option with strike price equal to one-half the current price.

²¹ Derivatives instruments such as stock index futures are in zero net supply: for every long position, there is an offsetting short position. One might presume that pyramiding/de-pyramiding by long position holders would therefore be offset by pyramiding/de-pyramiding by shorts. This is not true: in fact, both longs and shorts will buy as the market rises and sell as it falls. Consider a speculator with a short position. If the market falls, the speculator will realize profits which will enable him to increase his speculative position--i.e. take a larger short position by selling additional contracts. If the market rises, the short will have to cut his losses by buying (and reducing his short position). Thus his hedging behavior is similar to that of longs.

<u>A.5. 8% Speculators; 12.5% Margin</u>	<u>Slope $f'(\cdot)$</u>	<u>(Local) $\text{std}(p_0)$</u>	<u>Avg. Std.</u>
Base (no hedging)	.94791	.27505	.19977
Hedging; observed by all	.94823	.27514	.19983
Hedging; observed by market makers	1.00373	.29125	.21093
Hedging; not observed	1.52490	.44247	.31618

We conclude that, even with low margins, the hedging or "pyramiding/de-pyramiding" behavior of margined investors will have a very small impact on current and average volatility if all investors--uninformed as well as market makers--observe (or can accurately impute) the amount of hedging activity by speculators. When investors know selling activity has no informational content, they will absorb such selling with little price impact.

Volatility will increase slightly if market makers alone are aware of the magnitude of hedging, including forced margin sales. Despite their relatively small numbers--only 0.5% of market capital--market makers will be able to absorb a large amount of hedge selling, knowing that it does not reflect information. The average standard deviation of prices has now risen a bit above the level of the base case, when low-margined futures were unavailable. Offsetting this volatility increase is the greater informational efficiency of prices.

In the extreme case where no investors are cognizant of the extent of forced margin sales, then volatility may be significantly increased by the relaxation of margin requirements. Our examples show average volatility increases by 40-50% in this situation, even when only a fraction of speculators take full advantage of the lower margins.²²

IV. Case B: Informed and Naive Speculators

We now consider the case where relaxing margin requirements leads a fraction of liquidity or "noise" traders to increase their positions. In

²²The reader may wonder why the impact of reduced margins is not much larger when all speculators take advantage of them; the 8% case versus the 4% case. The explanation is that while more hedging is occurring in the 8% case, which potentially is more destabilizing, the liquidity of markets is improved because of the greater number of informed traders.

contrast with Friedman's [1953] view that speculators tend to be informed, other writers such as DeLong, Shleifer, Summers and Waldmann [1990] have argued that "naive" speculators may trade on the basis of purely noisy signals, which they mistakenly interpret as information. Lower margin requirements would allow such naive speculators (as well as informed speculators) to take larger positions.

We can examine the consequences of increased naive speculation in the GL model by increasing the volatility of exogenous "liquidity" demand. We presume that other investors recognize the increased volume of purely noisy speculation following the relaxation of margins.

To facilitate the comparison, we assume initially that (with 50% margins) the demand of "naive" speculators is commensurate with the demand of informed speculators. Using the GL model, it can be shown that (in the base case) informed speculators as a group have a variance of demand of .000101, resulting from their information signals and prices. We therefore assume that the variance of naive speculators' (random) trading before margin reduction also is .000101, and is included as part of the total variance of liquidity demand.²³

Doubling the positions of naive speculators (consistent with half of them taking full advantage of the margin drop from 50% to 12.5%) will increase the variance of their demand by a factor of four. The variance of total liquidity demand will therefore increase from .000345 to .000648. Quadrupling their positions (the maximum if all take full advantage of the margin drop) will increase the volatility of their demand by a factor of sixteen, raising the variance of total liquidity demand to .001860. As before, only market makers can observe (imperfectly) the actual realization of the amount of this trading; we presume the signal-to-noise ratio of their information remains unchanged.²⁴

We now examine the effects of an equal increase in both informed and naive speculation by adding these amounts of extra variance to liquidity demand as

²³Thus uninformed speculation accounts for about 30% of the variance of liquidity demand, which is .000345 in the GL base case.

²⁴ The signal-to-noise ratio in our base case is one. This is equivalent to market-makers observing the actual noisy trading of one-half the participants. Equivalently, they could receive an unbiased signal on the total liquidity trading, with a variance (about the true volume) equal to the ex ante variance of the trading volume itself.

well as increasing the number of informed speculators. As before, we first consider the case where there is no hedging by margined investors.

