Mixed Manipulation Strategies in Commodity Futures Markets

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INTRODUCTION

Section 5 of the Commodity Exchange Act (CEA) proscribes manipulation and requires exchanges to take extensive precautions to deter it. Moreover, the Commodity Futures Trading Commission expends considerable resources on surveillance of trading activities to attempt to identify potential manipulative situations. In addition, many restrictions on trader activities—most notably position limits—are intended at least in part to deter manipulation.

This extensive regulation is predicated on a belief that futures markets are inherently vulnerable to the exercise of market power. This view is expressed clearly in the Senate Report on the bill reauthorizing the CFTC in 1977. This report states that the anti-manipulation provisions in the CEA were "based on conclusions by Congress that . . . *[futures] transactions are susceptible to manipulation and control*, and may generate sudden and unreasonable price fluctuations, and . . . such fluctuations are a burden on interstate commerce." (Emphasis added.)

Although historical evidence from the period preceding the passage of Federal commodity laws strongly suggests that manipulation is a potential policy concern, such categorical assertions that manipulation would be rife in futures markets absent regulation are largely

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unsupported by theory or evidence. Given that anti-manipulation regulations can demoralize legitimate trading activity, government intervention premised on the view that corners are chronic in unregulated markets could impose appreciable costs on market users without providing a larger benefit in return.

A more balanced evaluation of the vulnerability of modern futures markets to manipulation requires a clear understanding of (a) how manipulation can occur in equilibrium, and (b) what determines the severity and frequency of corners. The first issue is important because it is by no means a trivial task to acquire market power from intelligent traders alive to the possibility of a squeeze. The second issue is fundamental to the determination of the potential benefits of alternative means of deterring manipulation.

The existing literature does not address these issues in a satisfactory way. The model of Kyle (1984) derives sufficient conditions for manipulation to occur in equilibrium, but these conditions are so restrictive that they cannot explain how a corner or squeeze occurred in any actual market. For example, the Kyle model seems incapable of explaining how traders were able to corner periodically the grain and cotton markets in the 19th and early 20th centuries. In contrast, the model of Jarrow (1992) suggests that manipulation should almost always occur. His model cannot explain why so many markets are *not* cornered. Moreover, neither model provides much insight regarding the factors that determine the degree to which a market is vulnerable to manipulation.

The third, fourth, and fifth sections of this article present a formal model that sheds light on each of these issues. The model demonstrates that two conditions are sufficient for manipulation to occur in equilibrium. First, in the model, the flow of orders for execution on the trading floor is random. That is, there are "noise traders." Second, the supply curve in the delivery market is upward sloping. Given these conditions, a trader with sufficiently large capital can utilize a randomized trading strategy to amass a position that allows him to corner the market with positive probability. The increasing marginal cost of delivery makes squeezing the market profitable if a trader holds a large enough position, whereas the variability of the order flow provides the camouflage necessary for him to acquire from time to time such a large position at a price sufficiently low to make this strategy profitable.

It is important to note that although the model implies that the probability of manipulation is positive, it does *not* imply that this probability is large. A simulation analysis in the sixth section of the article demonstrates that this probability depends upon the variance of the order flow and the elasticities of supply and demand in the delivery market. The probability of manipulation is small if the net order flow varies little and/or if supply in the delivery market is very elastic. Thus, futures markets are not uniformly vulnerable to manipulation.

It must also be recognized that although the formal model focuses on some important features of futures markets, it necessarily abstracts from other factors that influence the profitability of manipulation. The seventh section of the article shows that if market makers or commercial traders have sources of information in addition to the order flow, or if the short side of a market is sometimes concentrated, the profitability of manipulation is less than what the article's formal model predicts.

LITERATURE REVIEW

The fundamental problem confronting any would-be manipulator is: How can he induce other traders (who are alive to the prospect of a potential corner) to sell contracts to him at a price low enough to allow him to squeeze the market and earn a profit in the process? Three models have attempted to answer this question. For a variety of reasons, however, each of these models fails to explain some important stylized facts about manipulation.

Kyle's (1984) theory represents the most rigorous attempt to date to show how manipulation can occur in equilibrium.[1] In Kyle's model a trader with superior information about the futures market order flow from hedgers exploits this advantage by amassing a large long position (which allows him to squeeze the market at delivery) when hedgers sell large numbers of contracts. Hedgers and other traders, who can only observe the combined hedger-informed trader order flow, cannot detect his presence in the market. They therefore sell at a price that on average is below the spot price that prevails at expiration in the event of a squeeze. Thus, the informed trader earns a profit, and manipulation occurs in equilibrium in Kyle's model.

Although the model is quite elegant, the sufficient condition for manipulation that drives this result is very restrictive; a trader must have superior information on hedger order flow. It is quite doubtful whether this condition obtains in practice, given the great lengths to which traders go to conceal their activities, and the large numbers

[1]The model of Vila (1988) is very similar to Kyle's. Most importantly, Vila's manipulator also observes the hedger order flow.

of hedgers and speculators present in most markets. Thus, this model cannot explain how the historical manipulations in the grain and cotton markets chronicled by Taylor (1917), Andreas (1887), and Bouilly (1973) occurred. Moreover, the very stylized model of the costs of delivery makes it difficult to determine how the susceptibility of a market to manipulation varies with cash market characteristics.

Jarrow (1992) also presents a model in which manipulation occurs in equilibrium. He argues that a large trader that acquires a long position in a derivative security and the security deliverable against the derivative that is larger than the total deliverable supply can profitably squeeze shorts by forcing them to settle their positions at an arbitrarily high price. Jarrow proves that if the large long can indeed specify any settlement price he chooses, he can always profitably corner and squeeze the market (with no risk of a financial loss) *regardless of the price generating process prior to the delivery period.*

This theory presents some rather serious problems. Most importantly, it seems to explain too much. If a large trader can always manipulate the market by simply buying a large position and then charging an arbitrarily high price to ensure that he can liquidate this position at a profit, why doesn't manipulation occur more frequently? Thus, the Jarrow theory cannot explain the relative rarity of corners, even during their heyday in the late 19th century.

The reason manipulations do not always occur (even in the absence of regulatory or legal impediments to this practice) is clear: Jarrow's assumption that a large long trader can force shorts to settle at an arbitrarily high price is clearly wrong. In the context of a physical commodity market, in almost all circumstances additional supplies can be brought to the delivery market at finite cost, and this cost places an upper bound upon the price a manipulator can extract. See Pirrong (1993) for a detailed analysis of the determinants of the marginal cost of augmenting deliverable supplies. Even if a trader accumulates claims that exceed the total supply of a commodity or security, however, the price he can squeeze from shorts is limited by their ability to default against their obligations to deliver. At most, the manipulator can extract all his (finite) wealth. As long as such an upper bound on the price a manipulator can set exists, Jarrow's result no longer holds for an arbitrary equilibrium price process even if this upper bound is very large.

