Manipulation of Cash-Settled Futures Contracts

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Abstract Replacement of delivery settlement of futures contracts with cash settlement is frequently proposed to reduce the frequency of market manipulation. This article shows that it is always possible to design a delivery-settled futures contract that is less susceptible to cornering by a large long than any given cash-settled contract. Such a contract is more susceptible to manipulation by large shorts, however. Therefore, cash settlement does not uniformly dominate cash settlement as a means of reducing the frequency of market power manipulations in derivatives markets. The efficient choice of settlement mechanism depends on whether supply and demand conditions favor short or long manipulation.

1 Introduction

The prevention and deterrence of manipulation are major objectives of the regulation of futures markets worldwide. Recent allegations of manipulation in the copper market involving Sumitomo and the soybean market involving Ferruzzi have subjected manipulation on futures exchanges to a level of scrutiny not seen since the 1920s. Futures market regulators from around the world have made policing of manipulation a high priority in the aftermath of the Sumitomo episode (Hargreaves, 1996).

Regulators have focused on improved contract design as a means of defeating futures market manipulations.[1] Among the design mechanisms sometimes advanced as a means of reducing the frequency of manipulation is the use of cash-settled, rather than delivery-settled, contracts. This article examines in detail the relative susceptibility of cash-settled and delivery-settled contracts to manipulation.

Most commodity futures contracts are settled by delivery of the underlying asset.[2] Some, however, are cash-settled. In a cash-settled contract, the settlement price at expiration is set equal to the value of some reference price or index value. Cash settlement is often adopted because delivery settlement is impractical as is the case with Eurodollar deposits and stock indices. In addition, some have advocated the adoption of cash settlement because cash-settled futures contracts are purportedly less susceptible to market-power manipulation than delivery-settled contracts. For example, Jones (1983), Garbade and Silber (1983a), Edwards and Ma (1994), and Manaster (1994) state that a lower vulnerability to corners is one of the benefits of cash settlement. Exchanges that have adopted cash settlement for commodity contracts also claim that this has made them less vulnerable to manipulation. For instance, the International Petroleum Exchange claims that cash settlement of its Brent crude oil futures contract "nearly eliminates the potential for squeezes" (International Petroleum Exchange, 1995), while the President of the Finnish Options Exchange states that the exchange adopted cash settlement for its paper pulp futures contract "because you don't have physical delivery . . . excessive buying will not . . . affect the underlying market as it would with physical delivery. The cornering element is not there"

[1]The US Commodity Exchange Act requires exchanges to adopt contract designs that "tend to prevent or diminish price manipulation."

[2]Over 98 percent of physical commodity futures contracts by volume are delivery-settled.

(Henley, 1996.) More generally, the increasing use of cash settlement is sometimes attributed to the lower susceptibility of these contracts to manipulation (Santoli, 1997).

Manipulation has numerous deleterious effects, including: deadweight losses attributable to temporal and spatial distortions in consumption, production, storage, and transportation; reductions in hedging effectiveness; increases in futures price volatility; reductions in the informativeness of futures prices; and a decline in market liquidity (Pirrong, 1993, 1995, 1997). Since squeezes can seriously impair the efficiency of a futures market, if correct these arguments would provide a strong rationale for the use of cash settlement instead of delivery settlement where feasible.

This article demonstrates, however, that cash-settled contracts are *not* necessarily less susceptible to manipulation than delivery-settled contracts. In fact, it is always possible to design a delivery-settled contract *with multiple varieties* that is less susceptible to market power manipulation by large long traders than any cash-settled contract based on the prices of the same varieties. This delivery-settled contract is always more vulnerable to manipulation by large *shorts* than its cash-settled counterpart. There is no difference in the manipulability of single-variety cash- and delivery-settled contracts.

The intuition behind these results is straightforward. A large long trader can manipulate a delivery-settled futures contract by forcing shorts to make excessive deliveries, thereby driving up the cost of further enhancing deliverable supplies (Pirrong, 1993). An exchange can reduce the costs of delivery by allowing shorts to deliver a number of varieties. Shorts choose to deliver the varieties with prices that are *least* sensitive to increased purchases. In contrast, a trader with a large long position in a cash-settled contract can drive up its settlement value by buying excessive quantities of the varieties whose prices are *most* sensitive to increased buying to maximize the effect on the index. Put differently, the manipulator of a cash-settled futures contract can choose which varieties to purchase and in what amounts to *maximize* his profits, whereas the manipulator of a delivery-settled contract can choose only the total quantity of deliveries, in response to which shorts choose which varieties to purchase to *minimize* his profits. Due to this greater control over the pattern of purchases inherent in cash settlement, it is always possible to design a delivery-settled contract that is less profitable for a large long to manipulate than the cash-settled contract. However, the options extended to shorts by a delivery-settled contract makes it more vulnerable to manipulative acts by sellers. Moreover, there is no difference in the manipulability of single-variety contracts because there is no difference between the options that longs and shorts possess.

This implies that exchanges face a trade-off when choosing between cash- and delivery-settlement. The former is less vulnerable to short manipulation, whereas the latter is less vulnerable to long manipulation. Since the supply and demand conditions that favor long manipulation tend to disfavor short manipulation and vice versa, an exchange's efficient contract choice for a given commodity depends on which problem is more acute. For storable commodities (such as corn or copper) long manipulation is likely to be the more serious problem; delivery settlement is appropriate for these commodities. In contrast, short manipulation is a greater concern for perishable commodities (such as potatoes) because they are inelastically demanded; cash settlement may be preferable for such goods.

The remainder of this article is organized as follows. Section 2 presents a brief overview of the trading environment studied in the body of the paper. Section 3 presents a model that demonstrates the lower susceptibility of delivery-settled contracts to manipulation by large longs than cash-settled contracts. Section 4 extends the analysis to short manipulation, and demonstrates that it is always possible to design a cash-settled contract that is less susceptible to manipulation by a large *short* than any given delivery-settled contract. Section 5 analyzes how these considerations influence optimal contract design. Section 6 summarizes the article.

2 A Simple Model of Futures Trading

Consider the following simplified characterization of a futures market. There are two trading periods. In the first period, the "contract initiation" stage, traders negotatiate futures contracts that expire at some later date T. During these negotiations the buyer and seller agree upon a futures price F_0. At date T, the "contract liquidation" stage, market participants who have established positions in the contract initiation stage can either off-set their positions, or have their positions closed according to the settlement mechanism selected by the exchange. To off-set, traders who sold (bought) contracts in the initiation stage buy (sell) contracts in the liquidation phase. The price determined in this liquidation stage is F_T, which may differ from F_0. The net profit to a buyer (seller) of futures if $F_T - F_0$ $(F_0 - F_T)$.

The price at which traders are willing to liquidate positions through off-setting transactions at T depends on the profitability of closing their positions via the settlement mechanism. Two settlement mechanisms are considered: delivery settlement and cash settlement.

In delivery settlement, those holding open short positions must deliver some commodity specified by the exchange. For example, the shorts who do not off-set their positions in a wheat futures contract must deliver a contractually specified quantity and quality of wheat at a location specified by the exchange. The contract may specify delivery options giving the short some choice of locations or varieties that can be delivered. Longs who do not off-set positions must accept delivery and remit the futures price agreed upon at the contract initiation stage.