B.1. Doubling Informed & Naive Speculation: No Hedging

$$\begin{aligned} p_0 &= 1.022 + .683[(p - \bar{p}) - 9.976L - 3.917S], \\ &= 1.022 + .683(p - \bar{p}) - 6.813L - 2.675S \end{aligned}$$

$$\text{Std}(p_0) = .2336; \text{Std}(p|p_0) = .1593; \text{Avg. Std.} = .19995$$

B.2. Quadrupling Informed & Naive Speculation: No Hedging

$$\begin{aligned} p_0 &= 1.029 + .738[(p - \bar{p}) - 4.988L - 2.400S], \\ &= 1.029 + .738(p - \bar{p}) - 3.681L - 1.771S \end{aligned}$$

$$\text{Std}(p_0) = .2429 \text{ Std}(p|p_0) = .1449; \text{Avg. Std.} = .20002$$

In contrast with case A above, we observe that additional speculation by naive investors dilutes but does not totally eliminate the advantages of lower margins that were previously observed. Relative to the initial situation with high margins, prices are more informationally efficient. Average volatility falls in the doubling case and rises marginally in the quadrupling case--despite the substantial increase in noise trading. This is because markets are more liquid than before, to unobserved as well as (partially) observed liquidity trading.

We turn now to the case when margined speculators--both informed and naive--follow hedging strategies that limit losses. Relative to the previous case, in which only informed speculators followed hedging strategies, hedging will be greater. The effects of increased hedging on volatility will partially be offset by the greater liquidity of the market, as noted above.

B.3. Doubling Case; 12.5% Margin Slope $f'(\cdot)$ (Local) $\text{std}(p_0)$ Avg. Std.

Base (no hedging)	.68296	.23363	.19995
Hedging; observed by all	.68464	.23420	.20029
Hedging; observed by market makers	.92213	.31544	.24988
Hedging; not observed	2.01217	.68833	.49959

B.4. Quadrupling Case; 12.5% Margin Slope $f'(\cdot)$ (Local) $\text{std}(p_0)$ Avg. Std.

Base (no hedging)	.73821	.24294	.20002
Hedging; observed by all	.74110	.24389	.20060
Hedging; observed by market makers	1.10285	.36294	.27634
Hedging; not observed	2.35863	.77621	.55835

Again, we see little impact of forced margin sales if all investors can observe the total hedging activities by speculators. Yet most of the benefits of more efficient pricing and greater market liquidity are preserved. This is because hedging has no informational content and forced margin sales will be readily absorbed by all investor types. But if this activity is imperfectly observed, it will have more significant impacts than in the previous situation. When market makers alone (representing 0.5% of market capital) can observe hedging, the average standard deviation increases by twice the amount of case A.

In the admittedly extreme case of no observability, hedging activity overwhelms the ability of the market to absorb it, volatility soars, and discontinuities (crashes) can occur.

V. Case C: Informed Speculators, Naive Speculators and Market Makers

We finally examine the case where market makers as well as speculators can increase their positions as margin requirements are lowered. While market makers typically are not subject to the margin requirements of other investors, they may still be able to take larger positions with the advent of derivatives markets. We consider the case where both informed and naive speculation are doubled and quadrupled, but accompanied by the doubling and

quadrupling of market-makers' positions as well. This is possible within the context of the GL model by doubling or quadrupling (to 1% and 2%, respectively) the size of market makers.

C.1. Doubling Market Makers and Speculation: No Hedging

$$\begin{aligned} p_0 &= 1.024 + .701[(p - \bar{p}) - 9.976L - 2.437S], \\ &= 1.024 + .701(p - \bar{p}) - 6.993L - 1.708S \end{aligned}$$

$$\text{Std}(p_0) = .2367; \text{Std}(p|p_0) = .1547; \text{Avg.Std.} = .19993$$

C.2. Quadrupling Market Makers and Speculation: No Hedging

$$\begin{aligned} p_0 &= 1.032 + .770[(p - \bar{p}) - 4.988L - .939S], \\ &= 1.032 + .770(p - \bar{p}) - 3.841L - .723S \end{aligned}$$

$$\text{Std}(p_0) = .2481; \text{Std}(p|p_0) = .1357; \text{Avg.Std.} = .19995$$

With hedging, we find that the doubling and quadrupling scenarios yield the following volatility impacts:

C.3. Doubling Case; 12.5% Margin Slope $f'\{\bullet\}$ (Local) $\text{std}(p_0)$ Avg. Std.

