Transparency in Commodities Markets

Angelo Aspris,[a] Sean Foley,[a] Fergus Gratton[a] and Peter O'Neill [b]
[a] *University of Sydney*[b] *University of New South Wales*

Abstract

The London "Fix" for precious metals was recently replaced by a number of unique electronic platforms following concerns about the lack of transparency and potential manipulative conduct by previous price-setting participants. The change principally increased the level of pre-trade transparency for market participants, allowing them to view aggregate order flow information throughout the auction process. In this paper we analyse the duration of the price discovery process across the three introduced regimes and show that it has become more efficient. We observe a decline in the length of time required to reach the final benchmark price, and also show a reduction in the adjusted returns, volatility, and return predictability of the associated futures contract. Our results are consistent with the Amihud et al. (1997) liquidity externality hypothesis, which prescribes that more timely and transparent information in one market facilitates better price discovery in correlated markets, improving overall market efficiency.

JEL classification: G13, G14

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1. Introduction

Pricing benchmarks in interest rate, currency, and commodity markets have received a great deal of attention recently. Sparked by evidence of improprieties in the LIBOR in 2008, legal and regulatory probes into precious metals markets have revealed widespread misconduct among key market participants. In May 2014, the Financial Conduct Authority (FCA) fined Barclays for inadequate oversight of the gold price setting benchmark, allowing the bank to manipulate the gold fix.[1] Such agency transgressions have persisted due to the structural weakness of the previous pricing mechanism, which was opaque and lacked regulatory oversight.[2] In this paper we examine the market quality effects associated with changing the precious metals benchmarking process.

Wholesale participants of the over-the-counter market for gold, silver, platinum, and palladium (GSPP) have historically set benchmark prices via a closed-auction process. The 'fix', introduced to the wholesale Silver market in 1897, and other precious metals after this time, primarily served to lower overall search costs to market participants. Operated by a limited number of participants at the time, the original fix required members to set a market clearing price based on the supply and demand schedules of their clients. The determination of a single benchmark price allowed inventory to be cleared in an efficient manner and also provided the greater market with a reference point for hedging and royalty agreements.[3] The change in the price-setting process, which began with Silver in 2014, arose from the wide-ranging criticism about the opacity and vulnerability of this system to market abuse. The London Bullion Market Association (LBMA) responded to these criticisms by seeking tenders for the administration and governance of a new process.[4] The new landscape was to be founded on an electronic based platform, characterised by improved pre-trade transparency.

In formulating our empirical investigation, we have found it useful to think about the consequences of a change in transparency in terms of its potential impact on market efficiency and integrity. With respect to the former, there are a number of channels through which this transmission may take place. In a high-frequency trading environment, a trader's optimal strategy will be influenced by the degree of pre-trade transparency. Although we cannot observe the direct actions of participants in the wholesale market, exchange related contracts (such as futures and ETF's on precious metals) are informationally linked, so how prices are determined during the fix period, including what information is revealed during this process, will have implications for these associated markets (Amihud, 1997). The overall impact on market quality and welfare will be dictated by the dynamic and strategic response of traders in this new equilibrium.

We examine the role of a transparency change in the over-the-counter market for precious metals. The recent transformation of this market through the adoption of an electronic-based auction platform now allows order characteristics, including the aggregate imbalance, to be published in real-time during each round of the fix. In all other regards, the new system does not materially deviate from the old. Our examination is motivated by a key number of considerations. Chief among them is the idea that real-time disclosure of participant quotes in the OTC market can have appreciable implications for the market liquidity and price discovery of related markets. The idea of a positive externality is discussed in Amihud et al. (1997) who state that 'improved value discovery for one security facilitates value discovery for the other (correlated) security".

It is not just in terms of market efficiency where pre-trade transparency has been deemed to be desirable. Caminschi and Heaney (2014) examined trading patterns of a number of Gold exchange traded

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[1] See FCA final notice 2014 - https://www.fca.org.uk/your-fca/documents/final-notices/2014/barclays-bank-plc

[2] Historically benchmarks have not been regulated. From 1 April 2015, the London Gold Fixing and the LBMA Silver Price became a regulated benchmark following the recommendations of the Fair and Effective Markets Review. The benchmark administrators are required to be FCA-authorised according to Art 63O of the Financial Services and Markets Act 2000 (Regulated Activities) Order 2001.

[3] The creation of a benchmark reduces overall market opaqueness and improves efficiency if search frictions for customers are mitigated. A benchmark also reduces the local monopoly power of a dealer in a bilateral negotiation with a customer which is a source of overall welfare improvement.

[4] A list of these parties is provided in the Appendix.

instruments under the previous fix scheme and concluded that movements during this interval showed leaking price information ahead of the publication of the benchmark price.[5] The suggestion that participants in the fix gained an unfair advantage in public markets has also been intimated in previous anecdotal evidence.[6] Higher levels of transparency under the new electronic platform mark a change in this process, as more comprehensive and reliable information about supply, demand, and inventory is now available. If trading interest is exposed in real time then the information advantage gained by participants involved in the benchmark fix is reduced significantly, thereby reducing the transfer of informational rents from informed to uninformed investors.

The case for increased transparency in markets is however, far from unanimous and unsurprisingly the current literature on the impacts surrounding a change have produced mixed outcomes (see Madhavan et al (2005); Bessembinder et al. (2006); Eom et al. (2007)).[7] Increasing transparency can result in firms exposing their proprietary positions which may impact on total market volume and frequency of trading. Additionally, there are potential risks to liquidity stemming from the willingness of market participants to commit liquidity when their positions are exposed to other market participants (Madhavan et al. 2005). The largely untested empirical interactions associated with this market change allow us to add to the debate on optimal market design. The issues that are the focus of this paper have implications for investor strategies, market liquidity, price efficiency, market integrity and ultimately investor welfare.

Our empirical results strongly support the view that transparency matters. Several interesting results emerge from this analysis. First, we observe a substantial decline in the time required to resolve the Fix for all of our precious metals contracts. The LBMA Silver Price, which was the first of the OTC metals to switch to the new and more transparent electronic system, has seen a 60% reduction in the time taken to determine the benchmark price. The other metals also exhibit similar declines, providing evidence of a more efficient system of price discovery. Second, we observe a significant improvement in market quality for futures and ETF contracts on these precious metals. In particular, our analysis shows that execution costs, both during and around the fix period, are significantly lower after the change in process, even after controlling for other factors affecting trading costs. Similarly, we observe a significant increase in market depth giving weight to Glosten's (1999) argument that increased transparency should lead to greater commonality of information, implying more efficient prices and narrower spreads. As such, the reluctance to offer a 'free option' is mitigated by an informed market, where particular participants are no longer able to gain a significant trade advantage through preferential access to order flow information.

Lastly, our results concerning the potential returns to informed traders in futures and ETF contracts around the conducting of the fix provides some interesting insights. We show in the former fix period, significant return advantages accrue to informed participants ahead of the announcement of the benchmark price. This pattern is consistent across all the precious metals, with the average amount of leakage between 4-10 basis points. Following the move to a transparent electronic auction, our results reveal a similar course to price discovery. As information in the current fix system is now disclosed in

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[5] The authors concede that that nature of the causality is not necessarily clear. For example, the fix results could be affected by short-term price movements in these exchange traded instruments with the view to affect the fix price.

[6] The Fair and Effective Markets Review (FEMR) established by the Chancellor of the Exchequer and the Governor of the Bank of England in 2014 to conduct a review of the way wholesale Fixed Income, Currency and Commodities (FICC) markets stated that the previous fix process 'lacked sufficient transparency and relied on a small number of contributors, which meant there was greater potential for any given trader to influence the fix' (p.43).

[7] Differences in transparency can also be observed across asset classes and instruments. The majority of the research conducted to date, however, is equities based.

real time, then the immediate incorporation of this material reflects an efficient form of price discovery. The lower levels of price impact observed in the post period reflect lower levels of adverse selection associated with trading with an informed party. Overall, our results indicate that an improvement is market transparency plays a critical role in delivering positive economic welfare benefits.

The remainder of this article is organised as follows: Section 2 describes the institutional detail of the precious metals market. Section 3 describes the data and method, including details of the contracts and measures used to assess market quality. Section 4 presents the results and discusses the implications of the change in transparency. Section 5 concludes.