In cash settlement, shorts do not deliver a physical commodity at T. Instead, the exchange calculates a settlement price based on some formula that utilizes prices from transactions in the cash market. For instance, in a cash-settled wheat contract the exchange may calculate a settlement price based on some average of the cash prices of wheat in several different geographic markets. If the settlement price calculated using this formula at T exceeds the futures price negotiated in the contract initiation stage, shorts pay longs the difference between these prices multiplied by some contract quantity.

Under the delivery-settled contract, the price that atomistic shorts are willing to pay to liquidate their positions via off-setting transactions at T equals the marginal cost of obtaining the cheapest deliverable commodity. Under the cash-settled contract shorts are willing to pay a price equal to the settlement price implied by the exchange's formula. This is a weighted average of the prices of the varieties included in the settlement index.

If all traders are atomistic price takers, either mechanism results in a competitive outcome. It may be the case, however, that some traders accumulate large positions at the contract initiation stage. These large traders may not act as price takers at liquidation. That is, these traders may be able to take actions that influence the cost of obtaining the cheapest deliverable commodity or that affect the value of the settlement index. I refer to such activities as "manipulation," and analyze a particular means of manipulating each of the settlement mechanisms.

In the delivery settlement mechanism, large longs can manipulate the settlement mechanism by demanding too many deliveries and large shorts can manipulate by making too many deliveries (Pirrong, 1993). Long manipulation of a delivery-settled contract is sometimes referred to as a corner or squeeze. In the cash settlement mechanism, large longs manipulate by making excessive purchases on the cash market and large shorts manipulate by making excessive sales on the cash market.[3]

These actions of large traders distort prices and induce deadweight losses. It is desirable to minimize these distortions. One means of doing so is by designing contract settlement mechanisms that are relatively immune to the strategic behavior of large traders. One basic issue regards whether or not delivery-settled contracts are inherently more or less susceptible to manipulation than cash-settled contracts.

In evaluating alternative contract designs it is important to consider that traders' expectations about the liquidation process will influence trading and prices at contract initiation. Evaluation of settlement mechanisms therefore requires an analysis of both initiation and liquidation phases. This article focuses on contract liquidation because the results of Pirrong (1995) show that the ranking of the profitability of manipulation including both phases is determined by the ranking of profitability in the liquidation phase alone. That is, if the revenue manipulating contract A exceeds the revenue of manipulating contract B holding position size constant, then the total profit (i.e., the liquidation period revenue net of the cost of acquiring the position) of manipulating contract A exceeds the total profit of manipulating contract B. Market participants respond to the threat of manipulation during liquidation by adjusting the prices at which they are willing to trade during contract initiation. However, Pirrong (1995) shows that if the revenue from manipulating contract A exceeds that from manipulating contract B holding position size fixed, a bigger position is required to manipulate B than A. It is more difficult to accumulate a larger position because big trades can be de-

[3]It should be noted that the type of manipulation considered here is different than that analyzed in the primary extant work on manipulation of cash-settled futures contracts, namely the article of Kumar and Seppi (1992). They demonstrate that holders of positions in cash-settled futures contracts can enhance the value of these positions by "punching the settlement price." For example, a trader short stock index futures contracts can enhance the value of this position by selling the stocks underlying the index if the markets for these stocks are not infinitely deep due to asymmetric information. In contrast, this article concentrates on market power manipulation, which is typically called a "corner" or a "squeeze" in delivery-settled futures markets. Although cash settlement does not allow the buyer of the contract to demand an excessive number of deliveries, traders long futures have an incentive to squeeze the cash markets for the varieties underlying the index in order to inflate the futures contract's settlement price. Such squeezes can be more profitable than squeezing delivery-settled futures contracts due to the greater control a trader can exercise in the cash-settled market.

tected more reliably in the noisy order flow at contract initiation than small ones. This increases the cost of obtaining a position in the less-manipulable contract. As a result, the net profit of manipulating B is smaller for contract B than contract A. This justifies the subsequent focus on the liquidation "end game."

3 Cash Settlement and Long Manipulation

This section evaluates the economics of manipulation for cash- and delivery-settled contracts during the liquidation phase for a particular commodity assuming that a large long has established a futures position of $X > 0$. To isolate the factors that influence the relative susceptibility of cash- and delivery-settled contracts to manipulation, it is useful to consider first the simple case of contracts on a commodity with a single variety. Assume that the marginal cost of creating q units of this variety is $MC(q)$ and the demand for the variety is $D(q)$. In a competitive market, $MC(q^*) = D(q^*)$ at the optimal quantity q^*.

If there is a delivery-settled futures contract on the commodity, the holder of X long futures positions can manipulate the contract by requiring shorts deliver more than q^* units. This drives up the marginal cost of delivery and thereby increases the price shorts are willing to pay to liquidate their positions. The long chooses the number of deliveries Q to maximize:

$$(X - Q)MC(Q) + QD(Q) \tag{1}$$

The first term is the long's revenue from selling $X - Q$ futures contracts at the inflated price. The second term is the long's revenue from selling the Q units delivered to him.

Now consider a cash-settled futures contract in which the settlement price equals to the price of the single variety immediately prior to contract expiration. A long can drive this price above the competitive price by purchasing more than q^* units on the spot market. If he purchases Z units of the physical commodity immediately prior to expiration, the settlement price is equal to $MC(Z)$. After settlement, the long sells the commodity for a price of $D(Z)$. This generates a total revenue of:

$$XMC(Z) + ZD(Z) - ZMC(Z) = (X - Z)MC(Z) + ZD(Z) \tag{2}$$

It is obvious that if $Q = Q^*$ maximizes (1), then $Z = Q^*$ maximizes (2). Thus, both contracts will be manipulated equally.[4] This implies that a necessary condition for differential susceptibility of cash-settled and delivery-settled contracts to long manipulation is the existence of multiple deliverable varieties and the use of multiple varieties to calculate the settlement index.

The existence of multiple varieties also turns out to be sufficient to create different susceptibilities to long manipulation. The intuition underlying this result is straightforward. Choice over varieties creates optionality, and the holder of the option differs in cash and delivery-settled contracts. Longs hold the effective options for cash-settled contracts, whereas shorts hold them for delivery-settled contracts. If an exchange awards the delivery of high value varieties and penalizes the delivery of low value ones, shorts can always exploit their options so that the long's profit from manipulating a delivery-settled contract is smaller than his profit from manipulating a cash-settled one.

Formal demonstration of this result requires the introduction of some notation. Consider a good with $j = 1, \ldots, N$ varieties. Call the set of varieties $\mathbf{V}$. These varieties may be spatially distinct (e.g., wheat in Chicago vs. wheat in Toledo) or qualitatively distinct (e.g., red soft winter wheat vs. hard spring wheat).

A delivery-settled contract requires delivery of one of the N varieties. The exchange specifies (1) a set of deliverable varieties $\mathbf{D} \subseteq \mathbf{V}$ and (2) a set of delivery differentials $d_i, i \in \mathbf{D}$. If there is more than one variety, a short has an option to choose which one to deliver from a set of deliverables set by the exchange. The delivery differentials mean that the short's liquidation period revenues depend on which variety he chooses to deliver. If a short delivers variety $i \in \mathbf{D}$ against the contract when the futures settlement price is F, he receives $F + d_i$. Variety p is the "par" variety, with $d_p = 0$. Premium varieties have $d_i > 0$ and discount varieties have $d_i < 0$.[5]

If all spot and futures market participants are atomistic competitors, the price of variety j is the competitive price P_j^c. If all market participants are perfect competitors at the expiration of a futures contract, the equilibrium futures price is $\min_{j \in \mathbf{D}}[P_j^c - d_j]$ because always deliver the variety that min-

[4]Paul (1985) makes a similar point.

