Financial intermediaries in the midst of market manipulation: Did they protect the fool or help the knave?

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Abstract

We examine a fund manager's alleged manipulation of platinum and palladium futures settlement prices. Using benchmarks from parallel electronic markets, we find that the manager's market-on-close trading causes significant settlement price artificiality. Defying predictions that competition among floor traders should limit any artificiality, the artificiality increases in the second half of the alleged manipulation period. Between 35% and 52% of the latter-period artificiality is directly attributable to noncompetitive floor prices. Inflated floor volume contributes a similar proportion to artificiality via the exchange's trade-weighted settlement price formula. We estimate that floor counterparties reaped more than $6.0 million in excess profits.

Keywords: Market manipulation; Bang the close; NYMEX; Futures contracts; Platinum; Floor trading

1. Introduction

In this paper, we study the response of floor traders on an organized commodities futures exchange to a well-documented case of alleged trade-based manipulation of closing prices. Detailed court records provide us with a unique opportunity to examine whether the floor traders mitigated, facilitated, or magnified the alleged manipulative scheme. Our evidence suggests that these traders, operating in an environment with repeated interaction by a small number of participants, extracted significant rents from their noncompetitive pricing and that their behavior may have been consistent with tacit (implicit) collusion. We show how the microstructure of financial markets and, in particular, the mechanism for determining the closing settlement price, played a central role in the overall impact of the alleged manipulation.

Our findings have implications for optimal market design, rules for settlement price determination, market surveillance, and litigation settlement. By examining how other market participants dynamically respond to a single instigator's repetitive, long-term alleged manipulative trading scheme, we provide insights into how manipulative schemes can persist for surprisingly long periods of time. These insights are valuable in the broad context of understanding the recent allegations of widespread long-term misconduct in the setting of key interest rate benchmarks, such as LIBOR, as well as the setting of exchange rate and commodity price benchmarks.

Regulatory enforcement actions and our own empirical evidence suggest that a hedge fund portfolio manager (PM) directed unusually large market-on-close (MOC) orders to the New York Mercantile Exchange's (NYMEX) platinum and palladium futures trading floors to "bang the close."[1] These MOC orders had the apparent aim and effect of inflating daily contract settlement prices

[1] See Commodity Futures Trading Commission (CFTC) dockets 10-09 and 11-17: "In the matter of Moore Capital Management, LP, Moore Capital Advisors, LLC and Moore Advisors, Ltd., Respondents" http://www.cftc.gov/ucm/groups/public/@lrenforcementactions/documents/legalpleading/enfmooreorder04292010.pdf and "In the matter of Christopher Louis Pia, Respondent" http://www.cftc.gov/ucm/groups/public/@lrenforcementactions/documents/legalpleading/enfpiaorder072511.pdf.

throughout an extended period beginning in November 2007 and ending in May 2008. By that time, the bulk of futures trading volume had migrated to an electronic trading platform. Nevertheless, floor trades still accounted for about 20% of total NYMEX platinum and palladium futures contract volume. By rule, both exchange floor and electronic limit order book trades during the closing two minutes of trading were averaged to calculate each contract's daily settlement price. We use the PM's alleged attempt to manipulate official daily platinum and palladium contract settlement prices as a natural experiment within which to examine whether floor traders, acting as financial intermediaries, reduce or magnify the price impact of manipulative trades.

This episode qualifies as a well-specified natural experiment for three reasons. First, a class action lawsuit provides detailed publicly available data on the actual trades executed by the PM, as well as his private communications with floor brokers.[2] These data permit the precise identification of the dates and times of bang-the-close trades necessary to compare market outcomes on days with and without the PM's alleged manipulative trading. Second, the specific trades of this PM are likely to be non-informative regarding commodity fundamentals.[3] Moreover, the PM focused his trading on the floor, rather than seeking potentially more competitive prices on the electronic trading platform; this behavior limited outside competition for his order flow from participants other than the floor traders. Third, the side-by-side electronic trading platform provides natural benchmarks to assess whether floor traders executed these bang-the-close trades at competitive prices.

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[2] See *In Re: Platinum & Palladium Commodities Litigation*, No. 10-cv-3617, 2011 WL 4048780 (United States District Court, Southern District of New York, December 8, 2011) http://www.classlawsuit.com/wp-content/uploads/2012/01/Platinum-Complaint.pdf

[3] Allen and Gale (1992) derive conditions under which profitable trade-based manipulation can occur when all agents are rational. In their model, the manipulator mimics an informed trader. For the manipulation strategy to work in a competitive market, other market participants must assign a positive probability to the manipulator being an informed trader. In our setting, while the alleged manipulative trades might have been initially mistaken as information-based, the long-term repeated nature of the bang-the-close trades in a market with a small number of market participants makes it highly improbable that, over time, market participants would have believed that the trades contained information.

Court records provide numerous express admissions of the PM's desire to overpay and purchase platinum and palladium contracts at the highest price possible. These documents provide evidence that the PM intended to influence other persons to purchase platinum and palladium by triggering "buy signals" through new highs or broken trend lines.[4] The PM's fund held net long positions in platinum and palladium contracts worth almost a billion dollars at one point during the alleged manipulation period. This position gave the PM a significant financial motive to increase the price of platinum and palladium futures. Higher profits in the fund would result in higher compensation for the PM (typically 20% of profits), plus further prospective management fees by attracting additional fund inflows. While the PM's actions are interesting, we emphasize that the focus of this paper is on the response of the floor traders, acting as financial intermediaries, to the PM's orders. Whether the PM's large MOC orders were the work of a fool or a knave is irrelevant: a competitive market should protect a fool and otherwise neutralize a knave.

NYMEX floor trading participants include floor brokers, who execute customer orders, and floor traders (often called "scalpers"), who trade solely for their own accounts. Floor traders have no implicit or explicit responsibilities to customers. Instead, they make a two-way market, and as such, act as financial intermediaries between the end users (buyers and sellers) of the futures contract. While floor traders must obey exchange rules and are prohibited from manipulating prices by the Commodity Exchange Act, they are otherwise free to bid and offer for contracts on their own terms. In the spirit of Schwartz's (1991) observation about NASD dealers, a futures exchange relies on the constraints of a competitive market to discipline floor traders and other liquidity providers to keep markets fair, orderly, and liquid. Indeed, a fundamental premise of a futures exchange is that competition for orders will

[4] Jarrow (1992) derives conditions under which a large trader can generate price momentum using a trade-based manipulation strategy. Aggarwal and Wu (2006) examine 142 known manipulation cases and find that slightly over half of the cases involved at least partial trade-based manipulation, in which the manipulator first bought and then sold stock.

produce fair prices and narrow bid-ask spreads. NYMEX rules specifically require that "bidding and offering practices must at all times be conducive to the competitive execution of transactions."[5]

The open outcry exchange floor has traditionally been viewed as a model competitive trading environment for futures contracts, well suited for both price discovery and order execution. One would expect the floor traders to price the end-of-day trades competitively according to the expected costs of unwinding them. Instead, we find evidence that the floor traders consistently executed portions of these MOC trades at much higher prices that were simultaneously available on the electronic limit order book. We generate this "smoking gun" evidence by comparing the prices for that portion of the PM's filled exchange floor orders to the volume-weighted average price (VWAP) for the same contract amount that was simultaneously available on electronic market (i.e., the VWAP for tradable Globex depth). Furthermore, we find that over the alleged manipulation period these noncompetitive prices increased for platinum (palladium), from an average of 1-20 ticks (10-36 ticks) above benchmarks in the first half of the alleged manipulation period to an average of 67-75 ticks (40-80 ticks) above benchmarks in the second half. We estimate that, in the latter period, 35% to 52% of the observed settlement price artificiality is directly attributable to excess mark-ups on floor trade executions rather than the manager's market-stressing order choices. Moreover, during the alleged manipulation period, an *ex post* simulated trading exercise for platinum suggests that floor traders may have reaped excessive profits of more than $6.0 million over roughly 100 trading days with minimal drawdowns. Thus, we provide evidence that an open outcry floor can produce trade prices that deviate radically from competitive benchmarks.

While alternative explanations for the observed price patterns may exist, we cannot rule out the existence of tacit collusion among NYMEX floor traders. Tacit collusion refers to coordination without direct communication. It is a process by which agents recognize their shared, interdependent economic interests and, in response, set prices at supra-competitive levels.

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[5] Rule 521 of the NYMEX Rulebook, CME Group, 2009, http://www.cmegroup.com/rulebook/NYMEX/.

Pirrong (1996) suggests that repeated interactions among futures exchange floor traders in a setting where the activities of all parties can be observed make an open outcry system conducive to collusive behavior. For instance, floor traders might jointly raise their offers to the disadvantage of a customer who needs to buy a large number of contracts within a short period of time. Pirrong conjectures that incentives for individual traders to deviate from the collusive equilibrium, as well as outside competition from non-floor traders, limit any collusive profits of floor traders to perhaps one to two ticks. The persistent, noncompetitive pricing distortions we find during the alleged bang-the-close manipulation episode in the fragmented platinum and palladium futures markets are orders of magnitude larger than those conjectured by Pirrong (1996) for a typical open outcry market. The net effect of the prices offered by the platinum and palladium floor traders reinforced the impact of the customer's alleged manipulative trades.[6] Regulators appear to have become aware of the alleged manipulation only after *non-floor participants* complained that they were unable to sell at the more favorable closing period prices.

In the ongoing debate about the role of high frequency trading, some might argue that reducing direct human interaction in the trading process could increase the tendency for manipulation. Our research suggests that humans in the trading process may reinforce, rather than suppress, manipulation and compliments the findings of Cumming, Zhan, and Aitken (2013b), who show that the presence of high frequency trading has mitigated the frequency and severity of end-of-day price dislocation.

Given our focus is on the role of financial intermediaries, our research parallels McNally, Shkilko, and Smith (2014), who provide evidence that brokers use information about insiders' outstanding orders to tip their other clients, and that this behavior is more pronounced in independent brokerages that are subject to less regulation and supervision. To the extent that some company insiders' trades are improper (based on material, non-public information), the brokers magnify the effect of these trades by informing their best clients. We also find that the floor traders, acting as financial intermediaries, appear

[6] Tacit collusion could occur even if some floor traders were not counterparties to the alleged manipulative trades. Some traders may have been aware of these trades, but hesitant to report them to authorities for fear of being penalized by their peers (both financially and socially).

to have magnified the effect of the alleged manipulative trades. These results contrast to those of Bernile *et al*. (2013) who find that institutions, acting as intermediaries during the option backdating scandal, tended to act as informed investors and, in general, may have improved price efficiency.

2. Background

Platinum and palladium futures contracts are listed by, and subject to, the rules and regulations of NYMEX. Though acquired by CME Group in August 2008, NYMEX remains a separate self-regulatory organization. A platinum (palladium) futures contract calls for delivery of 50 (100) troy ounces. Prices are quoted in U.S. dollars and cents per troy ounce with a minimum price fluctuation ("tick size") of $0.10 per troy ounce for platinum and $0.05 per troy ounce for palladium. Trading terminates on the third last business day of the delivery month. NYMEX lists platinum contracts for a quarterly cycle of January, April, July, and October, but also fills out the trading menu with contracts for the current and next two calendar months. Similarly, palladium contract listings cover the quarterly cycle of March, June, September, and December, as well as the current and next two calendar months.

Open outcry trading of platinum futures takes place on a NYMEX trading floor for a session beginning at 8:20 a.m. and ending at 1:05 p.m. (henceforth all times are Eastern). Electronic trading takes place via the Globex platform for a near 24-hour session beginning at 6:00 p.m. on the date preceding a given day's open outcry session and ending at 5:15 p.m. (more than four hours after the open outcry session's 1:05 p.m. close). During the period under study, the daily settlement price for a platinum futures contract is calculated as the Volume-Weighted Average Price (VWAP) of all NYMEX floor and Globex transactions during a two-minute closing period that begins at 1:03 p.m. and ends at 1:05 p.m.

Palladium's open outcry trading session begins at 8:30 a.m. and ends at 1:00 p.m. Electronic trading takes place for the same near 24-hour session described for platinum futures. During the period under study, the daily settlement price for a palladium futures contract is calculated as the VWAP of all

NYMEX floor and Globex transactions conducted during a two-minute closing period that begins at 12:58 p.m. and ends at 1:00 p.m.

During the period under study, the NYMEX platinum and palladium open outcry markets were characterized by a small number of traders (fewer than ten on any given date)[7], intermittent supervision by compliance officers[8], and frictions that limited participation by off-floor participants. Indeed, trading volumes on open outcry venues have shriveled over the past decade with the rise of much less expensive electronic trading platforms. Many futures contracts now trade exclusively on an electronic platform. But beyond trading costs, open outcry markets differ from electronic markets across a number of dimensions. Among these, Sarkar and Tozzi (1998) list differences including the identities of the main suppliers of liquidity, primary costs of the trading infrastructure, information sources, operating efficiency, and possible sources of trading abuse. One important difference concerning information flow relates to potential trading abuse. Whereas the orders entered in the newer electronic markets via offsite keyboards are anonymous, open outcry floor traders observe the actions of other floor traders.

2.1 Noncompetitive Prices in Financial Markets

Recent investigations have alleged that certain money market traders working for major banks colluded to set daily LIBOR fixings at artificial levels in order to profit from positions in related derivative contracts (Financial Services Authority, 2012). Gandhi *et al*. (2013) estimate that this manipulation could have increased the market value of panel banks by over $22 billion. Abrantes-Metz, *et al*. (2012) find statistical evidence of patterns in LIBOR rate submissions that appear inconsistent with those expected to occur under conditions of market competition.

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[7] See Commodity Futures Trading Commission (CFTC) docket 10-09.

[8] A review of the 14-person NYMEX Market Surveillance Department concluded that "...its size has not kept pace with the approximate tripling of volume, quadrupling of product offerings, and 400-fold increase in the volume of over-the-counter transactions...", page 3, *Market Surveillance Rule Enforcement Review of the New York Mercantile Exchange*, Division of Market Oversight, Commodity Futures Trading Commission, May 19, 2008.

In an earlier example, Christie and Schultz (1994) provide evidence of tacit collusion among NASDAQ stocks dealers, who systematically inflated effective bid-ask spreads and increased dealing profits by avoiding odd-eighth quotes. Christie and Schultz argue that NASDAQ dealers engaged in an infinitely repeated game with complete and perfect information, in which the current and historical quotes were available to all dealers. Friedman (1971) shows that, under such conditions, collusion may be a possible equilibrium outcome if the future costs to each player of deserting the equilibrium exceed the immediate gains. Similar conditions appear to characterize the LIBOR fixing process, as well as many other financial markets.

Dutta and Madhavan (1997) argue that implicit collusion can arise even from non-cooperative behavior among dealers. In an experimental setting, Cason (2000) shows that dealers can tacitly collude to widen spreads, even without any direct communication. Similarly, in other experiments, Kluger and Wyatt (2002) find that the ability for dealers to internalize order flow allows them to coordinate on a less competitive equilibrium. In the context of uniform-price auctions for Treasury securities, Back and Zender (1993) show that collusive strategies can be self-reinforcing. Khwaja and Mian (2005) find instances in which stock brokers in Pakistan colluded to trade among themselves to artificially raise prices in a "pump and dump" price manipulation scheme. These brokers, acting as financial intermediaries, traded for their own advantage at the expense of outside investors.

Pirrong (1996) points out that tacit collusion may also emerge among futures floor traders since these traders interact in a transparent setting on a daily basis over a long period of time. Thus, floor traders as a group can punish any individuals who defect from the cooperative agreement by refusing to trade with them, or by only offering business on unfavorable terms. In contrast, those who cooperate can be rewarded. Pirrong (1996) posits that two forces limit the impact of such collusive behavior in futures markets. First, the gains from any one trader's defection from the tacit cooperative agreement may exceed the costs of punishment if price distortions become too large. Second, competition from off the floor ("upstairs") traders submitting limit orders disciplines the degree by which collusive floor traders can move prices through cooperation. In the case of NYMEX metals contracts, the Globex trading platform

should resolve this potential collusion by opening the system to client limit orders to the extent that floor and electronic order flows are fully integrated. Such outside competition fits the Pirrong conjecture why even collusive floor prices should be kept close to competitive prices. Markham (1991) describes the Federal Bureau of Investigation's 1989 sting operations on the Chicago futures exchanges.[9] This investigation resulted in indictment of 48 traders charged with hundreds of violations of federal laws and provided evidence of an anti-competitive symbiotic relationship between brokers and floor traders. Supporting Pirrong's contention, however, many of the convictions in these cases involved transgressions of limited size.