2. Institutional Detail

2.1 Benchmarks and the 'Fix'

Transactions executed on OTC markets are generally negotiated on the basis of a benchmark price. Benchmarks are ubiquitously found in commodities markets – including gold, silver, oil, natural gas, and many others. They are similarly important in the makeup of the foreign exchange market (the WM/Reuters daily fixing) and the market for derivatives, such as swaps and forward rate agreements, which are normally negotiated at a spread to the LIBOR or other such benchmarks. The use of benchmarks in OTC markets is commonplace because they lower search costs by reducing information asymmetries between dealers and market participants (Duffie et al. 2014). Without a reference price, customer quotes would have to be sourced from individual dealers, which imposes significant search costs on these participants. It is for this reason that despite the rapid transformation in exchange traded markets over recent decades that the market for commodities has remained relatively unchanged.

Tracing its origins back to the London Silver Fixing in 1897, and the London Gold Fixing in 1919, the fix began with a small number of London bullion dealers meeting on a daily basis to set a clearing price based on customer inventories.[8] The wholesale fixing process served as an important reference price and would eventually become the global benchmark, used by miners, central banks, jewellers, and also the financial services industry to price derivative contracts and construct hedging agreements. Notwithstanding subtle nuances between the four precious metals, members would declare how much metal they were seeking to purchase or sell on behalf of their clients and register their own proprietary interests.[9] Information about the supply and demand schedules were relayed back to clients and the chairperson (a role typically rotated between the banks) would allow the auction to pass through a series of rounds until the volume imbalance fell to within a pre-determined threshold. Once this point was reached, the price was disseminated to the market and all volume executed at this price.

This efficacy of benchmarks in OTC markets has received greater attention in the literature over the last few years. Caminschi (2013) investigates the impact of the London gold fix on two exchange-traded instruments and concludes that information gleaned during the fix process was more than likely disseminated to exchange traded financial markets prior to the formal announcement of the fix price. Abrantes-Metz (2012) analyses the LIBOR around several periods associated with allegations of market abuse and concludes that the benchmarking process was unlikely to have been systematically manipulated. Despite evidence of a non-random clustering of submitted quotes, the authors show that a predicted benchmark based on highly correlated indicators is insignificantly different from the actual

[8] This pricing process was later expanded into Platinum and Palladium in 1989 through a closed-call telephone system.
[9] The fix for Gold, Platinum, and Palladium occurs twice-daily. The Silver fix operates once daily.

LIBOR. Atanasov (2015) focus on the settlement pricing procedures of Platinum and Palladium futures contracts and show that a pricing mechanism which was based on the average of the exchange floor and electronic limit order book trades was artificially manipulated allowing floor counterparties to extract significant economic rents. Despite this, Duffie et al. (2014) model the impact of benchmarks on the efficiency of markets characterised by search frictions and show that benchmarks improve market transparency and promote efficiency by reducing information asymmetries.

Following the withdrawal of Deutsche Bank AG as an administrator of the Silver fix, the final price-fix meeting took place on August 14, 2014. The demise of the fix raised questions in the market about where the new reference price would come from and the LBMA through a consultative process of market participants tendered the process to a number of solutions providers. Following a general consensus for an electronic auction-based platform characterised by greater transparency and auditability, the joint proposal of the Chicago Mercantile Exchange (CME) and Thomson Reuters (TR) emerged as the winning proposal.[10] A similar processes was undertaken for Platinum and Palladium - to be administered by the London Metals Exchange (LME) and Gold which was to be administered by the Intercontinental Exchange (ICE). The market for Platinum and Palladium and Gold began trading on the 1st December 2014 and the 20th March 2015, respectively.

The new structures represent an electronic solution to the old fix system.[11] The twice daily (with the exception of Silver) auction process that was previously maintained by UK limited liability companies continues to resolve the order flow imbalance with a proprietary pricing mechanism. In each round of the auction participants submit bid and offer orders against a suggested price for the round. If the aggregate bids and offers match within a pre-specified tolerance level then the auction comes to an end. If however, there is a mismatch between aggregate bid and ask volume, there is a subsequent round with an adjusted price. The benchmark price will be the price derived from the final round of an auction. Anonymous bids and offers are now published in real-time with the imbalance calculated and the price updated until the buy and sell orders are matched. The new silver (gold) system proceeds through a series of rounds, each lasting 60 seconds (45 seconds) and under this system agency orders are separated from client orders.[12] In the first live version of the LBMA Gold Price, the benchmark was set at $1,1171.75/oz, following a five round auction.

The most recent changes to the pricing mechanisms of the wholesale GSPP markets attempts to ameliorate a process that was thought to be vulnerable to market abuse and opaque to market participants. With higher levels of pre-trade transparency and a full audit history of principal and agency orders, the change in microstructure of this setting will have implications for the associated financial derivatives markets.

3. Data

3.1 Data Source and Sample Selection

The data used in this study is obtained from the Thompson-Reuters Tick History (TRTH) database. This data comprises of intraday (5-second interval) updates on the price and volume for the primary futures

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[10] The methodology considers the recommendations of the International Organization of Securities Commissions (IOSCO) Principle of Benchmarks. See http://www.iosco.org/library/pubdocs/pdf/IOSCOPD415.pdf

[11] A full description of the LBMA Silver Price benchmark methodology is provided in Appendix A.

[12] Under the LMEs administration, the price for platinum is determined first, followed by the price of palladium.

contracts of each of the precious metals (Gold:GC, Silver:SI, Platinum:PL, Palladium:PA). It includes the high, low, open, close and traded volume per minute. Data on the quotes in the underlying wholesale markets contain: high, low, open and close per minute for each metal (Gold:XAU=, Silver:XAG= , Platinum:XPT=, Palladium:XPD=). We also obtain trade and quote data for two ETF contracts: the S&P Depository Receipts (SPDR) Gold Trust (GLD) and the iShares Silver Trust (SLV) which are two of the largest and most liquid physically backed funds during the selected sample period. The time and price of the afternoon fix is obtained using the following codes: Gold (XAUFIXPM), Silver (Old:XAGFIX, New: LDNXAG), Platinum (XPTFIX) and Palladium (XPDFIX). Our data extends from the 14th February 2012 to the 30th of April, 2015, a sample period that allows us to examine the interactions between the OTC and the financially linked futures and ETF markets.[13]

In order to determine the duration of each fix, we acquire details about the publication time of the benchmark price and use this information to inform our measure.[14] The end of the fix requires members to reach a price that satisfies a pre-determined imbalance threshold. For this reason, the duration of this process can vary widely. Figure 1 provides a series of histograms on the duration of the fix for each of the precious metals over the sample period. For gold and silver, the fix is almost always complete within ten minutes of the opening submission. For platinum and palladium the time to complete the process is significantly longer and more variable. This can be partly explained by the fact that in the pre-reform period, Platinum and Palladium were determined in the same meeting and the resolved prices not released until an outcome was reached for both metals.

<Insert Figure 1 >

The introduction of the new fix mechanism has resulted in a sharp decline in the time taken to resolve prices in the OTC market for precious metals. Results for the durations are outlined in Table 1. The silver (gold) fix has become noticeably shorter, with a 37% (22%) reduction in the average time to complete. The results for Platinum and Palladium also show an improvement at the average. Our table additionally reveals a shorter duration for the morning (AM) fix as compared to the afternoon (PM) fix for gold in the pre-reform period. This is perhaps unsurprising as the afternoon session is scheduled to correspond with the opening of U.S markets and is typically where the majority of order flow is transacted. Under the new system, durations between the AM and PM session are quantitatively similar, which appears symptomatic of the new electronic trading system. Overall, these results provide preliminary evidence of a more efficient price discovery process.

<Insert Table 1 >

3.2 Contract Specifications

3.2.1 Futures

[13] A number of metal-days were excluded due to data errors. These include 3/5/12, 13/6/12, 19/7/12, 19/4/13 and 28/4/14 for Silver due to the fix time being prior to the explicit start time, 2/2/15 for Gold due to the fix end occurring 99 minutes after the fix start and 4/3/13, 2/1/14, 20/1/14, 21/1/14, 23/6/14, 24/6/14, 4/11/14, 11/11/14, 20/11/14, 1/12/14, 31/12/14, 2/1/15, 21/1/15 and 31/3/15 for Platinum/Palladium due to the lack of a unique end time.

[14] Durations for Platinum and Palladium cannot be cleanly estimated in the pre-reform period as the benchmark price is only announced upon the completion of both metals. The price of platinum is determined first, but it is not until the price of platinum is determined that both prices are announced to the market.

The sample for this study is based on the CME futures contracts for four metals contracts (GSPP). Contract months for a) Gold and Silver include: February, April, June, August and December; b) Platinum: March, June, September and December c) Palladium: January, April, July, and October.[15] These futures contracts were selected because they are the most actively traded futures in their respective categories. This minimises any issue surrounding stale quotes and infrequent trading. The first contract of each maturity month is the nearby contract and the remainder are deferred contracts. The inclusion of multiple contracts, from varying maturities was made to ensure that a representative cross-sectional sample of the future markets was obtained. We select the near futures contracts for our analysis, which is rolled over to the next nearest-to-maturity contract 30 days prior to expiry. This ensures we capture the contract with the highest trading volume that is uncontaminated by expiry trading.