[5]As an example, the CBOT soybean contract has a 4 cent/bushel discount for delivery in Toledo and a 2 cent premium for delivery of #1 soybeans. If the futures price is \$5.00, deliveries of #2 soybeans in Toledo receive a price of \$4.96, while deliveries of #1 soybeans in Chicago receive \$5.02.

imizes their costs.

A large long may not act as a price taker, however. The susceptibility of a delivery-settled futures contract to the exercise of market power by a large long depends upon (1) the marginal cost of delivery of the underlying good and (2) the post-delivery demand for the good.[6]

If a long demands delivery of $Q \leq X$ units, shorts choose what to deliver to minimize the total cost (net of differential payments) of delivering this quantity. Formally, shorts select a vector $\mathbf{Q} = \{q_i\}_{i \in \mathbf{D}}$ such that $\sum_{i \in \mathbf{D}} q_i = Q$; element i of this vector gives the deliveries of variety i. The cost of delivering $\mathbf{Q}$ is the convex function $TC(\mathbf{Q})$. Shorts choose $\mathbf{Q}$ to minimize:

$$TC(\mathbf{Q}) - \sum_{j \in \mathbf{D}} d_j q_j + \lambda(Q - \sum_{j \in \mathbf{D}} q_j)$$

The first term is the cost of acquiring the commodity on the cash market. The second term is the net delivery differential payments made to shorts by the long taking delivery, and the third term represents the constraint that total deliveries must equal at least Q, where λ is the Lagrangean multiplier corresponding to this constraint.

Let $\mathbf{Q}^* = \{q_i^*\}_{i \in \mathbf{D}}$ represent the cost minimizing delivery vector. The first order conditions for a minimum imply

$$MC_j(\mathbf{Q}^*) - d_j = MC_k(\mathbf{Q}^*) - d_k = \lambda(\mathbf{Q}^*) \equiv MC^*(Q) \tag{3}$$

for all j, k such that $q_j^* > 0$ and $q_k^* > 0$, where

$$MC_j(\mathbf{Q}) = \frac{\partial TC(\mathbf{Q})}{\partial q_j}$$

In words, shorts allocate deliveries by variety to equalize marginal costs net of delivery differentials across varieties. Due to the convexity of $TC(\mathbf{Q})$,

[6] These marginal cost of delivery functions and the price at which a manipulator sells what is delivered to him depend on what market participants expect that he will do with what is delivered to him after the expiration of the futures contract. Pirrong (1993) derives the marginal cost and price functions in a spatial market under the assumption that the party receiving delivery sells the units delivered to him at the price that clears the spot market in the period immediately following the expiration of the futures contract. That is, in that article the long is assumed to act as a perfect competitor after contract expiration. The marginal cost of delivery and marginal value of delivery curves will differ if other assumptions are made about post-delivery behavior. The subsequent analysis is invariant to the assumptions made about this behavior.

$MC^*(Q)$ is increasing in Q. For varieties such that $q_k^* = 0$, $MC_k(\mathbf{Q}^*) - d_k > MC^*(Q)$ and $q_k[MC_k(\mathbf{Q}^*) - d_k] = 0$.

The marginal cost implied by shorts' cost minimization determines the long's revenues from liquidation of futures positions. The long also cares about the price at which he sells what he acquires via delivery. The average revenue realized from sales of variety j by the large long (per unit delivered to him, not per unit sold) equals $P_j(\mathbf{Q})$. If the long merely dumps what is delivered to him on the spot market after contract expiration these $P_j(.)$ functions are the spot market demand curves $D_j(\mathbf{Q})$. Under other assumptions about post-delivery behavior, $P_j(\mathbf{Q}) > D_j(\mathbf{Q})$.

In what follows, I define the profit of manipulation as the difference between the amount the long earns by choosing Q to maximize delivery period revenues and the revenues he would earn if he acted as a price taker. Acting as a price taker, for the delivery-settled contract the long would earn $X \min_{j \in \mathbf{D}}[P_j^c - d_j]$. This definition facilitates comparison of the relative profitability of manipulating cash- and delivery-settled contracts.

Knowing how shorts will respond to a demand to deliver Q units, the holder of X long futures positions chooses Q to maximize:

$$(X - Q)MC^*(Q) + \sum_{j \in \mathbf{D}} \{q_j^* P_j[\mathbf{Q}^*(Q)] - d_j q_j^*(Q)\} - X \min_{j \in \mathbf{D}}[P_j^c - d_j]$$

The first term in this expression is total revenue from sales of $(X - Q)$ futures contracts at a price equal to the marginal cost of delivery.[7] The first part of the summation term gives the revenue the long earns by selling what shorts deliver to him. The second part of the summation term gives the delivery differential payments paid by the long.

To allow comparison between delivery and cash-settled contracts, the settlement price at the expiration of the cash-settled contract is based on the cash market prices of the varieties in $\mathbf{D}$. Formally, at expiration the settlement price of this contract is set equal to a weighted average of the prices of the varieties included in the delivery-settled contract:

$$\sum_{j \in \mathbf{D}} \alpha_j [MC_j(\hat{\mathbf{Q}}) - d_j]$$

[7]This expression neglects the cost of initiating the position. This cost is $-XF_0$. Since this cost is sunk as of the liquidation phase at time T, it has no effect on the long's decision on how many deliveries to take.

where α_j is a set of weights with $\alpha_j > 0$ and $\sum_{j \in \mathbf{D}} \alpha_j = 1$. The reason for deducting the delivery contract's price differentials from the price for each variety in the cash settlement index will become apparent shortly. These differentials have no effect on the marginal incentives facing the holder of a large long position in the cash-settled contract, so this assumption has no effect on his choices.

A large long can drive up the prices of the varieties underlying the settlement index by purchasing them in supercompetitive quantities. By purchasing $\hat{\mathbf{Q}} > \mathbf{Q_C}$ units the long drives up the price of each variety to equal the marginal cost of supplying the relevant quantity to each market. After expiration the long disposes of the units he bought at an average revenue per unit purchased of $P_j(\hat{\mathbf{Q}})$, $j \in \mathbf{D}$.

The buyer of X cash-settled futures contracts chooses $\hat{\mathbf{Q}}$ to maximize:

$$X \sum_{j \in \mathbf{D}} \alpha_j [MC_j(\hat{\mathbf{Q}}) - d_j] + \sum_{j \in \mathbf{D}} q_j^* P_j(\hat{\mathbf{Q}}) - \sum_{j \in \mathbf{D}} q_j^* MC_j(\hat{\mathbf{Q}}) - X \sum_{j \in \mathbf{D}} \alpha_j (P_j^c - d_j)$$

The first term in this expression is the large long's revenue from settlement of his X futures positions.[8] At expiration, the price of variety j equals the marginal cost of producing an additional unit of it. The second term is the revenue that the large long realizes from selling the $\hat{\mathbf{Q}}$ units he purchased in the cash market immediately after contract expiration. The third term is the cost of acquiring the $\hat{\mathbf{Q}}$ units immediately prior to contract expiration. The last term is the value of the cash-settled contract at competitive prices.

Given this framework and notation it is possible to make comparisons of the profitability of manipulating cash and delivery-settled contracts. Proposition 1 shows that an exchange can always choose the delivery differentials so that long manipulation of the delivery-settled contract is less profitable than long manipulation of the cash-settled contract.

