Intraday Seasonality in Efficiency, Liquidity, Volatility and Volume: Platinum and Gold Futures in Tokyo and New York

Kentaro Iwatsubo
Clinton Watkins
Tao Xu

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Kentaro Iwatsubo[1], Clinton Watkins and Tao Xu

Kobe University, 2-1 Rokkodai-cho, Nada, Kobe, Japan 657-8501

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Abstract

We investigate intraday seasonality in, and relationships between, informational efficiency, volatility, volume and liquidity. Platinum and gold, both traded in overlapping sessions in Tokyo and New York, provide an interesting comparison because Tokyo is an internationally important trading venue for platinum but not for gold. Our analysis indicates that both platinum and gold markets in Tokyo are dominated by uninformed trading, while there is evidence supporting both uninformed and informed trading in New York. Separating global trading hours into Tokyo, London and New York day sessions, we also find that uninformed trading is more prevalent during the Tokyo day session while informed trading dominates the New York day session for both metals in both locations. This evidence suggests that futures markets for the same underlying commodity on different exchanges have different microstructure characteristics, while both informed and uninformed traders choose when to trade depending on market characteristics in different time zones.

JEL classification: G14, G15, Q02

Key words: intraday patterns, microstructure, efficiency, commodity futures

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[1] Corresponding author. *Email address:* iwatsubo@econ.kobe-u.ac.jp
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1. Introduction

Why do multiple exchanges that trade the same commodity exist? A number of futures exchanges have extended their trading hours to include night sessions, overlapping with each other. It is now common for different exchanges to trade futures based on the same underlying commodity at the same time. Arbitrage activity, assisted by the globalisation of commodity markets and advances in trading technology, encourages commodity futures mid-prices on different exchanges to be virtually identical after adjusting for contract specifications and exchange rates. A straightforward argument would suggest that market participants prefer to trade on the exchange with superior price discovery, efficiency and liquidity. Therefore, trade in the futures of a particular commodity would be expected to agglomerate to one exchange, as higher liquidity and scale economies encourage traders to the venue. However, multiple futures exchanges persist for many commodities.

In this paper, we aim to shed light on why this may be the case. We investigate whether markets for commodities futures contracts on different exchanges have different microstructure characteristics. Such differentiated characteristics may be advantageous for certain investors, and provide a competitive advantage for the exchange. We address this question by estimating and comparing the intraday seasonality of informational efficiency, volatility, volume and liquidity in platinum and gold futures traded in overlapping sessions on exchanges in Tokyo and New York.

Platinum and gold futures are traded on the Tokyo Commodity Exchange (TOCOM), while in New York, platinum futures are listed on the New York Mercantile Exchange (NYMEX) and gold on the Commodity Exchange, Inc. (COMEX). Historically, TOCOM has been an important global venue for trading platinum futures. In the past, activity in the global market for platinum has been heavily influenced by the hedging trades of large industrial end consumers of platinum metal in Japan who access the futures market via TOCOM. Until recently, the total weight of platinum represented by futures traded on TOCOM far outweighed that of NYMEX. In 2008 for example, 3.5 million kilograms was traded on TOCOM[2], or 4.4 times that of NYMEX. However, annual volume on the Tokyo market has been in long-term decline, down from over 16 million contracts in 2001 to just over 3.1 million contracts in 2016

[2] Refer to http://www.tocom.or.jp/historical/dekidaka.html for TOCOM trading volume.

(including both the platinum standard and mini contracts). In 2015 NYMEX was about 2.9 times larger than Tokyo by weight of platinum, and 4.2 times larger in 2016. However, in terms of contract volume, monthly turnover in Tokyo usually exceeds that of New York (see Figure 1). The TOCOM contract unit is 500 grams or 16.08 troy ounces of metal for the standard future and 100 grams for the mini contract, versus the NYMEX standard specification of 50 Troy ounces[3]. Despite the decline in TOCOM volume, a not insubstantial share of the global platinum futures trade still occurs on the exchange. Important end users of physical platinum continue to use TOCOM futures for hedging. Global futures trade in platinum is concentrated on the two venues TOCOM and NYMEX. This contrasts with gold, for which TOCOM's annual futures turnover by weight of metal is small compared to that on COMEX. As also shown in Figure 1, COMEX gold turnover by number of contracts still dwarfs that on TOCOM despite the COMEX contract being 100 troy ounces compared with 1 kilogram or about 32.15 troy ounces for the TOCOM standard contract. Gold pricing is considered driven by global risk and monetary factors, and trading is decentralised (Hauptfleisch et al., 2016). Further, there are no features of the gold business in Tokyo that would suggest the location is particularly important in the determination of global gold futures prices. Tokyo gold futures trade represented about 6 percent and 5 percent of COMEX trade by weight in 2015 and 2016, respectively. Accordingly, platinum and gold futures traded in Tokyo and New York provide an interesting comparison for the analysis of intraday microstructure patterns.

TOCOM has become a more internationalised market over time. Trade orders originating outside Japan have been an increasing proportion of total trade on TOCOM since May 2009 after the exchange launched a new trading platform and night session (TOCOM, 2015). International buy and sell orders make up a substantial portion of both the platinum and gold trade on TOCOM during our sample period[4]. Foreign buy and sell trades in the platinum market made up approximately 36 percent and 45 percent of the total in 2014 and 2015, respectively. The proportion of foreign transactions in the gold market was higher, with 46 and 51 percent

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[3] TOCOM contract specifications can be found at http://www.tocom.or.jp/guide/youkou/platinum.html and http://www.tocom.or.jp/guide/youkou/gold.html, NYMEX at http://www.cmegroup.com/trading/metals/files/platinum-and-palladium-futures-and-options.pdf, and COMEX at http://www.cmegroup.com/trading/metals/precious/gold_contractSpecs_futures.html.

[4] Data on foreign customer transactions is obtained from http://www.tocom.or.jp/jp/historical/download.html.

of both buy and sell trades in 2014 and 2015, respectively. Most foreign orders over this period originated from the United States, Australia, Singapore and Hong Kong.

An important difference between the Tokyo and New York futures markets for both platinum and gold is the most actively traded maturity. In New York, as with most commodity futures markets, nearby contract months are the most actively traded, while deferred contract months tend to be inactively traded. As noted in Kang et al. (2011), platinum and gold in Tokyo are actively traded in deferred contract months and inactively traded in nearby contract months. Our analysis uses data for the most liquid contract month for each metal on each exchange. Accordingly, we use the nearby contract months for platinum and gold in New York, and the deferred contract months for platinum and gold in Tokyo. Although this introduces a maturity mismatch, we do not believe this makes a material difference to our analysis. We are interested in comparing the microstructure characteristics of the most actively traded contract for each metal and exchange. Tokyo platinum contract trading volume in the deferred contract exceeds that of New York in the nearby and the deferred contracts (Kang et al. 2011). Indeed, part of the differentiation between exchanges that may be advantageous to a trader transacting in Tokyo is the longer horizon on a market with reasonable liquidity.

