Anticipatory Trading in Brent Futures: Evidence from the Unregulated Dated Brent Benchmark

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Abstract

We examine the observed response of Brent futures to the spot Dated Brent benchmark published daily by Platts. We report enhanced levels of futures market activity during the benchmark assessment window. We find informed anticipatory trading in Brent futures after the start, and before the end of the benchmark price fixing. Results suggest significant abnormal returns of 27 bps, realizable by informed futures traders front-running the crude oil market ahead of the Dated Brent publication. Our findings inform policy makers on the influence of unregulated physical commodity price benchmarks on regulated exchange-traded financial derivatives.

JEL classification: G13, G14, G18, Q02, Q48

Keywords: Dated Brent, physical oil benchmark, price fixing, ICE Brent Crude futures

I Introduction

This paper demonstrates the critical influence of the unregulated spot crude oil benchmark, the Dated Brent, on regulated exchange-traded Brent futures contracts, by providing evidence of informed front-running ahead of the daily benchmark price publication. Benchmarks occupy a central role in stimulating the flow of information between on-exchange financial and over-the-counter (OTC) spot markets, by establishing settlement prices and thereby improving price discovery and pricing efficiency (see Duffie, Dworczak and Zhu (2015)). Due to their importance in market operations, benchmarks and their administration are increasingly gaining the attention of national and international regulatory bodies (see FCA (2015)). The *Principles for Oil Price Reporting Agencies,* published by the International Organization of Securities Commissions (IOSCO) in 2012, set out recommendations to enhance the quality and strengthen the reliability of unregulated oil price benchmarks serving as reference prices for oil derivatives contracts. Likewise, the *2015 Fair and Effective Markets Review,* conducted by the Bank of England (BoE), HM Treasury, and the Financial Conduct Authority (FCA), identifies several shortcomings in the Fixed Income, Currencies and Commodities (FICC) markets, such as impairment of market integrity, effectiveness and confidence arising from deficiencies in the benchmarks' architecture and oversight. Historically benchmarks in the UK have not been subject to regulatory supervision, however this has changed recently for a number of essential FICC instruments[1]. Starting July 2016, the *Market Abuse Regulation* (MAR) will regard benchmark manipulation as a civil offence in the

[1] Starting with the LIBOR, the FCA introduced the first regulatory benchmark regime in April 2013. Two years later, in April 2015, the FCA expanded its regulatory supervision to seven other key benchmarks: LIBOR, SONIA, RONIA, WM/Reuters London 4pm Closing Spot Rate, ISDAFIX, LBMA Gold Price Fixing, LBMA Silver Price Fixing and the ICE Brent Index (FCA (2015)).

UK and the EU. Additionally, the proposed *EU Benchmark Regulation* will even intensify the focus on commodity benchmarks in the future. Despite these recent efforts, one crucial element of the largest commodity market, namely spot oil, remains largely unregulated. *"The Brent market is reputed to determine the price for about two-thirds of the world's oil trade. Yet Brent is probably the least appropriately regulated commodity market in the world."* (Bossley (2012), p. 6). The Dated Brent benchmark, assessed daily based on activity in the spot (physical) North Sea oil market and operated by Platts, has come to dominate this space, pricing approximately 67% of the world's physical oil trade (see Davis (2012)) and, due to countless entanglements, is of vital importance to oil derivatives as well.

In this study, focusing on the period from 9th January 2012 to 24th September 2015, we examine the daily assessment process of the most important physical crude oil price benchmark, the Dated Brent, and its implications for the world's largest crude oil futures contract, the ICE Brent Crude futures[2]. Of particular interest is the 30-minute time frame immediately after the start of the price fixing window at 16:00, up to the publication of the daily Dated Brent price at 16:30 London time, known as the Platts window. The first proposition we test relates to information leakage from the physical oil benchmark fixing into the futures market, also called the leakage hypothesis. Specifically, we examine whether or not the price reaction(s) in the ICE Brent Crude futures precede the end of the Platts Dated Brent price assessment at 16:30 London time. Secondly,

[2] In early 2012, average daily volume in ICE Brent Crude futures overtook trading in CME's WTI futures, making it the largest single crude oil futures contract (see Nguyen (2012)). Accounting for trading activity on an individual contract basis, as well as combining activity on both the ICE and CME venues, the balance of power shifted again in favour of the WTI futures in the first months of 2015 (Meyer (2015)). Nevertheless, the ICE Brent Crude futures contract dominated the Light Sweet Crude Oil (WTI) futures contract for the most part of our period of investigation.

we aim to test the anticipation hypothesis: do informed market participants exploit abnormal profit opportunities in the ICE Brent Crude futures market by front-running the direction of the Dated Brent price ahead of the fixing end?