Proposition 1 *If an exchange chooses delivery differentials such that $P_j^c - d_j = P_k^c - d_k$ for all $j, k \in \mathbf{D}$ then a trader who holds a position of X long cash-settled futures contracts earns a profit at least as large as the holder of X delivery-settled futures contracts.*

Proof. See Appendix ∎

The different optionality inherent in cash-settled and delivery-settled contracts drives this result. In the delivery-settled contract, in response to the

[8] The $-XF_0$ term is again omitted because it has no bearing on the choice of $\hat{\mathbf{Q}}$.

long's demand for Q deliveries shorts choose what to deliver to minimize the cost of liquidating their positions; this also minimizes the long's revenues from liquidation of his futures position. Moreover, they do not take the long's revenues from sales of the deliverables into account. In the cash-settled contract, the long chooses the vector of purchases himself. He can earn at least as much revenue in the cash-settled case as in the delivery-settled context because he can choose the same vector of purchases as shorts choose in the delivery-settled market. In fact, he will typically earn more revenue because $\mathbf{Q}^*(X)$ does not necessarily maximize

$$X \sum_{j \in \mathbf{D}} \alpha_j [MC_j(\hat{\mathbf{Q}}) - d_j] + \sum_{j \in \mathbf{D}} \hat{q}_j P_j(\hat{\mathbf{Q}}) - \sum_{j \in \mathbf{D}} \hat{q}_j MC_j(\hat{\mathbf{Q}})$$

(where $\hat{\mathbf{Q}} = \{\hat{q}_j\}_{j \in D}$). Therefore, the long's revenues under a cash-settled futures contract are never lower than with a delivery-settled one. Moreover, with competitive differentials $P_j^c - d_j = P_k^c - d_k = P^*$ for all j and k, so $\min_{j \in \mathbf{D}}[P_j^c - d_j] = P^* = \sum_{j \in \mathbf{D}} \alpha_j (P_j^c - d_j)$. That is, with competitive differentials the value of the cash- and delivery-settled contracts are the same at competitive prices. Thus, the long gains at least as much (relative to the competitive value of his position) by manipulating the cash-settled contract as the delivery-settled one.

Indeed, it is typically strictly more profitable to manipulate the cash-settled contract than its delivery-settled counterpart if the exchange chooses competitive price differentials. This is true because the cash-settled contract extends the long more economically relevant options in this case. Whereas the long manipulator of a delivery-settled contract can choose only the total amount of quantity distortion, the long manipulator of a cash-settled contract can choose where the distortion takes place so as to maximize profits. Thus, except under unusual circumstances in which these additional options are irrelevant, it is more profitable to manipulate the cash-settled contract than the delivery-settled one.

The contrast between the relative susceptibility of cash and delivery-settled futures in multiple variety and single variety cases is illuminating. Recall that with single-variety contracts, cash and delivery settlement are equally susceptible to long manipulation. In contrast, a multi-variety delivery-settled contract with competitive price differentials is less subject to long manipulation than any cash-settled contract. This is true because with competitive differentials, shorts possess at-the-money delivery options that allow them to mitigate the "delivery pressure" the long exerts. No such delivery option exists for single variety or cash-settled contracts. Indeed, for a multi-variety cash-settled contract the large long has the relevant options to exert delivery pressure on the varieties whose prices are most susceptible to it.

It should be emphasized that the choice of delivery differentials is essential to this result. Proposition 1 holds for any "economic par" contract with delivery differentials that equal competitive price differentials. It does not imply that any delivery-settled contract with arbitrary differentials is less susceptible to long manipulation than all cash-settled contracts. If an exchange does not choose delivery differentials equal to competitive price differences, a delivery-settled contract may be more or less susceptible to long manipulation than a cash-settled one. The logic of Proposition 1 implies that the holder of X cash-settled contracts can earn at least as much revenue at expiration as the holder of X delivery-settled contracts. However, if the exchange does not choose differentials equal to competitive price differences, the value of a cash-settled position is always greater than the value of a delivery-settled position when both at competitive prices because $\min_{j \in \mathbf{D}}[P_j^c - d_j] < \sum_{j \in \mathbf{D}} \alpha_j [P_j^c - d_j]$ in this case. Absent economic par differentials, it is thus impossible to determine whether the difference between expiration revenue and competitive value is higher for the cash-settled contract than for the delivery-settled one. In essence, economic par differentials are necessary to ensure that the shorts' delivery options are at-the-money. If they are not, they may not serve as a reliable check on the long's market power. Without economic par, longs may possess more or fewer options under cash settlement than under delivery settlement.

Two examples to illustrate this point. There are two deliverable varieties in each example. For simplicity, the marginal cost and marginal benefit of delivery of each variety depend only upon the amount of that variety delivered, i.e., there are no cross-effects.

Example 1 The marginal cost of delivering variety 1 equals $MC_1(q_1) = 2+2q_1$. The price received after taking delivery of variety 1 is $P_1(q_1) = 4-q_1$. The marginal cost of delivering variety 2 is $MC_2(q_2) = 4.6 + .5q_2$ and the price received upon taking delivery of variety 2 is $6.1 - 5q_2$. The exchange sets $d_1 = d_2 = 0$.

Given competition, $q_1^c = \frac{2}{3}$, $P_1^c = 3.333$, $q_2^c = \frac{3}{11}$ and $P_2^c = 4.7364$, where q_j^c is the competitive quantity with $MC_j(q_j^c) = P_j(q_j^c)$. Thus, in this example the low price market has a more elastic marginal cost curve and a less elastic post-delivery demand curve than the high price market. Given these competitive prices, differentials, and marginal cost and demand curves, shorts always choose to deliver variety 1 unless a long demands delivery of at least 1.3682 units. If $Q > 1.3682$, the shorts choose q_1 such that $2 + 2q_1 = 4.6 + .5(Q - q_1)$ to equate marginal costs across locations. Thus, $q_1(Q) = \max[Q, 1.04 + .2Q]$.

A large long owns a futures position $X = 3$. Initially conjecture that the long demands less than 1.3682 deliveries. With a delivery-settled contract, given this conjecture he chooses Q to maximize

$$\Pi_D(Q) = (3 - Q)[2 + 2q_1(Q)] + q_1(Q)[4 - q_1(Q)].$$

The solution to this problem is $Q = 4/3$, which satisfies the conjecture. The resulting manipulated price is $4\frac{2}{3}$. The value of $\Pi_D(4/3) = 10\frac{8}{9}$. If the long liquidates the entire position (i.e., acts as a price taker) the position value is (3)(10/3)=10. Thus, manipulation increases the value of the position by about 8.89 percent.

Now consider a cash-settled contract with $\alpha_1 = \alpha_2 = .5$. The large long chooses q_1 and q_2 to maximize

$$\begin{aligned}\Pi_C(q_1, q_2) &= (3)(.5)(2 + 2q_1 + 4.6 + .5q_2) + q_1(4 - q_1)\\ &\quad + q_2(6.1 - 5q_2) - q_1(2 + 2q_1) - q_2(4.6 + .5q_2).\end{aligned}$$

If the solution to this problem results in $q_1 \leq 2/3$ ($q_2 \leq 3/11$) then $q_1 = q_1^c$ ($q_2 = q_2^c$) because the relevant marginal cost curves are upward sloping as assumed in the maximum problem only if the long buys more than q_1^c and q_2^c.