Tokyo conducts an evening trading session that runs in parallel with most of the New York day session. New York is also open for trade during the Tokyo day session. Do these markets follow their own distinct intraday patterns in efficiency, liquidity, volatility and volume, or do they have a common seasonality? Do relationships between microstructure characteristics suggest informed[5] or uninformed trading on these exchanges? We estimate a regression model for intraday seasonality in each microstructure characteristic for each metal on each exchange, and use the estimates to investigate the extent to which the markets on each exchange follow a common intraday seasonal pattern. We also analyse the intraday relationships between

[5] We differentiate between informed and uninformed traders as is typical in microstructure modelling (de Jong and Rindi, 2009). Informed traders use costly private information about the future value of the asset traded with the aim of transacting for a profit. This information may be research on the asset's expected future value, knowledge of order flow in the market, or inside information. Uninformed traders such as liquidity traders, noise traders and hedgers do not possess such private information. Liquidity traders transact only for liquidity reasons which are not related directly to the future payoffs of financial assets. Noise traders transact for reasons neither based on liquidity nor fundamental information. Hedgers trade to mitigate risks that arise from holding other correlated assets. Uninformed traders, particularly liquidity traders, may or may not have discretion over the timing of their transactions.

informational efficiency and return volatility, trading volume and liquidity for indications on the prevalence and patterns of informed versus uninformed trading in the platinum and gold markets.

We find similarities in intraday informational efficiency and return volatility patterns between futures for the same metal traded on different exchanges, and differences in volume and liquidity patterns. Relationships between these patterns suggest that, over global trading hours, the Tokyo markets for platinum and gold are dominated by uninformed trading, while there is evidence of both uninformed and informed trading in New York. During Tokyo's daytime session, the markets for platinum and gold in both Tokyo and New York display uninformed trading characteristics. Conversely, both markets for both metals have characteristics consistent with informed trading over the hours of New York's daytime session. Our analysis suggests that both informed and uninformed traders choose when to trade depending on market characteristics in different time zones.

The paper proceeds as follows. In the next section, we summarise relevant literature on intraday patterns in informational efficiency, volatility, volume and liquidity in financial markets, and the intraday relationships between informational efficiency and volatility, volume and liquidity. In section three, we describe our platinum and gold data and the regression model. In section four, we present and discuss our empirical results, and section five concludes.

2. Review of Previous Research

2.1. Intraday Seasonality

Researchers have long sought to confirm the existence of intraday seasonality in security prices and explain persistent intraday patterns in market microstructure characteristics such as return volatility, trading volume and liquidity. Most studies conducted during and after the 1990s analyse intraday patterns over the daytime trading sessions in equity markets, while few studies examine those in commodity markets.

Intraday trading volume and return volatility are typically characterised as following a U-shaped pattern in empirical studies. Both volume and volatility tend to be relatively high at market open, relatively low for most of the trading day, and rise into the close. Equity return volatility is shown to have a U-shaped pattern over the day in Harris (1986), Lockwood and Linn (1990), McInish and Wood (1990a), Werner and Kleidon (1996) and Abhyankar et al.

(1997). Similarly, equity trading volume has an intraday U-shaped pattern in Jain and Joh (1988), McInish and Wood (1990b), Brock and Kleidon (1992) and Chan et al. (1995). Intraday patterns have been described as a reverse-J for some markets, where volume or volatility ahead of the close remains substantially lower than at the open but higher than for the middle of the trading day. Hussain (2011) reports a reverse J-shaped pattern in DAX index return volatility, while Harju and Hussain (2011) show the same type of pattern in other European equity indices. Further, L-shaped patterns have been observed in markets where volume or volatility fails to rise at the end of the trading day, such as for trading volume in DAX30 equities (Hussain, 2011). Abhyankar et al. (1997) report an M-shaped pattern for trading volume in UK stocks.

Bid-ask spreads, a proxy for market liquidity, have also been shown to exhibit intraday U-shaped or reverse-J patterns. Brock and Kleidon (1992) find U-shaped bid-ask spread patterns in US equities, while Ahn and Cheung (1999) and Ahn et al. (2002) discover U-shaped patterns in Hong Kong and Japanese equities, respectively. Theissen and Freihube (2001) and Hussain (2011) document reverse-J shaped intraday bid-ask spread patterns in German equities, while Abhyankar et al. (1997) find the same shape in UK equities. Although McInish and Wood (1992) provide evidence of a reverse-J pattern in New York Stock Exchange bid-ask spreads, they describe it as relatively crude.

Less research has been conducted on intraday patterns in commodities and other exchange traded asset classes. Eaves and Williams (2010), one of the few papers to analyse intraday patterns in a commodity markets, observe U-shaped intraday volume and L-shaped return volatility on the Tokyo Grain Exchange. Cyree and Winters (2001) find reverse-J intraday patterns in return variances and volume in the US Fed Funds market. Their results suggest this pattern is the result of trading stoppages rather than activity clustering around the transactions informed traders.

Foreign exchange markets trade continuously, and despite being an over-the-counter market, provide a close analogy in terms of trading hours to the markets we analyse in this paper. The full TOCOM trading day that we refer to as global trading hours includes the Tokyo day session plus the night session, and spans the normal working hours of Tokyo, London and much of New York. Most research on intraday patterns in currencies has focussed on return volatility and bid-ask spreads, for example, Bollerslev and Domowitz (1993) and Hsieh and Kleidon (1996). Ito and Hashimoto (2006) analyse intraday seasonality in quote revision frequency, trading volume, return volatility and bid-ask spreads for the USD/JPY and EUR/USD exchange markets over a 24 hour trading day, and describe intraday patterns during Tokyo, London and New York working hours. They find that quote revision frequency, trading volume and return volatility co-move, while spreads move in the opposite direction. Contrary to what is normally expected in equity markets, bid-ask spreads are low when volatility is high. Given that Tokyo hours overlap with London, and London hours overlap with New York, but New York hours do not overlap with Tokyo, U-shaped patterns in trading volume exist during Tokyo and London working hours, but not New York. There is no increase in activity at the end of New York working hours. Overlapping business hours appear to boost market activity and inter-regional transactions.

2.2. Relationships between microstructure characteristics

Researchers have also examined the intraday relationships between market microstructure characteristics. In particular, patterns of intraday informational efficiency may be correlated with intraday patterns in return volatility, trading volume and market liquidity. Theoretical explanations in the literature justify both positive and negative signs on these correlations based on whether transactions in the market are those of informed or uninformed traders. A variety of empirical evidence has been generated to support both interpretations.

Informational efficiency and return volatility may be related positively or negatively. The efficient markets hypothesis suggests that return volatility results when new information randomly hits the market. Volatility indicates the adjustment of prices to new information, and in that sense, is associated with informational efficiency. Alternatively, behaviouralists propose that volatility cannot be explained exclusively by changes in fundamentals. Noise traders transact irrationally, which leads to volatility in returns. Empirical studies suggest noise traders contribute to a substantial portion of volatility in asset price returns, for example, Shiller (1981), French and Roll (1986) and Schwert (1989). Informational efficiency and returns volatility should be negatively related if volatility resulting from the activities of noise traders dominates.

There are also two views regarding the relationship between volume and informational efficiency: the "asymmetric information view" and the "inventory control view". The asymmetric information view argues that trades are more informative when trading volume is high, while the inventory control view holds that trades are less informative when trading volume is high. Theory admits both possibilities, depending on the posited information structure.

To understand the asymmetric information view, consider the model of Admati and Pfleiderer (1988). To minimize their losses to informed traders, discretionary liquidity traders prefer to trade when they have little impact on prices. More liquidity trading in a given period encourages informed traders to transact at the same time as liquidity traders. Competition among informed traders reduces their total profit, benefiting liquidity traders and encouraging their further participation. An increase in the number of informed traders contributes to more informed prices because they cause prices to adjust faster to information. In this situation, trading volume and the informational efficiency of prices are positively related.