Finally, in the context of a structural noise trader model in the spirit of Kyle (1985), Kumar and Seppi (1992) demonstrate that manipulation can occur in a cash-settled futures contract. This theory does not specify a model of market clearing via delivery, and therefore it cannot explain how squeezes and corners occur in equilibrium. It does contain a key insight, however, that can be used to construct a model in which a delivery settled contract is manipulated. Specifically, Kumar and Seppi show that if order flow in the futures and cash markets is unpredictable, randomized trading may allow an individual to obtain a futures position that permits him to manipulate profitability the cash market at the expiration date of the futures contract. This sort of trading is especially profitable if the manipulator's wealth is unpredictable, as this adds an additional element of noise to the problem facing market makers.

Although the Kumar–Seppi theory is not directly applicable to delivery settled markets, the models in the fourth and fifth sections demonstrate that a different sort of randomization strategy is profitable in this case as well. To demonstrate this result, it is first necessary to specify models of (a) the price determination process during the delivery period, and (b) the futures trading process prior to the delivery period. This is the subject of the next section.

A MODEL OF FUTURES TRADING

Consider the following simple model of a futures market. At time t traders can negotiate futures contracts that expire at $T > t$. The futures contract is delivery settled. Traders may therefore exit their positions at T either via delivery, or by taking an offsetting position in the futures market.

As in the insider-trading model of Kyle (1985) both noise traders and market makers participate in the t period futures market. Noise traders are either hedgers or speculators, and are uniformed and atomistic. They trade by submitting market orders to the floor of the exchange at t. The net order flow from the noise traders equals η, where η is a random variable with probability density $\phi(\eta)$. Market makers observe the order flow, act as perfect competitors, and absorb the net order flow at a price equal to the price expected to prevail at T, where the expectation is conditional upon the order flow. In addition to the noise traders and market makers, there is a large risk neutral trader—trader 1—who can buy or sell an arbitrarily large quantity of contracts at his discretion.

Conditions in the market at T are as follows. Stocks of the commodity at the delivery point equal $q_D^*(\tilde{\Theta})$, where $\tilde{\Theta}$ is a vector of parameters that affect supply and demand conditions. At time t traders do not necessarily observe $\tilde{\Theta}$, although they do observe these parameters at T. Thus, at t there may be some uncertainty about supply and demand conditions at T.

The demand curve in the delivery market at T is $P_D(q, \tilde{\Theta})$ where q is the quantity of stocks on hand there, and $\partial P_D(q, \tilde{\Theta})/\partial q < 0$. The marginal cost of increasing deliverable stocks to $Q \geq q_D^*(\tilde{\Theta})$ equals $MC(Q, \tilde{\Theta})$, where $MC(Q, \tilde{\Theta}) > P_D(q_D^*, \tilde{\Theta})$ and $\partial MC(Q, \tilde{\Theta})/\partial Q > 0$.

The delivery market conditions at T satisfy the necessary conditions for a long manipulation derived in Pirrong (1993).[2] In particular, the increasing marginal cost of delivery implies that if trader 1 acquires a futures position of size $X > q_D^*(\tilde{\Theta})$ and demands delivery of $Q \geq q_D^*(\tilde{\Theta})$ contracts, atomistic shorts are willing to pay a price equal to $MC(Q, \tilde{\Theta}) > P_D(q_D^*, \tilde{\Theta})$ to liquidate their remaining $X - Q$ positions. This is true because any short that does not liquidate must pay the marginal cost of delivery to satisfy his contractual obligations, and is therefore willing to pay any price less than or equal to that marginal cost to close his position by off-set. These consideration simply that the large trader can force an artificially high liquidation price at contract expiration, and may therefore be able to manipulate profitably.

It is important to note that $X > q_D^*(\tilde{\Theta})$ is *not* a sufficient condition for manipulation to occur due to the so-called "burying the corpse" effect. When a trader takes delivery of $Q > q_D^*(\tilde{\Theta})$ units of the commodity, stocks in the delivery market rise and post-delivery spot price (i.e., the price at $T + dt$) in that market falls due to the inflation in stocks. The manipulator sells the units delivered to him at this depressed price. Thus, the large long sells these units at a price lower than the competitive price in the market, $P_D(q_D^*, \tilde{\Theta})$. Unless the long liquidates enough contracts at the elevated price $MC(Q, \tilde{\Theta})$ the losses he incurs when "burying the corpse" exceed the profits he realizes from the contracts he sells to shorts. Trader 1 must own, therefore, some minimum futures position

[2] Pirrong (1993) also shows that short manipulation may also occur in spatial commodity markets. In a short manipulation, a trader sells a large number of futures contracts, then brings excessive supplies to the delivery point. This depresses the price there, which allows the manipulator to repurchase his futures position at an artificially low price.
To simplify the analysis, it is assumed that traders cannot employ such short manipulation strategies to force the delivery market price at T be low the competitive price, $P_D(q_D^*)$. Ruling out short manipulations does not alter dramatically the implications of the analysis. Giving trader 1 more options to distort the market must make him better off; thus, since the model shows that he earns a positive profit when only long manipulations are permitted, his profit would be even larger if short manipulation were possible as well. Moreover, Pirrong (1993) shows that the conditions that increase the profitability of long manipulation reduce the profitability of short manipulation. One form of manipulation is therefore likely to dominate in practice. Casual empiricism strongly suggests that long manipulation is far more common than its short cousin, so attention is focused on the more prevalent form of conduct.

$X_{\min}(\tilde{\Theta}) > q_D^*(\tilde{\Theta})$ to make manipulation profitable. For any such X, the revenues from restricting liquidations exceed $XP_D(q_D^*, \tilde{\Theta})$ because a trader can earn this revenue by liquidating his entire position at the competitive price. (The simulation analysis in the sixth section provides a simple example of the determination of $X_{\min}$, and how it depends upon supply and demand conditions.)

Formally, when trader 1 buys X futures contracts at t, at T he chooses Q to maximize:

$$R(Q, \tilde{\Theta}) \equiv (X - Q)MC(Q, \tilde{\Theta}) + QP_D(Q, \tilde{\Theta}) < XMC(Q, \tilde{\Theta}) \qquad (1)$$

The first term on the right-hand side equals the long's revenues from liquidating $X - Q$ contracts. The second term equals the long's receipts from sale of the Q units delivered to him. The inequality holds because $MC(Q, \tilde{\Theta}) > P_D(Q, \tilde{\Theta})$ due to the burying the corpse effect. Maximization of this expression defines an implicit function $Q(X, \tilde{\Theta})$, where $Q(X, \tilde{\Theta}) > q_D^*(\tilde{\Theta})$ for all $X > X_{\min}(\tilde{\Theta})$, and $Q(X, \tilde{\Theta}) = 0$ otherwise. This function reports the number of deliveries the manipulator accepts to maximize his profit, given the size of his position.[3]

The foregoing implies that the delivery market price at contract expiration—and hence the futures price at T—equals $P_D(q_D^*(\tilde{\Theta}), \tilde{\Theta})$ if trader 1 has acquired less than $X_{\min}(\tilde{\Theta})$ units of the commodity. Conversely, if he purchases $X > X_{\min}(\tilde{\Theta})$ units at t, the price at T equals $MC(Q(X, \tilde{\Theta}), \tilde{\Theta}) \equiv MC(X, \tilde{\Theta}) > P_D(q_D^*(\tilde{\Theta}), \tilde{\Theta})$.