The solution to this problem has $q_1 = 5/6$ and $q_2 = q_2^c = 3/11$. With the maximizing choice of q_1, the settlement price of the future is $.5[2+(2)(5/6)+4.7364] = 4.202$. The value difference between the value of the long's futures position if he manipulates and its value if he does not manipulate is $3[4.202 - .5(3.333 + 4.7364)] = 3(.5)(3.667 - 3.333) = .0833$.

In this example manipulation of the delivery-settled contract is more profitable than manipulation of a cash-settled contract for a long with a position of 3. This seems contrary to the results of Proposition 1, but this is attributable to the fact that delivery differentials do not equal competitive price differences in this example. Note that shorts deliver only variety 1 when the large trader manipulates the delivery-settled contract despite its inelastic supply because its competitive price is so far below the competitive price for variety 2. When manipulating the cash-settled contract, the large long restricts his purchases to variety 1 because purchases of variety 2 do not substantially increase the pre-settlement price in that market, but force the long to sell the units he buys at a substantial loss after the expiration of the futures contract. The long purchases fewer units of variety 1 in the cash-settled case than he takes deliveries of variety 1 in the delivery-settled case because a one unit price increase at that location leads to a mere one-half unit increase in the cash-settled futures price.

Here the disparity between prices (net of differentials) implies that shorts' delivery options are so far out of the money that they do not effectively constrain the long's market power. Combined with the fact that the "cheapest-to-deliver" variety is inelastically supplied, this makes manipulation of the delivery contract very profitable. This highlights the importance of the competitive differentials assumed in Proposition 1.

Example 2. The marginal cost and price received after taking delivery of variety 1 are the same as in example 1. For variety 2, $MC_2(q_2) = 3 + .5q_2$ and $P_2(q_2) = 4 - 5q_2$. In this case, $q_2^c = .1818$ and $P_2^c = 3.0909$. Thus, 2 is the cheapest-to-deliver variety as long as $3 + .5Q \leq 3\frac{1}{3}$, where $3\frac{1}{3}$ is the competitive price of variety 1. Thus, as long as $Q \leq \frac{2}{3}$ only variety 2 is delivered against a delivery-settled contract.

If the value of Q that maximizes the following expression is less than 2/3, then $q_2 = Q$ and $q_1 = q_1^c$ maximize the profits of a trader long 3 units of delivery-settled futures:

$$\Pi_D(Q) = (3 - Q)(3 + .5Q) + Q(4 - 5Q)$$

Maximization implies $q_2 = 5/22$ and $q_1 = q_1^c$. At the maximum the futures price equals 3.1136. The long sells the units delivered to him at a price of 2.8636. His manipulative revenues equal 9.28397, only slightly higher than his revenues if he takes no deliveries, which equal 9.2727.

It is straightforward to demonstrate that the profit earned by manipulating the cash-settled futures contract in this example is identical to the profit earned in Example 1–.0833–because the slopes of the supply and demand curves are identical in each case. Thus, in this example the cash-settled contract is more vulnerable to manipulation than its delivery-settled counterpart even though the shorts' delivery options are out-of-the-money. This occurs because the supply of the cheaper variety is so elastic and its demand so inelastic that it is unecessary to expand deliverable supply to make manipulation unprofitable; put differently, delivery options are not valuable in this case. This illustrates that competitive differentials are sufficient, but not necessary, to make delivery settlement less manipulable.

A final example illustrates Proposition 1.

Example 3. Consider the markets studied in Example 1. The exchange sets $d_2 = P_2^c - P_1^c = 4.736363 - 3.3333 = 1.40303$. Shorts deliver varieties in a ratio that ensures that the marginal cost of delivery net of delivery differential is equal for the two varieties:

$$2 + 2q_1 = 4.6 - 1.40303 + .5q_2$$

Since $q_1 + q_2 = Q$, if the long demands Q deliveries then solving the previous equation implies

$$q_1(Q) = .4788 + .2Q$$

and

$$q_2(Q) = -.4788 + .8Q$$

As a result, the marginal cost curve is

$$2 + 2(.4788 + .2Q) = 2.9576 + .2Q.$$

This function is relevant only if Q exceeds the total competitive supplies of the two varieties, $\frac{3}{11} + \frac{2}{3} = \frac{31}{33}$. (The marginal cost curve is perfectly elastic at a price of 3.333 up to this quantity.) A trader long three contracts maximizes:

$$(3 - Q)(2.9576 + .2Q) + q_1(Q)[4 - q_1(Q)] + q_2(Q)[6.1 - 1.403030 - 5q_2(Q)]$$

The value of Q that maximizes this expression is $.8795 < .9394$. Therefore, manipulation is not profitable and the large long acts as a perfect competitor.

It is readily demonstrated that the profit of a manipulation of the cash-settled contract in this example is the same as found in examples 1 and 2, .0833. Thus, it is less profitable to manipulate the "economic par" delivery-based contract than its cash-settled counterpart.

These various examples shed light on the factors that make long manipulation of a cash-settled contract more profitable than the long manipulation of a delivery-settled contract when delivery differentials do not exactly equal competitive price differentials. In general, a delivery-settled contract is less vulnerable to long manipulation when the cheapest-to-deliver variety (i.e., the variety with the smallest $P_j^c - d_j$) has a very elastic marginal cost function and a very inelastic demand function. Conversely, the delivery-settled contract is particularly vulnerable to long manipulation when the cheapest-to-deliver variety has a very inelastic marginal cost curve and a very elastic demand curve.

Similar considerations influence the susceptibility of cash-settled contracts to long manipulation. Specifically, a cash-settled contract that places large weights (i.e., large α_j) on varieties with elastic marginal costs and inelastic demand is less manipulable than a contract that places large weights on varieties with inelastic marginal costs and elastic demands. The long's revenue rises more by driving up the price of a variety j with a large α_j than by driving up the price of a variety with a smaller weight by an identical amount. Purchases of an inelastically supplied variety have a large effect on price; such purchases generate large profits for a large long if this variety also receives a large weight in the settlement formula. The incentive to manipulate the cash-settled contract is therefore acute when the inelastically supplied varieties receive large weight in the settlement formula.

The analysis of this section demonstrates that it is always possible for an exchange to design a delivery-settled contract for which manipulation by a large long trader is less profitable than for any cash-settled contract (holding X and F_0 constant). By choosing differentials that ensure that short's delivery options are at-the-money, an exchange provides more protection against long manipulation than a cash-settled contract based upon the prices of the same varieties that are deliverable against the delivery-based contract. If differentials do not create at-the-money delivery options, the relative susceptibility depends crucially on the supply and demand elasticities of (1) the cheaper varieties, and (2) the varieties that receive the greatest weights in the settlement index.

4 Cash Settlement and Short Manipulation

A trader short delivery-settled futures can reduce the cost of closing this position by selling excessive quantities of deliverable varieties of the good on the cash market prior to contract expiration or by delivering excessive quantities against futures (Pirrong, 1993). Similarly, a trader short a large position in a cash-settled contract can manipulate it by selling excessive quantities of those varieties whose prices are used to calculate the contract's settlement price. Given the symmetry of the situations, one might expect cash-settled contracts to be less susceptible to short manipulation than economic par delivery-settled contracts. This is in fact the case.[9]

[9] It is straightforward to show that single variety cash and delivery-settled contracts are equally susceptible to short manipulation.