Alternatively, trading volume and efficiency may be negatively related. Uninformed traders adjust their positions from time to time. Market makers operate in commodity futures markets, and as part of their normal business activities, unavoidably take on positions they desire to shed immediately. The representative model of the inventory control view, developed by Lyons (1997), relies on hot potato trading – passing unwanted positions from dealer to dealer following an initial customer order, which reduces the informativeness of prices. Information aggregation by dealers occurs through signal extraction applied to order flow. The greater the noise relative to signal, the less effective signal extraction is. Passing hot potato trades increases the noise in order flow and dilutes informational content. Hence, trading volume and the informational efficiency of prices are negatively linked.

Theoretical arguments and empirical evidence also relate market liquidity with informational efficiency. Two views propose alternative signs for the relationship. The "transaction cost view" of liquidity can be described as the situation where greater market liquidity reduces transactions costs for informed traders, and their trades contribute to informational efficiency. Illiquid markets imply high transactions costs for informed traders and thus are less efficient. Kyle (1985) develops a model where an increase in liquidity leads informed traders to take more risk on existing information, and provides greater incentives for informed traders to gain more accurate information. Recent papers provide empirical support for the view that security mispricing is greater in illiquid markets (Sadka and Scherbina, 2007; Chordia et al., 2008). Payne (2003) demonstrates that in the USD/DEM market, high volume and liquidity periods are associated with relatively low price response, suggesting volume and liquidity are positively related to informational efficiency.

Alternatively, the “noise trader view” says that liquidity may be a proxy for uninformed trading and thus is associated with informational inefficiency. As a representative empirical paper to support this view, Tetlock (2007) uses data from short-horizon binary outcome securities traded in online exchanges to show that the most liquid securities markets exhibit significant pricing anomalies.

3. Data, Variables and Model

3.1. Data

We use 1-minute intraday bid and ask futures prices and trading volume for platinum and gold futures contracts. The Tokyo prices for both metals are from TOCOM, while the New York prices for platinum are from NYMEX and those for gold are from COMEX. The TOCOM data was purchased directly from the exchange. COMEX and NYMEX data was obtained from Thomson Reuters. The sample spans 128 trading days from 1 September 2014 to 31 March 2015[6]. We use the most traded contract on each exchange, which is the deferred contract for each metal on TOCOM and the nearby contract in New York. Transactions are denominated in Japanese yen on TOCOM, and in U.S. dollars on COMEX and NYMEX.

Our analysis is conducted based on the times of TOCOM’s trading sessions. The TOCOM daytime trading session begins at 9:00 Japan Standard Time (JST) and ends at 15:15. After a break, the night session begins at 16:30 and ends at 4:00 the next morning[7]. We refer to the day plus the night session as global trading hours, which has a total of 1065 minutes of trading. Accordingly, we have 1065 one-minute price and volume observations for each trading day or set of global trading hours. We divide TOCOM’s day and night session into nine non-

[6] General financial market conditions during our sample period could be described as typical for markets following the global financial and European sovereign debt crises. Market volatility according to the Chicago Board Options Exchange VIX was elevated at times, but not extreme, due to news such as the Bank of Japan’s surprise decision to extend its Qualitative and Quantitative Easing program, weak economic data from Europe and China, and the snap presidential election in Greece.

[7] TOCOM extended its trading hours on 20 September 2016, after the sample period for our study. The day session opens 15 minutes earlier at 08:45 JST, and closes at 15:15. The new night session is 90 minutes longer, and runs from 16:30 to 05:30 the next day (TOCOM, 2016).

overlapping time intervals denoted TI1 to TI9. TI1 to TI3 represent TOCOM's daytime trading session, and TI4 to TI9 represent TOCOM's night session. The daytime intervals are 125 minutes in duration, while the night intervals are 115 minutes long. Table 1 shows the JST, London (GMT) and New York (EST) times for each interval. We adjust for summer time as also shown in Table 1. We refer to TI1 to TI3 as the Tokyo day session, TI4 to TI6 as the London day session, and TI7 to TI9 as the New York day session. In total, our sample contains 1152 time intervals, comprising nine intervals per day for 128 trading days. We calculate observations for the variables discussed in the following section for each of the 1152 time intervals, and this is the data we use in our linear regression model and for our correlation analysis.

3.2. Variables

We are interested in comparing market efficiency, volatility, volume and liquidity characteristics and relationships between the markets in New York and Tokyo. Accordingly, we construct five relevant variables from our intraday price and volume data for each of the four futures contracts: TOCOM Platinum, NYMEX Platinum, TOCOM Gold and COMEX Gold. The five variables are Lo and MacKinlay's (1988) variance ratio (VR), realised volatility (Vol), trading volume (TV), quoted half-spread (Sp), and Amihud's (2002) measure of illiquidity (ILLIQ). The prices used in constructing the variance ratio, realised volatility, spread and illiquidity are in local currency terms. Fluctuation in the U.S. dollar / Japanese yen exchange rate means that the variance ratio and realised volatility of a metal will not be equal across exchanges. The variables are defined as follows.

Lo and MacKinlay (1988) use a ratio of variance estimators to provide evidence against random walks in stock price formation. They note that an important property of a random walk is that the variance of the increments of the random walk is a linear function of the observation interval of the increments. Returns that do not adhere to this property suggest that prices are not formed according to a random walk. The distance of Lo and MacKinlay's (1988) variance ratio from one indicates relatively greater informational inefficiency due to the existence of either positive or negative serial correlation in the returns.

We compute the variances of 1-minute and 5-minute continuously compounded (log) returns, r_t, for mid-quote prices as defined below in equations (1) and (2), respectively. The subscript t refers to time in minutes.

$$r_t = \ln p_t - \ln p_{t-1} \tag{1}$$

$$r_t(5) = \ln p_t - \ln p_{t-5} \tag{2}$$

We define our statistic as the absolute value of one minus the variance ratio, since we are interested in departures from a random walk in either direction, according to the formula in equation (3). The total number of minutes during each time interval, denoted as T, is equal to 125 and 115 minutes for the TOCOM day and night sessions, respectively. The term μ is defined as the mean one-minute return over the time interval. Equation (3) is interpreted as a measure of inefficiency.

$$VR = \left|1 - \frac{Var[r_t(5)]}{5{*}Var[r_t]}\right| = \left|1 - \frac{\frac{1}{T-5}\sum_{t=5}^{T}(r_t + r_{t-1} + \cdots + r_{t-4} - 5\mu)^2}{\frac{5}{T-1}\sum_{t=1}^{T}(r_t - \mu)^2}\right| \tag{3}$$

Realised volatility (Vol) in each time interval is constructed using returns based on mid-quote prices to reduce spurious volatility due to bid-ask bounce. We multiply squared one-minute returns by 1065, representing the total number of minutes in global trading hours. Volatility is interpreted as daily percentage volatility during the time interval.

$$Vol = 100\sqrt{\frac{1065}{T}\sum_{t=1}^{T} r_t^2} \tag{4}$$

Trading volume (TV) represents the average number of contracts traded per minute in each time interval. C_t represents the number of contracts traded on the relevant exchange during each minute t of our sample.

$$\mathrm{TV} = \frac{1}{\mathrm{T}}\sum_{\mathrm{t}=1}^{\mathrm{T}} C_t \tag{5}$$

We gauge market liquidity using two different approaches. The quoted half-spread (Sp) is defined as follows.

$$Sp = \frac{1000}{2T}\sum_{t=1}^{T}\left(\frac{p_t^{ask} - p_t^{bid}}{(p_t^{ask} + p_t^{bid})/2}\right) \tag{6}$$

In addition, we construct the measure of illiquidity (ILLIQ) suggested by Amihud (2002), and referred to as Amihud's ILLIQ. This measure can be thought of as quantifying the sensitivity of returns to trading volume. The more illiquid a market is, the greater is the impact of a particular level of trade volume on a security's return. It is calculated as an average for each time interval of the absolute value of 5-minute returns $(r_t(5)_k)$ divided by 5-minute trading volume by weight of metal in kilograms (V_k) for futures contract k. Using weight of metal in the denominator facilitates comparison between New York and Tokyo on an amount of metal basis. We use 5-minute returns, as quoted prices do not always change within each minute.

$$ILLIQ = 10^6 \times \frac{5}{T}\sum_{k=1}^{T/5}\frac{|r_t(5)_k|}{V_k} \tag{7}$$

3.3. Analysing intraday seasonality and microstructure relationships

We employ two approaches to analyse the intraday patterns and relationships between informational efficiency and volatility, volume and liquidity. Estimates from a linear regression model for each microstructure variable are used to characterise intraday seasonal patterns in each futures market, controlling for daily effects. We also examine Pearson correlation coefficients between the intraday informational efficiency and volatility, volume and liquidity variables for global trading hours as well as the Tokyo, London and New York day sessions.