Bang-the-close trading is a blatant example of market manipulation. Closing prices are often the focus of manipulation, due to their importance in the determination of fund performance and net asset values, and for the settlement of derivative contracts. For example, Carhart *et al*. (2002) and Bernhardt and Davies (2005) find significant evidence that mutual fund managers "paint the tape" at the end-of-quarters. Ni *et al*. (2005) explore whether closing stock prices may be manipulated on option expiration dates. Kumar and Seppi (1992) consider the manipulation of settlement prices for futures contracts that are cash settled. Comerton-Forde and Putnins (2011) attempt to measure the quantitative impact of known instances of closing price manipulation in equity markets. Comerton-Forde and Putnins (2014) estimate that approximately one percent of closing stock prices are manipulated. Hillion and Suominen (2004) develop a model of agency-based incentives to manipulate closing prices, highlighting that these incentives to manipulate closing prices can occur in the context of merger and acquisition transactions, when there are value-based commissions or reputational gains from managing high value deals, or when the acquisition price is based on past closing prices.

Closing price manipulation using bang-the-close trades allegedly occurs in futures markets as well. A well-known recent case involves Optiver Holding BV. The CFTC accused Optiver Holding, two of its subsidiaries, and three employees with manipulation and attempted manipulation of crude oil,

[9] See Greising and Morse (1991) for details.

heating oil, and gasoline futures on the NYMEX.[10] The traders are alleged to have used bang-the-close trades in at least 19 instances during March 2007 to manipulate the settlement prices of the oil futures contracts. In contrast to the manipulation in platinum and palladium futures case we study, the alleged Optiver manipulative scheme is based on trades in the electronic market.

2.2 Details of the Alleged Manipulation of Platinum and Palladium Futures Settlement Prices

During the period between November 2007 and May 2008, a portfolio manager working for a major hedge fund allegedly engaged in closing price manipulation of the NYMEX platinum and palladium futures contracts. We do not analyze the motives behind the PM's bang-the-close trades. Clearly, artificially high settlement prices benefitted the daily marked-to-market cash flows on the PM's existing long platinum and palladium contract positions. But the benefits of such marked-to-market cash flows would only be transitory unless bang-the-close price impacts persist. Private communications with his brokers suggest that, on particular days, one aim was to push prices through certain technical targets ("new highs"), perhaps with the goal of inducing follow-on trading by momentum investors.

The PM placed large market-on-close (MOC) buy orders on the floor just seconds before the end of the closing period. By using such MOC orders, the portfolio manager placed no apparent limit on how high a price he would pay to buy large numbers of contracts during a short window of time in an illiquid market. Moreover, he ignored the obvious alternative of walking the book of limit orders concurrently available on the more liquid Globex platform.

The PM decided whether or not to trade after getting feedback from his futures commission merchant's floor broker about the likely price effect of various order sizes.[11] On the days he chose to trade, the PM typically entered his MOC buy orders in the last 10 seconds of the closing period.[12]

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[10] See: http://www.cftc.gov/ucm/groups/public/@lrenforcementactions/documents/legalpleading/enfoptiveruscomplaint072408.pdf

[11] For additional details about the alleged role of the registered futures commission merchant see Commodity Futures Trading Commission (CFTC) docket 1:12-cv-01873-WHIP.

If the PM did decide to trade, he then made his MOC order size decision (usually 50 or 100 contracts).

Under NYMEX Rule 521 governing open outcry trading, bids and offers must be made openly and competitively in the pit designated for the trading of the particular contract. In particular, transactions may take place only at the best price available in the open outcry market at the time the trade occurs and no bid or offer may be specified for acceptance by a particular trader. Under NYMEX Rule 522, while outstanding, all or any part of any bid or offer is subject to immediate acceptance by any trader. Floor traders seeing the PM's market order to buy, say, 50 contracts, should have responded with offerings based upon their knowledge of where platinum or palladium was trading concurrently on Globex and their perception of prices they will have to pay to offset the positions. The futures commission merchant's floor broker typically executed the buy order in a single trade that filled the PM's full desired size, but these trades sometimes involved multiple counterparties. For example, the PM's 50-lot buy order would be executed with two floor traders: one floor trader would sell 40-lots, and the other floor trader would sell 10-lots. During the alleged manipulation period, the PM never entered a MOC sell order.

2.3 Decomposition of Price Impact of Bang-the-Close Trades

The PM bypassed the Globex platform and chose to execute his large bang-the-close buy orders via the exchange floor. We use the prices from concurrent closing period trades on the Globex platform to discern market conditions absent the PM's activity. Specifically, we define a counterfactual *Globex Settlement Price* as the VWAP of Globex trades during the closing period. We then use the official daily *Settlement Price* to define *Settlement Price Artificiality* as:

$$\textit{Settlement Price Artificiality} = \textit{Settlement Price} - \textit{Globex Settlement Price}. \quad (1)$$

[12] MOC orders are market orders that are to be executed only in the closing range. If a customer places an MOC order prior to the beginning of the closing period, his broker withholds the order until the closing period begins. Since the PM only entered his orders with seconds left during the closing period, his MOC orders were effectively regular market orders.

Define *Floor Mark-Up*^{PM} as the difference between the VWAP of the PM's market-on-close floor trades (*Floor Price*^{PM}) and our counterfactual *Globex Settlement Price*:

$$Floor\ Mark\text{-}Up^{PM} = Floor\ Price^{PM} - Globex\ Settlement\ Price. \quad (2)$$

If, aside from the PM's bang-the-close trades, floor trades were priced competitively at the *Globex Settlement Price*, we can interpret *Settlement Price Artificiality* as the difference between the PM's average weighted execution prices and the VWAP of closing-period Globex trades, such that:

$$Settlement\ Price\ Artificiality \approx \Theta^{PM} * (Floor\ Price^{PM} - Globex\ Settlement\ Price). \quad (3)$$

where:

$$\Theta^{PM} = \frac{PM\ trade\ volume\ on\ floor\ during\ closing\ period}{Total\ trade\ volume\ (Floor + Globex)\ during\ closing\ period}.$$

The PM's bang-the-close trades were large and, as such, they should have impacted settlement prices. The relevant issue for us is determining the extent to which the price impact of these trades was larger than expected in a fully competitive market. Rather than attempt to estimate a price impact function, we develop a conservative measure based on the directly observable, and immediately tradable, depth of the Globex limit order book.

Define the *Walk-The-Book Price* as the average price that the PM (or anyone else) would have paid to buy up the available depth of offered contracts on Globex. This price is computed as the VWAP of available offers in the electronic limit order book at the close on each of the PM's trading days up to the PM's MOC order size (if book depth allows) or until book depth is exhausted (if the PM's MOC order size is larger than book depth). Thus, the *Walk-The-Book Price* accounts for the book depth contemporaneously available on Globex at the close of floor trading and is a natural benchmark for assessing the potential impact of a trader who demands to buy a large number of contracts at the close in an illiquid market. Define *Mark-Up*^{WTB} as a mark-up that Globex market participants charge for exposing

their limit orders that constitute available Globex book depth equal to the difference between the *Walk-The-Book Price* and the *Globex Settlement Price*:[13]

$$Mark\text{-}Up^{WTB} = Walk\text{-}The\text{-}Book\ Price - Globex\ Settlement\ Price. \quad (4)$$

Define $Artificiality^{WTB}$ as the component of overall *Settlement Price Artificiality* due to stressing the market by buying a quantity of contracts equal to the available depth of the Globex book:

$$Artificiality^{WTB} = \Theta^{WTB}\ (Walk\text{-}The\text{-}Book\ Price - Globex\ Settlement\ Price), \quad (5)$$

where

$$\Theta^{WTB} = \frac{Available\ walk\text{-}the\text{-}book\ depth\ at\ close}{\left(\begin{array}{c} Globex\ Closing\ Period\ Volume + Non\text{-}PM\ Floor\ Closing\ Period\ Volume \\ + Available\ walk\text{-}the\text{-}book\ depth\ at\ close \end{array}\right)}.$$

$Artificiality^{WTB}$ is solely due to the PM's decision to stress the market for the same trade size that Globex depth would permit at the best available (Globex) executable prices.

Walk-The-Book Price is a natural benchmark for the PM's filled exchange floor orders for at least the contract amount equal to the available Globex depth. To compare the PM's fills on the floor to this *Walk-The-Book Price*, we calculate a companion depth-matched ("D-Matched") $Floor\ Price^{D\text{-}Matched}$ from the PM's futures trades as a VWAP for the portion of the PM's futures volume that matches the available depth of the Globex book. While the PM's MOC orders were usually filled via one trade ticket at a single price (say, 100 contracts at $2,020 per oz.), sometimes his MOC orders were split across multiple transactions at different prices (say, 10 contracts at $2,000 per oz. and the remaining 90 contracts at $2,022.20). For trade days when closing Globex book depth (say, only 20 contracts) is smaller than that of the PM's trade (say, 100 contracts), we first order any split fills for the PM's contracts of floor futures

[13] Under this working approximation of the $Mark\text{-}Up^{WTB}$, we use the *Globex Settlement Price* as a substitute for the *Globex Best Offer* for at least one contract. This approximation eases the exposition and interpretations of our calculations though it overstates the $Mark\text{-}Up^{WTB}$ by one-half of the bid-offer spread on average.

trades on any given day from the lowest to the highest trade prices. We then calculate $Floor\ Price^{D\text{-}Matched}$ for the PM's futures trades as the VWAP that includes only the lowest ordered prices for the PM's floor trades that sum to the contemporaneously available Globex 20-contract book depth (in the example, $2,011.10, the weighted-average of the first 10 contracts traded at $2,000.00 and second 10 more contracts traded at $2,022.20). For trade days when the available book depth is at least as large as the total size of the PM's trade, we calculate $Floor\ Price^{D\text{-}Matched}$ simply as the VWAP of the book's available offerings up to the PM's trade size.

Define $Mark\text{-}Up^{D\text{-}Matched}$ as the mark-up that floor traders apply to the depth-matched portion of the PM's trades relative to contemporaneously available offerings on Globex:

$$Mark\text{-}Up^{D\text{-}Matched} = Floor\ Price^{D\text{-}Matched} - Globex\ Price^{WTB}. \quad (6)$$

$Mark\text{-}Up^{D\text{-}Matched}$ should tend toward zero in a competitive market since any floor trader could simultaneously fill the PM and offset the filled position on Globex via a hand-held electronic trading device. In a competitive market, quotes should tend toward the no-arbitrage price. By exchange rules, one cannot execute a trade that would cross over such a quote. Therefore, we interpret any positive $Mark\text{-}Up^{D\text{-}Matched}$ to be a direct measure of noncompetitive pricing.

Define $Artificiality^{D\text{-}Matched}$ as the component of overall *Settlement Price Artificiality* due to noncompetitive pricing of the portion of the PM's floor trades that matches the depth of the Globex book:

$$Artificiality^{D\text{-}Matched} = \Theta^{WTB} * Mark\text{-}Up^{D\text{-}Matched}. \quad (7)$$

$Artificiality^{D\text{-}Matched}$ is jointly caused by the PM's venue decision to bypass the available size on Globex and the floor traders' pricing of this portion of the PM's total order size at an average price that differs from the $Globex\ Price^{WTB}$.

These constructs provide a nested framework within which to attribute distortions in the official settlement price to decisions by the PM regarding trade size and venue choice in conjunction with the

pricing performance by floor trader intermediaries. Thus, the *Settlement Price Artificiality* from (1) can be decomposed as:

$$\begin{aligned} \textit{Settlement Price Artificiality} &= \textit{Walk-the-book price impact of PM volume} + \textit{Excess price impact on walk-the-book portion of PM volume} + \textit{Excess price impact on residual portion of PM volume} \\ &= \textit{Artificiality}^{WTB} + \textit{Artificiality}^{D\text{-}Matched} + \textit{Artificiality}^{Residual} \end{aligned} \tag{8}$$

$\textit{Artificiality}^{Residual}$, an impact solely due to the exchange floor, encompasses both residual size and price dimensions. First, the floor venue allows the PM to trade a larger quantity of contracts than is available at the close on Globex. Thus, floor trading allows the PM to increase his own trades' relative impact on the official daily contract settlement price relative to a pure *Globex Settlement Price*. Second, the impact on *Settlement Price Artificiality* from this residual quantity of the PM's trades executed on the floor depends on whether or not floor traders offer competitive prices against this residual portion. We do not interpret the magnitude of $\textit{Artificiality}^{Residual}$ since it lacks a natural Globex-derived price benchmark. It is beyond the scope of this paper to calculate a benchmark that adjusts for market conditions and is free of measurement error.

Figures 1a-1c provide a geometric interpretation for how the three components of the *Settlement Price Artificiality* in (8) relate to the sources of mark-ups on the PM's floor trades, the volume weights of the PM's order flow, and available walk-the-book depth. Consider three cases:

Case 1: Figure 1a illustrates the simplest case where the number of contracts traded for the PM on the floor equals the available walk-the-book depth on Globex, such that $\Theta^{PM} = \Theta^{WTB}$. Here, the mark-up of the PM's trades can be decomposed into the cost of walking the book ($\textit{Mark-Up}^{WTB}$) and the additional mark-up given by the floor traders over this amount due to noncompetitive pricing

($Mark\text{-}Up^{D\text{-}Matched}$).[14] Both $Mark\text{-}Up^{WTB}$ and $Mark\text{-}Up^{D\text{-}Matched}$ translate proportionally via Θ^{PM} into *Settlement Price Artificiality* via their corresponding $Artificiality^{WTB}$ and $Artificiality^{D\text{-}Matched}$ components. The PM's decision to focus his trading on the floor has a directly attributable impact of the floor on *Settlement Price Artificiality* that is proportional to the $Mark\text{-}Up^{D\text{-}Matched}$. Here, the PM's decision to trade on the floor does not increase his proportional weight on the settlement price.

Case 2: Figure 1b illustrates an intermediate case where the number of contracts traded for the PM on the floor exceeds the available depth of the Globex book, such that $\Theta^{PM} > \Theta^{WTB}$, but assumes the average price filled on the floor for the beyond the walk-the-book depth contracts equals that for the depth-matched size.[15] In this case, the inflated weighting (i.e., as measured by $\Theta^{PM} - \Theta^{WTB}$) of the PM's trades produces a third component, $Artificiality^{Residual}$. The impact of the floor on *Settlement Price Artificiality* now depends on both the $Mark\text{-}Up^{D\text{-}Matched}$ (produced by its floor traders) as well as the PM's volume inflation (i.e., the PM's decision to trade a contract size greater than concurrently available on Globex) interacted with the NYMEX's VWAP settlement price formula.

Case 3: Finally, Figure 1c illustrates the most complex case where $\Theta^{PM} > \Theta^{WTB}$ and the average price filled on the floor for the additional contracts beyond the walk-the-book depth is higher than that for the depth-matched size. Such extra floor depth at a higher price produces a $Mark\text{-}Up^{Tail}$ that affects only $Artificiality^{Residual}$, the exchange floor-related measure that now encompasses both size and price dimensions.

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[14] $Mark\text{-}Up^{D\text{-}Matched}$ could also incorporate a small risk premium for the risk that an electronic communication break-down could prevent the floor traders from being able to immediately unwind their positions on Globex. Later, we show that any time variation in the risk premium does not drive our main results.

[15] For example, this pricing behavior could occur if the electronic limit order book has hidden depth proportional to the existing quoted depth.

3. Data and Summary Statistics

From CME DataMine, we obtain exchange data for all NYMEX platinum and palladium futures contract trades during the period from July 1, 2007 to June 30, 2008. These data include the official record of trade times and prices, but include trade quantities only for the Globex trades as the floor trade tickets containing trade quantity and counterparty information are not publicly available. We also obtain all of the tick-by-tick, time-stamped-to-the-millisecond CME Group Market Data messages needed to recreate the 5-quote-deep Globex limit order book. We obtain daily platinum and palladium futures settlement prices from Bloomberg Financial.

We obtain the PM's bang-the-close trade data from public court records.[16] We define the alleged manipulation period as beginning with the PM's first reported bang-the-close trades (November 6, 2007 for palladium and November 19, 2007 for platinum) and ending with his last reported bang-the-close trade on May 21, 2008. On May 22, 2008, the CFTC began to investigate bang-the-close trading in metals futures contracts. The PM chose to trade in platinum on 95 days of the 125 alleged manipulation period days. We split these 95 bang-the-close trade days into two samples: the first 47 days ("first half") and the next 48 days ("second half"). The second half begins on February 13. To ease exposition, we use the same cutoff date of February 13 to split the halves of the alleged manipulation period for palladium.