Recall that at t, traders may not know $\tilde{\Theta}$. Thus, at this time they must make decisions on the basis of expectations about these supply and demand parameters. Define $MC^*(X) = E_{\tilde{\Theta}} MC(X, \tilde{\Theta})$ conditional on information available at t. Similarly, $R^*(X) = E_{\tilde{\Theta}} R(X, \tilde{\Theta})$, and $P_D^*(X) = E_{\tilde{\Theta}} P_D^*(X, \tilde{\Theta})$. Both expectations are conditional on information available at t. For simplicity, assume that all parties have access to the same information about $\tilde{\Theta}$ as of t.

Since the price at T varies with the size of trader 1's position, the price at t must depend upon the market makers' information concerning the size of trader 1's order. The order flow may communicate some

[3]It may be the case that the manipulator does not know $\tilde{\Theta}$ at T. In this case, he maximizes his expected revenue, conditional upon his information about the supply and demand parameters. Uncertainty about $\tilde{\Theta}$ at T can explain a phenomenon sometimes observed in actual corner attempts, namely the collapse of a manipulation caused by an unexpected avalanche of deliveries. If the large long under-estimates the elasticity of supply in the delivery market and demands too high a price to liquidate, shorts may deliver far more than he expects. This can impose ruinous losses upon the long. The spectacular failure of a wheat corner attempted in 1872 may represent one prominent example of this phenomenon. [See Taylor (1917), vol. 2.] The results of the models derived in the fifth and sixth sections still hold even in the case where trader 1 does not know $\tilde{\Theta}$ for certain at T.

information about his trading activity, and since market makers observe the order flow, they charge a price equal to the expected price at T conditional upon the realization of this variable. The following sections show that if the order flow varies randomly, market makers are unable to detect reliably the presence of a large trader. Therefore, an agent employing a randomized trading strategy may be able to acquire a large position and earn a positive expected profit by squeezing the market.

A SIMULTANEOUS MOVE MANIPULATION MODEL

It is clear that if trader 1 chooses a pure trading strategy, he earns a negative profit with certainty. To see why, assume he purchases $X^* > X_{\min}(\tilde{\Theta}_1)$ contracts with probability 1 by entering market orders where $\tilde{\Theta}_1$ is some value of $\tilde{\Theta}$ that is realized with positive probability at T. Although market makers cannot identify his particular order, if it is known that he is following this strategy, the equilibrium futures price equals $MC^*(X^*)$. This is true because market makers know with certainty that this is the price that will prevail at T. The cost of buying X^* contracts therefore equals $X^*MC^*(X^*) > R^*(X^*)$. The inequality follows from taking expectations over $\tilde{\Theta}$ on both sides of (1). Therefore, trader 1 expects to lose money if he employs a pure strategy of buying contracts; he can do better by staying out of the market altogether.

Since pure strategies are unprofitable, any manipulator must use mixed strategies. This section and the one following shows that under certain conditions, such mixed strategies are profitable on average, and result in corners with positive probability.

The model in this section assumes that trader 1 and the market makers choose their strategies simultaneously. The primary difference between this simultaneous-move model and the sequential model discussed in the next section is that in the latter, trader 1 recognizes how the market makers' price function responds to his choice of trading probabilities, and incorporates this response into his maximization problem. In the simultaneous-move model, trader 1 takes the market makers' price function as given. Thus, the essential distinction between simultaneous and sequential models is the information possessed by the market makers; the labeling of the models is standard terminology from game theory. The models are complementary in that some results are easier to demonstrate within the context of the simultaneous model, while others are best shown in the sequential model.

In the simultaneous model, trader 1 chooses a function $h(x)$ which gives the probability that he will trade x contracts at t, with $h(x) \geq 0$ for all x and $\int_{-\infty}^{\infty} h(x)\,dx = 1$. The trader can sell contracts; $x < 0$ represents such a sale. Simultaneously with trader 1's choice of $h(.)$, market makers choose a pricing function $P(y)$ which gives the price they charge as a function of the net order flow at t.

The functions $h^*(x)$ and $P^*(y)$ are Nash equilibrium strategies if and only if:

1. Given $P^*(y), h^*(x)$ is the choice of $h(x)$ that maximizes trader 1's expected profit, which is given by the function:

$$E(\Pi) = \int_{-\infty}^{\infty}\left[R^*(x) - x\int_{-\infty}^{\infty} P^*(x + \eta)\phi(\eta)d\eta\right]h(x)\,dx$$

and

2. Given $h^*(x), P^*(y)$ satisfies:

$$P^*(y) = E_x(MC^*(x)\,|\,y = x + \eta) = \int_{-\infty}^{\infty} MC^*(x)g(x\,|\,y)\,dx \qquad (2)$$

where by Bayes' rule the probability of x conditional on y equals:

$$g(x\,|\,y) = \frac{\phi(y - x)h^*(x)}{\phi(y - x)h^*(x) + \int_{z \neq x} \phi(y - z)h^*(z)\,dz}$$

Condition 1 states that given the pricing function the market makers choose, trader 1 chooses his probability function to maximize expected profit. Condition 2 states that given trader 1's choice of $h^*(x)$, competition among market makers ensures that the futures price equals the expected spot price at expiration, where the expectation is conditional on the order flow and on the information about $\tilde{\Theta}$ available at t.

The following propositions demonstrate that manipulation occurs with positive probability in the simultaneous move model, and that the manipulator earns a positive expected profit by employing a mixed strategy.

Proposition 1. *Assume that the distribution of η is continuous with infinite support. In equilibrium,* $h^*(x) > 0$ *for some* $x > X_{min}(\tilde{\Theta}_1)$, *where* $\tilde{\Theta} = \tilde{\Theta}_1$ *at* T *with positive probability.*

Proof. The proof is by contradiction. Assume that $h^*(x) = 0$ for all $x > X_{min}(\tilde{\Theta})$ for all realizations of $\tilde{\Theta}$. Given such an $h^*(.)$ function, by (4), $P^*(y) = P_D^*(0)$ for all y, where $P_D^*(0)$ is the expected price at T if no manipulation occurs. Given such a choice of $P^*(y)$, however, trader 1 chooses an arbitrarily large $x > X_{\min}(\tilde{\Theta}_1)$ with probability 1. This is true because he can purchase as much as he wants at the expected competitive price, and still profitably squeeze the market with positive probability. Thus, by contradiction, $h^*(x) = 0$ for all $x > X_{\min}(\Theta)$ for all Θ cannot be an equilibrium. Q.E.D.