We estimate the linear regression model represented by equation (8) for each of the five microstructure variables defined above: the variance ratio (VR), realized volatility (Vol), trading volume (TV), quoted half-spread spread (Sp), and Amihud's ILLIQ (ILLIQ).

$$y_{k,i,j} = \alpha_{k,1,1} + \sum_{i=2}^{9}\beta_{k,i}TI_i + \sum_{j=2}^{128}\gamma_{k,j}DD_j + \varepsilon_{k,i,j} \tag{8}$$

One regression model is estimated for each microstructure variable and futures contract combination. The dependent variable $y_{ki,j}$ is the microstructure variable for futures contract k at time i,j, where i refers to the time interval and j to the day. We regress the dependent variable on an intercept ($\alpha_{k,1,1}$), dummy variables for the time intervals (TI_i) for i equal to two to nine (TI2 to TI9), and daily dummy variables (DD_j) for each of the j days in our sample from day two to day 128.

The $\alpha_{k,1,1}$ and $\beta_{k,i}$ estimates are used to represent intraday seasonal patterns in the particular microstructure variable for contract k. The estimate for $\alpha_{k,1,1}$ represents the first time interval on the first trading day, and those for the $\beta_{k,i}$ represent the differential to $\alpha_{k,1,1}$ for each time interval of the day. The daily dummies are included to account for day effects, which control for to preclude large shocks from influencing intraday patterns and increasing correlations between variables. Our results do not change substantially if the daily dummies are omitted from the model. The model is estimated by ordinary least squares.

4. Empirical Results

4.1. Summary statistics

Summary statistics for each variable are shown in Tables 2.1 and 2.2 for platinum and gold, respectively. Statistics for the variables related to contracts on TOCOM are denoted “TY”, and those relating to contracts on the New York exchanges are denoted “NY”. The mean and median variance ratio statistics for both platinum and gold are lower in New York than Tokyo, suggesting that the New York markets are more efficient on average. Realised volatility in Tokyo is on average lower than in New York for both metals, however the distribution of realised volatility for Tokyo is much more leptokurtic. Tokyo platinum mean and median trading volume exceeds those of New York in contract terms, and are substantially more variable. New York dwarfs Tokyo in trading volume for gold. The average of the bid-ask spread measures in the platinum markets are similar over the two exchanges, although Tokyo spreads appear tighter and less variable but with greater likelihood of extreme observations. The average spread on gold is much higher in Tokyo than in New York. For platinum, Amihud’s ILLIQ tells a different story to the bid-ask spread, suggesting that the Tokyo market is notably less liquid than New York, since the measure normalises by trading volume in weight of metal. Both Amihud’s ILLIQ and the spread suggest that gold market liquidity is substantially greater in New York than Tokyo.

4.2. Intraday Seasonality

Figures 2.1 to 2.5 show the intraday seasonal patterns for each microstructure variable and futures contract combination implied by the estimates from equation (8). The intraday seasonal pattern estimates are $\alpha_{k,1,1}$ for TI1 and the sum of $\alpha_{k,1,1}$ and the appropriate $\beta_{k,i}$ for TI2 to TI9. The left pane of each figure shows the estimates for platinum and the right pane shows those for gold. Tables A1.1 and A1.2 in the Appendix show the regression estimates, their statistical significance, and the adjusted coefficient of determination for each regression.

The estimates for the variance ratio models (see Figure 2.1) suggest that the first time interval of the day, TI1, is by far the least informationally efficient period of global trading hours in both the platinum and gold markets on both exchanges. Inefficiency peaks again in TI4 during the open of the London day session, albeit at a lower level than at the beginning of the Tokyo day. In contrast, the open of the New York day session (and immediately prior) is a relatively efficient time for both platinum and gold on both exchanges. The Tokyo and London day sessions are similar in that at the open the markets are relatively inefficient and are relatively more efficient later in their respective sessions. Conversely, the New York day session is different in that the market is relatively efficient at the open and is less efficient later in the session. Over global trading hours, the evolution of the variance ratio model estimates loosely resemble a W shape for each of the markets. Inefficiency rises at the end of the trading day in all of the markets, particularly in platinum on both the Tokyo and New York exchanges. While Tokyo appears marginally less efficient than New York in the platinum market over most of global trading hours, this differential between exchange efficiency is notably greater in the gold market, particularly after TI1.

Figure 2.2 shows the estimates for the realised volatility models. These peak at the open of the Tokyo, London and New York day sessions for each market. Tokyo and New York open (TI1 and TI7, respectively) are the most volatile times. After the open, volatility during the Tokyo day is relatively low for both metals on both exchanges. Over global trading hours, volatility follows a U-shaped pattern over TI1 to TI4, and then rises into the New York open and then falls in an inverted U-shaped pattern from TI5 to TI9. During the Tokyo, London and New York day sessions, intraday volatility takes an L-shape in Tokyo hours, a U-shape in London hours, and declines in a linear fashion through New York hours. Patterns across the two metals are similar, while volatility is greater on the New York exchanges during most time intervals, and particularly during the New York day session.

The intraday patterns indicated by the estimates from the trading volume models (see Figure 2.3) show greater differentiation across the four metal-exchange combinations than is the case for the variance ratio and realised volatility. In the markets for both metals, trading volume on each exchange is concentrated during that exchange's day session. Most platinum trade in

Tokyo occurs soon after the open of the Tokyo trading day during the first time interval (TI1), when the market is at its least efficient and volatility is at its highest level. Platinum volume in Tokyo over the Tokyo day session is greater than the volume in Tokyo during either of the London or New York day sessions. Similarly, most platinum trade on the New York exchange occurs during the New York day session. Tokyo trading volume exceeds New York trading volume from TI1 to TI5, while the opposite is true from TI6 to TI9. During each of the Tokyo and London day sessions, TOCOM trading volume follows a reverse J-shaped pattern, but during the New York day session Tokyo trading volume falls off after peaking at the New York open. Gold trading volume in New York peaks at the New York open, and is at a relatively high level from TI6 to TI9. New York's trading volume in gold is far greater than Tokyo's, and trading volume in Tokyo fluctuates less over the nine time intervals.