3.1 Trading over the Sample Period

Figure 2 plots the daily contract trading volume (left axis) and daily settlement price (right axis) of the active platinum and palladium futures contracts from July 1, 2007 to June 30, 2008. Prior to January 2008, volume fluctuated around 1,000 contracts per day. But starting in January 2008 and continuing through March 2008, daily trading volume in each metal contract more than doubled and grew significantly more volatile. Trading volume remained volatile over the final three months of the sample,

[16] The details of the bang-the-close trades in NYMEX platinum and palladium futures contacts made by the PM's fund are reported on pages 68-74 and 89-93 of the Fifth Consolidated Amended Class Action Complaint, *In Re: Platinum and Palladium Commodities Litigation*, No. 10 Civ. 3617.

but declined to about 1,500 contracts per day in platinum. The increase in contract trading volume over the January 2008-March 2008 period contract coincided with a roughly 40% rise in platinum and palladium futures prices over the same period. This dramatic rise in precious metal futures prices reflected a general bull market in commodities that occurred in the first half of 2008.

Figure 3 presents the lot size distribution of all Globex-executed trades for front-month platinum and palladium contracts over the full sample. Clearly, both futures contracts trade in a "thin" market with a preponderance of one-lot trades. In this market, the PM's typical 50- or 100-lot order sizes are unusual.

Figure 4 plots the average Globex trading volume in platinum and palladium by hour across all days in our sample. Average hourly Globex trading volume in both metals peaks in the morning at the opening of NYMEX floor trading. For platinum, trading and declines each hour till the the floor's close (during the 1:00 p.m. hour). Volume is light during the afternoon, picks up with the 8:00 p.m. start of the Asian business day, and then increases again with the 3:00 a.m. start of the London business day. The main difference for palladium is that trading is more active during the closing period.

Figure 5 presents median contract volume on the Globex electronic market for 21 two-minute intervals centered on platinum's 1:03 p.m.-1:05 p.m. closing interval (plotted as two-minute interval number 11) and palladium's closing period of 12:58 p.m.-1:00 p.m. The left panels of this figure present results for data outside the alleged manipulation period. Not surprisingly, median contract volume peaks during the closing interval and then falls during the next 20 minutes. Note that a single PM order of 100 contracts would be more than seven times the median number of contracts traded during the closing interval outside of the alleged manipulation period in both platinum and palladium.

The middle and right panels show the same median number of contracts during the alleged manipulation period, separately for days that PM allegedly traded on versus days on which he did not. One striking difference between the results outside versus during the alleged manipulation period regards the change in volume during the two minutes immediately after floor's close (1:05 p.m. for platinum, 1:00 p.m. for palladium). The volume in the two minutes immediately post-close rises sharply as we move

from the left to the right panel. The difference in post-close volume in the 2-minute period post-close between the right and mid panels is roughly 10 contracts in both platinum and palladium.

3.2 Observed Trade Mark-Ups and Settlement Price Artificiality

Figures 6a-6d depict market conditions and trading activity in futures contracts on both Globex and the exchange floor for 15 minutes before and 15 minutes after the floor's close for two specific days in each platinum and palladium. Figure 6a presents data for November 19, 2007, the first date of the PM's alleged manipulative bang-the-close trading in platinum. Court records show that the PM bought a total of 50 January 2008 contracts in a single trade recorded at 1:05 p.m. at a price of $1,458 per ounce. The figure plots all individual trades during this 30-minute period. The sizes of the plotted symbols for the Globex trades and the PM's floor trades are proportional to the number of contracts constituting each trade. Because we have no contract size data for floor trades other that those of the PM, we plot these remaining floor trades without size variation. Finally, we depict two price benchmarks: the official settlement price (solid line) and the Globex closing period VWAP price (dashed line). Figure 6b presents corresponding data on the first day (November 6, 2007) of the PM's manipulative floor trades in palladium. Figures 6c and 6d present analogous data for May 21, 2008, the last date of the PM's alleged manipulation in both platinum and palladium futures.

Figures 6a-6d illustrate the main trade price patterns surrounding the PM's alleged bang-the-close trading strategy. First, the PM's trades are unusually large compared to those taking place on Globex in the prior 15 minutes. Second, the execution prices paid by the PM to floor traders who sold him his contracts is only modestly inflated on the initial days (about $3 per ounce in platinum and $2 per ounce in palladium). By May 21, 2008, the same trade mark-ups had risen dramatically to about $30 per ounce in platinum and $10 per ounce in palladium. Third, the PM's trades caused settlement price artificiality of about $2.50 per ounce in platinum and just about $2.00 per ounce in palladium in November 2007 and about $28 per ounce in platinum and about $8.50 in palladium on May 21, 2008 relative to the Globex closing period VWAP benchmark.

Figure 7 plots the active platinum and palladium contract's *Settlement Price Artificiality* (left axis) along with the *Settlement Price* (right axis). *Settlement Price Artificiality* values are plotted in a way that distinguishes the days on which the PM executed bang-the-close trades (light shaded bars) from those days that he did not (dark shaded bars). Table 1 summarizes the *Settlement Price Artificiality* data shown on Figure 7 via estimated means and median values for samples split into possible four periods (pre and post the alleged manipulation period, and two halves of the alleged manipulation period) for each of three PM trade size categories (days with no PM trades, days when the PM trades 25 or 50 contracts, and days when the PM trades 75 or 100 contracts). Table 1 also presents companion estimates of means and median values of $Floor\ Mark\text{-}Up^{PM}$ for all days on which the PM traded.

Panel A reports the results for platinum. In the "pre" period prior to the alleged manipulation period, the mean value for *Settlement Price Artificiality* is \$0.48 with associated p-value of 0.01 for a t-test that the mean equals 0. The median value for *Settlement Price Artificiality* is \$0.00 (p-value of 0.22). While a median value of zero for *Settlement Price Artificiality* is expected over this sample, the positive and statistically significant mean artificiality value prior to the alleged manipulation period is surprising.[17] The mean and median settlement price artificiality in "post" alleged manipulation period are statistically indistinguishable from zero, but similar in magnitude to those from the "pre" period sample. Given these similar magnitudes, we combine the pre and post period samples into one "Outside alleged manipulation period" sample in our remaining analysis.

Over the first half of the alleged manipulation period, we find mean and median *Settlement Price Artificiality* to be indistinguishable from zero on days in which the PM does not trade. When the PM does trade, the estimated means and medians of *Settlement Price Artificiality* are positive and depend on the

[17] We presume the court records to be reliable. But one potential explanation of this result would be that the court records do not capture a few of the PM's trades from the pre-class period. Alternatively, we cannot rule out the possibility that other traders might be engaging in bang-the-close trades in this earlier period. We note that, in the context of equity markets, Comerton-Forde and Putnins (2011) argue that many instances of closing price manipulation are undetected by authorities.

size of the trade. For platinum, mean *Settlement Price Artificiality* is $1.72 for trades of 25 or 50 contracts and $4.14 for trades of 75 or 100 contracts (the corresponding median values are $1.41 and $2.95). As is readily apparent, positive means for *Settlement Price Artificiality* are driven by companion positive means for *Floor Mark-Up*^{PM}. The estimated mean values of *Floor Mark-Up*^{PM} is $3.02 for trades of 25 or 50 contracts and $6.22 for trades of 75 or 100 contracts (the corresponding median values are $2.83 and $4.97). The ratio of mean *Settlement Price Artificiality* to mean *Floor Mark-Up*^{PM} is an approximate guide to the effective relative importance of the PM's trades to total closing period contract volume. In the first half of the alleged manipulation period, the Θ^{PM} implied by the ratio of the respective mean values (=1.72/3.02 and = 4.14/6.22) shows that the PM accounted for roughly two-thirds of total closing period contract volume.

Over the second half, mean *Settlement Price Artificiality* for days in which the PM does not trade is a statistically significant $3.06, while the corresponding median artificiality is just $0.01. When the PM does trade, the mean and median *Settlement Price Artificiality* are positive, statistically significant, and trade size-dependent. Moreover, *Settlement Price Artificiality* estimates are two to four times larger than corresponding estimates from the first half. For example, mean *Settlement Price Artificiality* is $7.91 (versus $1.72) for trades of 25 to 50 contracts and $9.88 (versus $4.14) for trades of 75 or 100 contracts. The roughly $10 mean *Settlement Price Artificiality* for the latter case represents 100 ticks. Estimates of the median show a similar pattern: median *Settlement Price Artificiality* is $4.81 (versus $1.31) for trades of 25 to 50 contracts and $8.30 (versus $2.95) for trades of 75 or 100 contracts. Again, these positive values for *Settlement Price Artificiality* are driven by corresponding positive values for *Floor Mark-Up*^{PM}. The estimated mean values of *Floor Mark-Up*^{PM} is $10.56 for trades of 25 or 50 contracts and $13.52 for trades of 75 or 100 contracts (the corresponding median values are $7.21and $12.02). In the second half, the Θ^{PM} implied by the ratio of the respective mean values (=7.91/10.56 and = 9.88/13.52) shows that the PM raised his trading to roughly three-quarters of total closing period contract volume.

In Panel B of Table 1, we present the analogous mean and median *Settlement Price Artificiality*

and *Floor Mark-Up*^{PM} estimates for the palladium futures contracts. The results reveal similar patterns as in platinum. Again, *Settlement Price Artificiality* and *Floor Mark-Up*^{PM} increase almost two times from the first to the second half for both days when the PM trades 25-50 contracts and days with 75-100 contract trades. And, similar to the platinum results, there is significant evidence for positive artificiality during the alleged manipulation period on days when the PM allegedly did not trade. The average estimate for Θ^{PM} for palladium is much higher in the first half of the period (around 80%), but the Θ^{PM} in the second half of the period closely matches the estimate for platinum of 75%.

4. Components of Price Artificiality

Figure 8 present the time series for platinum and palladium of the magnitudes of the three distinct components of observed *Settlement Price Artificiality* in the form of stacked bar graphs. These three components are *Artificiality*^{WTB}, which is solely due to the PM's decision to stress the market for the same trade size that Globex depth would permit at the best available executable prices; *Artificiality*$^{D\text{-}Matched}$, which is jointly caused by the PM's venue decision to bypass the available offered-side contract depth on Globex and the floor traders' pricing of this portion of the PM's total order size at a different average price; and *Artificiality*^{Residual}, which is solely due to the floor venue but encompassing both residual size and price dimensions.

Table 2 presents estimates of the mean values of these three artificiality concepts for each half of the alleged manipulation period. We also report the mean mark-ups, *Mark-Up*^{WTB} and *Mark-Up*$^{D\text{-}Matched}$ associated with the respective *Artificiality*^{WTB} and *Artificiality*$^{D\text{-}Matched}$ components. During the first half for platinum, the *Artificiality*^{WTB} component of \$1.03 accounts for most of the \$1.72 total *Settlement Price Artificiality* for 25- or 50-contract trades. In the 75- or 100-contracts trade sample, the *Artificiality*^{WTB} component of \$1.74 is roughly matched by \$1.80 in the *Artificiality*^{Residual} component. We highlight that *Artificiality*$^{D\text{-}Matched}$, the component of observed *Settlement Price Artificiality* due to the floor's mark-up on the depth-matched trade component of the PM's trades, while statistically significant, remained quantitatively small for platinum (just \$0.17 for 25- or 50-contract trades and \$0.83 for 75- or 100-

contract trades). The corresponding results for palladium show that the *Artificiality*$^{D\text{-}Matched}$ component is a bit larger than in platinum ($0.29 of the $1.35 total for smaller trades and $0.95 of the $2.37 total for large trades).

The contributions of the three factors to *Settlement Price Artificiality* shifted dramatically in the second half. The walk-the-book component, *Artificiality*^{WTB}, increased to $2.06 for 25- or 50-contract trades and $2.48 for 75- or 100-contract trades for platinum and $0.73/$0.70 for small/large trades in palladium. The residual component, *Artificiality*^{Residual}, also increased. Most importantly, the *Artificiality*$^{D\text{-}Matched}$ component of observed *Settlement Price Artificiality* jumped to $4.11 for 25- or 50-contract trades and to $3.42 for 75- or 100-contract trades in platinum, which is a direct result of the corresponding dramatic inflation in *Mark-Up*$^{D\text{-}Matched}$. The corresponding second-half increases in *Artificiality*$^{D\text{-}Matched}$ for palladium are $1.00 and $1.70.

Using these estimates, we can calculate the proportion of total *Settlement Price Artificiality* attributable to *Artificiality*$^{D\text{-}Matched}$. For example, in the case of 25- or 50-contract trades in platinum this proportion equals 4.11/(2.06+4.11+1.74) =52%. Across the two metals and two trade sizes this proportion ranges from 35% to 52%. We view these economically and statistically significant mean values for *Mark-Up*$^{D\text{-}Matched}$, and the resulting large percentage contributions of the depth-matched floor pricing component to *Settlement Price Artificiality*, to be "smoking gun" indicators of noncompetitive pricing by floor traders, because these mark-ups are based only on the portion of the PM's volume that was simultaneously executable by walking the electronic order book on Globex.

We next verify that the effects of order size and time period on artificiality and mark-ups reported in Table 2 are not caused by changes in market conditions over time. In Table 3, we report regressions of the different components of *Settlement Price Artificiality* (*Artificiality*^{WTB}, *Artificiality*$^{D\text{-}Matched}$, and *Artificiality*^{Residual}) and the two floor mark-up measures (*Mark-Up*^{WTB} and *Mark-Up*$^{D\text{-}Matched}$) on a dummy equal to one for the second half of the alleged manipulation period, and the PM's order size (number of contracts). To account for time variation in market conditions, half of the regressions in Table 3 also

include five control variables: 1) Globex book depth at the close, 2) Globex daily trading volume prior to the close, 3) price volatility, 4) the tracking error of platinum and palladium daily prices movements relative to gold price movements, and 5) the difference (expressed in seconds) between the PM's trade timestamp as reported in the NYMEX database and the official floor closing time. These regressions report *t*-stats based on Newey-West standard errors to adjust for first-order autocorrelation and heteroscedasticity.

Panel A of Table 3 presents results for platinum futures; Panel B presents the results for palladium. The left-hand side columns report results for $Artificiality^{WTB}$ and $Mark\text{-}Up^{WTB}$, components associated with the pricing of the available walk-the-book depth on Globex. The middle columns report results for $Artificiality^{D\text{-}Matched}$ and $Mark\text{-}Up^{D\text{-}Matched}$, components associated with floor trader pricing of that portion of the PM's order size that matches the available depth on Globex. The right-hand side columns report results for $Artificiality^{Residual}$, the component associated with that portion of the PM's total trade size above and beyond the available depth on Globex.

Consistent with Table 2, the regressions without controls for market conditions show that all three measures of artificiality increase in the second half of the alleged manipulation period, as indicated by the large and statistically significant coefficients on the second-half dummy. After controlling for market conditions, however, we find that the coefficients on the second-half dummy are large and statistically significant only for $Artificiality^{D\text{-}Matched}$ and $Mark\text{-}Up^{D\text{-}Matched}$. These results provide strong evidence that floor executions of the portion of the PM's order that could have been executed on Globex became much more noncompetitive in the second half of the alleged manipulation period in a way that is not explained by changes in market conditions. In contrast, the lack of significance on the second-half dummy in the $Artificiality^{WTB}$ and $Mark\text{-}Up^{WTB}$ regressions suggests that the market impact costs of the electronic platform did not increase relative to what would be predicted by changes in market conditions. Corresponding results for palladium presented in Panel B yield broadly similar conclusions.

The regressions in Table 3 assume that the effect of order size on the artificiality and mark-up metrics is linear and constant across both halves of the alleged manipulation period. In Table 4 we relax these assumptions by including dummy variables that measure the effects of time (first-half versus second-half of sample) interacted with trade size (trade size of 25 or 50 contracts versus trade size of 75 or 100 contracts). Note that the effect of 25- or 50-contract trades during the first half of the sample is the baseline effect subsumed within the regression equation's constant term. The three other dummy variables estimate differential effects versus this baseline due to (i) a change in trade size during the same sample period (75- or 100-contract trades during the first half of the sample); (ii) a change in sample period for the same trade size (25- or 50-contract trades during the second half of the sample); and (iii) both changes in size and sample period (75- or 100-contract trades during the second half of the sample).