May of our precious metals trade on multiple exchanges but we restrict our analysis to the primary exchange. Our contracts are traded on the COMEX, a division of the New York Mercantile Exchange (NYMEX) which was acquired by the CME group in 2008. We use data from the electronic GLOBEX platform and exclude quotes and trades from the open-outcry period.[16] The average execution cost for gold (silver) contracts on the CME are approximately 1-2 (3-6) basis points (Marshall et al (2011).

3.2.2 ETFs

The ETFs that we examine in this study are the SPDR Gold Trust and the iShares Silver Trust. These ETFs are backed by physical holdings and are designed to track the price of precious metals, thereby giving investors an avenue for direct exposure without needing to worry about storage costs or risk. The two funds represent the largest and most liquid exchange traded holdings of the physical assets. At present, net asset values for gold and silver equate to approximately $23 and $5 billion respectively and have delivered a return of 8.44% and 23.1% since inception, respectively. The ETFs are traded on the New York Stock Exchange (NYSE Acra) which is the primary listing exchange for almost all exchange traded products.

4. Method

To test whether or not the change to a more transparent price discovery process has improved market quality for our financially linked instruments, we compare a range of market quality measures before and after the event. An often voiced criticism of such an approach is that it is based on a single security-event date combination. An advantage of this study is that we are examining the change of four precious metals, with introductions staggered over a nine month period. We classify our measures of market quality as either pre-trade or post-trade metrics. Our pre-trade measures of market quality include quoted and effective spreads as well as market depth at the best bid and offer (BBO). Post-trade measures of market quality include returns earned by market participants, volume and volatility. We construct a number of order submission and trade characteristic measures to understand how trading strategies and characteristics have changed following this reform. The advantage of the measures in these groupings is that they provide readily and observable metrics that are familiar to market participants, whilst also providing a comprehensive assessment of market quality.

[15] Only the quarterly cycles are used for Platinum and Palladium. Palladium futures follow a January to October quarterly cycle.
[16] The Tokyo Commodity Exchange (TOCOM) offers liquid contracts in gold and platinum, however are not considered in this study since the majority of exchange traded volume runs through the CME.

Our analysis is concerned with the period directly surrounding the fix. As such we consider an event window beginning thirty minutes prior to the start of the fix and sixty minutes after. Event times relative to the start of the fix are denoted using $t_i \in [-29, +60]$ by indexing each minute *i* to the start of the fix.

4.1 Pre-trade Measures of Market Quality

Our pre-trade measures of market quality are related to the cost of transacting. We calculate quoted spread and effective spreads by calculating the proportion of the day for which the prevailing quotes are active. Doing so allows us to capture the proportion of liquidity supplied by high and low-frequency traders. The latter measure is perhaps a more relevant measure of the cost of transacting as it is based on how close the trade price comes to the quote midpoint. We additionally examine how the volume of contracts quoted in the order book has changed as market participants are now privy to continuous information disseminated during the fix.

4.2 Post-trade Measures of Market Quality

4.2.1 Leakage

To examine the impact of the spot fix on associated futures and physically-backed ETFs we analyse abnormal returns around the start of this benchmark process. In theory, the price discovery process exhibited through returns should follow a different learning path in the post period as pricing information is continuously revealed during the fix process. To capture this effect we calculate returns for interval *i* and compare them to a naïve benchmark from an undisturbed prior period.[17] Abnormal returns are then cumulated (CAR_i) assuming an informed view of the eventual direction of the fix and are averaged over the sample period. Return calculations are as follows:

$$AR_{i,d} = DIR_d \times \ln\left(\frac{C_{i,d}}{C_{i-1,d}}\right);\ \overline{AR_i} = \frac{1}{n(D)}\sum_{d \in D} AR_{i,d} \qquad (1)$$

$$CAR_i = \sum_{n=-29}^{i} \overline{AR_n} - \sum_{n=-60}^{-30} \overline{AR_n}$$

Where DIR_d is equal to 1 if $Fix_d > Spot_d$ and -1 if $Fix_d < Spot_d$; and 0.

4.2.2 Volume

To assess differences in trading activity during the fix for the two regimes, we analyse volume traded in five second buckets for each futures contract (and ETF). Due to the disparity in trading volumes across different metal contracts, we standardise the volume of each contract to a clean period prior to the fix process. Volume data is taken for each of the futures contracts examined (GC, SI, PL and PA), where $VM_{i,d}$ represents the volume traded in bucket *i,* on day *d.* The benchmark level of volume VMB_d and average excess volume $\overline{VM_i}$ across all sample days, *D* is computed as follows:

[17] In event time, the benchmark period is calculated between -60 and -30 minutes prior to the start of the fix.

$$VMB_d = \frac{1}{30}\sum_{i=-29}^{0} \ln(VM_{i,d}) \qquad (2)$$

$$\overline{VM_i} = \frac{1}{n(D)}\sum_{d\in D}\left(VM_{i,d} - VMB_d\right)$$

The benchmark level of trading VMB_d is the average log-transformed volume in a 30-minute interval prior to event period. We use the log transformation to normalize the data, especially in light of the minimum value that volume can take, being 0. This also has the effect of reducing the skewness of the volume data. As $\ln(VM_{i,d})$ is undefined for zero volume, all $VM_{i,d}$ are incremented by one, implying one contract was traded. This adjustment does not materially impact any of our results.

4.2.3 Volatility

We calculate the relative volatility for our respective futures contracts, at one minute intervals over the activity window. The Kraus-Satchell (2015) volatility estimator is used to estimate the level of volatility in each 5-second interval, denoted $V_{i,d}$, using high and low prices ($H_{i,d}$, $L_{i,d}$) for interval i on day d.[18] Each 5-second interval is then compared to the average volatility during the benchmark period, VB_d. Volatility for each interval ($V_{i,d}$), benchmark volatility (VB_d), and average excess volatility ($\overline{V_i}$) are defined as:

$$V_{i,d} = \sqrt{\frac{\pi}{8}}\left(ln\left(\frac{H_{i,d}}{L_{i,d}}\right)\right); \quad VB_d = \frac{1}{30}\sum_{i=-60}^{-30} VM_{i,d} \qquad (3)$$

$$\overline{V_i} = \frac{1}{n(D)}\sum_{d\in D}\left(V_{i,d} - VB_d\right)$$

4.3 Multivariate Analysis

Our multivariate analysis of the impact on market quality stemming from the regime change controls for a number of factors that have been previously shown to explain time-series variation. The following specification is adopted for this paper:

$$y_{id} = \alpha_i + \beta NewFix_{id} + \delta X_{id} + \varepsilon_{id} \qquad (4)$$

where y_{id} is our market quality metric measured over a ninety minute period around the start of the fix. These regressions are run separately for each of the metals Gold, Silver, Platinum and Palladium. $NewFix_d$ takes a value of 1 for periods during the new fix and 0 otherwise. X_{id} is a vector of control variables including price (the daily benchmark price), the number of days to expiry for the nearest to maturity contract, volume, and volatility. We proxy for volatility using the US VIX. We also consider contract fixed effects.

[18] The results were reconstructed using the Garman-Klass and Rogers-Satchell estimators for robustness, with no material change in the findings.

To understand the dynamics of markets during the fix period, we repeat the previous analysis with our event period spanning only the duration of the fix – from the start of the fix until the publication of the fix price. As the average duration of the fix has changed significantly, we match each one of our post-regime days to an observation in the pre-sample period, controlling for metal type and contract series (maturity). Our match is further refined by minimising the sum of squared relative differences in terms of the days to maturity of the contract and the fix duration. This is specified as follows:

$$MatchingScore_{NO} = \sum_{j=1}^{2}\left(\frac{x_j^N - x_j^O}{(x_j^N + x_j^O)/2}\right)^2. \quad (5)$$

where x_j is either fix duration or days to expiry, and the superscript *N* indicates the variable in the new fix period; *O* the variable in the old period. Minimising the matching score ensures that the duration of the fix and the time to expiry characteristics of the matched days are as close as possible.[19] Using this balanced panel, we estimate a model specification which captures the market dynamics during the fix period itself, rather than across a longer period of time. This specification is outlined below:

$$y_d = \alpha_d + \beta_1 NewFix_d + \beta_2 Price_d + \beta_3 VIX_d + \beta_4 Vol_d + \varepsilon_d \quad (6)$$

4.4 Difference in Difference Analysis

We exploit the staggered introduction of the metals to conduct a difference-in-difference analysis for the introduction of the silver fix. We take all 146 days where silver has the new fix mechanism and gold retains the old mechanism. We then collect the 146 days immediately prior, where both gold and silver are operating with the old fix. We then take the difference of the dependent and independent variables between silver and gold to account for any fluctuations in our dependent variables which are not related to the new fix mechanism. The specification is outlined below:

$$Y_{s,d} - Y_{g,d} = \alpha_d + \beta_1 NewFix_{s,d} + \beta_2 VIX_d + \beta_3 Price_{s,d} - Price_{g,d} + \beta_3 Vol_{s,d} - Vol_{g,d} \quad (7)$$

where the subscript *S* and *G* indicate the measure for silver and gold respectively. The remaining variables are as previously described.