The estimates for the spread regressions, shown in Figure 2.4, broadly trend up over global trading hours (TI1 to TI9) for platinum and gold in Tokyo. Spreads on platinum in New York are at their lowest during the New York day, while New York gold spreads are relatively stable over the day. Estimates for the gold spread equations vary noticeably less than for platinum. Also in the platinum markets, the estimates for the spread models are clearly lower during each exchange's day session, and higher otherwise, which makes sense as spreads would be expected to be lower during higher trading volume periods. The estimates for TOCOM are lower during TI1 to TI3 and higher thereafter, while spreads are lower over TI7 to TI9 for the New York exchange. Consistent with the relative importance and relative trading volume of Tokyo and New York in the global gold market, the estimates for spread in Tokyo are much larger than (about double) those for New York. In contrast, platinum spread model estimates for Tokyo are lower than those on New York during the Tokyo day session, while this situation reverses during the New York day session. During the London day session, platinum spread estimates for the Tokyo and New York exchanges are about the same.

Our estimates for the ILLIQ models are shown in Figure 2.5 and display more intraday variation, telling a more interesting story about intraday liquidity than the estimates from the spread models. The ILLIQ estimates show that each exchange is more liquid during its own day session. While the Tokyo platinum market is more liquid than New York during the Tokyo day, from TI5 onward New York is the more liquid market. In contrast, the Tokyo and New York gold markets start global trading hours at about the same level of liquidity, after which the Tokyo market becomes more illiquid while the New York market becomes more liquid.

4.3. Relationships between microstructure characteristics

Tables 3.1 and 3.2 show the correlations between the variance ratio variable and each of return volatility, trading volume, spread and ILLIQ, for platinum and gold, respectively. We reverse the signs of the correlations between the variance ratio and both realised volatility and trading volume. Accordingly, the results can be read more intuitively as the correlations between informational efficiency and volatility, and efficiency and volume. No such transformation is required to interpret the remaining correlations as being between efficiency and liquidity. The first two columns of Tables 3.1 and 3.2 refer to correlations between the variables over global trading hours (TI1 to TI9). These correlations are calculated over 1152 time interval observations. The subsequent three pairs of columns to the right reflect the Tokyo day session (TI1 to TI3), the London day session (TI4 to TI6) and the New York day session (TI7 to TI9), which are calculated over 384 time intervals. Correlations in bold are significant at the 10 percent level or less.

All global trading hours correlations for the Tokyo exchange are negative in both the platinum and gold markets, and all except the correlation between efficiency and volume for gold are significant. This suggests that over global trading hours, the gold and platinum markets on TOCOM are dominated by uninformed traders. New York platinum and gold market correlations for global trading hours provide evidence for both informed and uninformed trading. Efficiency is negatively correlated with volatility suggesting the transactions of uninformed traders, likely those with little discretion over when they trade, give rise to volatility. However, efficiency is positively correlated with volume, as hypothesised under Admati and Pfleiderer's (1988) asymmetric information view where informed and discretionary uninformed traders prefer to trade together such that they have low market impact. The correlations between efficiency and the two liquidity measures are not significant.

We find a more nuanced view of the intraday relationships between efficiency and volatility, volume and liquidity in the correlations for the Tokyo, London and New York day sessions. Consistent with anecdotal evidence from market participants that firms with large physical platinum exposures enter the market during the Tokyo morning to hedge via TOCOM, the correlations for both the Tokyo and New York platinum markets support uninformed trader interpretations during the Tokyo day. Efficiency is significantly negatively correlated with volatility, volume and the two liquidity measures for platinum traded on TOCOM. Similarly, all correlations are negative for platinum traded in New York during the Tokyo day. All except the correlation between efficiency and liquidity (spread) are significant. Efficiency is also negatively and significantly correlated with volatility for gold in both Tokyo and New York, with volume in New York only, and with ILLIQ in Tokyo only. While there is support for uninformed trading in both metals during the Tokyo day, the evidence for platinum is stronger than that for gold.

During the London day session, the correlations are less definitive. The correlation between efficiency and liquidity (ILLIQ) supports a noise trader view for the TOCOM platinum market. However, in the New York platinum market the correlations with volume and liquidity (ILLIQ) are both positive and significant, supporting the asymmetric information view and the transactions cost view, respectively. The correlation with volatility is negative and significant, suggesting uninformed trading. For the gold markets, negative correlations between efficiency and liquidity (ILLIQ) in Tokyo, and efficiency and volatility in New York, provide some support for uninformed trading during the London day session.

Our results for the New York day session support the dominance of informed trading for both metals traded on both exchanges. The evidence is stronger for gold than platinum in terms of the size of the correlations for both trade in Tokyo and New York, and in terms of the number of significant correlations for Tokyo. Correlations between efficiency and volatility are positive and significant over all four markets, and those between efficiency and volume are positive and significant for platinum and gold in New York, and gold but not platinum in Tokyo. These correlations suggest that uninformed traders are likely absent from the Tokyo market during the Tokyo night session when volume and liquidity are low. This concurs with anecdotal evidence that large hedgers of physical platinum enter the market primarily during the Tokyo morning. Informed traders appear to trade in Tokyo at night while overlapping with the New York day, despite the relatively low liquidity compared with the Tokyo day session. They are likely arbitraging between the two markets during the New York day.

The evidence from the correlation analysis is consistent with the patterns evident in the charts of the regression estimates. Relatively high variance ratio (Figure 2.1) and realised volatility (Figure 2.2) model estimates occur in TI1 and TI4. This implies informational efficiency is negatively related to volatility, implying that volatility is the result of the market transactions of uninformed traders. From around the New York open (TI7) low variance ratio model estimates are associated with high realised volatility estimates, consistent with the rational adjustment of prices to new information. Taken together, Figures 2.1 and 2.3 suggest efficiency is negatively related to trading volume during the Tokyo day, particularly for platinum on TOCOM. TI1 is the busiest trading time for platinum on TOCOM, and also the least efficient time. By the New York day session, the regression model estimates suggest a positive relationship between efficiency and volume for both metals on both exchanges. The spread model estimates (Figure 2.4) do not show a great deal of intraday variation, and accordingly their relationship with efficiency is less clear than for the preceding variables. However, it would appear that efficiency and liquidity are negatively related, at least for platinum and gold on TOCOM over global trading hours, suggesting liquidity is a proxy for uninformed trading. Similarly, the variance ratio and ILLIQ (Figure 2.5) estimates broadly suggest a negative relationship between efficiency and liquidity in the Tokyo markets and a positive relationship in New York over global trading hours.

5. Conclusion

This paper examines the intraday seasonality of informational efficiency, return volatility, trading volume and market liquidity in the platinum and gold futures markets on exchanges in Tokyo and New York using high frequency 1-minute data covering global trading hours from September 2014 to March 2015. Platinum and gold provide an interesting comparison as Tokyo is an internationally important centre for platinum trading but not for gold. We also examine the relationships between market microstructure characteristics to determine whether trading in these markets is predominantly informed or liquidity driven. The article aims to contribute to the understanding of commodity futures market microstructure, on which there has been little research to date.

We find the following regularities in intraday market characteristics. Informational inefficiency in both the platinum and gold markets conforms to a W-shape over global trading hours. The Tokyo and London open, and later in the New York day, show the highest levels of inefficiency. Day sessions in Tokyo and London start relatively inefficient and become more efficient. In the New York day session, the markets start relatively efficient and become inefficient by late in its session. Volatility also follows a similar pattern for both metals and exchanges. It is relatively high at the open of the Tokyo, London and New York day sessions, being L-shaped in Tokyo hours, U-shaped in London hours, and declining approximately linearly in New York hours. In contrast, intraday volume and liquidity patterns differ between the metals and/or exchanges. Trading volume in platinum is concentrated on each of the Tokyo and New York exchanges during their day sessions, while comparatively more platinum volume on TOCOM occurs through the New York day than NYMEX volume through the Tokyo day. Tokyo platinum volume shows reasonably clear reverse-J and L-shaped patterns during the Tokyo and London day sessions, respectively. Volume in all the markets declines monotonically during the New York day session. In the gold market, volume builds to a peak at the New York open on COMEX that dwarfs the volume on TOCOM. Liquidity on each exchange is greatest during that exchange's day session, and Amihud's ILLIQ shows Tokyo liquidity deteriorating over global trading hours.