As in Table 3, we estimate regressions with and without the inclusion of the five control variables. The coefficient estimates from "No Controls" regressions can be interpreted directly as the differences of each of the other three estimated means presented in Table 2 versus the sample baseline mean of 25- or 50-contract trades in the first half of the period. For each regression, we focus on tests for shifts in trade size-controlled effects between the halves of the sample. The first is a *t*-test of whether the coefficient for the dummy variable for 25- or 50-contract trades during the second half of the sample is statistically different from zero. The second is an F-test for equality of the coefficients for the 75- or 100-contract trades dummy variable between the first and second half of the alleged manipulation period.

Consistent with the more restrictive specifications in Table 3, the results for $Artificiality^{D\text{-}Matched}$ and $Mark\text{-}Up^{D\text{-}Matched}$ suggest economically and statistically significant shifts in mean levels in the second half of the sample relative to the first half. For the "No Controls" $Mark\text{-}Up^{D\text{-}Matched}$ regression, based on the dummy variable for trade sizes of 25 or 50 contracts in the second half of the sample, the mean value of $Mark\text{-}Up^{D\text{-}Matched}$ increased by \$6.67 (significantly different from zero beyond the 1% level). Likewise, based on the estimated \$5.52 (= \$7.430 - \$1.907) difference between the value of each corresponding dummy variable's coefficient, the F-test for equality between coefficients for the 75-or-100-contract-trade

dummy variables for the first half and that for the second half of the sample rejects this hypothesis. Expanding the regression specification to include the five control variables detects an inverse relation between $Mark\text{-}Up^{D\text{-}Matched}$ and daily Globex volume but does not alter the basic patterns found in the "No Controls" results. In fact, the estimated second-half differential impacts for $Mark\text{-}Up^{D\text{-}Matched}$ increase in this regression. Corresponding results for palladium presented in Panel B yield broadly similar conclusions, though introducing control variables reduces the significance of the F-test for hypotheses concerning the 75-or-100-contract trade dummy variables.

These results for $Mark\text{-}Up^{D\text{-}Matched}$ support the hypotheses that floor traders increased their mark-ups over competitive benchmark prices of the PM's MOC trades during the second half of the sample period and that these price effects cannot be attributed to changes in background market conditions. Again, we view these results as "smoking gun" evidence of noncompetitive pricing by floor traders because these findings relate to the portion of the PM's volume that was simultaneously executable by walking the electronic order book on Globex. The introduction of the control variables again removes the statistical significance of the second half of the alleged manipulation period comparisons of $Mark\text{-}Up^{WTB}$. The coefficients of the dummy variables decrease in platinum and even reverse signs in palladium. In addition, the F-tests examining hypotheses concerning the 75- or 100-contract trade dummy variables now cannot reject the null.

5. Estimating Pro-Forma Floor Trader Excess Profits

We estimate the realized profit of a hypothetical floor trader using two methods. The first method uses our concept of $Mark\text{-}Up^{D\text{-}Matched}$, which measures the hypothetical immediate profit of a floor trader who takes a portion of the PM bang-the-close order and immediately unwinds against the available depth on the book at the close (1:04 or 1:05 PM EST for platinum, 12:59 or 1:00 PM for palladium). The mean $Mark\text{-}Up^{D\text{-}Matched}$ values reported in Table 2 can thus be interpreted as Pro Forma unit profits (per ounce) from this immediate partial unwind strategy. We convert these Pro-Forma unit profit numbers into daily

profit by multiplying the price/ounce by the contract size (50oz/contract or 100oz/contract) times the number of contracts available for purchase on Globex at the closing time.

Figure 9 presents the time series of daily and cumulative profits from this immediate partial unwind strategy. Our calculations suggest that floor traders could have reaped excess profits of approximately $650,000 with virtually no risk using this partial unwind strategy. Potential profits from this strategy in palladium are about $500,000. All of the cumulative profit time series are essentially drawdown free (i.e., monotonically increasing), indicating that floor traders filling the PM's MOC orders consistently traded at noncompetitive prices. Recent NYMEX disciplinary action reports profits for selective improper trades during this time that have values that are broadly consistent with our estimates.[18] Class action lawsuit documents also state that many of the floor brokers earned "double or triple their typical salaries" during this period.[19]

Our second method assumes that a hypothetical trader executed the entire PM MOC order, and then unwound his short position on Globex using actual buyer-initiated trades executed after the floor close (1:05 PM EST). We use either 100% or 50% of all buyer-initiated trades post-close. We define *B-VWAP (100%)* as the VWAP of the sequence of actual post-close, buyer-initiated Globex trades that sum to the bang-the-close contract amount traded by the PM and *B-VWAP (50%)* as the VWAP of the sequence of actual post-close, buyer-initiated Globex trades that sum to twice the bang-the-close contract amount traded by the PM. Buyer-initiated trades are identified using the algorithm proposed by Lee and Ready (1991). We define *Pro Forma Unit Profit (% =100 or 50)* in terms of a price spread measured in dollar per ounce as:

$$\textit{Pro Forma Unit Profit (\% =100 or 50)} = \textit{Trade Price}^{PM} - \textit{B-VWAP (\% =100 or 50)} \qquad (8)$$

[18] See http://www.cmegroup.com/, CME Notice of Disciplinary Action, File No.: NYMEX 10-7443-BC.
[19] See page 135 of the Fifth Consolidated Amended Class Action Complaint, *In Re: Platinum and Palladium Commodities Litigation*, No. 10 Civ. 3617.

Table 5 presents estimated mean and median values of *Pro Forma Unit Profit*. We present results for the 25- or 50-contract and 75- or 100-contract trade size groupings during each half of the alleged manipulation period under the two alternative unwind scenarios (100% or 50% of post-close buyer-initiated volume). P-values for tests of the null hypothesis that the respective sample's mean and median *Pro Forma Unit Profit* equal zero are presented in parentheses. The P-values presented in the bottom row are for tests of null hypothesis that the means (or medians) of *Pro Forma Unit Profit* in each half of the alleged manipulation period are equal.

In the first half of the alleged manipulation period, estimated mean and median values of *Pro Forma Unit Profit* are positive and significant under either unwind scenario for both platinum and palladium. For platinum, the first half estimated profits range from $1.47 to $2.64 for 25- or 50-contract trades and from $4.03 to $4.39 for 75- or 100-contract trades. For palladium, the first half estimated profits range from $1.63 to $2.07 for 25- or 50-contract trades and from $1.80 to $2.45 for 75- or 100-contract trades. All of these values are considerably higher in the second half, with unit profits approximately two to four times as high. For platinum, the second half estimated profits range from $8.46 to $12.86 for 25- or 50-contract trades and from $9.02 to $12.47 for 75- or 100-contract trades. For palladium, the second half estimated profits range from $2.36 to $3.54 for 25- or 50-contract trades and from $4.61 to $6.28 for 75- or 100-contract trades. There is strong evidence against the null hypothesis that the mean (or median) *Pro Forma Unit Profit* is the same in each half for all cases. Based on historical buyer-initiated trade records, we estimate that it would have taken 4 to 10 hours, on average, to unwind this position. In the worst cases, it may have taken as much as a couple of calendar days.

Figure 10 presents cumulative dollar profit of a hypothetical floor trader who executed the PM's bang-the-close trades and unwound the acquired short positions through offsetting purchases of contracts beginning immediately after the close on Globex using the actual sequence of observed buyer-initiated trades (complete unwind). Our calculations suggest that floor traders could have reaped excess profits of $2.5-2.8 million over the 95 days of the PM's bang-the-close platinum trading, with minimal apparent

risk using this complete unwind strategy. Potential excess profits in palladium are also around $3 million. As with the immediate partial unwind strategy, the cumulative profit time series in both metals are essentially drawdown free (i.e., monotonically increasing).

6. Observations and qualifications

Taken altogether, our results provide evidence that (1) the PM's MOC trades were unusually large and stressful for the platinum and palladium futures markets; (2) these MOC trades should have been priced by floor traders to reflect an appropriate mark-up as determined by a competitive market; (3) a significant portion of the PM's trades were actually executed on average at prices that exceeded competitive benchmarks simultaneously observable on the Globex limit order book; (4) these trades caused artificiality in daily settlement prices on days in which the PM traded; (5) the magnitudes of the trade mispricing and settlement price artificiality were larger in the second half of the alleged manipulation period than in the first half; (6) the noncompetitive pricing of floor traders magnified the PM's effect on settlement prices through his bang-the-close trading by a factor of two in the second half; and (7) that a representative floor trader filling the PM's platinum and palladium orders would have earned excess profits of more than $1 million with no risk and roughly $6 million with minimal risk from filling the PM's bang-the-close orders.

Our results identify an important question: Why didn't off-the-floor futures market participants (who might normally have traded exclusively on the Globex platform) consistently place limit orders through floor brokers to sell contracts at attractive levels above the Globex price during the last seconds of floor trading? Such orders, even in small lot sizes, would have captured a portion of the excess floor trader profits we measure. We observe no evidence that such limit orders were submitted consistently, and if these orders were submitted, they do not appear to have had the opportunity to interact with the portfolio manager's orders. Apparently, the fragmentation of order flow across the two alternative trading

channels was extreme.[20] We emphasize, however, that the fragmentation between the markets was effectively one-directional. By this time, all floor traders had handheld devices that provided complete order book information from Globex and the ability to submit orders instantly to the electronic market.

A possible alternative explanation of our findings is that the floor traders merely responded to the bang-the-close trades in a manner consistent with rent extraction in a noncompetitive environment. In contrast to tacit collusion, this explanation only requires that market frictions prevented floor traders from competitively undercutting each other by asking lower prices for the PM's bang-the-close trades. This interpretation would imply that NYMEX market surveillance and floor trading processes were inadequate to ensure a competitive market, since under the exchange's rules, bidding and offering practices must at all times be conducive to the competitive execution of transactions. In this version of events, certain floor traders may have been shown the PM's market-stressing MOC orders while other would-be competing traders were somehow kept in the dark.

While this alternative rent extraction explanation may be plausible, there are two reasons to think that the evidence is more supportive of the tacit collusion explanation. First, we note that NYMEX rules 521 and 522 explicitly require all trades and quotes to be accessible to all floor participants. While it may have been possible for floor traders to be unable to respond to an occasional noncompetitive price, systematic trading at prices inaccessible to other floor traders would require so-called pre-arranged trades. These pre-arranged trades are against exchange rules. In a market with such a small number of market participants (typically less than 10 floor traders), it is highly unlikely that such pre-arranged trading would have remain undetected by other participants over such a long period of time. As such, other participants would have had to make a *deliberate* decision to not report them to exchange surveillance. Second, we

[20] Kumar and Seppi (1994) and Cheng *et al*. (2005) explain that price and quantity uncertainty are major obstacles to arbitrage. Prices are reported manually in an open outcry market and this information can be broadcast with a time lag. Furthermore, trader quotes in an open outcry market become stale if not immediately executed and do not contain market depth information until hit. It is possible that some floor quotes and orders were not visible to all market participants and may not have been broadcast outside of the floor trading environment. This potential uncertainty and incomplete information may have limited the ability of off-the-floor traders to participate in these profitable trading opportunities on the floor.

note that all of the bang-the-close trades could have been partially filled at better prices by any competing floor trader. Therefore, floor traders had the opportunity to respond competitively to the bang-the-close trades up to the amount that they felt confident that they could unwind immediately on Globex even if that quantity was lower than the PM's full order size. Furthermore, the predictable nature of these bang-the-close orders meant that floor traders could anticipate and prepare to unwind their positions immediately using their handheld devices (either before the close of trading, or shortly afterwards).

Regardless of whether one believes that the noncompetitive pattern of trade represents rent extraction or tacit collusion, our findings show that the floor traders did not act in a manner that mitigated the impact of the alleged manipulative trades.

7. Conclusion

A truly competitive market should protect a fool and neutralize a knave. Regardless of the true motives of the hedge fund portfolio manager, competition among market participants should have resulted in his repetitive bang-the-close trades having price impacts consistent with their predictable arrival and low information content. They did not. Our focus has been the response of NYMEX floor traders, interpreted here as financial intermediaries, to the portfolio manager's order flow. We find that these floor traders do not always set prices in a manner to limit the impact of a single customer's large bang-the-close futures contract trades, and in fact, by their actions, may increase this impact. We show that the price impact of such bang-the-close futures contract trades *increase* over time, contrary to the predictions of a competitive market environment. During the second half of the alleged manipulation period, floor traders execute the portfolio manager's platinum futures contract buy orders at prices that were 40 to 80 ticks above competitive benchmarks. This impact is much larger than that conjectured by Pirrong (1996) as possible for collusion among traders in a typical open outcry market.

While our empirical analysis has focused on trading in a specific market and time period, our results have more general implications for regulators and market venues. We show that even trades conducted by a single customer can trigger price impacts that are larger and more persistent than

predicted by standard competitive market models. Our evidence is consistent with theoretical predictions that tacit collusion among financial intermediaries may arise in a setting with frequent, repeated interaction among a small number of similar participants in a transparent market for a homogenous product. For platinum and palladium futures, we find that noncompetitive prices persisted in an open outcry setting characterized by a small number of traders, intermittent supervision by compliance officers, and fragmented order flow from outside participants.

After this alleged manipulation incident, the NYMEX removed floor trades from platinum and palladium settlement pricing formulas.[21] Settlement prices are now determined as per our counterfactual *Globex Settlement Price* as the VWAP of Globex trades during the closing period. Not long after this change, floor trading in platinum and palladium effectively disappeared. Finally, since June 2013, six individuals involved in platinum and palladium futures floor trading during the period of our study have settled charges of exchange rule violations brought by the NYMEX Business Conduct Committee regarding (1) execution of noncompetitive pre-arranged trades; (2) wash trading or accommodation trading; (3) dishonest conduct; (4) failure to record transactions in chronological order of execution; (5) failure to produce a trading card; (6) failure to supervise any employee of a Member or Member Firm adequately to prevent violations by such employee; and (7) committing acts which are substantially detrimental to the interests or welfare of the Exchange.[22] The settlements involved suspensions varying from three weeks to life, disgorgements of trading profits, and additional fines, though these individuals neither admitted nor denied the rule violations upon which the penalties were based.[23]

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[21] Floor prices are still used to settle some CME Group contracts, including non-Treasury interest rate options, livestock futures, and copper futures.

[22] See http://www.cmegroup.com/, CME Notice of Disciplinary Action, File No.: NYMEX 10-7443-BC.

[23] In the context of insider trading before accounting scandals, Agrawal and Cooper (2014) find that managers "brazenly trade on a crime for which they are potentially culpable" (from abstract). Much of the confidence of these managers appears to be due to the difficulty in enforcement of trading infractions. In the context of trading metal futures, the long delay in disciplinary action for these apparent rule violations suggests that enforcement is also difficult in this setting.

In light of the findings in our paper, we believe that exchange surveillance needs to incorporate the possibility of tacit collusion; as such, incentives may need to be provided for other market participants to alert authorities of possible market misconduct. Indeed, financial market misconduct can be curtailed by well-designed rules and surveillance, as shown by Cumming, Zhan, and Aitken (2013a) in the context of suspected insider trading cases.[24]

Our findings have implications for the wide-ranging discussions about how to improve the process used to set a wide range of currency, interest rate, and commodity benchmarks. For instance, there are parallels between how platinum and palladium futures settlement prices were set, and how the WM/Reuters currency benchmarks are determined in the $5.3 trillion/day foreign exchange (FX) market.[25] The WM/Reuters benchmarks are established at regular times by interbank trades occurring in a 1-minute interval (2-minutes for less active currencies).[26] These interbank trades represent only a subset of FX trades and are conducted by a small group of participants, in a repeated setting, in a process that is not easily accessible by outsiders. Dealers in this market are alleged to have colluded to move these currency rates in anticipation of the settlement of customer orders, for which they were acting in the role of a financial intermediary.[27] Because many of the economic incentives of dealers in the FX market are similar to those of floor traders in the closing settlement process, our study provides additional insights into the mechanism by which manipulation can occur and persist.

Despite impacting the value of an estimated $300 trillion of securities worldwide, misconduct and collusion in the LIBOR rate setting process appears to have gone on for over 10 years. Other interest rate

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[24] Cumming, Zhan, and Aitken (2013a) show that more detailed exchange rules and increased surveillance reduces the frequency (but increases the severity) of suspected insider trading cases.