We find evidence of informed trading during the 30-minute Dated Brent price assessment operated by Platts ahead of the official daily benchmark price release at 16:30. The market activity in the ICE Brent Crude futures is significantly higher before of the Dated Brent price publication. In addition, the Brent futures experience a significant price run-up in the direction of the upcoming Dated Brent benchmark price, immediately after the Platts fixing commences and reaches its peak just before the Platts fixing end. This is also followed by a noticeable price reversal after the Dated Brent publication. Combined with the adjusted returns, the abnormal fixing direction-aligned order imbalances, observable during the Platts benchmark assessment from 16:00 to 16:30, imply that informed market participants, with knowledge of the fixing progression, are able to realize abnormal profits in the ICE Brent Crude futures market simply by anticipating the direction of the daily Dated Brent price announcement by Platts.

In early 2013, after the European Commission and the European Free Trade Association (EFTA) surveillance authorities conducted unannounced searches of the offices of several crude oil market participants[3], reports began to emerge in the financial press regarding manipulation of the Platts Dated Brent price. Suspicions were raised amid claims that the benchmark assessment is prone to price distortions and collusion by fixing participants (Mackey and Lawler (2013), Makan, Blas and Spiegel (2013), Van Voris, Nguyen, Olson and Martinuzzi (2013)), and comparisons to the LIBOR scandal were made (Kemp (2013)). For example, fixing participants

[3] Please refer to http://www.shellnews.net/documents/WhiteOaksFund.pdf and http://www.businessweek.com/pdfs/crude-complaint-11-6.pdf for further information.

may try to influence the direction of the Dated Brent price during its assessment and simultaneously take leveraged positions in coupled derivative contracts in order to benefit from the anticipated price move (Makan (2013)). Several reviews (e.g. Fattouh (2011a), Fattouh (2011b)) and industry comments (e.g. Davis (2012), Montepeque (2012)) discuss the international oil pricing system and elaborate on the role of price reporting agencies (PRA). The Platts Dated Brent benchmark has been the subject of a handful of qualitative evaluations inspecting the operation of its assessment window and its shortcomings in pricing crude oil markets (e.g. Fattouh (2011a), Fattouh (2011b), Barret (2012a), Barret (2012b), Bossley (2012), Davis (2012), Montepeque (2012)). Addressing many of the issues raised in these reviews, the Dated Brent assessment process was modified in 2012. Our study, focusing on the period after the said changes, is the first empirical investigation of the implications of the benchmark price fixing process on related financial products.

By nature, bilateral negotiations and transactions in the OTC spot market are non-public, thus physical oil prices are not directly observable prior to settlement. The transparency vacuum between the physical (cash) and the financial (paper) dimension of oil is bridged by price reporting agencies monitoring the market, interpreting market talk and directly inquiring information on trading activity[4]. McGraw Hill Financial's Platts is the undisputed industry leader and the Dated Brent crude oil benchmark is its flagship product. Dated Brent is estimated to serve as price marker for anywhere from 50% to 80% of the world's physical crude oil trade (see Barret (2012a), Barret (2012b), Davis (2012), Mathur (2013), Tuson (2014)) and is therefore of crucial importance as its

[4] PRAs classify themselves as journalistic media organisations and information providers, collecting and channelling commodity market intelligence into independent benchmark assessments and price referencing services. The four major independent PRAs active in the international crude oil pricing market are Platts, Argus, ICIS and OPIS.

daily price levels are used for the settlement of thousands of spot and derivative deals worth billions of dollars[5]. Dated Brent refers to a cargo of North Sea BFOE[6] crude oil that has become *wet*, that is, which has been assigned a loading date for shipping. In essence, Platts runs an OTC online data-entry, communications and trading platform called *eWindow*[7], allowing it to establish the Dated Brent price in a process named Market on Close (MOC), with physical trading activity culminating during the 16:00 – 16:30 period called 'window'. During the half-hour assessment window, Platts considers a combination of three OTC variables: grade differentials, forward Brent (also called cash BFOE) and Contracts for Difference (CFD, the difference between Dated Brent and forward Brent). Based on these variables Platts calculates a price for each of the four North Sea grades (Brent, Forties, Oseberg, Ekofisk)[8], with the cheapest grade setting the daily Dated Brent price.