Relationships uncovered between informational efficiency and volatility, volume and liquidity suggest that over global trading hours both the platinum and gold markets in Tokyo are dominated by uninformed trading, while there is evidence supporting both uninformed and informed trading in New York. During the Tokyo day session, uninformed traders dominate the platinum and gold markets in both Tokyo and New York. Conversely, during the New York day session, informed traders dominate.

Arbitrage means the intraday patterns of return related market characteristics, such as efficiency and volatility, remain closely related across exchanges trading the same commodity. However, market activity measures such as volume and liquidity can differ substantially between the exchanges over the course of global trading hours. The Tokyo and New York exchanges examined in this research have overlapping trading sessions. Night sessions supplement the exchanges' daytime trading hours. This overlap of trading influences intraday microstructure patterns on each exchange over global trading hours, and the absence of an overlap between day trading sessions at the end of global trading hours also influences microstructure patterns. The resulting intraday patterns share similarities with the intraday patterns seen in the continuously traded foreign exchange markets, as identified by Ito and Hashimoto (2006). Market participants in different time zones and different geographical locations have different motivations for trading. Uninformed trading is prevalent during the Tokyo day session when most volume goes through Tokyo markets. While during New York hours, informed trading dominates during the New York exchanges' busiest times. This evidence suggests that futures markets for the same underlying commodity on different exchanges have different microstructure characteristics, while both informed and uninformed traders choose when to trade depending on market characteristics in different time zones.