[25] "The anatomy of the global FX market through the lens of the 2013 Triennial Survey" by Dagfinn Rime and Andreas Schrimpf, Bank for International Settlements, December 8, 2013. Accessed online: http://www.bis.org/publ/qtrpdf/r_qt1312e.htm

[26] For a description of the process, see "WM / Reuters: Spot & Forward Rates Methodology Guide", WM Company, 2010. Accessed online: http://www.wmcompany.com/pdfs/026808.pdf.

[27] "Traders Said to Rig Currency Rates to Profit Off Clients" by Liam Vaughan, Gavin Finch, and Ambereen Choudhury, *Bloomberg* (online), June 12, 2013. Accessed online: http://www.bloomberg.com/news/2013-06-11/traders-said-to-rig-currency-rates-to-profit-off-clients.html

benchmarks (e.g., HIBOR in Hong Kong) also have alleged misconduct over long periods. In this light, it is not surprising that the alleged manipulation in the less widely followed platinum and palladium markets could have gone on for a 7-month period.

Consumers and producers of platinum and palladium incurred direct and indirect costs associated with the artificial and uncertain futures prices during the alleged manipulation episode. As shown by Haushalter, *et al*. (2002), uncertainty in futures prices can impact shareholder value, through both financial distress and underinvestment. Recent events have highlighted how the design of auctions and the process to establish benchmarks and settlement prices can have wide ranging impacts across the economy. As Lipson (2003) explains, the microstructure of financial markets can have important implications for corporate finance. Our paper provides a rare and detailed overview of manipulation and its impact on the market, facilitated by the use of court documents. The empirical analysis provides a comprehensive picture of the alleged manipulative activity, its impact on prices, and the response of intermediaries.

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Table 1. Settlement Price Artificiality and PM Floor Trade Mark-ups across Alternative Bang-the-Close Trade Sizes

Settlement Price Artificiality is defined as the difference between actual daily settlement price and the VWAP of contracts traded on Globex during the 2-minute closing period. *Floor Mark-Up* is defined as the difference between the VWAP of the PM's floor trades and the VWAP of contracts traded on Globex during the 2-minute closing period. This table presents estimated mean and median values of *Settlement Price Artificiality* for three different trade size groupings (No trading; 25 or 50 contracts; 75 or 100 contracts) and *Floor Mark-Up* for two size groupings (25 or 50 contracts; 75 or 100 contracts) during four different sample periods: 1) outside alleged manipulation period (Pre), which begins July 1, 2007 and ends November 18, 2007 for platinum (November 5, 2007 for palladium); 2) outside alleged manipulation period (Post), which begins May 22, 2008 and ends June 30, 2008; 3) the first half of the alleged manipulation period, which begins November 19, 2007 for platinum (November 6, 2007 for palladium) and ends February 12, 2008; and 4) the second half of the alleged manipulation period, which begins February 13, 2008 and ends May 21, 2008. P-values for tests of null hypothesis that the respective sample's mean or median *Settlement Price Artificiality* or *Floor Mark-Up* equals zero are presented in parentheses. The P-values presented in the bottom row are for tests of null hypothesis that the means (or medians) in each half of the manipulation period are equal.

Panel A. Platinum

PM Bang-the-Close Trade Size:	None			25 or 50 contracts					75 or 100 contracts				
	Artificiality		No.	Artificiality		Floor Mark-Up		No.	Artificiality		Floor Mark-Up		No.
Period	Mean	Median	obs.	Mean	Median	Mean	Median	obs.	Mean	Median	Mean	Median	obs.
Outside alleged manipulation period (Pre)	0.48 (0.02)	0.00 (0.22)	97										
Outside alleged manipulation period (Post)	0.42 (0.28)	0.00 (0.56)	22										
First half of alleged manipulation period	-0.44 (0.52)	-0.32 (0.37)	9	1.72 (0.00)	1.41 (0.00)	3.02 (0.00)	2.83 (0.00)	28	4.14 (0.00)	2.95 (0.00)	6.22 (0.00)	4.97 (0.00)	19
Second half of alleged manipulation period	3.06 (0.02)	0.01 (0.02)	21	7.91 (0.00)	4.81 (0.00)	10.56 (0.00)	7.21 (0.00)	22	9.88 (0.00)	8.30 (0.00)	13.52 (0.00)	12.02 (0.00)	26
P-value of test second half different from first	0.09	0.03		0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	

Table 1. (Cont.)

Panel B. Palladium

PM Bang-the-Close Trade Size:	None			25 or 50 contracts					75 or 100 contracts				
	Artificiality		No.	Artificiality		Floor Mark-Up		No.	Artificiality		Floor Mark-Up		No.
Period	Mean	Median	obs.	Mean	Median	Mean	Median	obs.	Mean	Median	Mean	Median	obs.
Outside alleged manipulation period (Pre)	0.74 (0.00)	0.74 (0.00)	82										
Outside alleged manipulation period (Post)	0.15 (0.37)	0.00 (0.52)	26										
First half of alleged manipulation period	0.57 (0.14)	0.15 (0.10)	11	1.35 (0.00)	1.10 (0.00)	1.55 (0.00)	1.36 (0.00)	46	2.37 (0.00)	2.25 (0.00)	2.89 (0.00)	3.02 (0.00)	11
Second half of alleged manipulation period	3.48 (0.01)	2.32 (0.01)	9	2.33 (0.00)	2.13 (0.00)	3.20 (0.00)	3.11 (0.00)	22	4.64 (0.00)	4.29 (0.00)	6.21 (0.00)	5.50 (0.00)	38
P-value of test second half different from first	0.01	0.01		0.00	0.00	0.00	0.00		0.02	0.02	0.01	0.01	

Table 2. Mean Components of Settlement Price Artificiality and Corresponding Mark-Ups

The table presents the decomposition of Settlement Price Artificiality into 1) Artificiality^{WTB} defined in equation (5) and its corresponding *Mark-Up*^{WTB} defined in equation (5); 2) Artificiality$^{D\text{-}Matched}$ defined in equation (7) and its corresponding Mark-Up$^{D\text{-}matched}$ defined in equation (6); and 3) Artificiality^{Residual}. Artificiality^{Residual} equals the difference between Settlement Price Artificiality and Artificiality^{WTB} and Artificiality$^{D\text{-}Matched}$. We do not report a corresponding mark-ups for Artificiality^{Residual}, because it is driven not only by the excess mark-up on the PM's orders (Mark-Up$^{D\text{-}Matched}$ + Mark-Up^{Tail}) but also the order excess size over the depth at the book (the difference between Θ^{PM} and Θ^{WTB}). We present the mean artificialities and mark-ups separately for bang-the-close orders of 25/50 contracts and 75/100 contracts. The first half of the alleged manipulation period begins on November 19, 2007 for platinum (November 6, 2007 for palladium) and ends on February 12, 2008. The second half of the alleged manipulation period begins on February 13, 2008 and ends on May 21, 2008. P-values for tests of null hypothesis that the respective sample's mean artificiality or mark-up equals zero are presented in parentheses. The P-values presented in the bottom row are for tests of null hypothesis that the means (or medians) in each half are equal.

Panel A. Platinum

PM Bang-the-Close Trade Size:	25 or 50 contracts						75 or 100 Contracts					
	Walk-the-book		Depth Matched		Residual	No.	Walk-the-book		Depth Matched		Residual	No.
Period	Artificiality	Mark-Up	Artificiality	Mark-Up	Artificiality	obs.	Artificiality	Mark-Up	Artificiality	Mark-Up	Artificiality	obs.
First half of alleged manipulation period	1.03 (0.00)	2.86 (0.00)	0.17 (0.02)	0.06 (0.04)	0.53 (0.00)	28	1.74 (0.00)	3.83 (0.00)	0.83 (0.02)	1.97 (0.04)	1.80 (0.00)	18
Second half of alleged manipulation period	2.06 (0.00)	3.70 (0.00)	4.11 (0.00)	6.73 (0.00)	1.74 (0.00)	22	2.48 (0.00)	5.31 (0.00)	3.42 (0.00)	7.49 (0.00)	3.97 (0.00)	26
P-value of test second half different from first	0.00	0.09	0.00	0.00	0.00		0.11	0.07	0.01	0.01	0.04	

Panel B: Palladium

PM Bang-the-Close Trade Size:	25 or 50 contracts						75 or 100 Contracts					
	Walk-the-book		Depth Matched		Residual	No.	Walk-the-book		Depth Matched		Residual	No.
Period	Artificiality	Mark-Up	Artificiality	Mark-Up	Artificiality	obs.	Artificiality	Mark-Up	Artificiality	Mark-Up	Artificiality	obs.
First half of alleged manipulation period	0.59 (0.00)	1.12 (0.00)	0.29 (0.00)	0.52 (0.00)	0.36 (0.00)	35	0.62 (0.00)	1.05 (0.00)	0.95 (0.00)	1.83 (0.00)	0.80 (0.00)	11
Second half of alleged manipulation period	0.73 (0.00)	1.41 (0.00)	1.00 (0.00)	2.06 (0.00)	0.74 (0.00)	20	0.70 (0.00)	1.90 (0.00)	1.70 (0.00)	4.07 (0.00)	2.46 (0.00)	37
P-value of test second half different from first	0.24	0.47	0.00	0.00	0.01		0.63	0.05	0.23	0.06	0.00	

Table 3. Time Series Regressions of Artificiality and Mark-up Components with and without Control Variables

This table presents time series regressions of artificiality and mark-up components on a dummy variable for the *Second half of the alleged manipulation period*, and *Order size* measured as number of contracts traded by the PM. The artificialities and mark-ups are defined in Table 2 and equations (4)-(8). The first half of the alleged manipulation period begins on November 19, 2007 for platinum (November 6, 2007 for palladium) and ends on February 12, 2008. The second half of the alleged manipulation period begins on February 13, 2008 and ends on May 21, 2008. The regressions labelled "controls" include the following variables: 1) Globex depth at close equals the number of contracts available for purchase at the floor closing time; 2) Daily volume pre-close equals the sum of all contracts traded on Globex before the floor close time of the same trading day; 3) tracking error equals the root mean squared error of a regression of daily price changes of platinum/palladium settlement prices on the daily changes in gold settlement prices. The regressions use a rolling window of 20 trading days; 4) Volatility equals the standard deviation of one-minute returns calculated at the midpoint of the Globex best bid and offer using the time period from the open of floor trading to 3 minutes before the close of floor trading; and 5) Time PM trades were recorded equals the average number of seconds difference between the trade recorded time (as included in the NYMEX database) and the floor closing time. In parentheses, we report *t*-stats calculated using Newey-West standard errors with lag 1 autocorrelation, implemented by Stata 13 procedure *newey …, lag(1)*. *, **, *** indicate significance at the 10%, 5%, and 1% levels. Significant results (at 5% or better) are in **boldface**.

Panel A. Platinum

	WTB				**D-Matched**				**Residual**	
	Artificiality		Mark-Up		Artificiality		Mark-Up		Artificiality	
	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls
Second half of alleged	**0.899*** **	0.641	**1.121*** **	0.349	**3.283*** **	**4.127*** **	**6.086*** **	**7.208*** **	**1.631*** **	0.524
manipulation period	**(3.61)**	(1.49)	**(2.64)**	(0.44)	**(4.00)**	**(2.67)**	**(4.34)**	**(2.88)**	**(3.09)**	(0.63)
Order Size	**0.558** **	**0.013** **	**0.026*** **	**0.022*** **	0.003	0.012	0.030	0.043	**0.036*** **	**0.027*** **
	(2.18)	**(2.15)**	**(3.43)**	**(2.64)**	(0.23)	(0.69)	(1.17)	(1.45)	**(3.46)**	**(2.95)**
Globex depth at close		-0.000		-0.007		0.044		0.056		-0.008
		(-0.04)		(-0.50)		(1.63)		(1.42)		(-0.75)
Daily volume pre-close		-0.186		-0.280		**-0.827** **		-2.132*		-0.373
		(-0.73)		(-0.97)		**(-2.30)**		(-1.87)		(-0.88)
Tracking error		0.018		0.018		-0.015		-0.078		-0.004
		(0.88)		(0.73)		(-0.28)		(-0.78)		(-0.16)
Volatility		-17.141		2234.149*		20.639		5072.839		**4997.021** **
		(-0.02)		(1.88)		(0.02)		(1.35)		**(2.50)**
Time PM trades were		0.001		**0.009** **		0.003		0.009		0.012
recorded		(0.63)		**(2.02)**		(0.98)		(1.14)		(1.53)
Constant	**1.087*** **	0.409	**1.487*** **	0.656	0.195	-0.431	-1.245	-2.446	**-1.384** **	**-2.806** **
	(7.84)	(0.70)	**(2.95)**	(0.85)	(0.19)	(-0.35)	(-0.72)	(-1.03)	**(-2.06)**	**(-2.38)**

Table 3 (Cont.)
Panel B. Palladium

	WTB				**D-Matched**				**Residual**	
	Artificiality		Mark-Up		Artificiality		Mark-Up		Artificiality	
	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls
Second half of alleged	0.111	-0.191	**0.465****	-0.649*	**0.718*****	**0.957****	**1.788*****	**1.666****	**0.882*****	0.365
manipulation period	(1.10)	(-1.20)	**(2.22)**	(-1.88)	**(3.65)**	**(2.02)**	**(4.85)**	**(2.04)**	**(4.46)**	(0.94)
Order Size	0.023	-0.000	0.005	0.003	**0.012*****	**0.012****	**0.031*****	**0.027*****	**0.021*****	**0.020*****
	(0.22)	(-0.02)	(1.22)	(0.68)	**(2.81)**	**(2.17)**	**(4.12)**	**(2.78)**	**(5.17)**	**(4.85)**
Globex depth at close		0.006*		-0.003		0.002		-0.008		**-0.018*****
		(1.99)		(-0.72)		(0.36)		(-0.74)		**(-3.90)**
Daily volume pre-close		-0.074		0.066		-0.043		0.318		0.107
		(-0.81)		(0.29)		(-0.21)		(0.62)		(0.36)
Tracking error		**0.044****		**0.115****		-0.031		-0.052		0.007
		(2.01)		**(2.54)**		(-0.55)		(-0.45)		(0.15)
Volatility		125.700		578.428*		37.624		975.299		**736.471****
		(1.00)		(1.71)		(0.12)		(1.26)		**(2.31)**
Time PM trades were		-0.000		-0.001		0.000		0.001		-0.001
recorded		(-0.04)		(-1.12)		(0.32)		(0.34)		(-0.81)
Constant	**0.589*****	0.242	**0.837*****	0.117	-0.245	-0.209	**-0.934****	-1.306*	**-0.743*****	**-0.885*****
	(7.26)	(1.59)	**(3.03)**	(0.33)	(-0.91)	(-0.61)	**(-2.05)**	(-1.83)	**(-3.19)**	**(-2.80)**

Table 4. Time Series Regressions of Artificiality and Mark-up Components Incorporating Full Interactions between Order Size and Time Period

This table presents time series regressions of artificiality and mark-up components on dummies that identify the combinations of small (25 or 50 contracts) vs. large (75 or 100 contracts) PM orders and first versus second halves of the alleged manipulation period. The baseline combination captured by the constant term is 25 or 50 contract orders & the first half of the period. The artificialities and mark-ups are defined in Table 2 and equations (4)-(8). The first half of the alleged manipulation period begins on November 19, 2007 for platinum (November 6, 2007 for palladium) and ends on February 12, 2008. The second half of the alleged manipulation period begins on February 13, 2008 and ends on May 21, 2008. The regressions labelled "controls" include the following variables: 1) Globex depth at close equals the number of contracts available for purchase at the floor closing time; 2) Daily volume pre-close equals the sum of all contracts traded on Globex before the floor close time of the same trading day; 3) tracking error equals the root mean squared error of a regression of daily price changes of platinum/palladium settlement prices on the daily changes in gold settlement prices. The regressions use a rolling window of 20 trading days; 4) Volatility equals the standard deviation of one-minute returns calculated at the midpoint of the Globex best bid and offer using the time period from the open of floor trading to 3 minutes before the close of floor trading; and 5) Time PM trades were recorded equals the average number of seconds difference between the trade recorded time (as included in the NYMEX database) and the floor closing time. In parentheses, we report *t*-stats calculated using Newey-West standard errors with lag 1 autocorrelation, implemented by Stata 13 procedure *newey …, lag(1)*. *, **, *** indicate significance at the 10%, 5%, and 1% levels. Significant results (at 5% or better) are in **boldface**.