5. Results and Discussion

5.1 Market Quality Findings

In this section we provide a discussion of the key results from this paper. We begin by comparing market quality metrics around the regime change and follow on by considering why this transparency change should have an impact on market quality.

The results in Table 2 provide preliminary evidence on the impact of the change in market structure on market quality. The reported statistics are based on a ninety minute period around the conducting of the fix in the underlying market. They show that the change in process to allow order flow to be more transparent has had a favourable impact on measures of liquidity and efficiency in financially linked markets. The improvements observed are reflected across each of the metal contracts and are consistent

[19] The durations of the matched fix days differ by an average of 17% while the days to expiry differ by an average of 8%, indicating the matches are very precise.

with the a priori view that agents having more accurate information during a heightened period of price discovery will experience positive market welfare benefits.

<< Insert Table 2>>

Specifically, a decline in quoted and effective spreads is both recognisable and statistically significant for the silver, gold, and platinum contracts. On average, quoted spreads decline by approximately 24%, 15%, and 23%, respectively for the three contracts. While there is a small but discernible change in palladium, we find that it is not statistically significant at standard levels. Table 2 additionally reports changes in depth at the top of the order book. Across each of the metals, we observe a significant increase in depth in the post period. This is consistent with the hypothesis that positive changes in transparency can have an appreciable impact on market liquidity.

Table 2 also presents statistics on returns earned by participants around the start of the fix. Utilising a number of event periods, our results show a significant decline in cumulative adjusted returns for silver futures. An obvious potential explanation for this decline is that informed participants of the underlying process are no longer able to able to use information about the future fix direction to their advantage when the process becomes transparent to the market. The results for gold and platinum are consistent in terms of their direction, but are statistically insignificant. A possible cause of this is the small sample of data in the post period.

Our results can perhaps be better appreciated when examining the change in efficiency metrics both within and around the fix duration period. Figure 2 shows quoted bid-ask spreads under the two regimes. In the panel of figures on the left we observe changes in the bid-offer spread in the ninety minute period around the fix for each metal contract. For the panel of figures on the right, we standardise each fix period per trading day to reveal how the spread changes from the start of the fix to its publication to the market. A number of key results emerge from this analysis. First, quoted spreads are on average higher in the period before the regime change. The extent of the change is more apparent in the gold and silver contracts which are more liquid, however the change in Platinum is economically significant. Second, quoted spreads are typically at their highest point immediately prior to the start of the fix, reflecting the uncertainty in the market about what the fix price will be. This uncertainty is however, typically resolved within a matter of minutes from the start. Interestingly, quoted spreads around the beginning of the fix exhibit greater variation than under the previous regime, which promotes the idea that greater disclosure lowers adverse selection costs. Finally, our panels on the right of Figure 2 document the change in quoted spreads from the start of the fix period until the end. Quoted spreads are highest at the start of the fix and trend down throughout the remainder of the period. Curiously, the trend line associated with the more transparent price discovery process (post-period) mirrors that of the prior regime, characterised by limited transparency. This is perhaps suggestive that participants in the prior regime inferred the direction of the fix on the basis of trades in the opening minutes. This explanation corresponds to findings presented in Caminschi et al. (2014) which show that trades at the start of the fix are highly correlated with the direction of the fix, in some cases exceeding 90%.

<<Insert Figure 2>>

Figure 3 plots best bid and offer (BBO) depth for a ninety minute period around the start of the fix. Similar to patterns exhibited in the previous figure, we observe a noticeable decline in depth prior to the start of the fix, followed by a steady recovery as information is revealed to the market. We also observe a noticeable increase in depth across all four contracts.

<<Insert Figure 3>>

To investigate suggestions by Caminschi et al. (2014) that returns to informed participants are potentially reflective of informational leakage under the old regime, we replicate this analysis for the two periods. Our results can be observed in Figure 4. The panels of the left document the cumulative adjusted returns, accounting for price direction adjustments during a ninety minute period around the start of the fix for all four precious metals futures contracts. The panels on the right standardise the duration of the fix to observe the returns process within this pricing period. The panels in Figure 4 reveal a similar returns process for the two periods; there is no significant leakage prior to the start of the fix and within minutes of the start, most of the price discovery process is complete. Whilst in theory, the consistency in return dynamics should not be a source of discussion, the fact that the process of incorporating information into prices is similar despite the increase in transparency suggests that some kind of leakage of information occurred in the prior period. In the panel of figures on the right, the upward trend in CARs from the start to the end of the fix is consistent with real-time information about price and order imbalance. The fact that this trend is comparable in the prior period, where the state of the order book was unknown until its publication at the end of the fix, is suggestive of leakage in the prior period. It is important at this point to emphasise that this does not suggest that a particular group of participants engaged in illegal trading activity. It is plausible that traders involved in the spot market at the time of the fix were also engaged in other associated markets, and so the causality may run in both directions.

5.2 Panel Data Analysis

Tables 3 and 4 report the results from the fourth specification for the sample of precious metals futures contracts during and around the fix period under the two regimes. The dependent variable in Table 3 is the quoted bid-ask spread. The coefficient NewFix which is a dummy variable marking the change in the fix process is negative for all specifications, and statistically significant in 5 of the 8 regressions. This implies that the change in transparency has had a positive impact on market liquidity in and around the fix period. It is consistent with the view that greater market transparency reduces the asymmetry of information about the order flow, resulting in tighter quoted spreads on average. Looking at the results in Table 4 further supports this view. Depth is higher across all our contracts in and around the fix period in the post regime. Of these, 6 out of 8 specifications are statistically significant. Overall, our results suggest that improving disclosure of the value discovery process in the underlying mitigates the ‘free option’ cost of limit-order provision in associated derivatives markets, thereby improving market quality.

<<Insert Table 2 and 3>>

Table 5 presents the results of the market quality analysis for gold and silver ETF contracts. Contrary to our expectations, the impact of the change in the market structure of the underlying has had a negligible effect on market efficiency. A possible explanation for this result lies in the fact that despite the size of the gold and silver ETF’s, these markets are significantly less liquid than their futures counterparts in terms of depth and trading activity. In a sense best execution or competitive quoting has no teeth in a setting where securities are so thinly traded that it makes no sense for any market maker to spend the time and effort needed to quote continuous prices at which she is prepared to trade. This conjecture, however, is subject to further investigation.

<<Insert Table 4>>

Our difference-in-difference estimates reported in Table 6 support the findings documented in the main analysis. The introduction of the silver fix results in a relative reduction in both quoted and effective spreads and volatility, as well as a significant increase in depth, when compared to gold over the same period. The difference-in-differences methodology used in this specification controls for changes in the dependent variables which are unrelated to the introduction of the new silver fix mechanism. This specification also indicates that the results are robust to much shorter periods of analysis.

<<Insert Table 5>>

6. Conclusion

In response to concerns regarding the integrity of the spot market benchmark “Fix” mechanisms for precious metals, the price determination mechanism was changed from an opaque, “closed-door” process to three new electronic formats. These new formats differ significantly in their operation and transparency. In the case of the new fix mechanisms for silver and gold, the new mechanism appears to have significantly improved market quality. There appears to be far less information leakage of the eventual fix direction, implying an improvement in the integrity of the mechanism. There has also been a significant reduction in transactions costs and volatility, and a commensurate increase in the quoted depth. Taken together, these improvements in efficiency and integrity indicate that participants are more willing to trade in the newly arranged market.

The third mechanism which was introduced for platinum and palladium does not experience such improvements. Most measures of market quality remain either unchanged from their prior levels, or have become slightly worse than under the original fix methodology. The differences may indicate that increased transparency is most valued for highly liquid commodities.