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Figures

Figure 1: Monthly Contract Volume

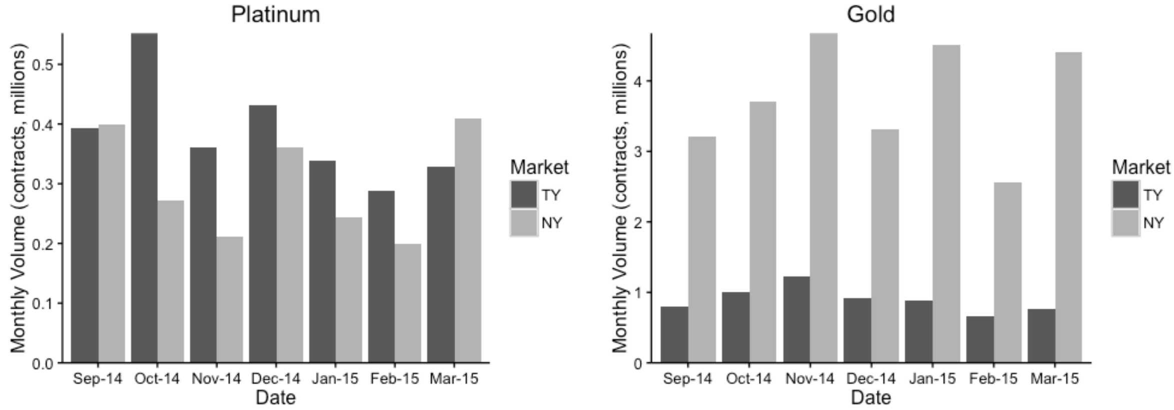


Figure 2.1: Variance Ratio

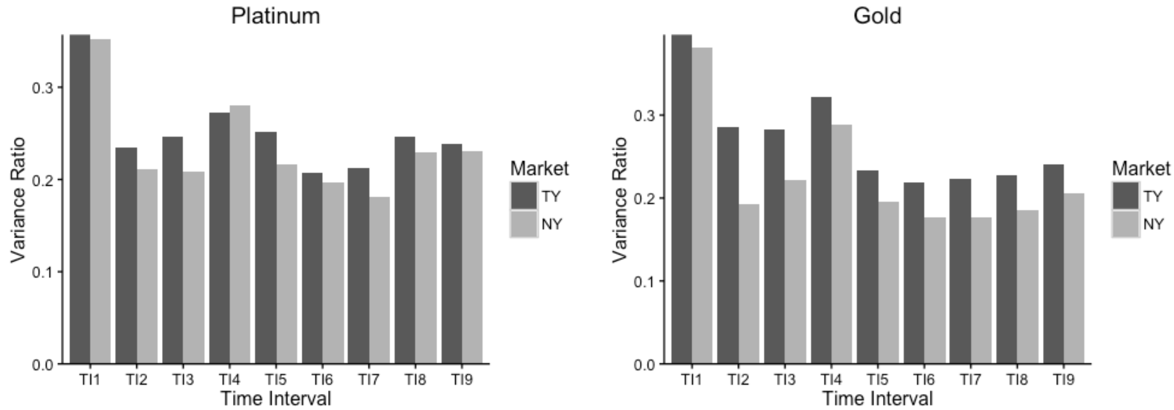


Figure 2.2: Realised Volatility

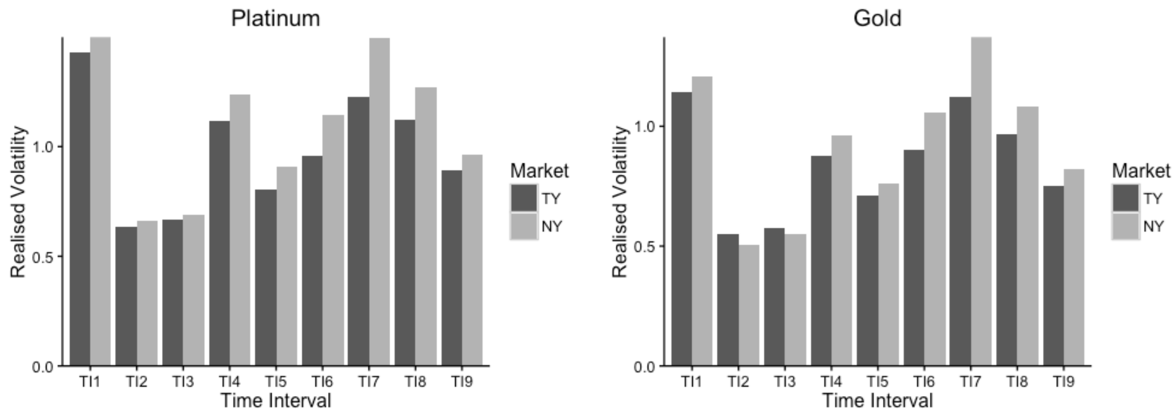


Figure 2.3: Trading Volume

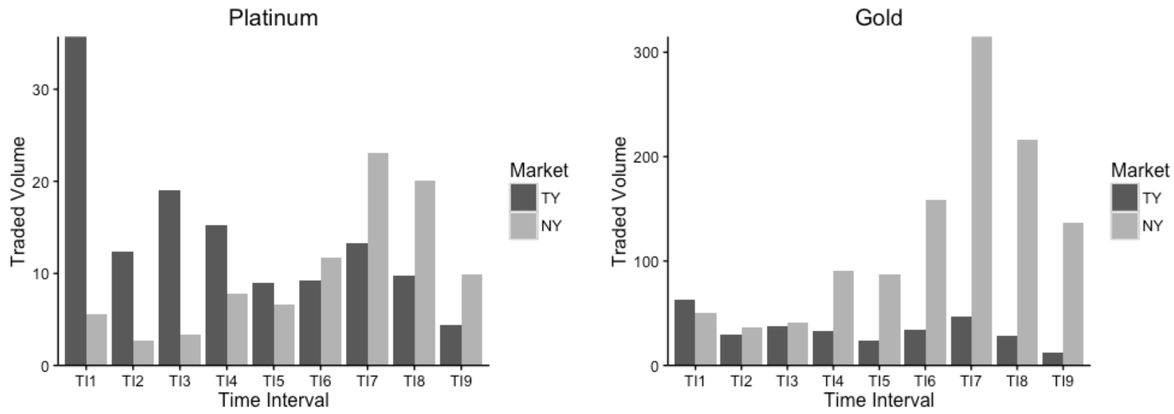


Figure 2.4: Spread

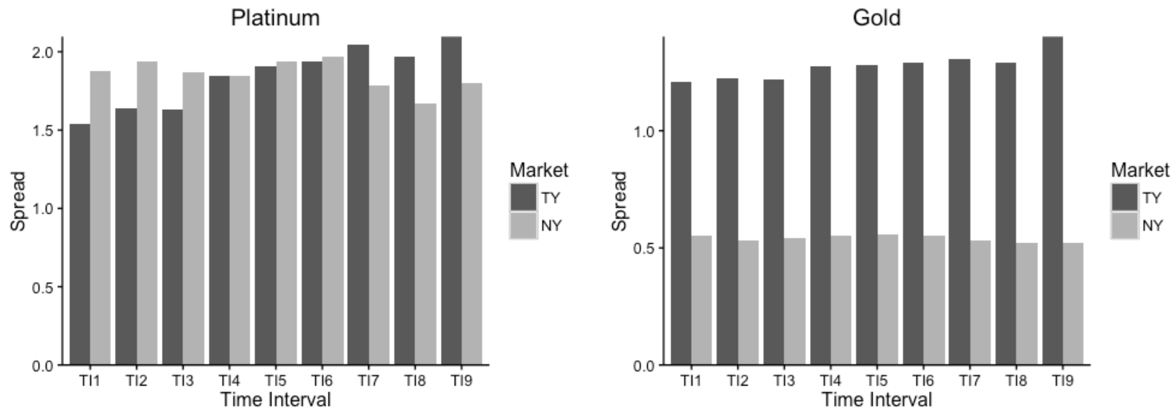
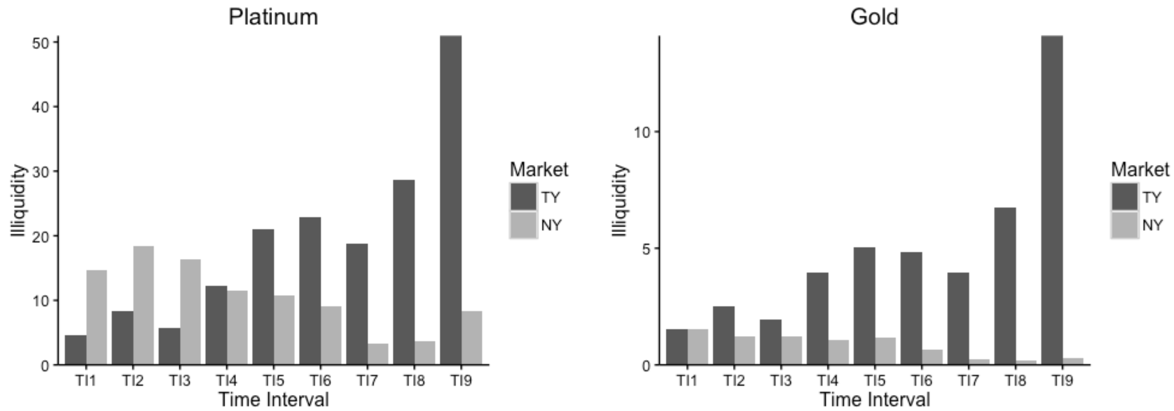


Figure 2.5: Illiquidity



Tables

Table 1: Time Intervals

Time Interval	Duration (minutes)	Session Described As	Tokyo (JST)		London (GMT)		London (DST) (London Summer)		New York (EST)		New York (DST) (New York Summer)	
			Start Time	**End Time**	**Start Time**	**End Time**	**Start Time**	**End Time**	**Start Time**	**End Time**	**Start Time**	**End Time**
TI1	125	Tokyo Day	09:00:00	11:04:59	0:00:00	02:04:59	01:00:00	03:04:59	-19:00:00	-21:04:59	-20:00:00	-22:04:59
TI2	125	Tokyo Day	11:05:00	13:09:29	02:05:00	04:09:59	03:05:00	05:09:59	-21:05:00	-23:09:59	-22:05:00	00:09:59
TI3	125	Tokyo Day	13:10:00	15:14:59	04:10:00	06:14:59	05:10:00	07:14:59	-23:10:00	01:14:59	00:10:00	02:14:59
TI4	115	London Day	16:30:00	18:24:59	07:30:00	09:24:59	08:30:00	10:24:59	02:30:00	04:24:59	03:30:00	05:24:59
TI5	115	London Day	18:25:00	20:19:59	09:25:00	11:19:59	10:25:00	12:19:59	04:25:00	06:19:59	05:25:00	07:19:59
TI6	115	London Day	20:20:00	22:14:59	11:20:00	13:14:59	12:20:00	14:14:59	06:20:00	08:14:59	07:20:00	09:14:59
TI7	115	New York Day	22:15:00	+00:09:59	13:15:00	15:09:59	14:15:00	16:09:59	08:15:00	10:09:59	09:15:00	11:09:59
TI8	115	New York Day	+00:10:00	+02:04:59	15:10:00	17:04:59	16:10:00	18:04:59	10:10:00	12:04:59	11:10:00	13:04:59
TI9	115	New York Day	+02:05:00	+03:59:59	17:05:00	18:59:59	18:05:00	19:59:59	12:05:00	13:59:59	13:05:00	14:59:59

Table 2.1: Summary Statistics for Platinum

Statistic	Variance Ratio TY	Variance Ratio NY	Realised Volatility TY	Realised Volatility NY	Trading Volume TY	Trading Volume NY	Spread TY	Spread NY	Illiquidity TY	Illiquidity NY
Mean	0.252	0.234	0.983	1.096	14.223	10.127	1.841	1.854	19.142	10.654
Median	0.239	0.209	0.872	0.976	10.400	6.625	1.875	1.802	12.613	8.603
Minimum	0.000	0.000	0.245	0.233	0.287	0.528	1.077	0.900	0.858	0.833
Maximum	0.965	0.932	9.823	9.152	131.040	60.278	3.447	3.890	180.336	52.357
Standard Deviation	0.170	0.165	0.628	0.656	13.082	9.471	0.261	0.416	20.105	7.855
Skewness	0.644	0.842	6.412	4.685	2.939	1.741	0.109	0.729	2.914	1.255
Kurtosis	0.159	0.567	73.100	44.166	13.860	3.469	3.208	0.830	12.853	1.725
Observations	1152	1152	1152	1152	1152	1152	1152	1152	1152	1152