Panel A. Platinum

	WTB				**D-Matched**				**Residual**	
	Artificiality		Mark-Up		Artificiality		Mark-Up		Artificiality	
	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls
Size 25 or 50 & Second Half	**1.033*** ** (3.56)**	0.857* (1.70)	0.842* (1.93)	0.142 (0.17)	**3.941*** ** (3.05)**	**5.029** ** (2.51)**	**6.668*** ** (3.61)**	**8.199*** ** (2.73)**	**1.211*** ** (2.84)**	0.136 (0.16)
Size 75 or 100 & First-Half	**0.709** ** (2.50)**	**0.868** ** (2.35)**	0.975* (1.71)	0.836 (1.50)	**0.663 (1.57)**	**1.389** ** (2.25)**	**1.907** ** (2.10)**	**3.034** ** (2.44)**	**1.275*** ** (3.12)**	0.833* (1.68)
Size 75 or 100 & Second Half	**1.453*** ** (3.96)**	**1.313*** ** (2.74)**	**2.451*** ** (4.14)**	1.537 (1.62)	**3.257*** ** (3.58)**	**4.472*** ** (3.22)**	**7.430*** ** (3.73)**	**9.246*** ** (3.20)**	**3.445*** ** (3.64)**	1.944* (1.87)
Globex depth at close		0.000 (0.06)		-0.008 (-0.54)		0.048* (1.70)		0.060 (1.48)		-0.010 (-0.91)
Daily volume pre-close		-0.195 (-0.77)		-0.263 (-0.90)		**-0.826** ** **(-2.29)**		-2.133* (-1.84)		-0.342 (-0.82)
Tracking error		0.018 (0.86)		0.015 (0.61)		-0.013 (-0.22)		-0.079 (-0.76)		-0.008 (-0.31)
Volatility		-4.053 (-0.00)		**2276.937*** **(1.88)**		64.380 (0.05)		5159.280 (1.33)		**5056.532** ** **(2.62)**
Time PM trades were recorded		0.002 (0.80)		**0.009** ** **(2.04)**		0.003 (1.05)		0.010 (1.19)		0.012 (1.60)
Constant	**1.028*** ** (8.10)**	**0.910** ** (2.15)**	**2.858*** ** (10.42)**	**1.853** ** (2.34)**	0.166 (1.22)	-0.377 (-0.34)	0.064 (0.24)	-0.907 (-0.45)	**0.528*** ** (5.24)**	-1.289 (-1.20)
F-test P-value: Size 75 or 100 & First Half equal to Size 75 or 100 & Second Half	0.080	0.382	**0.046**	0.453	**0.010**	**0.033**	**0.013**	**0.027**	**0.037**	0.251

Table 4 (Cont.)
Panel B. Palladium

	WTB				**D-Matched**				**Residual**	
	Artificiality		Mark-Up		Artificiality		Mark-Up		Artificiality	
	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls	No Controls	Controls
Size 25 or 50 & Second Half	0.118	-0.185	0.227	-0.784*	**0.714*** **	**0.910** **	**1.537*** **	**1.448***	**0.380** **	-0.024
	(1.01)	(-0.96)	(0.99)	(-1.94)	**(3.28)**	**(1.99)**	**(3.46)**	**(1.75)**	**(2.57)**	(-0.07)
Size 75 or 100 & First-Half	0.033	0.073	-0.072	0.032	**0.665*** **	**0.631*** **	**1.309*** **	**1.155** **	**0.441** **	0.479
	(0.20)	(0.50)	(-0.37)	(0.13)	**(4.14)**	**(2.90)**	**(4.42)**	**(2.44)**	**(2.05)**	(1.65)
Size 75 or 100 & Second Half	0.134	-0.172	0.743**	-0.451	**1.414*** **	**1.627** **	**3.555*** **	**3.119*** **	**2.105*** **	**1.472*** **
	(1.07)	(-0.98)	(2.44)	(-1.14)	**(3.97)**	**(2.51)**	**(6.07)**	**(3.11)**	**(7.13)**	**(3.25)**
Globex depth at close		**0.005** **		-0.003		0.003		-0.006		**-0.016*** **
		(2.01)		(-0.60)		(0.44)		(-0.56)		**(-3.58)**
Daily volume pre-close		-0.086		0.070		-0.028		0.366		0.173
		(-0.92)		(0.30)		(-0.14)		(0.71)		(0.59)
Tracking error		0.044*		**0.119** **		-0.026		-0.037		0.023
		(1.96)		**(2.63)**		(-0.45)		(-0.32)		(0.52)
Volatility		141.174		528.600		9.697		855.875		534.434
		(1.06)		(1.53)		(0.03)		(1.03)		(1.57)
Time PM trades were recorded		-0.000		-0.001		0.000		0.001		0.000
		(-0.32)		(-0.92)		(0.54)		(0.54)		(0.09)
Constant	**0.586*** **	0.226*	**1.122*** **	0.282	0.287	0.318	0.519	-0.115	0.359	0.113
	(6.81)	(1.88)	**(6.65)**	(1.02)	(3.16)	(1.12)	(3.53)	(-0.19)	(4.53)	(0.36)
F-test P-value: Size 75 or 100 & First Half equal to Size 75 or 100 & Second Half	0.567	0.165	**0.007**	0.144	**0.045**	0.132	**0.000**	0.067	**0.000**	0.066

Table 5. Floor Trader Pro Forma Unit Profit Using Complete Unwind

The *Pro Forma Unit Profit* is defined as the difference between the VWAP of the PM's bang-the-close trades and the VWAP for hypothetical post-close unwinding trades on Globex for a position of matching size. This table presents estimated mean and median values of *Pro Forma Unit Profit* for two trade size groupings (25 or 50 contracts; 75 or 100 contracts) during the halves of the alleged manipulation period. We present results for two alternative unwind trade scenarios. The first assumes that floor traders account for 100% of all observed post-close buyer-initiated trading activity on days that the PM trades beginning immediately after the close and continuing until the position size sold to the PM is unwound. The second assumes that floor traders account for only 50% of all observed post-close buyer-initiated trading activity on days that the PM trades beginning immediately after the close and continuing until the position size sold to the PM is unwound. P-values for tests of the null hypothesis that the respective sample's mean or median *Pro Forma Unit Profit* equals zero are presented in parentheses. The P-values presented in the bottom row are for tests of null hypothesis that the means (or medians) of *Pro Forma Unit Profit* in each half of the alleged manipulation period are equal.

Panel A. Platinum

Bang-the-Close Trade Size:	25 or 50 contracts						75 or 100 contracts					
Calculation:	100% of Post-Close Volume			50% of Post-Close Volume			100% of Post-Close Volume			50% of Post-Close Volume		
Statistic:	Mean	Median	No. obs.	Mean	Median	No. obs.	Mean	Median	No. obs.	Mean	Median	No. obs.
First half of alleged manipulation period	2.64 (0.00)	2.14 (0.00)	28	2.57 (0.00)	1.47 (0.00)	28	4.39 (0.00)	4.03 (0.00)	19	4.03 (0.03)	4.13 (0.02)	19
Second half of alleged manipulation period	10.66 (0.00)	8.46 (0.00)	22	12.86 (0.00)	10.86 (0.00)	22	10.47 (0.00)	9.02 (0.00)	26	12.47 (0.00)	9.56 (0.00)	26
P-value of test of null that first- and second-half values are equal	0.00	0.00		0.00	0.00		0.03	0.03		0.05	0.07	

Panel B. Palladium

Bang-the-Close Trade Size:	25 or 50 contracts						75 or 100 contracts					
Calculation:	100% of Post-Close Volume			50% of Post-Close Volume			100% of Post-Close Volume			50% of Post-Close Volume		
Statistic:	Mean	Median	No. obs.	Mean	Median	No. obs.	Mean	Median	No. obs.	Mean	Median	No. obs.
First half of alleged manipulation period	1.63 (0.00)	1.70 (0.00)	48	2.07 (0.00)	1.76 (0.00)	48	2.01 (0.00)	1.97 (0.00)	11	1.80 (0.06)	2.45 (0.11)	11
Second half of alleged manipulation period	3.85 (0.00)	3.14 (0.00)	22	3.54 (0.00)	2.36 (0.00)	22	5.95 (0.00)	4.61 (0.00)	37	6.28 (0.00)	5.15 (0.00)	37
P-value of test of null that first- and second-half values are equal	0.00	0.01		0.12	0.40		0.01	0.00		0.03	0.02	0.00

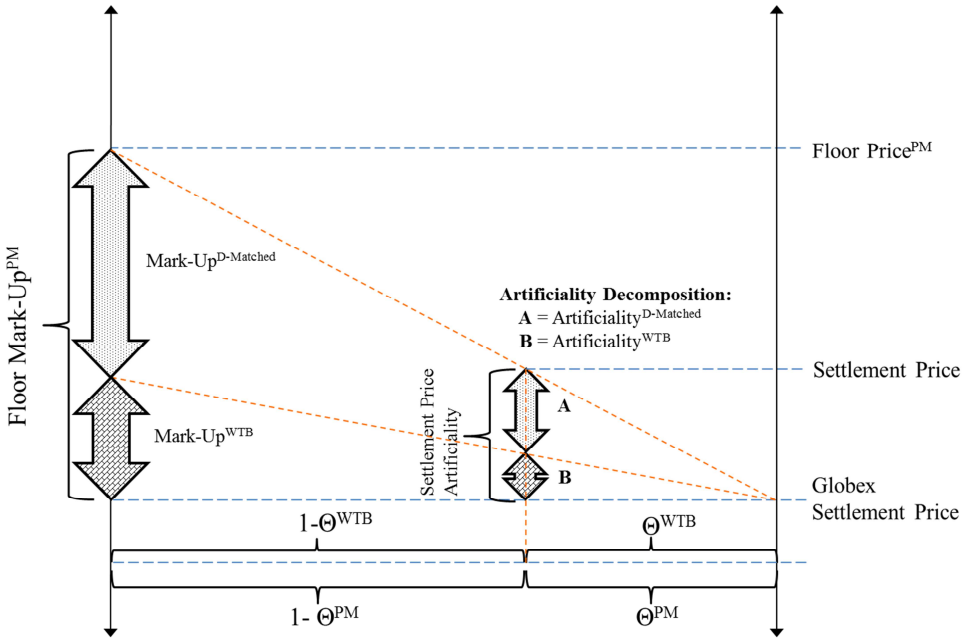

Figure 1a. **Case 1:** Decomposition of Settlement Price Artificiality when the number of contracts traded for the PM on the floor equals the available walk-the-book depth on Globex, $\Theta^{PM} = \Theta^{WTB}$. In this case, the mark-up of the PM's trades can be decomposed into the amount equal to the cost of walking the book (*Mark-Up*^{WTB}) and the additional mark-up given by the floor traders over this amount, due to apparent non-competitive pricing (*Mark-Up*$^{D\text{-}Matched}$). Here, the components of the *Floor Mark-Up*^{PM} scale proportionally into the components of the settlement price artificiality, according to the share of the PM's order flow in the overall settlement period volume.

The figure also assumes that, excluding trades involving the PM as a counterparty, the average price of floor trades executed during the 2-minute closing period is equal to the VWAP of Globex trades during the period (the *Globex Settlement Price*).

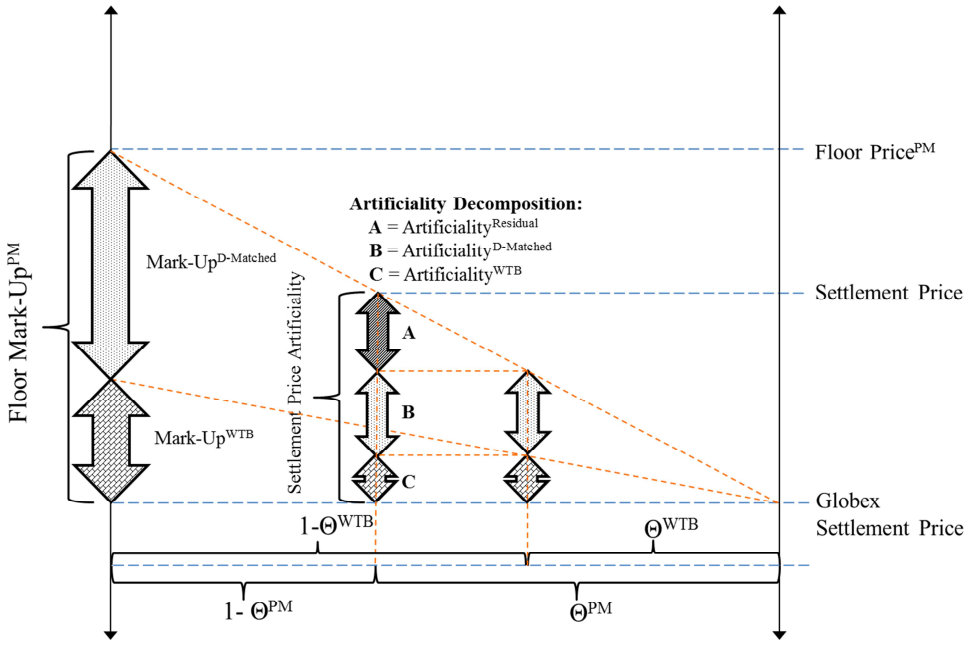

Figure 1b. **Case 2:** Decomposition of Settlement Price Artificiality when the number of contracts traded for the PM on the floor exceeds the available walk-the-book depth on Globex, $\Theta^{PM} > \Theta^{WTB}$, and the average price of the PM's floor trades have the same mark-up as in Case 1 (i.e., there is no additional mark-up for the contract volume beyond that available on Globex). Here, the ability of the PM to trade a larger amount on the floor than available on Globex generates a residual impact on the settlement price artificiality (denoted $Artificiality^{Residual}$).

The figure also assumes that, excluding trades involving the PM as a counterparty, the average price of floor trades executed during the 2-minute closing period is equal to the VWAP of Globex trades during the period (the *Globex Settlement Price*).

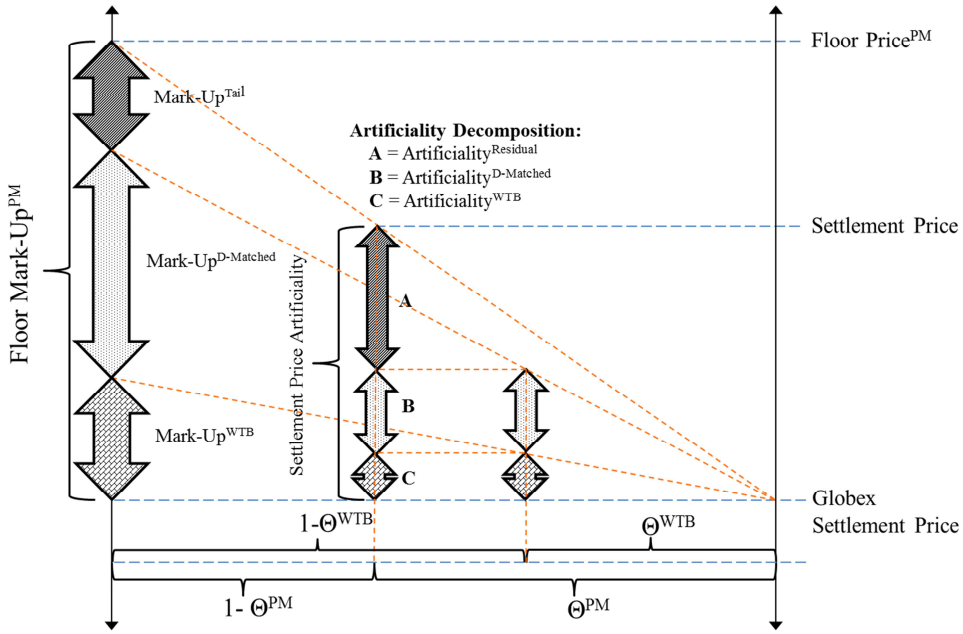

Figure 1c. **Case 3:** Decomposition of Settlement Price Artificiality when the number of contracts traded for the PM on the floor exceeds the available walk-the-book depth on Globex, $\Theta^{PM} > \Theta^{WTB}$, and there exists an additional mark-up for the contracts that cannot be immediately executed on Globex (Mark-Up^{Tail}>0). Now, the residual settlement price artificiality (*Artificiality*^{Residual}) can be attributed to both the ability of the PM to execute larger volume on the floor than Globex and to the additional price impact of this larger volume.

The figure also assumes that, excluding trades involving the PM as counterparty, the average price of floor trades executed during the 2-minute closing period is equal to the VWAP of Globex trades during the period (the *Globex Settlement Price*).