Base (no hedging)	.70106	.23668	.19993
Hedging; observed by all	.70266	.23722	.20025
Hedging; observed by market makers	.83816	.28296	.22803
Hedging; not observed	2.12211	.71642	.51826

C.4. Quadrupling Case; 12.5% Margin Slope $f'\{\bullet\}$ (Local) $\text{std}(p_0)$ Avg. Std.

Base (no hedging)	.77009	.24806	.19995
Hedging; observed by all	.77267	.24890	.20047
Hedging; observed by market makers	.88711	.28576	.22370
Hedging; not observed	2.57270	.82873	.59381

In comparison with cases A and B, we find that the expansion of market making activity permitted by lower margins has the expected effect of deepening liquidity to trades which market makers observe, as reflected in a lower price impact of observed liquidity trading S . The price impact of unobserved liquidity trading L is slightly increased.²⁵ Despite the fact that market makers have no special information about future prices, prices become somewhat more informationally efficient. Most importantly, the impact on volatility of hedging by speculators is now moderated in the more realistic case where market makers can observe the amount of forced margin sales.

VI. Robustness of the results

The results in the preceding sections all take our base case as a starting point. Here, we analyze the changes in our quantitative conclusions which would result from different market parameters. To emphasize the robustness of our results, we consider markets with very different characteristics from our base case. Our assumptions on the fraction of the market composed of informed investors and the quality of their information is the most critical one. Hence, we changed the initial percentage of informed investors from its 2% value in the base case to 10%. Importantly, we maintained the requirement that the risk premium be 6% and the variances of the current price, p_0 , and of future prices, p , conditional on p_0 be equal to 20% per annum. The equation for prices becomes:

$$\begin{aligned} p_0 &= 1.000 + .500[(p - \bar{p}) - 3.95L - 2.88S], \\ &= 1.000 + .500(p - \bar{p}) - 1.975L - 1.44S \end{aligned}$$

$$\text{Std}(p_0) = .2000; \text{Std}(p|p_0) = .2000$$

Not surprisingly, the responsiveness of equilibrium prices to liquidity shocks is markedly smaller than in the base case. Incorporating hedging for margins of 50% yields the following table.

²⁵ When unobserved liquidity trading occurs, market makers assume that the price movement may be caused by informed trading, and hence trade in the same direction as (rather than absorb) liquidity trading.

<u>D.1. 10% Speculators; 50% Margin</u>	<u>Slope $f'(\bullet)$</u>	<u>(Local) $\text{std}(p_0)$</u>	<u>Avg. Std.</u>
Base (no hedging)	.49997	.20000	.20000
Hedging; observed by all	.49997	.20000	.20000
Hedging; observed by market makers	.50014	.20007	.20003
Hedging; not observed	.50021	.20010	.20005

The results obtained for this case are almost identical to the statistics of the base case. In the absence of hedging, the slope of f' is to be compared to .50000 for the base case and the variance levels are identical by construction. As in the base case, hedging has very little impact although 10% of investors follow a portfolio insurance strategy. The impact of this large amount of hedging on price stability would be large in the base case, but it is greatly reduced here because the larger fraction of informed agents also provides greater liquidity.

We now quadruple the fraction of informed agents to 40% and correspondingly increase the amount of hedging done by speculators for margins of 12.5%.

<u>D.2. 40% Speculators; 12.5% Margin</u>	<u>Slope $f'(\bullet)$</u>	<u>(Local) $\text{std}(p_0)$</u>	<u>Avg. Std.</u>
Base (no hedging)	.95393	.27471	.19890
Hedging; observed by all	.95532	.27511	.19918
Hedging; observed by market makers	1.12301	.32340	.23264
Hedging; not observed	1.52788	.43999	.31404

All these values are also very similar to the results obtained by quadrupling the number of speculators to 8%, from the starting point of 2% in the base case (Case A.5). The intuition is similar: the increase in price informativeness almost exactly offsets the adverse effects of increased hedging.

In additional computations, we increased the informativeness of the signal privately observed by agents. Multiplying the informativeness by a factor of five yields exactly the same equilibrium equation in the absence of hedging as an increase of the number of informed speculators from 2% to 10%. A relaxation of the margin requirements then leads to an increase in the amount of hedging

but the effects are reduced relative to case D.1.-D.2. because the number of agents following hedging strategies increases from 2% to 8%, as opposed to an increase from 10% and 40%.