Table 2.2: Summary Statistics for Gold

Statistic	Variance Ratio TY	Variance Ratio NY	Realised Volatility TY	Realised Volatility NY	Trading Volume TY	Trading Volume NY	Spread TY	Spread NY	Illiquidity TY	Illiquidity NY
Mean	0.270	0.225	0.845	0.924	34.456	125.895	1.277	0.539	4.958	0.843
Median	0.256	0.193	0.716	0.781	26.756	81.239	1.268	0.532	3.377	0.366
Minimum	0.000	0.000	0.229	0.192	1.826	0.328	1.082	0.442	0.544	0.074
Maximum	0.879	0.907	12.630	11.587	219.360	807.609	1.755	1.286	63.842	56.556
Standard Deviation	0.177	0.169	0.613	0.652	27.120	121.566	0.086	0.076	5.587	3.901
Skewness	0.568	1.042	9.136	5.913	2.190	2.024	1.200	4.170	4.231	8.833
Kurtosis	-0.152	0.960	146.010	72.775	7.169	5.044	3.590	29.249	26.006	10.394
Observations	1152	1152	1152	1152	1152	1152	1152	1152	1152	1152

Table 3.1: Correlations between Efficiency and Volume, Volatility and Liquidity for Platinum

	All Sessions (Global Trading Hours)		Tokyo Day Session		London Day Session		New York Day Session	
Correlation of Efficiency with	**Tokyo**	**New York**	**Tokyo**	**New York**	**Tokyo**	**New York**	**Tokyo**	**New York**
Volatility (Realised Volatility)	**-0.151 *****	**-0.219 *****	**-0.370 *****	**-0.486 *****	-0.004	**-0.087 ***	**0.113 ****	**0.091 ***
Volume (Trading Volume)	**-0.144 *****	**0.098 *****	**-0.223 *****	**-0.174 *****	0.007	**0.100 ****	0.059	**0.099 ***
Liquidity (Spread)	**-0.127 *****	-0.019	**-0.120 ****	-0.029	-0.056	-0.030	-0.013	-0.047
Liquidity (Illiquidity)	**-0.087 *****	0.031	**-0.144 *****	**-0.187 *****	**-0.129 ****	**0.090 ***	0.022	0.081

Note: ***, **, and * denote significance of the Pearson correlation coefficient at the 1, 5 and 10 percent levels, respectively.

Table 3.2: Correlations between Efficiency and Volume, Volatility and Liquidity for Gold

	All Sessions (Global Trading Hours)		Tokyo Day Session		London Day Session		New York Day Session	
Correlation of Efficiency with	**Tokyo**	**New York**	**Tokyo**	**New York**	**Tokyo**	**New York**	**Tokyo**	**New York**
Volatility (Realised Volatility)	**-0.104 *****	**-0.222 *****	**-0.302 *****	**-0.503 *****	-0.078	**-0.170 *****	**0.209 *****	**0.156 *****
Volume (Trading Volume)	-0.041	**0.150 *****	-0.069	**-0.133 *****	0.019	0.028	**0.118 ****	**0.163 *****
Liquidity (Spread)	**-0.123 *****	0.026	0.062	0.065	-0.012	-0.031	-0.051	-0.016
Liquidity (Illiquidity)	**-0.116 *****	0.037	**-0.108 ****	0.059	**-0.115 ****	-0.024	0.013	-0.009

Note: ***, **, and * denote significance of the Pearson correlation coefficient at the 1, 5 and 10 percent levels, respectively.

Appendix

Table A1.1: Estimates for Platinum

Variable	Constant	TI2	TI3	TI4	TI5	TI6	TI7	TI8	TI9	Adjusted R^2
Variance Ratio TY	0.357 ***	-0.122 ***	-0.111 ***	-0.084 ***	-0.106 ***	-0.150 ***	-0.145 ***	-0.110 ***	-0.118 ***	0.053
Variance Ratio NY	0.352 ***	-0.141 ***	-0.143 ***	-0.072 ***	-0.136 ***	-0.155 ***	-0.171 ***	-0.123 ***	-0.121 ***	0.083
Realised Volatility TY	1.430 ***	-0.796 ***	-0.761 ***	-0.313 ***	-0.626 ***	-0.471 ***	-0.206 ***	-0.310 ***	-0.519 ***	0.151
Realised Volatility NY	1.499 ***	-0.837 ***	-0.808 ***	-0.263 ***	-0.591 ***	-0.354 ***	-0.002	-0.230 ***	-0.537 ***	0.196
Trading Volume TY	35.717 ***	-23.321 ***	-16.639 ***	-20.457 ***	-26.708 ***	-26.488 ***	-22.494 ***	-25.967 ***	-31.370 ***	0.425
Trading Volume NY	5.558 ***	-2.818 ***	-2.144 **	2.300 ***	1.067	6.199 ***	17.579 ***	14.574 ***	4.360 ***	0.505
Spread TY	1.540 ***	0.097 ***	0.089 ***	0.309 ***	0.369 ***	0.399 ***	0.467 ***	0.428 ***	0.557 ***	0.489
Spread NY	1.874 ***	0.067	-0.004	-0.030	0.064	0.096 *	-0.086 *	-0.207 ***	-0.074	0.039
Illiquidity TY	4.647 ***	3.766 **	1.106	7.560 ***	15.287 ***	18.280 ***	14.129 ***	23.996 ***	46.335 ***	0.456
Illiquidity NY	14.749 ***	3.627 ***	1.529 **	-3.323 ***	-3.944 ***	-5.746 ***	-11.411 ***	-11.087 ***	-6.501 ***	0.391

Note: ***, **, and * denote significance of the Pearson correlation coefficient at the 1, 5 and 10 percent levels, respectively.

Table A1.2: Estimates for Gold

Variable	Constant	TI2	TI3	TI4	TI5	TI6	TI7	TI8	TI9	Adjusted R^2
Variance Ratio TY	0.397 ***	-0.111 ***	-0.115 ***	-0.075 ***	-0.164 ***	-0.178 ***	-0.174 ***	-0.170 ***	-0.156 ***	0.093
Variance Ratio NY	0.381 ***	-0.188 ***	-0.160 ***	-0.092 ***	-0.186 ***	-0.205 ***	-0.205 ***	-0.195 ***	-0.175 ***	0.139
Realised Volatility TY	1.142 ***	-0.590 ***	-0.568 ***	-0.267 ***	-0.433 ***	-0.241 ***	-0.018	-0.173 **	-0.389 ***	0.104
Realised Volatility NY	1.210 ***	-0.707 ***	-0.660 ***	-0.247 ***	-0.447 ***	-0.152 **	0.162 **	-0.127 *	-0.391 ***	0.172
Trading Volume TY	63.094 ***	-33.170 ***	-24.951 ***	-30.503 ***	-39.068 ***	-29.068 ***	-15.764 ***	-34.962 ***	-50.256 ***	0.243
Trading Volume NY	50.712 ***	-13.753	-9.232	39.694 ***	35.948 ***	107.688 ***	264.237 ***	166.044 ***	86.021 ***	0.513
Spread TY	1.207 ***	0.018 **	0.010	0.069 ***	0.071 ***	0.084 ***	0.099 ***	0.085 ***	0.195 ***	0.421
Spread NY	0.550 ***	-0.018 *	-0.009	0.000	0.005	0.002	-0.016 *	-0.028 ***	-0.028 ***	0.019
Illiquidity TY	1.529 ***	0.989 *	0.429	2.429 ***	3.488 ***	3.305 ***	2.421 ***	5.219 ***	12.584 ***	0.408
Illiquidity NY	1.513 ***	-0.298	-0.294	-0.471	-0.361	-0.838 *	-1.256 ***	-1.316 ***	-1.196 **	0.007

Note: ***, **, and * denote significance of the Pearson correlation coefficient at the 1, 5 and 10 percent levels, respectively.