The foregoing result demonstrates that manipulation must occur in equilibrium of the simultaneous move game. That is, $h^*(x) > 0$ for some $x > X_{\min}(\tilde{\Theta}_1)$ is a necessary condition of an equilibrium. Thus, corners and squeezes must occur with positive probability in equilibrium. The following proposition demonstrates, moreover, that trader 1 earns a strictly positive expected profit in this equilibrium.

Proposition 2. *In equilibrium,* $E(\Pi) = k > 0$.

Proof. In a mixed strategy equilibrium trader 1 earns the same profit for any x such that $h^*(x) > 0$. That is, for all such x, trader 1 earns a profit equal to k. Thus,

$$k = R^*(x) - x\int_{-\infty}^{\infty} P^*(x + \eta)\phi(\eta)\,d\eta$$

for all such x. For any x'' such that $h^*(x'') = 0$,

$$k > R^*(x'') - x\int_{-\infty}^{\infty} P^*(x'' + \eta)\phi(\eta)\,d\eta$$

Thus, if $\pi(x)$ equals the large long's profit when he chooses x, $k \geq \pi(x)$ for all x.

Note that for some $x' < 0$, $k \geq \pi(x')$ and $R^*(x') = x'P_D^*(0) < 0$. Moreover, since by Proposition 1 $h^*(x) > 0$ for some $x > X_{\min}(\tilde{\Theta}_1)$, $P^*(y) > P_D^*(0)$ for all y. Therefore, $\overline{P} \equiv \int_{-\infty}^{\infty} P^*(x' + \eta)\phi(\eta)\,d\eta > P_D^*(0)$. Consequently,

$$k \geq R^*(x') - x'\int_{-\infty}^{\infty} P^*(x' + \eta)\phi(\eta)\,d\eta = x'(P_D^*(0) - \overline{P}) > 0$$

for $x' < 0$. Since the manipulator earns this profit for all x such that $h^*(x) > 0$, his expected profit equals k and is, therefore, positive. Q.E.D.

Together these propositions demonstrate that mixed manipulative trading is profitable *on average*, and corners and squeezes occur in equilibrium. This does not imply that trader 1 earns a positive profit regardless of the value of η. If η is a large positive number, $R^*(x)$ may be smaller that $xP^*(x + \eta)$. For such a realization of η, which occurs with positive probability, the large long loses money. Similarly, for a given η, trader 1 may experience an unfavorable draw of $\tilde{\Theta}$ at T. Given such an unfavorable draw, $R(x, \tilde{\Theta}) < xP^*(x + \eta)$. The manipulator, however, does earn a positive profit on average; thus, the profitable manipulative episodes more than off-set the unprofitable ones.

It should be noted that Proposition 1 continues to hold even if there are several large traders acting strategically. That is, the validity of these propositions is not limited to the case where there is a single manipulator. This can be demonstrated easily by using the logic of the proof of Proposition 1. Specifically, if there are several large traders, it cannot be an equilibrium for all of them to choose $h(x) = 0$ for $x > X_{\min}(\tilde{\Theta})$, for all possible $\tilde{\Theta}$, as a profit opportunity would be present in this case. Thus, although entry of large traders may dissipate the profits earned by manipulators, this does not imply that entry eliminates corners altogether.

Several results flow from this basic model. The first result characterizes the manipulator's trading activities. Specifically:

Result 1. Trader 1 sells contracts with positive probability in equilibrium.

To prove this result by contradiction, assume for all $x > 0$ such that $h(x) > 0$,

$$k = R^*(x) - x \int_{-\infty}^{\infty} P^*(x + \eta)\phi(\eta)\, d\eta$$

while for all $x' < 0$, $h(x') = 0$. Therefore, for such x',

$$k > R^*(x') - x' \int_{-\infty}^{\infty} P^*(x' + \eta)\phi(\eta)\, d\eta$$

Assume that $\hat{x}$ is the smallest x such that $h(x) > 0$. Therefore, in equilibrium, $P^*(y) \geq MC^*(\hat{x}) \geq P_D^*(0)$ for all y, with $P^*(y) > MC^*(\hat{x})$ for some y. Given such a $P^*(y)$, however, trader 1 can earn an expected profit greater than k by *selling* $\hat{x}$, contracts, i.e., by choosing $x = -\hat{x} < 0$. To see why, note that by doing so he earns a profit equal to

$$\begin{aligned} \hat{x}EP_{\eta}^*(\eta - \hat{x}) - P_D^*(q_D^*)\hat{x} > \hat{x}MC^*(\hat{x}) - \hat{x}P_D^*(q_D^*) > \\ \hat{x}MC^*(\hat{x}) - \hat{x}E_{\eta}P^*(\eta + \hat{x}) > \\ R^*(\hat{x}) - \hat{x}EP^*(\eta + \hat{x}) = k \end{aligned}$$

Thus, $h(-\hat{x}) = 0$ cannot be an equilibrium strategy. By contradiction, this implies that in equilibrium the trader 1 must *sell* contracts with positive probability.

The foregoing result implies that manipulators should both buy and sell futures contracts, and do so in an unpredictable fashion. Historical descriptions of the activities of famous manipulators (such as Thomas "Old Hutch" Hutchinson at the Chicago Board of Trade and Arthur Patten on that exchange and the New York Cotton Exchange) are consistent with the behavior predicted by the model. In particular, as Taylor (1917) and Kolb and Spiller (1990) note, these men traded erratically and unpredictably. Sometimes they bought contracts, and sometimes they sold them. Other traders tried to ascertain the activities of these "plungers," but their ability to trade actively and secretly in the tumult of the grain and cotton pits allowed them to change direction and manipulate successfully with some frequency.

The other two results pertain to the effects of mixed manipulative strategies on the depth of the futures market and the informativeness of futures prices.

Result 2. Mixed manipulative strategies reduce market depth.