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Appendix:

LBMA Silver Price Discovery Process

The LBMA Silver price is determined using an equilibrium auction that is conducted daily at 12:00:00 London Time. Prior to the first round of the auction, the platform displays a notification to participants that are logged in that the auction is about to begin. The auction platform operator (CME Benchmark Europe Ltd) is responsible for providing the initial auction price which is determined by comparing multiple sources of market data. In each round of the auction, participants are allowed to place one firm order either on the buy or sell side by entering a quantity they would like to execute. Quantities are in units of Lakkhs, where 1 Lakh is 100,000 ounces. When orders are placed in an auction, it is time stamped and displayed on the auction platform audit log for participants to view in real time. Participants are able to see both individual order submissions (but not which registered participant has provided the submission) and the total buy and sell quantity entered. Each participant is also able to amend or cancel their orders prior to the end of the round and are not required to submit to future rounds if they so choose. At the end of each round of the auction, orders on the bid and ask are compared and if the quantity falls below a tolerance value of 3 Lakhs then the auction is closed and the LBMA Silver Price is established. If the difference is greater than this amount then all orders from the previous round are cancelled, and a new round begins with a different price. This process continues until the auction is balanced. The auction platform then matches the orders using a price time priority algorithm until the unfilled quantity on one side is exhausted. Any imbalance is made of all participants who placed orders in the auction process by executing against the participant orders causing the imbalance. A trade report is then created for each participant and counterparty.

LBMA Gold Price Discovery Process

The LBMA Gold Price which replaces the London Gold Fix is administered by the ICE Benchmark Administration (IBA). The IBA auction process is an electronic auction, with the imbalance calculated, and the price adjusted in rounds that are 45 seconds in duration. The auction is run twice daily at 10:30am and 3:00pm London time. It is overseen by a chairperson independent of any firm associated with the auction, appointed by IBA to determine the price for each round and ensure that the prices responds appropriately to market conditions. The auction process is hosted on the WebICE platform which provides real-time order management, separation of client and house orders (though participants can choose to enter a single netted order), and a full audit history. In the auction process, the chairperson sets the starting price and the price for each round. Participants are required to enter buy or sell orders by volume (ounces) and should the net volume of all participants fall within the pre-determined tolerance at the end of a round, the auction will be complete, with all volume tradeable at that price. Netting off orders is processed automatically for participants with all house and client orders, plus any share of the imbalance (which is distributed on a pro-rata basis), contributing to their final net volume. This net volume is then matched against other participants to produce trades with immediate trade confirmations. Once the auction is concluded, the benchmark price is published. During the auction, IBA published auction details live to re-distributors, containing the starting price of each round as well as the final aggregate bid and offer volumes entered in that round.

LBMA Platinum Price and LBMA Palladium (LPP) Price Discovery Process

The LBMA Platinum and Palladium process commences daily at 9:45am and 2:00pm. The Chair of the price discovery event, who is a member of the Benchmark pricing function, commences the auction when a minimum number of participants (3) have logged into LMEbullion. The opening price is determined by the Chair and this is submitted to LMEbullion. This opening price is determined using discretion and expert judgement to analyse relevant sources and/or data feeds as necessary. When the opening price is entered, participants are required to submit in LMEbullion whether they are a buyer or seller and the volume of their orders. If they have no interest at the stated price they are also required to disclose this. Each member participant is allowed to net client order off together with their principal interest to work out the member participant's overall interest. Alternatively, the participant may enter house and client orders separately. Unlike the CME's system for Silver, auction rounds are only resolved when all participants present have entered their interest. At this point LME bullion will enter a 'grace' period for five seconds, where calculations to determine the imbalance of trading volume based on participant interest will occur. If the imbalance calculated is 4,000 troy ounces or less then the proposed price will become the discovered price. In the event that the imbalance amount is higher than the specified threshold, LMEbullion will calculate the proposed price based on a pre-determined price schedule. For example, if the imbalance is between 4001-6001 troy ounces then the price will be adjusted by $US1 dollar, however, if the imbalance is greater than 10,001 troy ounces then the price will be adjusted by $US3 dollars. Where the price direction changes more than six times during the process, specific conditions are in place to resolve the imbalance. Once the LPP prices have been discovered, buy and sell orders may not be altered or withdrawn by participants. LMEBullion will subsequently generate a report stating that the price is the discovered price, which is the final price. Net interest is then matched and all trades are then bilaterally executed between member participants. Once this process has been followed for both platinum and palladium, the price discovery process ends. Price information relating to proposed prices and cumulative buy/sell volumes is published as live data to licensed vendors during the process. LMEBullion will also display a commentary of proposed prices and buy and sell orders on an anonymised basis with relevant timestamps. The discovered price is published at the end of the auction. Current member participants in the process are BASF Metals Ltd, Goldman Sachs International, HSBC Bank USA NA, Johnson Matthey plc and Standard Bank plc.

Table 1
Fix Durations

This table reports the average duration in minutes to complete the fix calculations for each metal in our analysis. We report the AM and PM fix for each of the metals separately. New and Old refer to the periods pre and post the introduction of the new regulations respectively. Number indicates the number of fix's considered. Other statistics including the mean, standard deviation, minimum time, first quartile, median, third quartile and maximum duration are also presented.

	Silver		Gold				Palladium				Platinum			
	New	Old	AM New	AM Old	PM New	PM Old	AM New	AM Old	PM New	PM Old	AM New	AM Old	PM New	PM Old
Number	221	653	67	812	67	807	140	735	143	728	142	736	143	731
Mean	1.35	2.15	3.71	3.11	3.50	4.31	18.22	19.14	16.83	19.73	17.58	19.15	16.28	19.73
Standard Deviation	0.74	1.92	1.79	1.68	2.14	2.49	8.81	11.84	7.55	9.43	9.11	11.84	7.26	9.45
Minimum	0.50	0.00	0.92	0.00	0.93	0.53	6.77	7.80	6.53	5.10	5.53	7.80	5.55	5.10
Q1	0.53	0.90	2.63	1.87	1.86	2.58	12.16	13.90	11.04	14.2	10.80	13.90	11.06	14.20
Median	1.50	1.82	3.57	2.77	3.42	3.75	16.42	16.32	16.05	18.22	16.18	16.32	15.3	18.22
Q3	1.53	2.92	5.15	3.85	4.67	5.38	22.10	20.27	20.78	23.47	21.23	20.50	20.07	23.47
Maximum	5.00	23.67	8.12	11.22	10.25	19.18	51.08	150.38	52.80	95.82	57.30	150.38	52.80	95.82

Table 2
Descriptive Statistics

This table reports the mean pre and post the introduction of the new fix regime for each metal considered in our analysis. Each metric is measured at the 5second frequency and averaged across a 90 minute period starting 30 minutes before the beginning of the fix and ending 60 minutes after the fix beginning. Quoted spread is the time weighted quoted spread in cents divided by the tick size. Effective spread is volume weighted within each 5 second period and is measured in cents. Depth is the time weighted number of contracts available at the best bid and offer. Trade size is the average number of contracts traded in each 5 second period. Volatility is the Krause-Satchell (2015) volatility estimate measured in basis points. Volume is the average number of contracts traded daily in thousands. Price is the average Fix price for each metal. CAR refers to the adjusted cumulative average return at the end of the fix, and 10, 30 and 60 minutes after the beginning of the fix, respectively. Diff represents the difference in the means between the pre and post periods. ***, ** and * indicate statistical significance using a two-tailed Wilcoxon signed rank test at the 1%, 5% and 10% levels, respectively.

	Silver			Gold			Platinum			Palladium		
Metric	**Pre**	**Post**	**Diff**	**Pre**	**Post**	**Diff**	**Pre**	**Post**	**Diff**	**Pre**	**Post**	**Diff**
Quoted Spread (ticks)	1.60	1.22	-0.38***	1.38	1.17	-0.21***	10.98	8.45	-2.53***	10.38	9.88	-0.51
Effective Spread (cents)	0.67	0.56	-0.11***	0.14	0.12	-0.02***	0.40	0.32	-0.08***	0.38	0.38	-0.01
Depth (contracts)	10.06	15.04	4.98***	14.91	22.53	7.62***	4.49	5.20	0.71***	3.85	4.57	0.71***
Trade Size (contracts)	1.16	1.21	0.05***	1.36	1.43	0.07	1.30	1.39	0.09***	1.37	1.25	-0.12***
Volatility	24.96	20.42	-4.54***	55.46	45.25	-10.21	27.97	27.40	-0.57	32.71	33.52	0.81
Volume ('000s)	44.43	43.96	-0.47	149.85	138.70	-11.15***	10.50	12.07	1.57***	4.90	4.34	-0.57**
Price ($)	25.75	16.85	-8.90*	1,433.61	1,192.57	-241.04***	1,483.23	1,167.61	-315.62***	727.18	775.81	48.62***
CAR Fix (bps)	6.45	-1.49	-7.94***	9.08	6.70	-2.38	-1.03	3.78	4.81	5.66	2.64	-3.02
Car 10mins (bps)	7.68	-1.43	-9.11***	9.41	5.65	-3.76	-1.42	1.67	3.09	5.60	2.99	-2.62
Car 30mins (bps)	7.86	-1.55	-9.41***	9.43	6.51	-2.92	-0.47	4.73	5.20	4.32	1.49	-2.83
Car 60mins (bps)	6.17	-6.13	-12.30***	9.29	6.63	-2.66	-0.24	4.56	4.80	3.94	-4.77	-8.72