We also considered cases where the number of market makers is markedly higher than in the base case. We omit to report these results because they are again strikingly similar to the ones obtained for the base case. Finally, we increased the amount of liquidity trading and verified that the results are also very similar. Therefore, our results appear to be very robust with respect to changes in the parameters.

VII. Conclusion

We have provided a simple extension of the Gennotte and Leland [1990] model which allows us to examine the important issues of the impact of margin requirements on market volatility and on the informational efficiency of prices. We consider increases in both informed and naive speculation resulting from lower margins, and increases in market maker capacity. Equally importantly, the model permits the analysis of the impact of the additional hedging or "forced margin sales" which low margins may engender.

In a world in which all investors are fully cognizant of the extent of margin sales, we conclude that lower margins (as long as they are consistent with market integrity) have little adverse effect on market volatility, while bringing important benefits to the liquidity of markets and to the informational efficiency of prices. These benefits are most pronounced when speculative activity is based on informative signals of future values, and are diminished but not eliminated when there is equal speculative activity based on uninformative or "noisy" signals.

Even when a small fraction of investors (0.5%), whom we characterize as market makers, are fully informed about the extent of margin sales, the impact of low margins on volatility is relatively modest when speculators are informed, while the advantages of greater liquidity and informational efficiency remain. Naive speculation can lead to marked increases in volatility in this case. But this increase is small if market makers themselves can take larger positions because of lower margins.

In the extreme scenarios where virtually no investors are cognizant of the hedging activity of margined investors, low margins have a substantially negative impact on market performance. In these scenarios, low margins can lead to substantially greater market volatility and even the possibility of crashes.

Our analysis highlights the effect of information about forced margin sales on market stability. While a few investment professionals undoubtedly have some information about margin sales, it is not clear that most investors have such data. If the market falls 5% in the next week, what volume of selling (stocks and index futures) will be forced by margin calls? Not many investors would seem to know the answer to this question, since it requires not only current data on the extent of margin positions, but also on the initial cost bases of margined positions.²⁶

The open interest in stock index futures markets is a measure of the maximum amount of forced selling which futures could generate in a market decline. Relative to the total value of stocks (about \$3.5 trillion), the value of open interest in stock index futures is small; about \$30 billion, or less than 1%. Nonetheless, since a 12.5% or greater decline in market price could (at least theoretically) force all long holders to liquidate their positions, all \$30 billion could be sold during the course of a major market fall. If 20% of futures positions were liquidated, or \$6 billion, it would approximate the amount of selling by portfolio insurers on October 19, 1987.²⁷

While such a large amount of forced margin selling may look threatening, our results suggest that the market can absorb such volume with little price

²⁶If the market is currently at a new high, most margin buyers will be comfortably above the level of forced margin sales. Only when the market has fallen a significant amount beneath the high is it likely that serious hedge selling will be required. Interestingly, both the 1929 and 1987 crash occurred at levels some 15-20% less than newly established highs.

²⁷Still, the potential maximum forced margin selling in futures is far less than the 3.45% liquidation of positions that margin selling forced in 1929. Thus we might conclude that the current danger of forced margin selling of low-margined derivatives is small relative to the 1929 situation. The Brady Report [1988] indicates that investors were not particularly concerned with forced margin sales during the crash of 1987 (pp. V-51 - V-52). However, it is not clear that respondents included possible forced sales of stock index futures as well as forced sales of individual stocks.

impact, if investors realize that the selling is not triggered by negative information.²⁸

Thus our analysis leads to a very strong policy recommendation. The introduction of low margins (or derivatives with low margins) should be accompanied by the best possible data on the potential amount of forced margin sales that could occur, for various levels of market declines. If such information can be made widely available to investors, it appears that the liquidity benefits of low margins can be realized with minimal impact on market volatility.

²⁸ For example, on October 19, 1988 (one year after the crash), \$24 billion of a single security (NT&T) was sold in a single day with little price impact. Such liquidity was made possible because investors knew well in advance that such selling would occur, and because they knew that the selling was not related to negative information. There was little price impact even when the impending sale of stock was first announced.

Appendix A: Notations and parameter values

The parameter values used in the base case are in parentheses.

Prices

p_0 :	Current equilibrium price.
p :	Realized end of period price.
\bar{p} :	Unconditional expected end of period price (1.06).
\bar{p}_i :	Investor i 's conditional expectation of end of period price.
Σ :	Unconditional variance of end of period price (0.08).
Z_j :	Class j investor conditional variance of p .
Z :	Market power-weighted average conditional variance of p .