In a multi-variety delivery contract, a short delivers only the cheapest-to-deliver variety in order to minimize the futures price. He may also sell deliverable varieties on the cash market prior to contract expiration. Formally, a trader short X delivery-settled futures contracts chooses a vector of sales of each variety $\mathbf{Q_{SD}}$ (with q_j^{SD} indicating the j'th element of this vector) to minimize the cost of off-setting his position:

$$C_{SD}(X) = X \min_{j \in \mathbf{D}}[p_j(\mathbf{Q_{SD}}) - d_j] + \sum_{j \in \mathbf{D}} q_j^{SD}[mc_j(\mathbf{Q_{SD}}) - p_j(\mathbf{Q_{SD}})] - \min_{j \in \mathbf{D}}[P_j^c - d_j]$$

In this expression $mc_j(\mathbf{Q})$ represents the marginal cost the short incurs to obtain variety j and $p_j(\mathbf{Q})$ is the price the short receives per unit of variety j sold, where $\mathbf{Q}$ is his vector of purchases.[10]

The first term in the cost expression gives the cost of repurchasing X contracts at expiration. The repurchase price at expiration is $\min_{j \in \mathbf{D}}[p_j(\mathbf{Q_{SD}}) - d_j]$ because longs expect that the short will deliver only the cheapest variety. Atomistic longs are indifferent between taking delivery and liquidating at this price. The second term gives the difference between the short's revenues from selling $\mathbf{Q_{SD}}$ on the cash market net of the cost of acquiring these varieties. The short must pay prices equal to marginal costs to acquire $\mathbf{Q_{SD}}$ but then sells what he buys at prices that clear markets for all deliveries.

If the short sells quantities in excess of the competitive equilibrium quantities, the marginal cost paid to acquire the good will exceed the price received upon resale and the summation term will be positive.

A trader short cash-settled futures can also force down prices for varieties included in the settlement index by making excessive sales on the cash market. Call the vector of sales in this case $\mathbf{Q_{SC}}$ with individual elements q_j^{SC}. A trader short X contracts chooses $\mathbf{Q_{SC}}$ to minimize:

$$C_{SC}(X) = X \sum_{j \in \mathbf{D}} \alpha_j[p_j(\mathbf{Q_{SC}}) - d_j] + \sum_{j \in \mathbf{D}} q_j^{SC}[mc_j(\mathbf{Q_{SC}}) - p_j(\mathbf{Q_{SC}})] - \sum_{j \in \mathbf{D}} \alpha_j[P_j^c - d_j]$$

[10]Note that the marginal cost and price functions may differ between the long manipulation case studied earlier and the short manipulation case examined here because the atomistic traders buying the commodity in the short manipulation case may behave differently after contract expiration from the large long taking delivery in the long manipulation case. When the large long in the analysis of Section 3 acts as a price taker in the post-delivery period the marginal cost and price functions will be identical. The use of lower case type for the price and marginal cost functions in the present analysis is intended to emphasize the potential differences between the long and short manipulation case.

To determine the relative profitability of short manipulation of cash-settled and economic par delivery-settled contracts, assume that the exchange selects the d_j such that $P^c_j - d_j = P^c_k - d_k = P^*$ for all $j, k \in \mathbf{D}$. As noted earlier, the cash-settled and delivery-settled positions are of equal value under competition in this case, i.e., $C^c_{SD} = XP^* = C^c_{SC}$.

Assume that when minimizing C_{SC} a trader short X contracts chooses $\mathbf{Q}^*_{\mathbf{SC}}$. A trader short X delivery-settled contracts can choose the same sales vector. If so, $C_{SD}(X) \leq C_{SC}(X)$ because

$$X \min_{j \in \mathbf{D}} [p_j(\mathbf{Q}^*_{\mathbf{SC}}) - d_j] - XP^* \leq X \sum_{j \in \mathbf{D}} \alpha_j [p_j(\mathbf{Q}^*_{\mathbf{SC}}) - d_j] - XP^*.$$

Thus, the trader short X delivery-settled contracts can reduce the cost of closing that position by at least as much relative to its no-manipulation value as a trader short the same number of cash-settled contracts if the exchange selects delivery differentials equal to competitive price differences. This proves:

Proposition 2 *If an exchange sets $d_j - d_k = P^c_j - P^c_k$ for all $j, k \in \mathbf{D}$, then it is more profitable for a trader short X futures to manipulate a delivery-settled contract that gives shorts the option to choose which variety to deliver than a cash-settled one.*

Typically it is strictly more profitable to short manipulate a delivery-settled economic par contract than a cash-settled contract because a short need not force down the prices of all deliverables to force down the contract price due to the behavior of the minimum function that determines the equilibrium futures price. The ability to concentrate on driving down the price in a single market rather than in all markets may reduce the cost of distorting commodity flows. This is most clearly evident in the special case where there are no cross-effects. Specifically, assume:

$$\frac{\partial mc_j(Q)}{\partial q_k(Q)} = 0 \text{ and } \frac{\partial p_j(Q)}{\partial q_k(Q)} = 0$$

for all $j, k \in \mathbf{D}$ with $j \neq k$. Under this no cross-effects assumption the marginal cost and sales prices at j as functions of q_j alone. In this case, for each $j \in \mathbf{D}$ a short manipulator of a delivery-settled contract first chooses q_j to minimize $X[p_j(q_j) - d_j] + q_j[mc_j(q_j) - p_j(q_j)] - X \min_{k \in \mathbf{D}}[P^c_k - d_k]$. That is, for each j the short attempts to reduce the manipulated value of his position as far below the competitive value of his position as possible. He then selects the deliverable variety j for which this reduction is largest. If the exchange chooses $d_j - d_k = P^c_j - P^c_k$ for all $j, k \in \mathbf{D}$, this is equivalent to choosing the j that with the smallest value of $Xp_j(q_j) + q_j[mc_j(q_j) - p_j(q_j)]$. [11]

Call the minimized value of the short position in this case $V(S)$. With no cross-effects and delivery differentials equal to competitive price differentials, it must be the case that $V(S) < C_{SC}(\mathbf{Q}^*_{\mathbf{SC}})$. To see why, assume that a short manipulator optimally uses sales of q^D_v units of variety v to drive down the price of the delivery-settled contract. For this v, the first order conditions for a minimum imply

$$-p_v(q^D_v) + mc_v(q^D_v) + q^D_v mc'_v(q^D_v) + (X - q^D_v)p'_v(q^D_v) = 0$$

For the cash-settled contract, the first order conditions imply

$$\begin{gathered} 0 = -p_j(q^*_j) + mc_j(q^*_j) + q^*_j mc'_j(q^*_j) + (X\alpha_j - q^*_j)p'_j(q^*_j) > \\ -p_j(q^*_j) + mc_j(q^*_j) + q^*_j mc'_j(q^*_j) + (X - q^*_j)p'_j(q^*_j) \end{gathered}$$

for all j included in the settlement price index including $j = v$; the inequality holds because $p'_j(q_j) < 0$ and $\alpha_j < 1$. Thus, a short manipulator of a cash-settled contract does not choose the q^*_j's to minimize $(X - q_j)p_j(q_j) + q_j mc_j(q_j)$ for any j, including $j = v$. As a consequence,

$$(X - q^*_j)p_j(q^*_j) + q^*_j mc_j(q^*_j) > (X - q^D_v)p_v(q^D_v) + q_v mc_v(q^D_v)$$

for all $j \in \mathbf{D}$. Moreover,

$$\begin{aligned} (X - q^D_v)p_v(q^D_v) + q_v mc_v(q^D_v) &< \sum_{j \in \mathbf{D}} \alpha_j[(X - q^*_j)p_j(q^*_j) + q^*_j mc_j(q^*_j)] \\ &\leq \sum_{j \in \mathbf{D}} [\alpha_j X p_j(q^*_j) - q^*_j p_j(q^*_j) + q^*_j mc_j(q^*_j)] \end{aligned}$$

because $mc_j(q_j) \geq p_j(q_j)$ for all values of q_j for all j. Therefore, in the no-cross effects case, it is unambiguously more profitable for a short to manipulate an economic par delivery-settled contract than a cash-settled contract because the former requires reducing price in a single market, whereas the