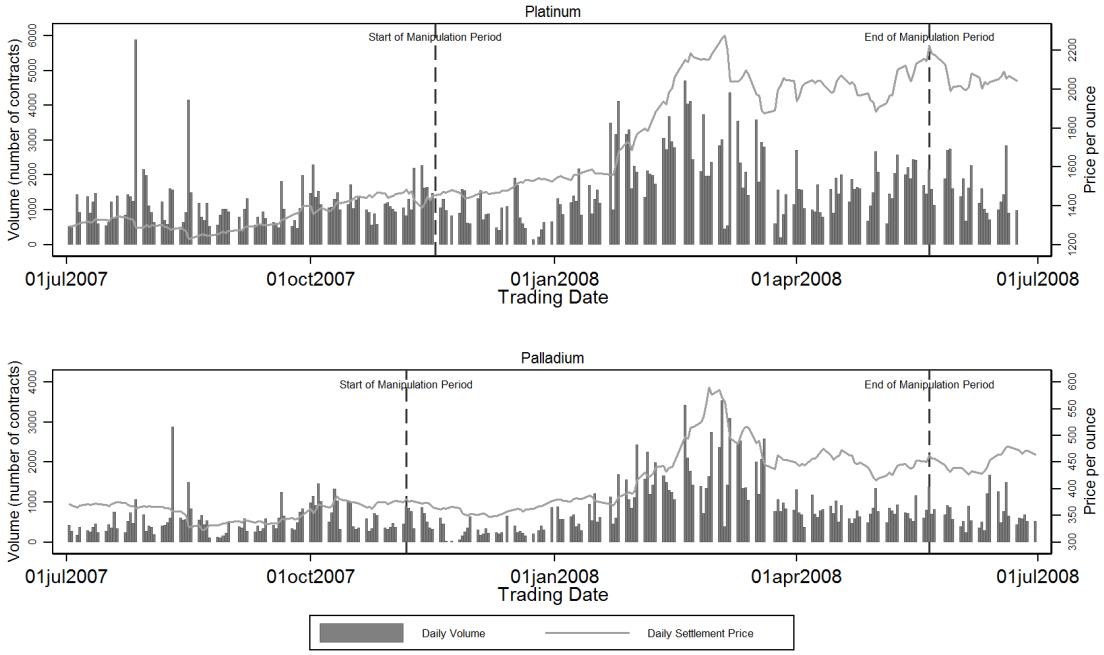

Figure 2. Daily Trading Volume (Number of Contracts) and Settlement Price of NYMEX Active Platinum and Palladium Futures Contracts

We plot only Globex trades in the NYMEX active future contracts. Sample period is July 1, 2007 to June 30, 2008.

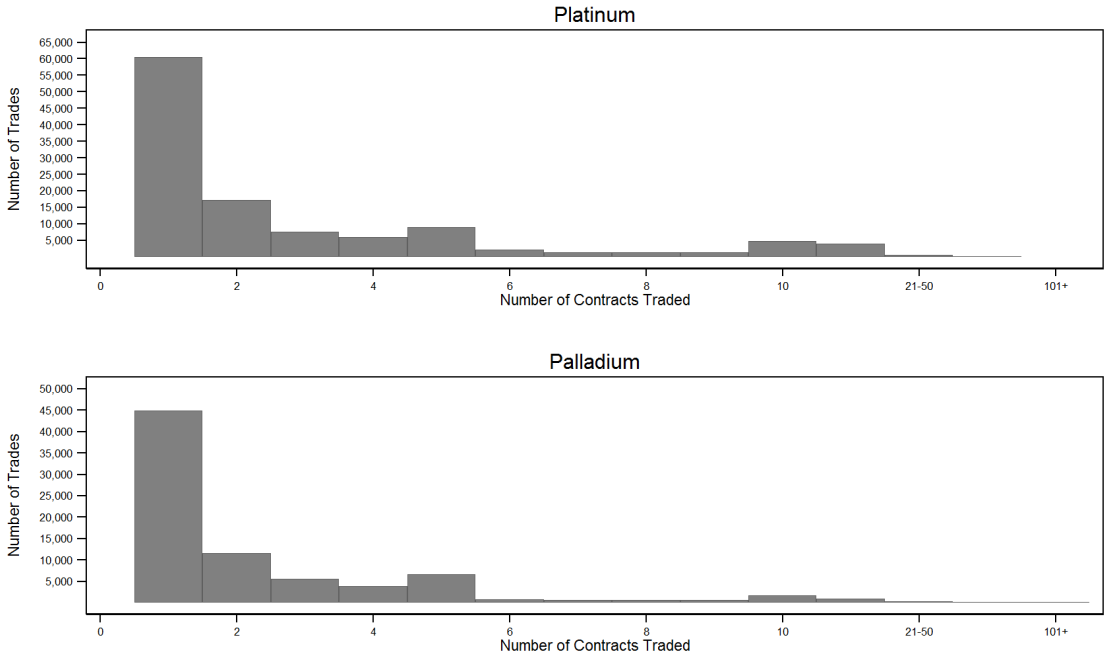

Figure 3. Number of Trades across Trade Size (Number of Contracts) for the Active Platinum and Palladium Contracts

We plot only Globex trades in the NYMEX active future contracts. Sample period is July 1, 2007 to June 30, 2008.

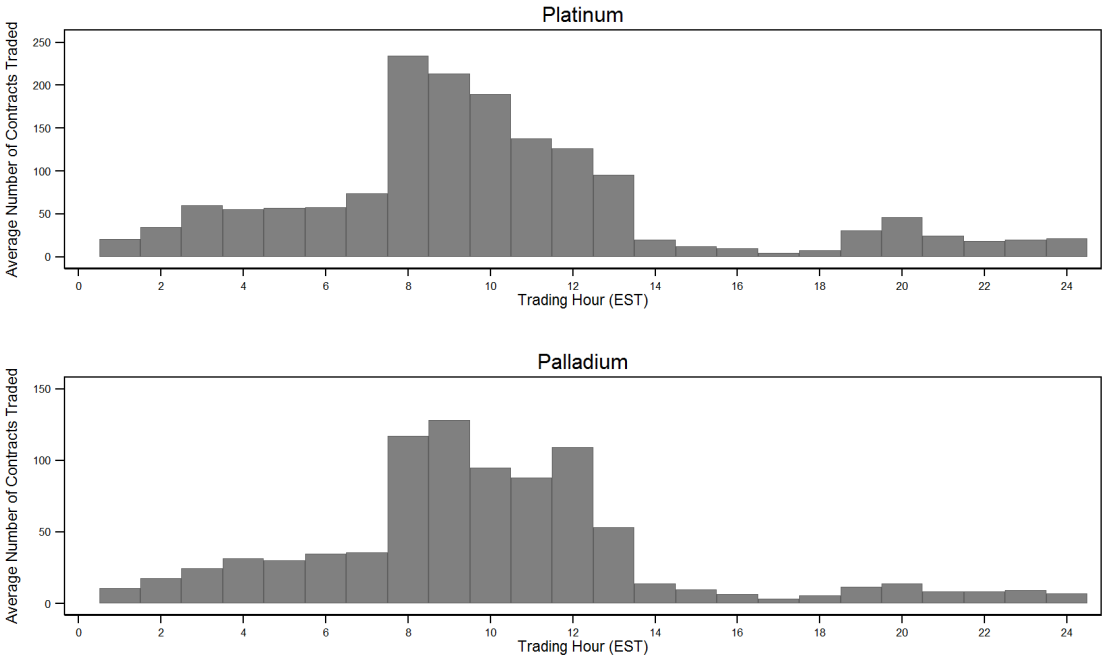

Figure 4. Average Trading Volume per Trading Hour

We plot only Globex trades in the NYMEX active platinum and palladium future contracts. Sample period is July 1, 2007 to June 30, 2008.

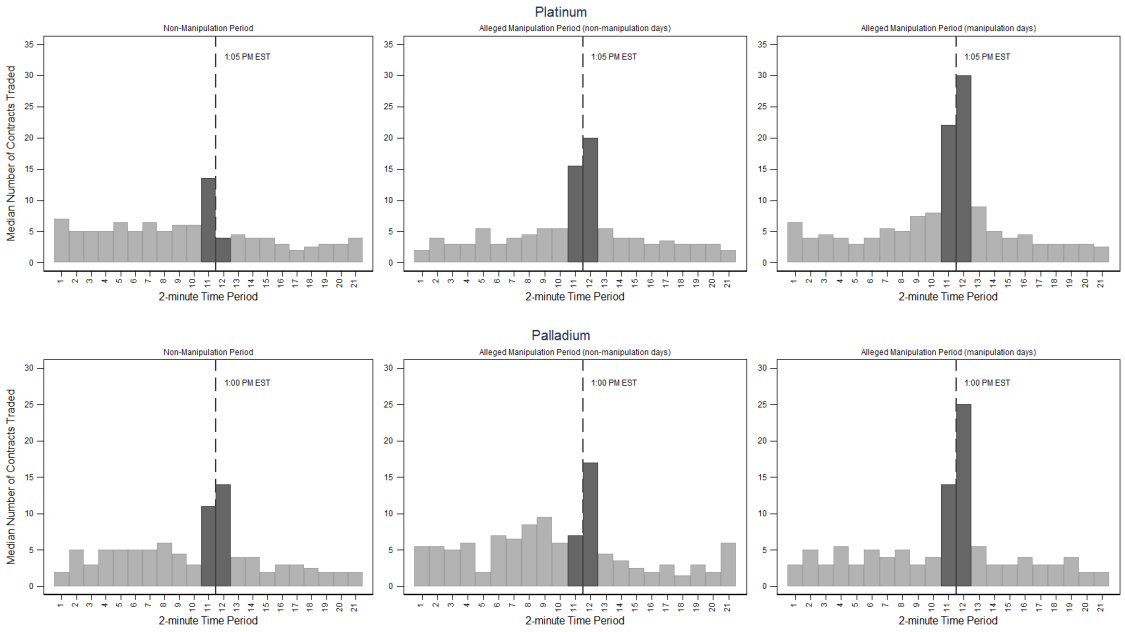

Figure 5. Median Globex Trading Volume per 2-minute Period around the Closing Time

Closing time for platinum is 13:03-13:05 EST and closing time for palladium is 12:58-13:00 EST. Closing time is indicated on the chart as time period No. 11. The alleged manipulation period for platinum is between November 19, 2007 and May 21, 2008 and for palladium is between November 6, 2007 and May 21, 2008. For platinum, the non-manipulation period combines data from July 1, 2007 to November 18, 2007 and May 22, 2008 to June 30, 2008. For palladium, the non-manipulation period combines data from July 1, 2007 to November 5, 2007 and May 22, 2008 to June 30, 2008.

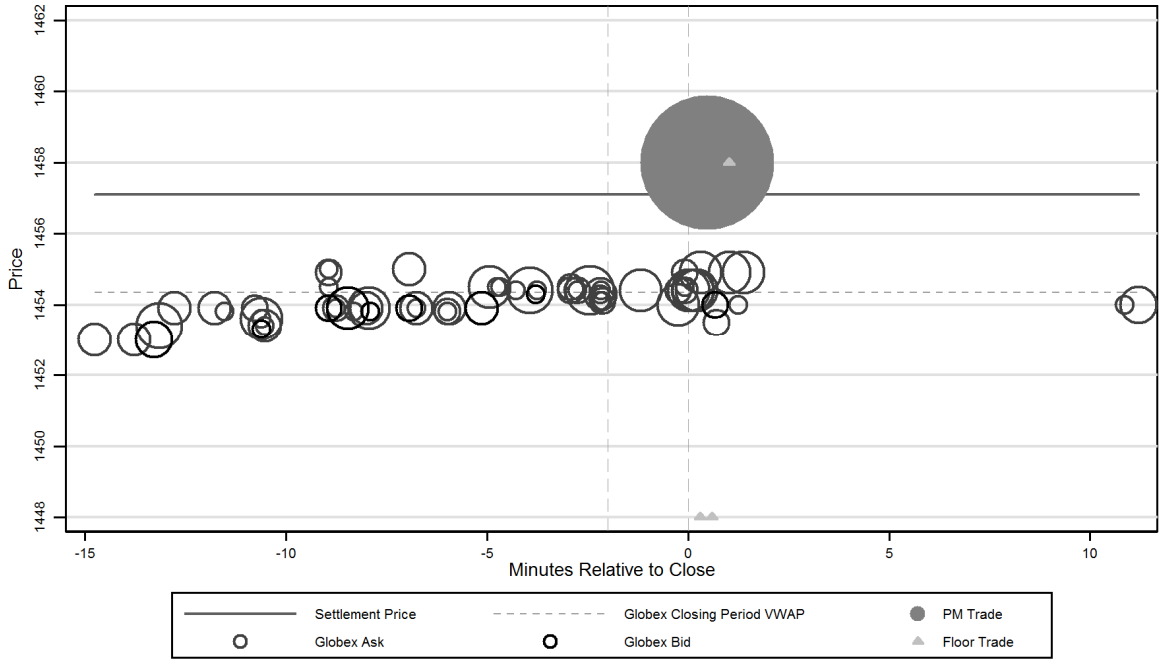

Figure 6a. Platinum Futures Trading on the Floor and Globex during the 30 Minutes around the Floor Close (November 19, 2007)

The size of the plotted symbol for each trade is proportional to trade size. November 19, 2007 is the first date of alleged manipulative trading in platinum. The PM bought a total of 50 January 2008 contracts in a single trade recorded at 1:05 PM EST at a price of $1458 per ounce.

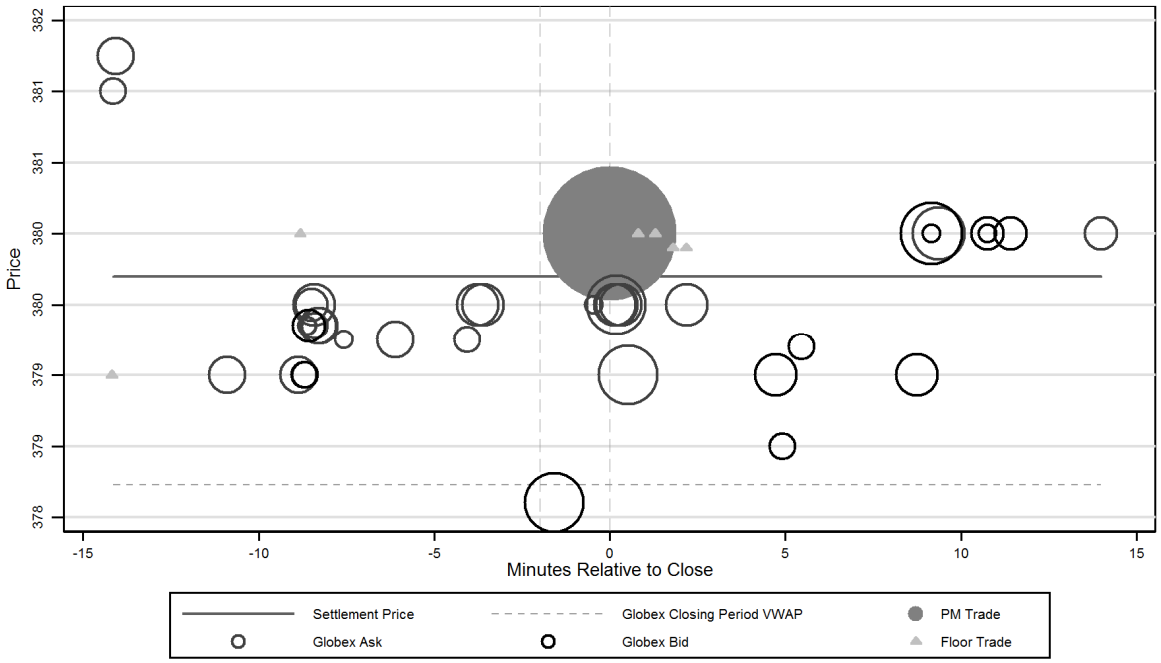

Figure 6b. Palladium Futures Trading on the Floor and Globex during the 30 Minutes around the Floor Close (November 6, 2007)

Otherwise similar to Figure 6a. The PM executed a single trade of 50 contracts in the December 2007 Palladium contract at 1:00 EST. November 6 is the first date in the Palladium alleged manipulation period when the PM executed closing period trades only on the floor.