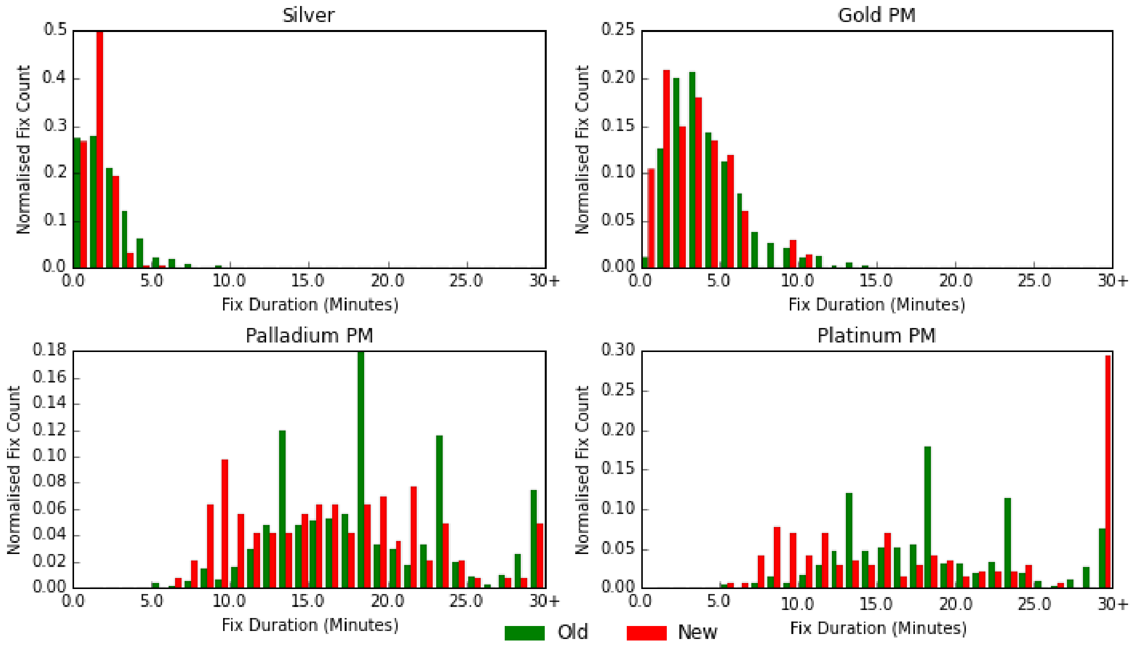

Figure 1. Distribution of Fix Durations
This histogram shows the distribution of the durations of the Fix per metal for each metal. The durations of both the old and new mechanisms are shown side by side.

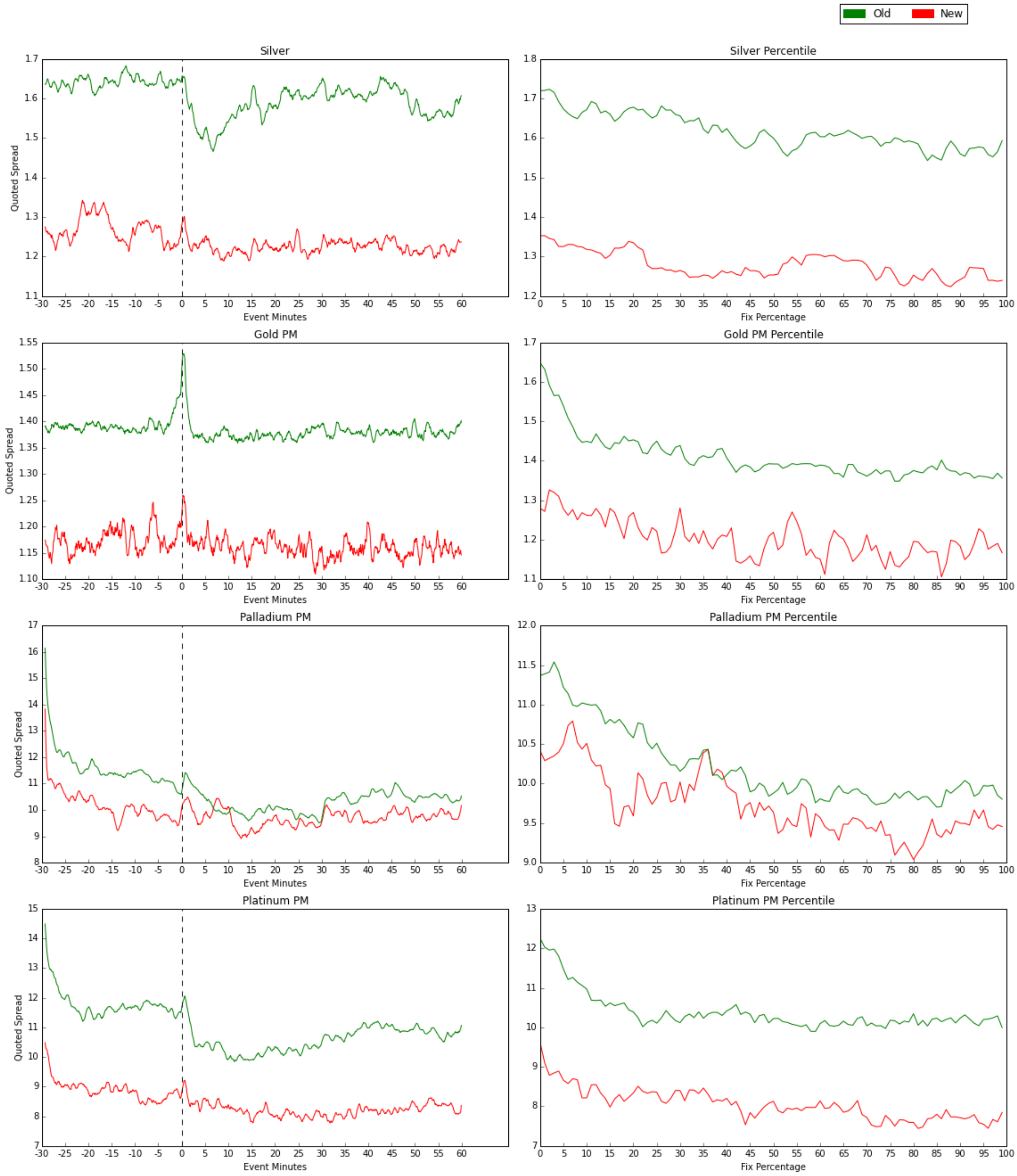

Figure 2. Quoted Spreads
These four graphs on the left document changes in the bid-ask spreads in the 90 minutes surrounding the start of the fix under both the old and new fix mechanisms. The vertical line at time 0 represents the start of the fix period. The graphs on the right hand side of this panel depict changes in the bid-ask spread for the precious metals contract during the fix period.