Every day at precisely 16:30 London time, Platts publishes the Dated Brent price. The 16:30 Dated Brent publication is the so-called 'moment of transparency' between the physical and financial oil markets. Only a limited number of companies qualify to participate in cash oil trading via Platts' *eWindow* and thus theoretically the daily publication should convey new information to

[5] More detailed information on both the spot and the derivatives markets and its interrelations can be found in the background section in Appendix 1 to this paper.

[6] BFOE refers to North Sea crude oil from the fields of Brent, Forties, Oseberg and Ekofisk. With declining supplies and the associated deteriorating market liquidity of Brent oil, Platts decided to expand the benchmark to include three additional North Sea grades; hence, the acronym BFOE.

[7] As an OTC trading platform, in the form of a visible, real-time open-order book, *eWindow* reveals bids and offers and the identity of the participants. Moreover, Platts journalists gather additional information over the phone and instant messenger.

[8] Prices for the four grades vary due to differing oil qualities.

the paper oil market. Apart from the *eWindow* participants, a larger, but still limited number of subscribers to Platts' *Global Alert* real-time information service can pay a fee to follow the live physical trading activity and order-flow information (transactions, bids, asks) throughout the benchmark assessment period. However, it is crucial to note that the daily Dated Brent quote is only announced to the market at large at 16:30 precisely. The Dated Brent is not a tick-by-tick index, nor does Platts publish estimations over the course of the day. Nonetheless, subscribers to the *Global Alert* service are able to track event-by-event market developments, such as completed deals, quotes, commentary and news during the Platts assessment window, potentially allowing them to approximate and hence anticipate the direction of the final Dated Brent price. More detailed information on the Dated Brent benchmark assessment procedure can be found in the background section in Appendix 1 to this paper.

The Platts Dated Brent price assessment procedure is akin to what is called a price fixing auction adopted in other physical commodity markets, such as the London gold bullion market (see Caminschi and Heaney (2014), Aspris, Foley, Gratton and O'Neill (2015)). The precious metals market has an official fixing mechanism, and most recently the FCA started regulating the London physical gold and silver price benchmarks. Conversely, the physical oil market has no official fixing system, but over time a few PRAs adopted the role of benchmark administrators. Platts has emerged as the industry leader for energy benchmark assessments. Fixing members, or in our case Dated Brent assessment participants, submit details on executed transactions, or new bids and offers, and thereby establish the fixing price. The 16:00 Platts window start and the 16:30 end are comparable to a fixing start and fixing end, resulting in the subsequent fixing price publication. We interchangeably refer to the Platts process as assessment or fixing.

Our study closely ties in with the research stream focusing on information leakage, anticipation and informed trading behavior, subsequently referred to as the short-lived private information literature. The Dated Brent benchmark architecture grants fixing members superior information on the fixing progression, enabling information leakage through early-informed trading, and, as claimed by market insiders, is potentially even prone to active price manipulation by assessment participants. A strong front-running incentive therefore exists, as informed anticipatory trading in the ICE Brent Crude futures market, ahead of the Dated Brent fixing end, promises economically important profit opportunities. It is in relation to this that the time period surrounding the 16:30 Dated Brent price publication provides an attractive setting for a study on short-lived private information. In our case, short-lived private information arises from the international oil pricing system and the distinct features of the cash and paper market, creating continuous information imbalances between the Dated Brent fixing members and subscribers and the common financial oil market participants. Hence, we contribute to the literature in multiple ways. Firstly, we add to the literature by identifying and analyzing a fundamental price-sensitive announcement in the FICC market; that is the daily Dated Brent benchmark publication. Secondly, this study is the first to shed light on the wider financial market implications of the opaque OTC physical crude oil benchmark assessments by PRAs such as Platts. Thirdly, we investigate the impact of the daily Dated Brent price fixing and publication on the exchange-traded financial layer of North Sea crude oil; namely the ICE Brent Crude futures. Fourthly, the exact and consistent price publication by Platts at 16:30 London time provides a unique opportunity for an intraday event study on short-lived private information. This is a significant advantage of this study, as for most corporate news releases the information event does not precisely coincide with the release timestamp (see Vega (2006), Tetlock (2010), Bernile, Hu and Tang (2015)). Lastly, we make