Information

m :	Supply of shares divided by the sum of risk-tolerance coefficients, expectation \bar{m} (1.503), and variance Σ_m (0.00034).
$p'_i = p + \epsilon_i$:	Price signal observed by investor i in class I .
ϵ_i :	Price signal noise, uncorrelated across investors, uncorrelated with other random variables, ex-ante variance Σ_ϵ (0.4).
S :	Liquidity supply observed by investors SI , mean zero, and variance Σ_S (0.00017).
L :	Unobserved liquidity supply, mean zero, and variance Σ_L (0.00017); L and S are independent.

Investors

SI :	Supply-informed investor class, observe p_0 and S .
I :	Price-informed investor class, observe p_0 and p'_i .
U :	Uninformed investor class, observe p_0 .
j :	Investor class SI , I , or U .
a_j :	Investor class j risk tolerance.
w_j :	Number of investors in class j .
k_j :	Relative market power of class j : ratio of the products of w_j and a_j to the sum across classes: $k_j = a_j w_j / \sum a_j w_j$ (k_I : 0.02, k_{SI} : 0.005, k_U : 0.975).
$\pi(p_0)$:	Hedging share supply.
ω :	Fraction of share total hedged (5%).

Appendix B: Equivalence of equilibria

The analysis is greatly simplified if the investors subject to margin constraints and willing to trade are actually constrained in equilibrium. If liquidity traders are subject to margin constraints, a tightening of margin constraints reduces the amount of liquidity trading proportionately.

We now turn to the case where speculators are subject to margin constraints. In order to obtain a tractable solution, we assume that speculators are risk neutral and pay transaction costs. Speculator i privately observes the signal $p+\epsilon_i$, as well as the equilibrium price p_0 . The expectation of the future price p conditional on the information available to investor i is denoted \bar{p}_i . A share purchase (or sale) will be profitable if the expected profit exceeds the transaction cost, c . In the case of a purchase, if:

$$\bar{p}_i - p_0 > c. \quad (B.1)$$

A sale is profitable if:

$$p_0 - \bar{p}_i > c. \quad (B.2)$$

Being risk-neutral, speculators willing to trade do trade the largest possible amount. Consequently, the margin constraint is binding in equilibrium for speculators willing to trade. If speculators were risk averse, their pattern of trading would be qualitatively similar. However, aggregate speculative trading would not be normally distributed and the rational expectation equilibrium would not have the usual linear structure.

Define the random variable $n(i,c)$ as equal to 1 if agent i faced with transaction cost c buys, -1 if agent i sells, and 0 in case of no transaction. The expectation \bar{p}_i of the future price p conditional on the information available to informed speculator i is a function of the equilibrium price p_0 and of his informative signal, $p+\epsilon_i$. This function is linear in the signal $p+\epsilon_i$ because of the joint normality assumptions (see GL). The distribution of \bar{p}_i conditional on future and equilibrium prices, p and p_0 , is therefore normal. Let q be the expectation of \bar{p}_i (conditional on p and p_0) and σ its standard deviation. q and σ are identical for all speculators. The expectation of $n(i,c)$, conditional on p and p_0 , is given by:

$$E(n(i,c)) = \text{Prob}(\bar{p}_i - q > c + p_0 - q) - \text{Prob}(\bar{p}_i - q < p_0 - q - c)$$

where the probabilities are cumulative normals with variance σ^2 and zero mean. Defining δ as $q - p_0$ and taking advantage of the symmetry of the distribution yields:

$$E(n(i,c)) = N(\delta - c) - N(-\delta - c),$$

where N denotes the cumulative normal distribution with mean zero and variance σ^2 .

The signals observed by speculators whose transaction cost is c are assumed to be independently and identically distributed. As in GL, we consider the limit of a sequence of finite economies where the relative proportion of investors in each class remains fixed and the total number of investors as well as the supply parameters grow without bound at the same rate. Hence the average demand by speculators whose transaction cost is c , $n(c)$, converges to the expectation as the number of speculators faced with transaction cost c tends to infinity (Law of Large Numbers). In the limit, the average $n(c)$ is equal to $E(n(i,c))$.

Finally, we assume that the population of speculators facing transaction cost c is the same for any level of transaction cost. The number of speculators who face a transaction cost comprised between c and $c+dc$ is thus αdc , where α is a positive constant.