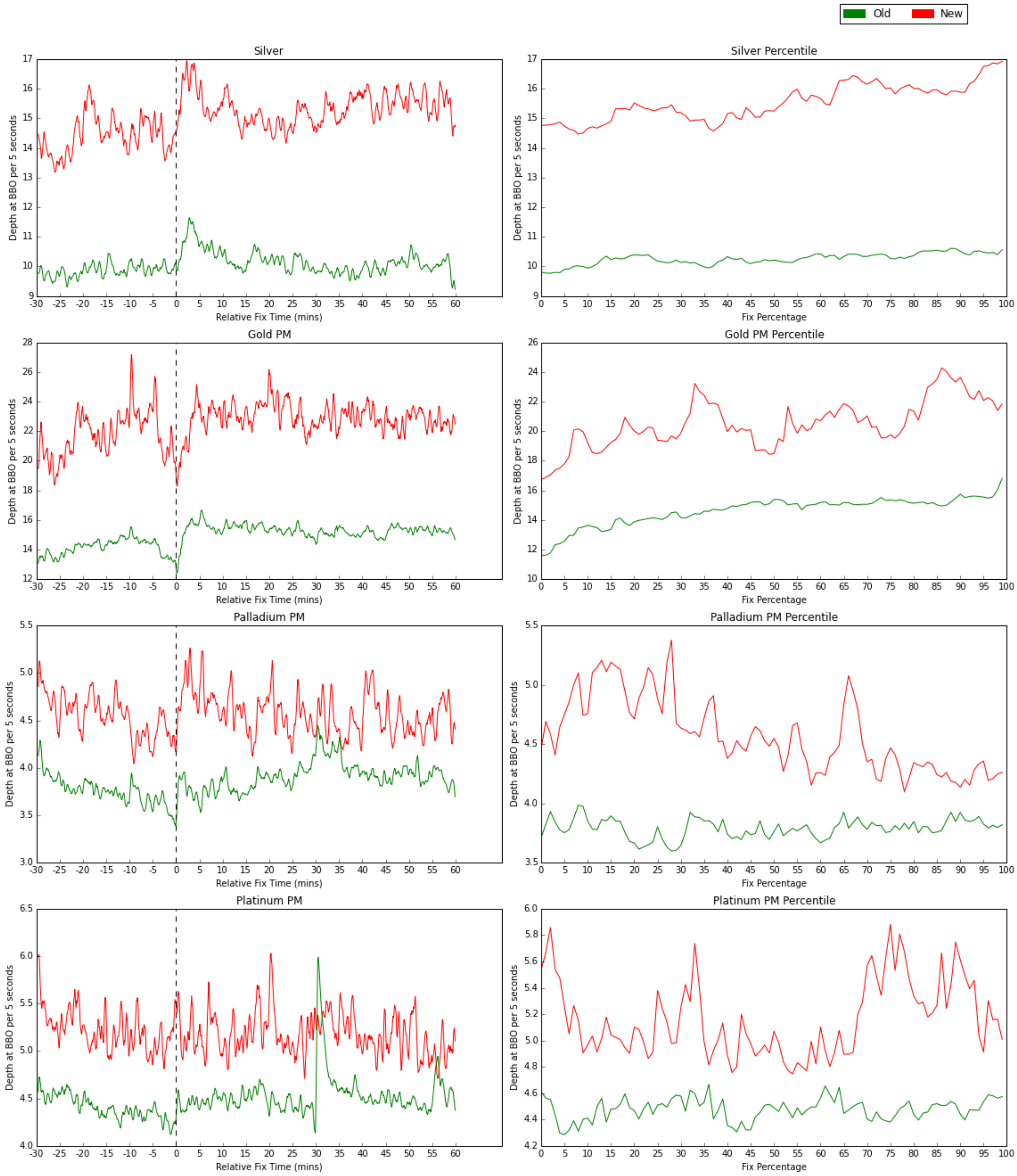

Figure 3. Depth at the BBO

These four graphs on the left document the amount of depth for futures contracts traded in the 90 minutes surrounding the start of the fix under both the old and new fix mechanisms. The vertical line at time 0 represents the start of the fix period. The graphs on the right hand side of this panel depict depth for the precious metals contract during the fix period.

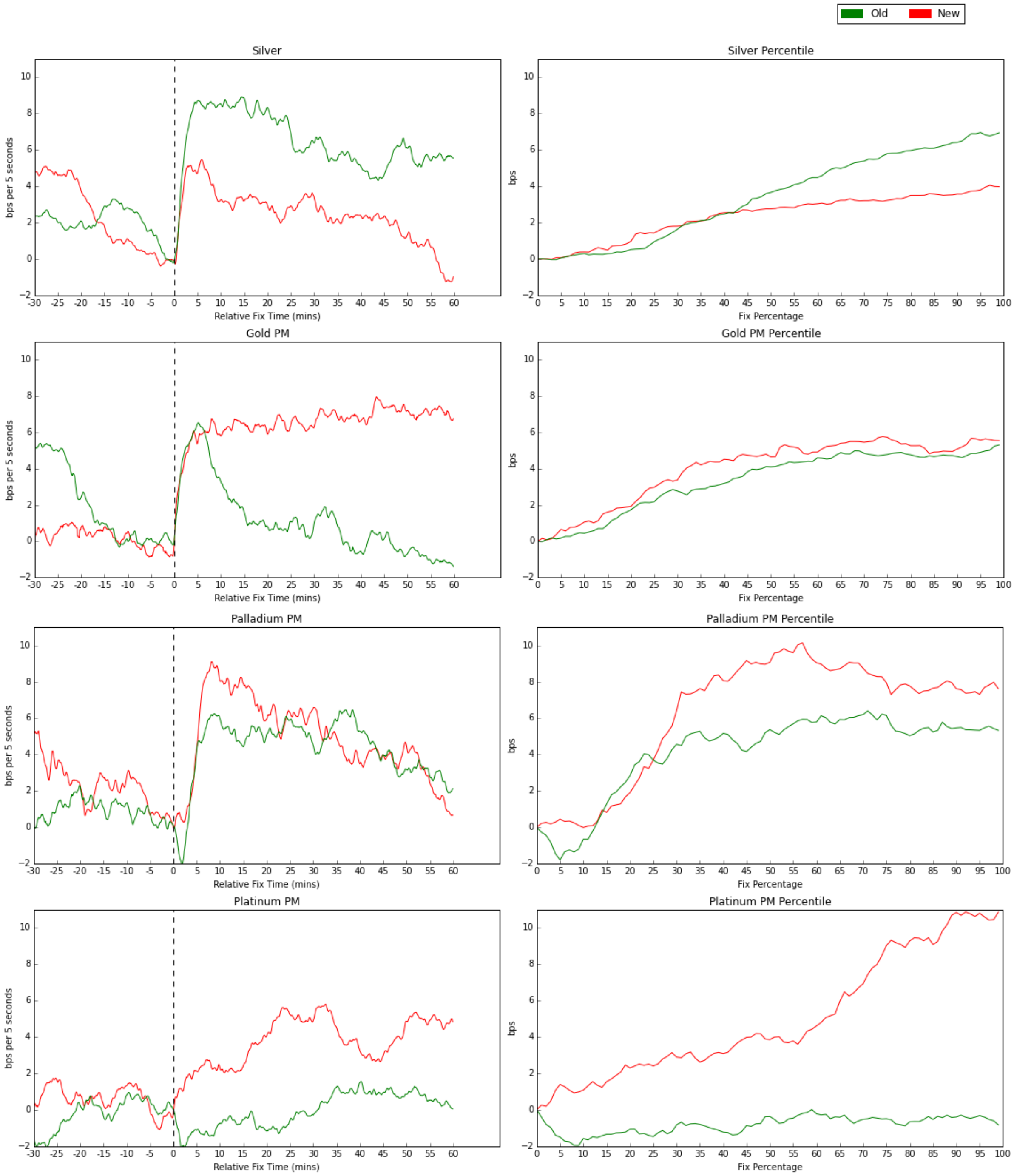

Figure 4. Cumulative adjusted returns (CAR)

These four graphs on the left illustrate the cumulative abnormal returns for futures contracts traded in the 90 minutes surrounding the start of the fix under both the old and new fix mechanisms. The vertical line at time 0 represents the start of the fix period. The graphs on the right hand side of this panel depict the CARs for the precious metals contract during the fix period.

Table 3

Impact of Fix Introduction on Quoted Spreads

This table reports the impact of the introduction of the new fix regime for each metal considered in our analysis. Each metric is measured at the 5second frequency and averaged across either a 90 minute period starting 30 minutes before the beginning of the fix and ending 60 minutes after the fix beginning, denoted "Daily" or across the duration of the fix, denoted "Fix". When the duration of the fix is used, each new-fix day is matched to an old-fix day by minimizing the difference of the fix duration and the days to expiry of the contract. The dependent variable, quoted spread, is the time weighted quoted spread in cents divided by the tick size. New Fix is a dummy variable which takes a value of 0 in the pre period and 1 after the introduction. Price is the average daily fix price for each metal. Days to expiry is the number of days remaining until the expiry of the futures contract. VIX is the daily estimate of the US volatility index. Volume is the average number of contracts traded daily in thousands. Fixed effects reports the use of contract series fixed effects. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Gold		Silver		Platinum		Palladium	
	Daily	Fix	Daily	Fix	Daily	Fix	Daily	Fix
New Fix	-0.174***	-0.186***	-0.208***	-0.117**	-0.486	-0.317	-0.428**	-0.096
	(-13.705)	(-4.129)	(-9.260)	(-2.424)	(-1.597)	(-0.443)	(-2.076)	(-0.306)
Price	0.000***	0.000***	0.000***	0.000**	0.005***	0.006***	-0.004**	-0.006
	(5.244)	(3.811)	(7.404)	(2.197)	(7.453)	(3.081)	(-2.139)	(-1.606)
Days to Expiry	0.000		-0.000		-0.001		-0.007**	
	(1.382)		(-0.458)		(-0.288)		(-2.147)	
VIX	0.034***	0.036***	0.051***	0.036***	0.592***	0.424***	0.179***	0.019
	(19.539)	(3.132)	(9.967)	(3.607)	(20.152)	(7.197)	(3.778)	(0.316)
Volume	0.100	-1.349	-0.441	0.404	-66.662***	-123.291***	-84.421	-64.796
	(0.679)	(-1.532)	(-0.534)	(1.590)	(-2.610)	(-3.669)	(-1.622)	(-0.626)
Constant	0.559***	0.602***	0.376***	0.212	-6.010***	-3.949	10.719***	14.401***
	(10.846)	(3.432)	(4.151)	(1.058)	(-5.611)	(-1.431)	(6.076)	(4.358)
Observations	856	429	852	133	853	273	778	279
Adjusted R^2	0.557	0.348	0.549	0.606	0.483	0.455	0.081	0.010
Fixed Effects	Yes	No	Yes	No	Yes	No	Yes	No