[11] If the exchange does not select delivery differentials equal to competitive price differentials it is not necessarily the case that the short chooses the j that minimizes $Xp_j(q_j) + q_j[mc_j(q_j) - p_j(q_j)]$.

latter requires driving down prices in many markets. It is typically cheaper to drive down price in a single market.[12]

If an exchange does not choose differentials equal to competitive price differences, short manipulation of a cash-settled contract is not necessarily less profitable than manipulation of a delivery-settled one. Examples along the lines of those in section 3 (omitted for brevity) demonstrate this point. Unsurprisingly, these examples provide conclusions that are symmetric to those in the previous section. When an exchange does not set differentials equal to competitive price differences, delivery-settled contracts that extend shorts delivery options are more (less) susceptible to short manipulation when the cheapest-to-deliver variety under competitive conditions has an elastic supply curve and inelastic demand curve (inelastic supply curve and elastic demand curve). Similarly, a cash-settled contract that gives large weight to the prices of elastically supplied and inelastically demanded varieties is more susceptible to short manipulation than a contract that places large weight on inelastically supplied and elastically demanded varieties.

If fundamental conditions favor short manipulation this analysis suggests that cash-settled contracts are preferable to economic par delivery contracts that give delivery options to shorts. Virtually all delivery-settled contracts in existence extend options to shorts, but it would be possible to design a delivery-settled contract that allows longs to choose which variety will be delivered. This is the subject of Proposition 3. The proof is almost identical to that employed in Propositions 1 and 2, so it is omitted.

Proposition 3 *If an exchange sets $d_j - d_k = P^c_j - P^c_k$ for all $j, k \in \mathbf{D}$, then it is less profitable for a trader short futures to manipulate a delivery-settled contract that gives longs the option to choose which variety to deliver than a cash-settled one.*

The intuition behind this result is by now familiar. Giving longs delivery options makes them less vulnerable to short manipulation. There is no free lunch, however; a contract that extends delivery options to longs must be more vulnerable to manipulation than a comparable cash-settled contract.

[12]The no-cross-effects case probably understates the relative immunity of cash-settled contracts to short manipulation. In a spatial market, a firm that raises prices temporarily in a particular market to attract additional supplies there typically draws those supplies from other markets, thereby raising their prices. Thus, it may be very difficult to depress prices in several markets simultaneously. This suggests that a cash-settled contract is even less vulnerable to short manipulation than the analysis in the text suggests.

5 Implications for Optimal Contract Design

The foregoing analysis demonstrates that an exchange faces a fundamental trade-off when choosing between cash settlement and delivery settlement. Choosing delivery settlement with differentials that equal competitive price differences instead of cash settlement results in lower vulnerability to long manipulation but higher vulnerability to short manipulation. Delivery settlement does not uniformly dominate cash settlement, or vice versa. This has implications for optimal contract design.

From among delivery-settled contracts, economic par contracts have features that reduce their vulnerability to long manipulation (compared to other non-par contracts), although it is not possible to state unambiguously that an economic par contract necessarily less susceptible to long manipulation than any other delivery-settled contract with different delivery differentials. The fact that an economic par contract has a less elastic demand curve at liquidation than any other contract is responsible for this tendency.

To see why a long's price impact is necessarily smaller with an economic par contract, increase the delivery differential for variety j to $d_j^* > d_j$ for some economic par contract.[13] This increase makes it more advantageous to deliver variety j. Due to this increase in d_j, for any $\mathbf{Q}$ such that (3) holds and $\sum_{i=1}^N q_i = Q$,

$$MC_j(\mathbf{Q}) - d_j^* < MC_k(\mathbf{Q}) - d_k \tag{4}$$

Due to the convexity of $TC(.)$, to restore the equation between differential-adjusted marginal costs while delivering Q, it is necessary to increase q_j and reduce some other q_k. Call this new delivery vector $\mathbf{Q}'$. Note that by convexity $MC_j(\mathbf{Q}') > MC_j(\mathbf{Q})$. This implies $MC_j(\mathbf{Q}') - P_j^c > MC_j(\mathbf{Q}) - P_j^c$. Therefore, the difference between the marginal cost of delivering Q units and the competitive price is higher with non-par differentials than par ones. Thus, a long who demands Q deliveries has a smaller effect on the futures price of the economic par contract than on the price of a non-par contract. In essence, with a par contract the delivery supply curve is the horizontal sum of the supply curves of all of the deliverable varieties. With a non-par contract, the supply curve is the supply curve for a single variety or some subset of varieties over some range of Q. The former supply curve is necessarily more elastic than the latter. This tends to reduce the profitability of manipulation.

[13] That is, since $P_j^c - d_j = P_k^c - d_k$, $P_j^c - d_j^* < P_k^c - d_k$ for all $k \neq j$. An identical argument holds for reducing some d_j.

One cannot say more than this because demand curves also influence the profitability of long manipulation. A non-par contract that induces shorts to deliver very inelastically demanded varieties could be less profitable for a large long to manipulate than an economic par contract despite the greater supply elasticity of the latter.

This analysis suggests that economic par delivery-settled contracts are typically least susceptible to manipulation by large longs but they are acutely vulnerable to manipulation by large shorts.[14] Optimal contract design therefore turns on which form of manipulation is most likely and deleterious. Economic considerations suggest that for a particular commodity, one type of manipulation is likely to predominate. Specifically, the conditions that favor long manipulation, inelastic marginal cost of delivery curves and elastic demand curves, disfavor short manipulation. Conversely, the conditions that favor short manipulation, elastic marginal cost curves and inelastic demand curves, disfavor long manipulation. Thus, for a given good, if conditions make long manipulation profitable, short manipulation is not lucrative.[15]

The optimal choice for the exchange therefore depends on whether conditions typically favor long or short manipulation. For most commodities, the historical record suggests that conditions tend to favor long manipulation.[16] This implies that for most goods economic par delivery contracts are superior to cash-settled contracts for purposes of manipulation deterrence.

Perishable commodities are the exception to the rule that long manipulation predominates. There were severe short manipulations in the delivery-settled onion market in the 1950s. Indeed, these led Congress to enact a statutory ban on the trading of onion futures. Similarly, short manipulations of delivery-settled potato futures in the 1970s induced the New York

[14] Even if an economic par contract is more susceptible to long manipulation than some other delivery-settled contract, there is always a delivery-settled contract less susceptible to long manipulation than any cash-settled one. Any non-par delivery settled contract that is relatively invulnerable to long manipulation due to inelastic demand is highly vulnerable to short manipulation for the same reason. Thus, the exchange faces a fundamental trade-off between short and long manipulation even if an economic par contract is not the least susceptible to long manipulation.

[15] Result 4.6, Pirrong, 1993.