In the absence of manipulation and asymmetrically informed trading in the model, the futures market is infinitely deep. That is, the price in the futures market does not depend upon the size of the order flow. If traders can employ mixed manipulative strategies, however, this is no longer true. To see why, take the derivative of the first order condition

$$k = R^*(x) - x\int_{-\infty}^{\infty} P^*(x + \eta)\phi(\eta)\,d\eta$$

with respect to x. This produces:

$$0 = MC^*(x) - \int_{-\infty}^{\infty} P^*(x + \eta)\phi(\eta)\,d\eta - x\int_{-\infty}^{\infty} \frac{dP^*(x + \eta)}{dx}\phi(\eta)\,d\eta$$

This equation holds because the envelope theorem applied to (1) implies $R_x(x, \tilde{\Theta}) = MC(x, \tilde{\Theta})$ for all realizations of $\tilde{\Theta}$. Thus for all x

$$x\int_{-\infty}^{\infty} \frac{dP^*(x + \eta)}{dx}\phi(\eta)\,d\eta = MC^*(x) - \int_{-\infty}^{\infty} P^*(x + \eta)\phi(\eta)\,d\eta$$

Take $x > 0$. (A similar argument holds for $x < 0$.) The right-hand side of this expression is strictly positive because $xMC^*(x) > R^*(x) = k + xEP(\eta + x) > 0$. Thus, the left-hand side is positive as well. For positive x, this implies:

$$\int_{-\infty}^{\infty} \frac{dP^*(x + \eta)}{dx}\phi(\eta)\,d\eta > 0 \tag{3}$$

This must be true for all x. Expression (3) can be rewritten as

$$\int_{-\infty}^{\infty} \frac{dP^*(y)}{dy}\phi(y - x)\,dy > 0 \tag{4}$$

Since $\phi(y - x) > 0$ for all y and x, (4) states that the expected change in the futures price at t that results from a small, positive (dy) increase in the observed order flow is positive for all x. Since noise traders and the manipulator do not know what the actual order flow will be when they submit their orders for execution at t, this means that they pay a higher price on average, the larger the net order flow. Thus, buyers anticipate that they will lose if order flow is an unusually large positive number, while sellers anticipate that they will lose if order flow is an unusually large negative number. Put another way, the market is no longer infinitely deep when a trader employs a mixed manipulation strategy.

Result 3. Mixed manipulative strategies reduce the informativeness of the futures price.

In the absence of manipulation, the futures price at t equals $E_{\tilde{\Theta}} P_D(\tilde{\Theta})$. Thus, uninformed individuals can infer information about $\tilde{\Theta}$ (i.e., about fundamental supply and demand conditions) by observing the futures price. When manipulation can occur, however, the futures price equals $E_{\tilde{\Theta},\eta,X}[P_D(\tilde{\Theta}) + \epsilon(\tilde{\Theta}, \eta, X)]$, where $\epsilon(.,.,.)$ is the manipulative price premium at t. Since η and X are random variables, the distribution of $\tilde{\Theta}$ conditional on $E_{\tilde{\Theta},\eta,x}[P_D(\tilde{\Theta}) + \epsilon(\tilde{\Theta}, \eta, x)]$ and $E_{\tilde{\Theta}} P_D(\tilde{\Theta})$ does not depend upon $E_{\tilde{\Theta},\eta,x}[P_D(\tilde{\Theta}) + \epsilon(\tilde{\Theta}, \eta, x)]$. That is, the manipulable futures price is noisier than the non-manipulable futures price. Therefore, the futures price is a less informative signal of $\tilde{\Theta}$ when manipulation can occur than when it cannot.

A SEQUENTIAL MOVE MANIPULATION MODEL

This section demonstrates that mixed manipulative strategies are profitable even if market makers choose their pricing strategies *after* observing trader 1's trading strategy as long as they do not observe his actual trade. This alternative model is useful for two reasons. First, it demonstrates that mixed manipulative equilibria are robust to assumptions about the information possessed by market makers. Second, given some simplifying assumptions, it is possible to simulate the optimal strategy in the sequential model, whereas this is not feasible in the simultaneous move set-up. This permits an analysis of the comparative statics results. This exercise is carried out in the following section.

In this model, trader 1's strategy specifies a function $f(x)$, where he purchases x contracts at t with probability $f(x)$. As before, $x < 0$ represents a sale of contracts. Since $f(x)$ is a probability function,

$f(x) \geq 0$ for all x, and $\int_{-\infty}^{\infty} f(x)\,dx = 1$. In the sequential model, trader 1 chooses $f(x)$ first. Competitive Bayesian market makers know this function, and observe a net order flow of y. Given this information, they choose a price equal to:

$$P_F(y) = E_x(MC^*(x) \mid y = x + \eta) = \int_{-\infty}^{\infty} MC^*(x) g(x \mid y)\,dx \qquad (5)$$

where, by Bayes' rule,

$$g(x \mid y) = \frac{\phi(y - x) f(x)}{\phi(y - x) f(x) + \int_{z \neq x} \phi(y - z) f(z)\,dz}$$

Given this response by market makers, trader 1 earns the following expected profit when he selects strategy $f(x)$:

$$E(\Pi) \equiv \int_{-\infty}^{\infty} [R^*(x) - xE_\eta(P_F(x + \eta))] f(x)\,dx$$

The first term inside the brackets equals trader 1's revenues at T, given that he acquires x contracts at t. The second term gives the cost he expects to pay for these x positions. This cost is uncertain because by (5) the price market makers actually charge depends upon the realization of η, which occurs after trader 1 submits his market order.

An examination of (5) reveals that it is possible that the market makers may underestimate the true probability of a manipulation and charge trader 1 a price below $MC(Q(X))$ when he purchases X contracts. Proposition 3 proves that this allows him to squeeze the market profitably.

Proposition 3. *Assume the distribution of η is continuous with infinite support. Then there exists a function* f(.), *where trader* 1 *purchases* x *contracts with probability* f(x), *such that* (a) *he manipulates at* T *with positive probability* (i.e., $\int_{X_{\min}(\tilde{\Theta}_1)}^{\infty} f(x)\,dx > 0$ *for some value of* $\tilde{\Theta}_1$ *that is realized with positive probability*), *and* (b) *he earns a positive* expected *profit* (*i.e.*, $E(\Pi) > 0$).

Proof. Assume that trader 1 submits a market order equal to $X^* > X_{\min}(\tilde{\Theta}_1)$ with probability p and submits no order with probability $1 - p$. Thus, $f(X^*) = p$ while $f(x) = 0$ for $x \neq X^*$. If the noise trader order flow equals η, the price trader 1 pays when he trades x contracts equals the expected price at T, conditional on $y = X + \eta$. Given this $f(x)$

and y, the futures price equals:

$$P_F(y) = \frac{MC^*(X^*)p\phi(y - X^*)}{p\phi(y - X^*) + (1 - p)\int_{-\infty}^{\infty} \phi(y - x)\,dx} + P_D^*(0)\left[1 - \frac{p\phi(y - X^*)}{p\phi(y - X^*) + (1 - p)\int_{-\infty}^{\infty} \phi(y - x)\,dx}\right] \quad (6)$$

Given this extremely naive strategy, trader 1's expected profit equals:

$$E(\Pi(X^*, p)) = (1 - p)\cdot 0 + p\int_{-\infty}^{\infty}[R^*(X^*) - X^*P_F(\eta + X^*)] \cdot \phi(\eta)\,d\eta$$

Consider the bracketed term $[R(X^*) - X^*P_F(\eta + X^*)]$. In the sequential game, trader 1 recognizes that his choice of p affects the $P_F(.)$ function. Note that $P_F(y)$ is continuous and increasing in p, and that given the restrictions on the order flow

$$\lim_{p \to 0} P_F(y) = P_D^*(0)$$

Moreover, $R^*(X^*) > P_D^*(0)X^*$ since $X^* > X_{\min}(\tilde{\Theta})$ with positive probability. Thus, for all η there exists a $p > 0$ such that $R^*(X^*) - X^*P_F(\eta + X^*) > 0$. This implies that there exists a $p > 0$ such that $E(\Pi(X^*, p)) > 0$. This strategy dominates any trading plan in which $X \le X_{\min}(\tilde{\Theta})$ for all possible realizations of $\tilde{\Theta}$, as the latter strategy generates zero profits. This implies that there exists at least one mixed strategy such that manipulation occurs in equilibrium. Q.E.D.