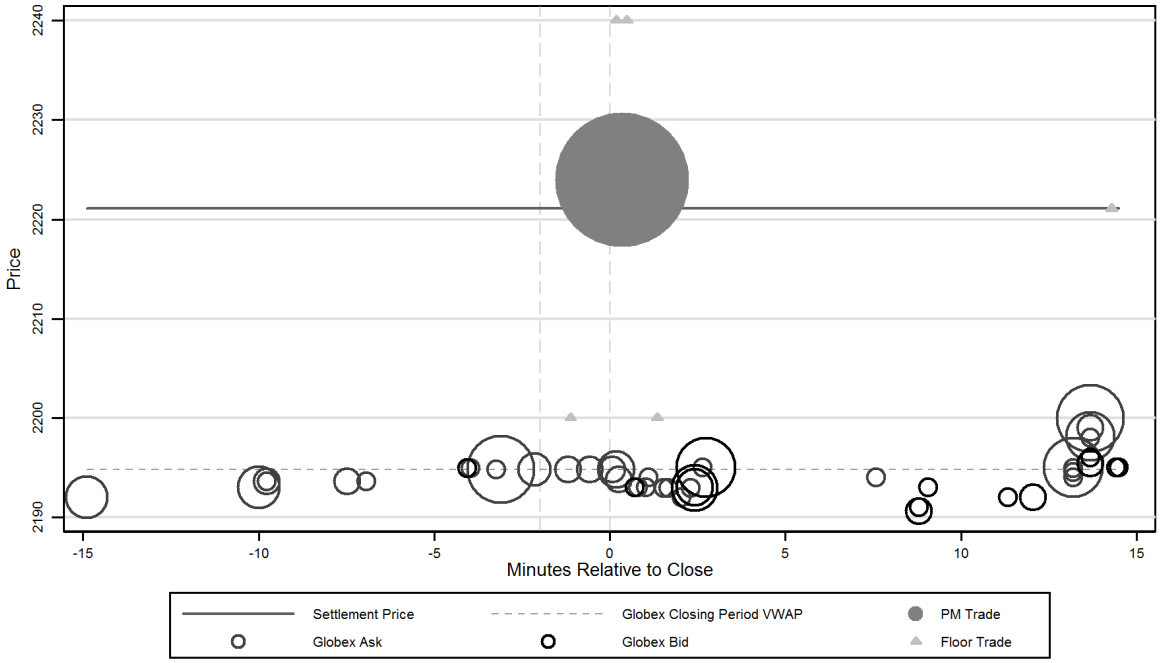

Figure 6c. Platinum Futures Trading on the Floor and Globex during the 30 Minutes around the Floor Close (May 21, 2008)

The size of the plotted symbol for each trade is proportional to trade size. May 21, 2008 is the last date of alleged manipulative PM trading in platinum. The PM bought a total of 50 July 2008 contracts in a single trade recorded at 1:05 PM EST at a price of $2224 per ounce.

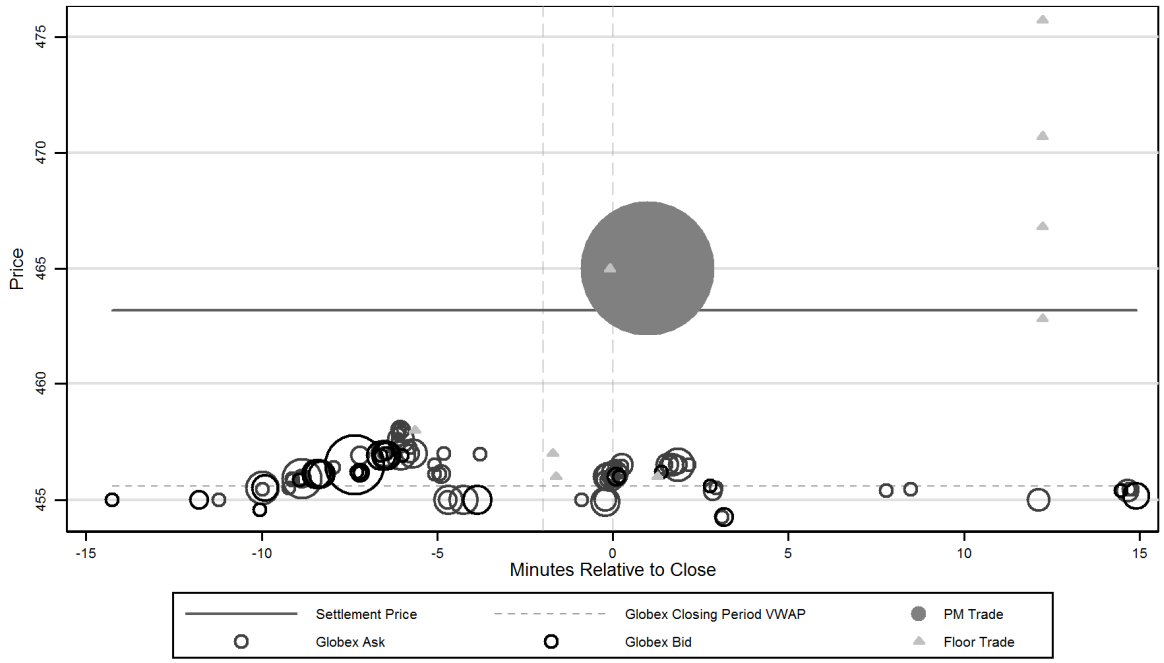

Figure 6d. Palladium Futures Trading on the Floor and Globex during the 30 Minutes around the Floor Close (May 21, 2008)

Otherwise similar to Figure 6c.

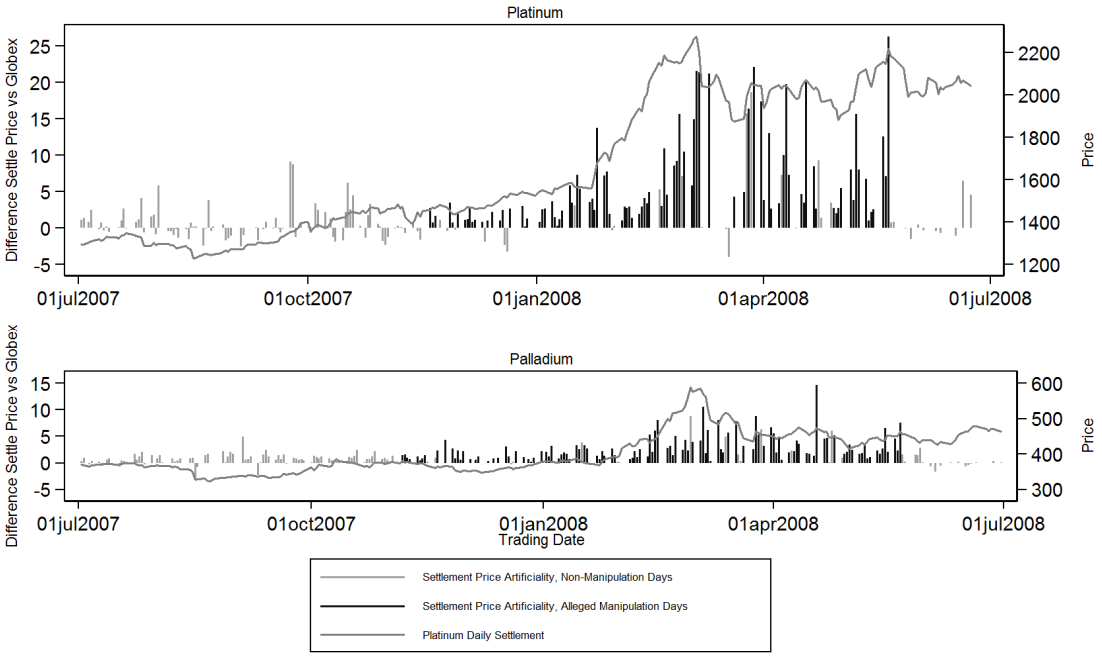

Figure 7. Settlement Price Artificiality on Alleged Manipulation vs. Non-Manipulation Days

We define Settlement Price Artificiality as the difference between Actual Daily Settlement Price and the Counterfactual Settlement Price estimated as the VWAP of trades on Globex during the 2-minute closing period.

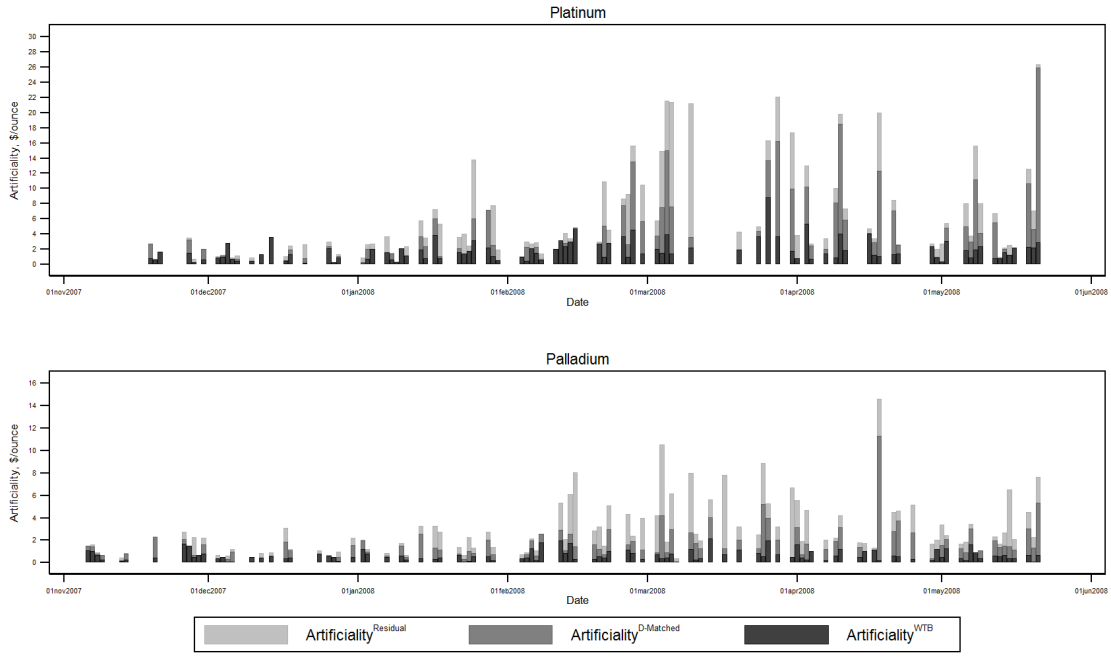

Figure 8. Time Series Comparison of the Three Components of Price Artificiality

The figure presents the daily decomposition of Settlement Price Artificiality into 1) $\text{Artificiality}^{\text{WTB}}$ (walk-the-book impact of the PM's volume); 2) $\text{Artificiality}^{\text{D-Matched}}$ (excess price impact from the PM's walk-the-book volume); and 3) $\text{Artificiality}^{\text{Residual}}$ (remaining price impact due to higher possible volume through floor trading and excess price impact on the floor).

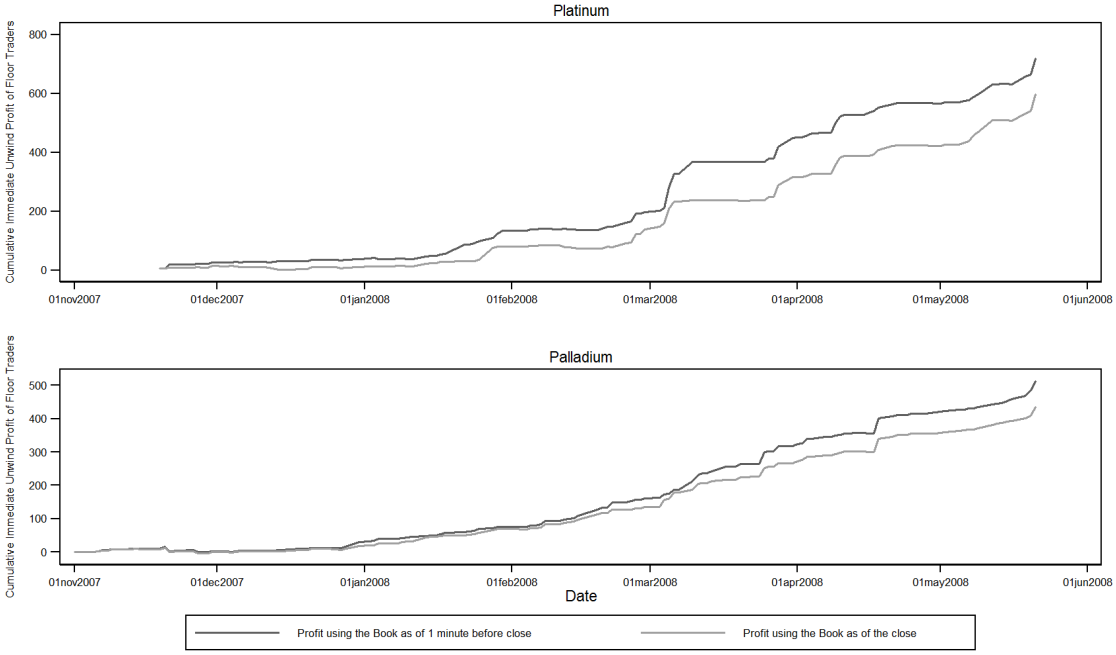

Figure 9. Pro-forma Daily and Cumulative Profit of Floor Traders Executing the Bang-The-Close Trades (Partial Immediate Unwind).

All numbers are in thousands of dollars. The pro-forma profits are calculated assuming that a hypothetical floor trader unwound the lowest priced trades executed against the PM's bang-the-close order using walk-the-book orders against the available offer depth on the limit order book as of 1:04 p.m. or 1:05 p.m. for platinum, and 12:59 and 1:00 p.m. for palladium.

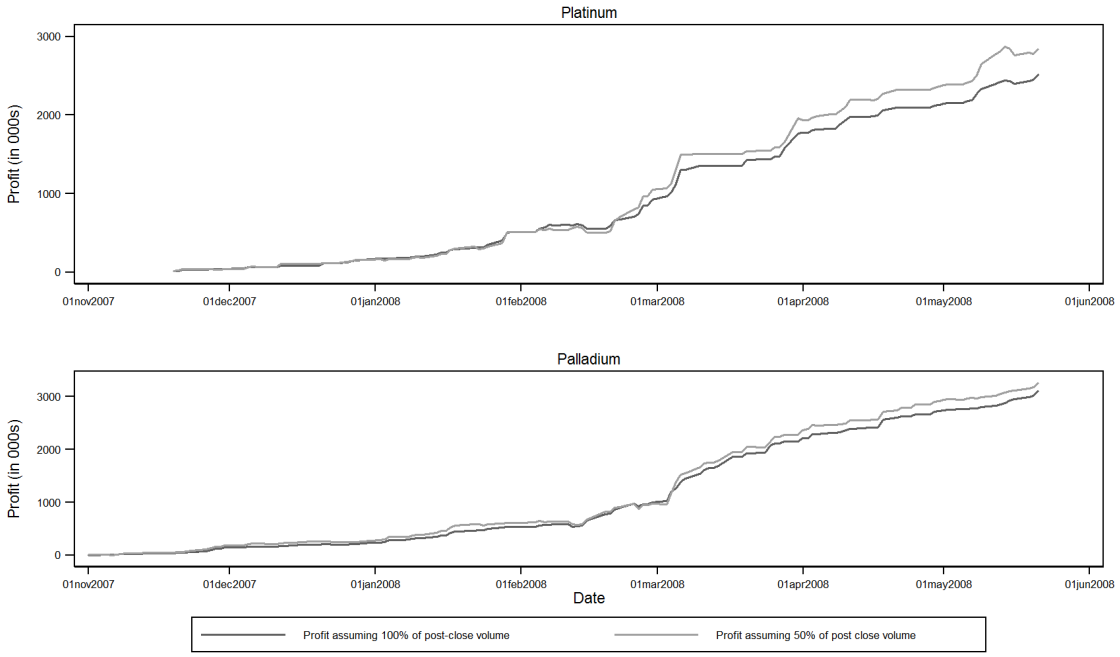

Figure 10. Pro-forma Daily and Cumulative Profit of Floor Traders Executing the Bang-The-Close Trades (Complete Unwind).

All numbers are in thousands of dollars. The pro-forma profits are calculated assuming that a hypothetical floor trader executed the PM's bang-the-close trades and unwound the acquired short positions through offsetting purchases of contracts beginning immediately after the close on Globex using 100% or 50% of the actual sequence of observed buyer-initiated trades.