[16] See Pirrong (1995b) for a list of more than 100 documented long manipulations on the Chicago Board of Trade in the pre-regulation (i.e., pre-1922) period. There are no documented short manipulations during this period. With the exception of potatoes and onions, (which are discussed later), all U.S. legal actions relating to manipulation pertain to long manipulation.

Mercantile Exchange (NYMEX) to cease trading in this commodity. The unique experience of these commodities is economically sensible because *ceteris paribus* the demand for perishable commodities is far less elastic than the demand for storable commodities (Williams and Wright, 1992) making them acutely vulnerable to short manipulation. Interestingly, NYMEX switched to cash-settlement when reintroducing its potato contract in the 1983. Similarly, the Chicago Mercantile Exchange shifted to cash-settlement for feeder cattle (which are effectively perishable because they age) in part because shorts were exploiting their option to deliver at unfavorable locations to drive down futures prices (Rich and Leuthold, 1993).

Manipulation deterrence is of course not the sole objective of contract design. Hedging effectiveness under normal, unmanipulated conditions is also relevant. When price differentials between different varieties of a given good vary randomly over time, economic par delivery contracts and cash-settled contracts offer different hedging effectiveness patterns.

Hedging effectivess for a particular variety is typically measured using the correlation between the futures price and the price of that variety. An economic par futures price is perfectly correlated with the forward price of the par variety, and imperfectly correlated with the forward prices of non-par varieties. This is true because the futures price converges to the cash price of the par variety. In contrast, the price of a cash-settled contract behaves like the price of a portfolio of the varieties underlying the index. As a result, the cash-settled contract likely produces poorer hedging effectiveness for the par variety than an economic par contract, but somewhat superior hedging effectiveness for other varieties.[17]

To summarize, long manipulation is typically a more serious concern than short manipulation for most storable commodities. Together with the analysis of sections 3 and 4 above, this implies that economic par delivery-settled contracts dominate cash-settled ones as a means of reducing deadweight losses from manipulation. This analysis is consistent with the facts that (1) most exchanges employ delivery settled contracts for commodities, and (2) these contracts typically extend delivery options to shorts and never extend options to longs. Conversely, short manipulation has been a more serious problem for very perishable commodities, such as onions and potatoes. Cash

[17]The portfolio-like nature of the cash settled contract tends to reduce its dependence on variety-specific price movements. This contributes to higher hedging effectiveness for most varieties. See Pirrong *et al* (1994) for a formal analysis of this effect.

settlement may be preferable for such commodities, and has been adopted in two cases. Although manipulation deterrence is important, since the hedging performance of cash-settled and delivery-settled contracts is likely to differ, hedging effectiveness considerations could also influence the optimal futures contract settlement mechanism.

6 Summary and Conclusions

It is sometimes claimed that if practical, cash settlement is preferable to delivery settlement because cash-settled futures contracts are less vulnerable to manipulation than delivery-settled ones. This paper demonstrates that this claim is incorrect. It is always possible to design a delivery-settled contract that is less profitable for large longs to manipulate than any given cash-settled contract. Specifically, it is more profitable to squeeze a cash-settled contract than a delivery-settled one with delivery differentials equal to competitive price differences. There is no free lunch, however, because a delivery-setted contract with competitive price differentials is more vulnerable to manipulation by large short sellers than a cash-settled one. It is of course true that susceptibility to manipulation is only one factor that must be considered when designing futures contracts and in some cases these other factors may favor the adoption of cash settlement. Nonetheless, this article demonstrates that lower vulnerability to long market power manipulation is not a valid reason to favor cash settlement over delivery settlement. Instead, exchanges face a fundamental trade-off between short and long manipulation; the appropriate choice in large part depends on how a commodity's characteristics affect supply and demand elasticities, which in turn determine its vulnerability to the two types of manipulation.

A Proof of Proposition 1

Assume that under the delivery-settled contract the long demands $Q(X)$ deliveries. Shorts deliver $q_j^*[Q(X)]$ units of variety j, $j \in \mathbf{D}$. The long's revenue at contract expiration equals

$$R_D(X) = [X - Q(X)]MC^*[Q(X)] + \sum_{j \in \mathbf{D}} q_j^* \{P_j[\mathbf{Q}^*(X)] - d_j\}$$

where $\mathbf{Q}^*(X) = \{q_j^*[Q(X)]\}_{j \in D}$ is the vector of deliveries as a function of the large long's position size, and the arguments of the $q_j^*[Q(X)]$ have been suppressed to simplify the expression. For all j and k such that $q_j^* > 0$ and $q_k^* > 0$, $MC_j[\mathbf{Q}^*(X)] - d_j = MC_k[\mathbf{Q}^*(X)] - d_k = MC^*[Q(X)]$. For varieties m such that $q_m^* = 0$, $MC_m[\mathbf{Q}^*(X)] - d_k \geq MC^*[Q(X)]$.

The holder of X cash-settled futures positions can purchase $q_j^*[Q(X)]$ units of variety j, for all $j \in \mathbf{D}$ immediately prior to expiration of this contract. His revenues at settlement when following this strategy are:

$$R_C(X) = X \sum_{j \in \mathbf{D}} \alpha_j \{MC_j[\mathbf{Q}^*(X)] - d_j\} + \sum_{j \in \mathbf{D}} q_j^* P_j[\mathbf{Q}^*(X)] - \sum_{j \in \mathbf{D}} q_j^* MC_j[\mathbf{Q}^*(X)]$$

where the arguments of $q_j^*[Q(X)]$ have been suppressed to simplify the notation. Since $MC_j[\mathbf{Q}^*(X)] - d_j \geq MC^*(Q)$ and $q_j^*\{MC_j[\mathbf{Q}^*(X)] - d_j\} = q_j^* MC^*(Q)$:

$$R_C(X) \geq X \sum_{j \in \mathbf{D}} \alpha_j MC^*[Q(X)] + \sum_{j \in \mathbf{D}} q_j^* P_j[\mathbf{Q}^*(X)] - \sum_{j \in \mathbf{D}} q_j^* \{MC^*[Q(X)] + d_j\}$$

Since $\sum_{j \in \mathbf{D}} \alpha_j = 1$,

$$R_C(X) \geq [X - Q(X)]MC^*[Q(X)] + \sum_{j \in \mathbf{D}} q_j^* P_j[\mathbf{Q}^*(X)] - \sum_{j \in \mathbf{D}} q_j^* d_j = R_D(X)$$

Thus, a trader long X cash-settled contracts earns at least as much revenue at settlement as the long with X delivery-settled contracts regardless of the choice of the d_j.

Finally, note that if $P_j^c - d_j = P_k^c - d_k$, the revenue earned from liquidating a cash-settled futures position at the competitive price equals the revenue earned from liquidating a delivery-settled contract at the competitive price:

$$XF^* \equiv X \min[P_j^c - d_j] = \sum_{j \in \mathbf{D}} \alpha_j [P_j^c - d_j]$$

Therefore, $R_C(X) - XF^* \geq R_D(X) - XF^*$. In words, the gains from manipulating the cash-settled contract (measured as the revenue earned at settlement in excess of the competitive value of the long's futures position) are no smaller than, and may exceed, the gains from manipulating the delivery-settled contract ■ [18]

[18] Note that the gains of manipulating the cash-settled contract are the same regardless of whether or not the d_j are included in the calculation of the settlement index because they have no influence on the long's behavior at contract expiration. Including them only serves to make the comparison of cash and delivery-settled contracts more transparent.

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