A SIMULATION ANALYSIS OF COMPARATIVE STATICS

The comparative statics of the mixed strategy manipulation model are of considerable importance, because they identify the factors which determine a contract's susceptibility to corners. Unfortunately, because of the complexity of the problem, it is intractable to determine these results in closed form. However, given some simplifying assumptions, a simulation analysis of the sequential choice model shows how the profitability and frequency of manipulation depend upon underlying structural parameters. These include the variance of the net order flow and the elasticities of supply and demand at the delivery point.

For simplicity it is assumed in this simulation that there is no uncertainty at t; all traders know $\tilde{\Theta}$ at that time. Moreover, the marginal cost of delivery and demand functions are assumed linear. Formally,

$$MC(Q) = \theta + \delta Q$$

and

$$P_D(Q) = \alpha - \beta Q$$

Given these functions, the optimal competitive quantity in the delivery market equates the marginal cost of delivery to the marginal value of the commodity. Thus, q_D^* solves

$$P_D(q_D^*) = \alpha - \beta q_D^* = \theta - \delta q_D^* = MC(q_D^*)$$

This implies:

$$q_D^* = \frac{\alpha - \theta}{\beta + \delta}$$

The marginal cost and demand parameters also determine the potential manipulator's optimal strategy at time T. Assume that this trader has amassed X long futures contracts. Applying (1) at T he chooses Q to maximize

$$[\theta - \delta Q][X - Q] + Q[\alpha - \beta Q]$$

Solving the relevant first order conditions implies:

$$Q = \frac{\delta X + \alpha - \theta}{2(\beta + \delta)} \tag{7}$$

For manipulation to be profitable, it must be the case that $Q \geq q_D^*$. If the large trader accepts fewer than q_D^* deliveries, he cannot elevate the price above the competitive level $P_D(q_D^*)$. Since (7) implies that Q is increasing in X, profitable manipulation at T therefore requires

$$\frac{\delta X + \alpha - \theta}{2(\beta + \delta)} \geq \frac{\alpha - \theta}{\beta + \delta} \tag{8}$$

The smallest X that satisfies this condition is $X_{\min}$. Solving (8) implies that

$$X_{\min} = \frac{\alpha - \theta}{\delta} = q_D^* \frac{\beta + \delta}{\delta}$$

Thus, $X_{\min}$ increases relative to q_D^* if demand at the delivery point becomes less elastic (i.e., as β increases), or if the marginal cost of delivery becomes more elastic (i.e., as δ decreases). In the simulations, these parameters are varied to determine how the profitability and frequency of manipulation depend upon the supply and demand conditions in the delivery market.

It is assumed that the net noise trader order flow is normal. The standard deviation of the distribution equals σ. This parameter is varied in the simulations to determine how the profitability and frequency of manipulation depends upon the variability of the order flow.

The most important simplifying assumption in the simulation analysis is that at t the manipulator can trade n different quantities of contracts X_i, where n is finite. That is, in contrast to the theoretical analysis of the preceding sections, where the manipulator has an infinite number of possible choices at t, in this section it is assumed that the number of possible trades is finite. This assumption is necessary to make simulation feasible. Simulations are executed for values of n ranging between 6 and 20; the upper bound is dictated by computational costs. The comparative statics results reported here are robust to changes in n.

Formally, at t trader 1 chooses $\{p_i\}_{i=1}^{i=n}$ to maximize his expected profit, where p_i is the probability that he trades X_i contracts at t, and where $\sum_{i=1}^{n} p_i = 1$. The X_i are both positive and negative, and are distributed at equal intervals along a line segment $[u, l]$. The parameters u and l are determined by experimentation so that the simulated profit maximizing strategy puts zero weight on these extreme points for all values of σ used. This is intended to ensure that the range of feasible choices available to the simulated manipulation is not artificially bounded.

Given the choices of $u, l, \sigma, \alpha, \beta, \theta, \delta$, and the X_i, the non-linear programming software MINOS 5.0 and a SUN workstation are used to solve for the $\{p_i\}_{i=1}^{i=n}$ that maximizes

$$E(\Pi) = \sum_{i=1}^{n} p_i[R(X_i) - E_\eta P_F(X_i + \eta)] \tag{9}$$

where

$$P_F(X_i + \eta) = \sum_{j=1}^{n} \frac{MC(X_j)p_j\phi(X_i + \eta - X_j)}{p_j\phi(X_i + \eta - X_j) + \sum_{k\neq j} p_k\phi(X_i + \eta - X_k)} \tag{10}$$

and the expectation in (10) is taken over the normal density $\phi(\eta)$, where η is of mean zero and variance σ^2. Fifteen point Gauss-Legendre quadrature is used to calculate the expectation integral.

Given a FORTRAN program to estimate $E(\Pi)$ and its gradients, and initial values for the probabilities, MINOS uses quasi-Newton, reduced-gradient, and projected Lagrangian methods to determine the solution to constrained non-linear optimization problems. To ensure that the program is locating global optima, rather than local ones, the simulations are started from a variety of initial values of $\{p_i\}_{i=1}^{i=n}$ for each set of parameters. In each case, the optimal solution provided by MINOS is the same regardless of these starting probability values. Thus, it appears that the reported solutions are globally optimal.

The baseline case in the simulation analysis is $\alpha = 20$, $\beta = 5$, $\theta = 10$, $\sigma = 1$. In this case, $q_D^* = 0.667$, $P_D(q_D^*) = 16.667$, and $X_{\min} = 1.00$. The effects of changes in δ, β, and σ are simulated. When varying the slopes of the supply and demand curves, the intercepts are varied as well to keep the competitive price and q_D^* unchanged. This is necessary to avoid confusing the effects of changing slopes upon the profitability of manipulation per se, with their effect on the value of long positions under competitive conditions. Formally, when δ is changed, θ is also changed according to the following formula:

$$\theta = P_D(q_D^*) - \delta q_D^* = 16.67 - 0.667\delta$$

The supply curve intercept therefore falls as its slope increases. Similarly, when β is changed, α is determined as follows:

$$\alpha = P_D(q_D^*) + \beta q_D^* = 16.67 + 0.667\beta$$

Given these adjustments, the simulations estimate the effects of rotating the supply and demand curves around the original equilibrium point. This is equivalent to changing the elasticities of these curves without changing the competitive equilibrium price or quantity.