essential policy-sensitive additions to current knowledge by providing evidence on the importance of unregulated physical commodity benchmarks on regulated exchange-traded financial products, in terms of the benchmarks' influence in driving the value of financial instruments. Under this circumstance, and depending on additional criteria such as the nature of contributors (supervised vs. non-supervised entities), the total value of financial instruments and investments utilizing the reference price, the number of available substitutes, and others, commodity benchmarks may indeed be considered as 'critical benchmarks' under the proposed EU regulation.

Kyle's (1985)) model of insider trading shows that a single informed trader gradually reveals his private information such that it is progressively accounted for in security prices. Holden and Subrahmanyam (1992) extend the Kyle (1985) framework, arguing that competition among several informed traders leads to aggressive trading and near-instant incorporation of virtually all of their private information into prices. Informed traders will trade aggressively, beginning with the discovery of private information, and then revert part of their position as soon as the general market becomes aware of the information (Hirshleifer, Subrahmanyam and Titman (1994)). Hence, price reactions caused by private information are typically followed by a partial reversal (Daniel, Hirshleifer and Subrahmanyam (1998)). A trader possessing early private information can exploit his informational advantage twice, on personal receipt and after public release of the news (Brunnermeier (2005)). The early-informed trader can best judge the extent to which the information is incorporated in the price ahead of the announcement and expects a price overshooting at publication, followed by a partial reversal (Brunnermeier (2005)). In terms of common stock market wisdom, this behavior is often referred to as 'buy the rumor, sell the news' (see Brunnermeier (2005)). According to Brunnermeier (2005), information leakage reduces

informational efficiency and the long term price informativeness, making it an important regulatory issue.

The short-lived private information literature addresses leakage and anticipation in advance of information disclosures likely to contain price-sensitive intelligence; such events may be official macroeconomic news releases, sovereign rating announcements, analyst recommendations, corporate earnings reporting or benchmark price publications. Bernile et al. (2015) and Lucca and Moench (2015) provide evidence of anticipatory trading in U.S. equity markets during the press pre-release lockup period ahead of Federal Open Market Committee (FOMC) announcements, but they do not document similar evidence for other macroeconomic news announcements. Contrarily, market reactions and adjustments of treasury instruments (Balduzzi, Elton and Green (2001), Green (2004)) and interest rates and foreign exchange futures contracts (Ederington and Lee (1993)) take place instantly after the U.S. macroeconomic news releases, as opposed to before. Michaelides, Milidonis, Nishiotis and Papakyriakou (2015) report systematic information leakage and early-informed trading in local stock indices during the consultation period between rating agencies and the respective national authorities ex ante of sovereign debt downgrade announcements, followed by a partial ex post reversal. Focusing on analyst recommendations, Womack (1996) establishes that stock returns trend in the right direction prior to new recommendation releases for both buy and sell initiations. Kim, Lin and Slovin (1997) scrutinize the priority release of analyst buy initiations to selected clients and report economically substantial profits accruing to early-informed traders, with their activity leading to the full incorporation of the private information in advance of the subsequent public announcement. In line with information leakage, Bradley, Jordan and Ritter (2003) identify a run-up in cumulative abnormal returns before the end of the IPO quiet period of publicly issued stocks that is succeeded by the

initiation of analyst coverage by its underwriters, followed by a post-event return reversal. Irvine, Lipson and Puckett (2007, p. 742) identify so-called "tipping" of institutional traders about the contents of analyst buy initiations, resulting in anticipatory trading behavior of the former ahead of the upcoming reports. Similar evidence, also called informed front-running, can be observed for analyst downgrades (Christophe, Ferri and Hsieh (2010)). With regard to corporate earnings announcements, Berkman, Dimitrov, Jain, Koch and Tice (2009) and Barber, De George, Lehavy and Trueman (2013) report a noteworthy imbalance between the pre- and post-release abnormal returns, with the latter referring to this observation as the pre-announcement premium. A major weakness of the aforementioned literature is that it is difficult to approximate the precise point in time when the private information is likely to have reached the early-informed traders and thus many of the studies have to resort to investigations at a daily frequency. Hence, the potentially large gap between the information event and the official release does not permit the studies to identify the accurate commencement of early-informed trading by analyzing market behavior at a high frequency intraday level.