Table 4
Impact of Fix Introduction on Depth

This table reports the impact of the introduction of the new fix regime for each metal considered in our analysis. Each metric is measured at the 5second frequency and averaged across either a 90 minute period starting 30 minutes before the beginning of the fix and ending 60 minutes after the fix beginning, denoted "Daily" or across the duration of the fix, denoted "Fix". When the duration of the fix is used, each new-fix day is matched to an old-fix day by minimizing the difference of the fix duration and the days to expiry of the contract. The dependent variable, depth is the time weighted number of contracts available at the best bid and offer. New Fix is a dummy variable which takes a value of 0 in the pre period and 1 after the introduction. Price is the average daily fix price for each metal. Days to expiry is the number of days remaining until the expiry of the futures contract. VIX is the daily estimate of the US volatility index. Volume is the average number of contracts traded daily in thousands. Fixed effects reports the use of contract series fixed effects. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Gold		Silver		Platinum		Palladium	
	Daily	Fix	Daily	Fix	Daily	Fix	Daily	Fix
New Fix	5.336***	3.431***	3.571***	2.335***	0.092	0.046	0.548***	0.424***
	(10.426)	(5.450)	(11.267)	(3.842)	(0.968)	(0.149)	(9.504)	(3.266)
Price	-0.006***	-0.003***	-0.001***	-0.009***	-0.002***	-0.000	0.004***	0.001
	(-9.173)	(-5.482)	(-5.581)	(-4.500)	(-8.273)	(-0.600)	(10.689)	(0.346)
Days to Expiry	-0.013**		-0.002		0.000		0.002**	
	(-2.443)		(-0.444)		(0.229)		(2.096)	
VIX	-0.648***	-0.851***	-0.478***	-0.401***	-0.003	-0.032	-0.016	-0.020
	(-12.848)	(-9.080)	(-11.251)	(-4.284)	(-0.458)	(-1.441)	(-1.501)	(-0.681)
Volume	-14.118***	2.792	-12.452*	-10.370***	26.664***	14.034	34.217***	6.601
	(-5.827)	(0.258)	(-1.931)	(-4.263)	(3.740)	(0.584)	(2.896)	(0.286)
Constant	37.304***	31.482***	22.058***	33.122***	6.979***	5.645***	1.177***	3.888***
	(35.080)	(22.205)	(28.023)	(15.415)	(21.346)	(3.742)	(2.937)	(2.968)
Observations	856	429	852	133	853	273	778	279
Adjusted R^2	0.460	0.586	0.507	0.668	0.254	0.009	0.373	0.043
Fixed Effects	Yes	No	Yes	No	Yes	No	Yes	No

Table 5

Impact of Fix Introduction on Gold and Silver ETFs

This table reports the impact of the introduction of the new fix regime on the GLD gold and SLV silver ETFs. Each metric is measured at the 5second frequency and averaged across either a 90 minute period starting 30 minutes before the beginning of the fix and ending 60 minutes after the fix beginning, denoted "Daily" or across the duration of the fix, denoted "Fix". When the duration of the fix is used, each new-fix day is matched to an old-fix day by minimizing the difference of the fix duration and the days to expiry of the contract. Quoted spread is the time weighted quoted spread in cents divided by the tick size. Effective spread is volume weighted within each 5 second period and is measured in cents. Depth is the time weighted number of contracts available at the best bid and offer. New Fix is a dummy variable which takes a value of 0 in the pre period and 1 after the introduction. Price is the average daily fix price for each metal. VIX is the daily estimate of the US volatility index. Volume is the average number of contracts traded daily in thousands. Fixed effects reports the use of contract series fixed effects. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Quoted Spread				Effective Spread				Depth			
	Gold ETF		Silver ETF		Gold ETF		Silver ETF		Gold ETF		Silver ETF	
	Daily	Fix	Daily	Fix	Daily	Fix	Daily	Fix	Daily	Fix	Daily	Fix
New Fix	0.000	0.000	0.001	-0.000	-0.003	-0.001	-0.006**	-0.000	-2.799***	82.211***	-7.601***	-0.593
	(0.827)	(0.088)	(0.607)	(-0.088)	(-1.335)	(-1.176)	(-2.360)	(-0.576)	(-3.833)	(10.192)	(-2.792)	(-0.414)
Price	-0.000***	-0.001***	-0.001***	-0.000	-0.000	-0.000	0.000	0.000***	-0.344***	-7.713***	-1.483***	-0.251***
	(-15.047)	(-2.929)	(-5.394)	(-0.706)	(-0.724)	(-1.036)	(1.612)	(3.670)	(-23.188)	(-11.951)	(-5.924)	(-4.359)
VIX	0.000***	-0.000	-0.000**	0.000***	0.001***	0.000	-0.001***	0.000***	-0.918***	-8.718***	-0.380	-0.699***
	(22.067)	(-1.185)	(-2.277)	(4.695)	(9.057)	(0.497)	(-2.793)	(2.761)	(-8.500)	(-8.161)	(-0.867)	(-3.338)
Volume	0.005***	-0.192*	-0.000***	-0.001	0.412	0.008	-0.000***	-0.027	-161.857***	18.843	0.269**	-76.214
	(4.431)	(-1.678)	(-4.778)	(-0.074)	(1.294)	(0.307)	(-3.586)	(-0.249)	(-3.502)	(0.037)	(2.025)	(-0.454)
Constant	0.001***	0.046***	0.043***	0.000	0.010	0.012***	0.046***	-0.004	101.937***	577.971***	120.240***	73.949***
	(18.249)	(6.705)	(12.289)	(0.427)	(1.084)	(11.656)	(8.719)	(-1.029)	(45.074)	(31.697)	(17.413)	(10.785)
Observations	854	425	853	133	854	425	760	133	854	425	853	133
Adjusted R^2	0.428	0.082	0.109	0.289	0.002	0.001	0.035	0.419	0.552	0.746	0.057	0.623

Table 6

Difference-in-difference Estimate of the New Silver Fix

This table reports a difference-in-difference estimate of the impact of the introduction of the new silver fix on silver futures. Each dependent and independent variable is constructed as the silver variable for each day minus the gold variable for each day. Each metric is measured at the 5second frequency and averaged across either a 90 minute period starting 30 minutes before the beginning of the fix and ending 60 minutes after the fix beginning. Quoted spread is the time weighted quoted spread in cents divided by the tick size. Effective spread is volume weighted within each 5 second period and is measured in cents. Depth is the time weighted number of contracts available at the best bid and offer. Volatility is the Krause-Satchell (2015) volatility estimate measured in basis points. New Fix is a dummy variable which takes a value of 0 in the pre period and 1 after the introduction of the new Silver fix. Price is the difference in the average daily fix price for each metal. VIX is the daily estimate of the US volatility index. Volume is the difference in the average number of contracts traded daily in thousands. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Quoted Spread	Effective Spread	Depth	Volatility
New Fix	-0.070***	-0.023***	1.490**	-8.433***
	(-2.847)	(-3.951)	(2.388)	(-3.384)
Price	-0.000	-0.000	-0.002	-0.008
	(-0.550)	(-0.788)	(-0.787)	(-0.911)
VIX	-0.014***	0.001	0.169	
	(-3.065)	(0.439)	(1.379)	
Volume	-0.000	0.000	0.008	0.109***
	(-1.268)	(0.768)	(1.484)	(3.364)
Constant	0.219*	0.460***	-6.210*	-7.573
	(1.823)	(12.118)	(-1.846)	(-1.063)
Observations	287	287	287	287
Adjusted R^2	0.12	0.08	0.11	0.15