Table I presents the simulated values of $E(\Pi)$ for a variety of choices of σ and δ, and for $n = 20$. Reading across any row of the table shows how expected manipulative profit increases as δ increases, i.e., as the delivery market supply curve becomes less elastic. These results show that reducing supply elasticity increases manipulative profit. Reading down any column of the table shows how manipulative profit increases as σ increases, i.e., as the net order flow becomes more variable. The results demonstrate clearly that the manipulator's expected

TABLE I
Manipulator's Profits

σ	δ 10	12	14	16	18
1.0	0.0148	0.0202	0.0267	0.0333	0.0406
1.5	0.0722	0.1014	0.1334	0.1664	0.2010
2.0	0.2084	0.3030	0.3881	0.4797	0.5747
2.5	0.4500	0.6112	0.7812	0.9867	1.1727
3.0	0.8192	1.0992	1.3909	1.6917	1.9991

profit increases as the net order flow becomes more volatile. Part of these profits is attributable to short selling. In the simulations, the manipulator short sells frequently (50% of the time or better) at a price that exceeds the competitive price.

Table II illustrates how the frequency and severity of manipulation changes with δ and σ. This table reports the average price at T as a function of these parameters. This average equals $\sum_{i=1}^{n} p_i MC(X_i)$. The average price at T increases as the manipulator chooses large, positive X_i with greater frequency. Thus, this number measures the average price distortion attributable to manipulation. The table shows that the expected price at T is increasing in both σ and δ. The severity and frequency of manipulation therefore increase as the order flow becomes more volatile, and as the elasticity of supply to the delivery market declines.

Tables III and IV depict the effect of changes in β on $E(\Pi)$ and the expected price at T. The simulations show that given the levels of σ and δ, manipulation becomes more profitable, more frequent, and more severe, as β *declines*. That is, the manipulator benefits from an increase in the elasticity of demand at the delivery point.

TABLE II
Average Price at T (Competitive Price = 16.67)

σ	δ 10	12	14	16	18
1.0	16.70	16.73	16.75	16.77	16.79
1.5	16.83	16.90	19.97	17.05	17.13
2.0	16.99	17.14	17.28	17.42	17.57
2.5	17.26	17.38	17.69	17.83	18.05
3.0	17.31	17.78	18.07	18.37	18.66

TABLE III
Manipulator's Profits

σ	β 1	2	3	4	5
1.0	0.0401	0.0311	0.0239	0.0187	0.0148
1.5	0.1607	0.1330	0.1081	0.08856	0.0722
2.0	0.4456	0.3682	0.3076	0.2584	0.2084
2.5	0.8795	0.7432	0.6336	0.5407	0.4500
3.0	1.4480	1.2439	1.0769	0.9377	0.8192

These various results are intuitive, and related. First consider the effect of an increase in σ. When the variance of the order flow increases, market makers have less reliable information about the activities of the would-be manipulator. As a result of this reduced precision, they are less likely to attribute a large, positive order flow to an attempt by trader 1 to accumulate a position larger than $X_{\min}$. Therefore, he can buy large numbers of contracts at a lower average price when the variability of the order flow is large than when it is small. This increases his profit, and induces him to trade more aggressively.

Next consider the effect of an increase in δ. Ceteris paribus, for any given X_i, as δ rises, both the revenues at T and the price paid at t increase; these effects have opposing effects on $E(\Pi)$. What is decisive, however, is that the increase in δ causes $X_{\min}$ to decline. This creates new manipulative opportunities for the large trader. Thus, for any given σ, market makers cannot reliably detect levels of trading that would not allow trader 1 to manipulate prior to the change in supply elasticity, but which are now profitable given the decline in δ.

Put another way, when supply to the delivery market is very elastic, trader 1 must buy a huge quantity of contracts to manipulate the market. Market makers are almost certain to detect such large purchases and

TABLE IV
Average Price at T

σ	β 1	2	3	4	5
1.0	16.78	16.76	16.73	16.71	16.70
1.5	17.04	16.97	16.90	16.86	16.83
2.0	17.35	17.24	17.14	17.07	16.99
2.5	17.69	17.54	17.41	17.31	17.26
3.0	18.11	17.91	17.75	17.62	17.31

charge the would-be manipulator a price that is quite close to the realized marginal cost of delivery at T. This induces trader 1 to buy and sell cautiously, and manipulate only infrequently. When supply is inelastic, however, trader 1 can manipulate even if he accumulates a relatively small number of contracts. Such relatively small purchases are more readily camouflaged in the normal variations of the net order flow. This allows the trader to escape undetected with greater frequency. As a result, he trades more aggressively, and manipulates more frequently given these circumstances.

The intuition behind the relation between β and the profitability and intensity of manipulation is similar. As demand in the delivery market becomes more elastic, $X_{\min}$ declines. This allows trader 1 to manipulate with a smaller position. Since smaller trades are more difficult to detect, trader 1 can increase the frequency and intensity of his manipulations without greatly increasing the cost of acquiring positions. This makes manipulation more attractive and, therefore, he does so more frequently and more intensively.

This simulation analysis implies that categorical statements to the effect that futures markets "are susceptible to manipulation and control" are inappropriate. The degree of vulnerability of a market to manipulation is contingent upon the characteristics of order flow and delivery market supply and demand elasticities. A futures contract with very stable net order flow and very elastic delivery market supply can be manipulated only very infrequently. In contrast, a contract with extremely volatile order flow and very inelastic supply may be very vulnerable to corners.

The analysis also implies that the susceptibility of a contract to manipulation can vary over time as order flow variability changes, or as delivery market supply and demand conditions change. In this vein, one potentially important conclusion is that improved transportation efficiency (e.g., the deregulation of rail transport or the creation of unit trains) should reduce the frequency and intensity of manipulation. Thus, ceteris paribus, at present manipulation should be a less serious concern than was the case in eras past (e.g., the 1880s in the grain market) when transportation systems were far less efficient than is currently the case.

Given this result, the prototypical example of a manipulable contract may be the New York Cotton Exchange contract in the late-19th and early-20th centuries. Secular changes in consumption patterns caused the stock of cotton held at the contract's delivery point (New York) to fall from over 9.9% of U.S. production in 1870–1880 to under 1.3% of U.S. production in 1900–1907 [U.S. Commissioner of

Corporations (1908), pt. 2 p. 50]. This decline in stocks in New York reflected a change in cotton shipping patterns away from Northern ports and towards Southern ones. The models of Pirrong (1993 and 1994) imply that such a change in shipping patterns would have made cotton supply in New York less elastic because it made it necessary to reverse the natural direction of commodity flows to attract additional supplies to New York. At the same time, improvements in telegraphic communication and a growth in the world wide trade of cotton led to substantial growth in hedging and speculative trading activity. This plausibly increased the variability of order flow. The model predicts that these developments should have led to an increase in the frequency and intensity of manipulation, and the historical record suggests that this was indeed the case. [See Bouilly (1975) for a detailed account of cotton manipulations in this period.]