The total number of buys minus sells is then obtained by integrating over the populations with different transaction costs:

$$\Pi = \int_0^{\infty} n(c) \alpha dc = \int_0^{\infty} [N(\delta - c) - N(-\delta - c)] \alpha dc$$

Integrating by parts and noting that the first term is zero yields:

$$\Pi = \int_0^{\infty} \alpha c [N'(\delta - c) - N'(-\delta - c)] dc,$$

where N' denotes the normal density function (variance σ^2).

Changes of variables yield:

$$\Pi = \int_{-\infty}^{\delta} \alpha N'(c)(\delta-c) dc - \int_{-\infty}^{-\delta} \alpha N'(c)(-\delta-c) dc ,$$

which may be written as:

$$\Pi = \alpha \delta (N(\delta)+N(-\delta)) + \alpha \int_{-\delta}^{\delta} N'(c)c dc.$$

By symmetry of the normal density, the second term is equal to zero, hence Π is given by:

$$\Pi = \alpha \delta (N(\delta)+N(-\delta)) = \alpha \delta = \alpha (q-p_0).$$

At the NYSE, the collateral required for an investment in stocks is equal to a fraction of the dollar value of the position. In futures markets, however, an investor is required to actually invest a fixed amount per futures contract. We focus on the latter specification of margin constraints because speculators would prefer to trade in the futures market because of its higher liquidity, lower transactions costs, and lower margin requirements. Hence for a given level of investment capital, W , an investor will be able to buy at most W/m futures contracts on the index where m is the margin requirement expressed as the dollar amount to be paid to purchase a position in futures contracts equivalent to one unit of the underlying asset.

Aggregate demand by speculators is thus given by:

$$\frac{W}{m} \alpha (q-p_0). \quad (B.3)$$

In the original GL model, the demand by informed speculators is proportional to $q-p_0$ as well. The proportionality factor in the GL model is the product of the fraction of informed traders, k_1 , and the inverse of the conditional variance of the future price, p_0 . In this case it is the ratio of the investment

capital controlled by speculators who face transactions costs comprised between c and $c+1$, αW , and the margin requirement, m .

All the results obtained in GL therefore obtain, provided that one reinterprets the average demand by informed traders as the average demand by speculators obtained here. In the analysis, we start with a base case identical to the one in GL and study the effect of changes in margin requirements. For example, doubling the margin requirement is equivalent to halving the fraction k_1 of informed investors in the original GL model.

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Låga säkerhetsmarginaler, derivatinstrument och volatilitet

Kraven på högre säkerhetsmarginaler för aktieindexderivat efter kraschen 1987 är ett eko av de krav på högre säkerhetsmarginaler i handeln med aktier, som restes efter 1929 års börskrasch. Ändå ger empiriska studier föga eller inget stöd alls för ett samband mellan marginaler (eller införande av derivat) och prisvolatilitet. Modeller med jämviktspriser och asymmetrisk information tar inte upp dessa frågor, som är viktiga för hur man formulerar marknadens spelregler.

Här görs en enkel utvidgning av en modell med rationella förväntningar, så att modellen även gäller för marknader med säkerhetskrav och påtvingad säkerhetslikvidering. Därefter analyserar vi volatiliteten i jämviktspriset då säkerhetsbestämmelserna ändras. Om välinformerade placerare i utgångsläget hämmas av bestämmelser om höga säkerhetsmarginaler kommer en sänkning att höja marknadens likviditet och prisinformativitet. Detta fortsätter att gälla även då både informerade placerare och sådana aktörer som handlar utgående från tekniska signaler ökar sina positioner med lägre säkerhetsmarginal. Volatiliteten tenderar att sjunka om ingen påtvingad säkerhetslikvidering förekommer eller ifall placerarna vet när det är fråga om sådan försäljning.

Volatiliteten ökar betydligt endast i det extrema fallet att alla investerare är okunniga om påtvingad säkerhetslikvidering och istället tror att denna försäljning beror på överlägsen information. Detta leder till låg marknadslikviditet och gör krascher möjliga.

Vår analys utmynnar i en stark rekommendation: inför låga säkerhetsmarginaler parat med bästa möjliga data om mängden potentiell, påtvingad likvidering. Kan sådan information göras lättåtkomlig för placerarna kan fördelarna av större likviditet pga. lägre säkerhetsmarginal uppnås samtidigt som effekten på marknadens volatilitet blir minimal.

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