These conditions are by no means the rule in futures markets, however. Thus, although the formal model implies that absent regulation, corners should occur with positive probability in all futures markets, it does *not* imply that manipulation should be a chronic problem in all markets. Instead, the vulnerability of a contract to manipulation is highly dependent upon the market environment. This conclusion is strengthened when one examines some practical considerations not explicitly incorporated into the formal model. The next section discusses these considerations.

OTHER FACTORS THAT INFLUENCE THE MANIPULABILITY OF A FUTURES CONTRACT

The foregoing has presented a simple theoretical model of manipulation in delivery settled futures markets. The model's results are potentially important, inasmuch as they reveal (a) that randomized manipulative trading is profitable when anonymity provides some camouflage to traders that desire to create large positions, and (b) the susceptibility of a market to manipulation depends upon the variability of order flow and supply and demand elasticities. In the interest of enhancing the practical contribution of this article, however, it is worthwhile to discuss other features of futures markets which may affect their susceptibility to the type of trading modeled here.

First, it is necessary to note that since a lack of information by market makers is the source of manipulative profit in this model, any information (in addition to that embodied in the net order flow) that allows market makers and other market participants to better detect impending manipulations will reduce the profitability and frequency of corners and squeezes.

In general, although a manipulator may attempt to conceal his activity by using many brokers (or other means), experienced local traders may be able to identify and detect trading patterns that distinguish the manipulator's buy and sell orders from those entered by noise traders. Locals may not be able to identify each of the manipulator's orders with certainty. However, to the extent that market makers have sufficient information so that their priors concerning the source of any order are not diffuse, they can raise the manipulator's costs by trading at a high (low) price when their information leads them to believe the manipulator is buying (selling). This increase in the manipulator's costs reduces the frequency and intensity of manipulation. Thus, experienced and observant locals can deter manipulation to some degree. It is important to note, however, that the model implies that they cannot eliminate it altogether unless they can identify a manipulative order with certainty.

Information can be valuable even if it is obtained *after* a would-be manipulator has acquired a large, long futures position. Given sufficient warning of an impending manipulation, commercial firms can make arrangements to ship additional supplies to the delivery market. Since supply curves are more elastic in the long run, the more warning time commercials have to make such shipments, the more elastic the delivery market supply curve becomes. Recall that the profitability and intensity of manipulation vary inversely with supply elasticity. Thus, if commercials learn through their myriad sources of an impending manipulation well before the delivery period, the would-be manipulator may face a very elastic supply curve at delivery. This makes cornering far less profitable than would be the case if commercials were ignorant of his activities.

Commercial traders in grains, metals, petroleum products, and other goods potentially vulnerable to manipulation have very well developed commercial intelligence systems. Thus, even though they may not be able to detect a would-be manipulator's trading when it occurs, they may learn of it in time to make arrangements that increase delivery market supply elasticity. This reduces the profitability of mixed manipulative strategies, and therefore deters manipulation to some degree.

Second, the formal model assumes that shorts are atomistic. In reality, some shorts may be large traders who may be able to exert market power themselves. In this case, the large long faces a classical bargaining problem. His profits in this situation are smaller than when all shorts are atomistic. Indeed, if there is a single short pitted against the single long, it is possible that the large long trader could lose money. This reduction in the profitability of manipulation attributable to the bilateral bargaining problem tends to deter manipulation.

This possibility is especially important if large shorts plan to participate in the futures market for a considerable time to come, and thus have a vested interest in deterring future manipulations. This plausibly characterizes large commercial hedgers. In this case, a large short may be willing to incur a loss today to undermine a manipulation attempt in the expectation that this action will serve to reduce the frequency of manipulation in the future. That is, a large short may be willing to incur costs in the short term to gain a reputation for crushing manipulators, in the expectation that this will deter would-be cornerers.

The heroic actions of P. D. Armour in getting wheat to market in 1897 to ruin Alfred Leiter during the latter's attempt to corner the CBT wheat contract may represent an example of such reputation building. Armour used specially converted ships to transport wheat from Duluth to Chicago through the ice of the frozen Great Lakes. It is quite possible that Armour could have settled with Leiter at a lower cost than he incurred to complete this mammoth undertaking. Nonetheless, the salutary effect of his actions on the calculations of other potential manipulators may have justified this additional cost.

It should be noted that the various considerations just discussed serve to reduce the frequency and intensity of manipulation. They do not necessarily eliminate it altogether. Thus, as long as market makers cannot *always* identify manipulative trades, or commercial traders cannot *always* make delivery market supply infinitely elastic, or the short side of the market is not *always* concentrated, mixed manipulation strategies will still be profitable. To the extent that better information and short side concentration serve to reduce the profitability of manipulation, however, it will be a less severe problem than the formal model suggests.

It also deserved mention, however, that efforts to collect information and create reputations are costly. These expenditures must be included in any evaluation of the costs of manipulation. They must also be included in the calculation of the benefits of alternative forms of manipulation deterrence, including self-policing measures by exchanges, and market oversight by government agencies.

SUMMARY AND CONCLUSIONS

This article constructs a model that explains two stylized facts about corners and squeezes in unregulated futures markets. First, corners sometimes occur in futures markets. Second, not all markets are cornered all the time. The models presented in this article show that corners and squeezes may occur with a probability strictly between 0 and 1 in markets where (a) noise traders cause unpredictable variations in order flow, and (b) the supply curve in the delivery market is less than perfectly elastic. Since these are quite plausible conditions in physical commodity futures markets settled by delivery (e.g., grains and industrial metals), the model suggests that absent exchange or government intervention, *some* manipulation will occur in delivery settled futures markets. (This statement should not be taken to imply that regulation necessarily eliminates corners, or that the benefits of anti-manipulation regulations exceed their costs.)

The article also shows that the frequency and severity of corners that occur in a particular market depend upon the magnitude of order flow variability, and the elasticities of supply and demand in the delivery market. Markets with very volatile order flows, very inelastic delivery market supply curves, and/or elastic delivery market demand curves may be acutely vulnerable to corners; whereas, other markets with stable order flows, elastic supplies, and inelastic demands should experience very little manipulation.

Existing models of market manipulation cannot credibly explain each of the two stylized facts concerning manipulation. Moreover, they do not specify the factors that determine a market's vulnerability to manipulations. Thus, this article sheds some new light on a subject that has vexed market participants and policy makers since the birth of futures trading in the United States.

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