In a recent paper Caminschi and Heaney (2014) analyze the implications of the London gold price fixing on gold futures contracts and Exchange-Traded Funds (ETF) concluding that information is leaking into the derivatives markets well before the price publication. They show increased overall market activity and a run-up in informed traders' returns instantly after the fixing start and before the fixing end, as opposed to an expected reaction around or after the results publication. The authors point out that insight into the assessment proceeding may provide fixing members with market-sensitive information (e.g. price direction), giving them a profitable head start over the general market until the fixing result is publicly announced. Aspris et al. (2015) also investigate the effects of the replacement of the traditional and opaque OTC closed fixing auction

for gold, silver, palladium and platinum by an electronic-based auction platform on the related futures contracts[9]. The authors show that the new regime leads to a significant increase in market quality, and a reduction in information leakage and abnormal returns accruing to informed traders (Aspris et al. (2015)). The downside of these two studies in comparison with ours is that, while the auction start time in the precious metal market is fixed, the auction end time varies depending on the assessment duration, thereby introducing an additional element of uncertainty to the market, making it more difficult to identify anomalies.

An extensive body of energy literature has developed around the causal relationship and interdependencies of different crude oil benchmarks and their financial derivatives, and the order of price discovery and price innovation (see for example Quan (1992), Schwarz and Szakmary (1994), Silvapulle and Moosa (1999), Bekiros and Diks (2008), Kaufmann and Ullman (2009), Maslyuk and Smyth (2009), Elder, Miao and Ramchander (2014), Inci and Seyhun (2014), Liu, Schultz and Swieringa (2015)). Although on this occasion oil benchmarks have received ample attention, surprisingly, only a limited number of studies utilize data from the leading PRA Platts[10] in order to focus on Dated Brent, let alone investigate the implications of its price assessment procedure on the paper oil market. To the best of our knowledge, there are two studies that have utilized Dated Brent data from Platts; these are Inci and Seyhun (2014) and Swinand and O'Mahoney (2014). Inci and Seyhun (2014) examine the market dynamics between the spot and

[9] The new approach aims to improve trading transparency and to reduce manipulative behaviour by the fixing members, by allowing market participants to follow the order flow throughout the auction process (Aspris et al. (2015)).

[10] Most likely, this is caused by the fact that the PRAs occupy oligopolistic positions and Dated Brent data are only available from the industry leader Platts against payment of a substantial fee.

futures markets, while Swinand and O'Mahoney (2014) explore calendar spread differentials to highlight potential price manipulation in the Brent crude complex. The difficulty in using calendar spreads to identify price manipulation lies in the increasing level of spread mispricing as the front month futures contract approaches maturity (see Frino and McKenzie (2002)).

The remainder of this article is organized as follows: the next section introduces the data used, section three sets out the methodology and describes and discusses the empirical analysis and results, while section four concludes.

II Data

A Sample Selection and Description

The summary of the sample data is reported in Table 1. The high frequency intraday data for the ICE Brent Crude futures and the BFO crude oil spot[11] are obtained from the Thomson Reuters Tick History (TRTH) database. The data are received in duplicate; the first set consists of transactions and quotes time stamped to the nearest millisecond and the second set contains observations for volume, number of trades and open, close, bid, ask, high and low prices at 1-minute intervals. Full ranges of observations for both datasets are collected for the regular trading hours of the ICE Brent Crude futures (01:00 – 23:00). We sample only the front month, closest-

[11] It is important to note that the Brent-Forties-Oseberg (BFO) North Sea crude spot is not comparable to the actual Dated Brent benchmark, which is only assessed once daily by Platts based on physical market activity. The intraday BFO time series is calculated by Thomson Reuters based on a combination of the futures price (either ICE Brent or NYMEX WTI depending on the time of the day), EFP values and the ICE close. We use the BFO series as an approximation of the Brent crude oil spot price immediately ahead of the Platts window start at t_{-31} = 15:59 (see Figure 1).

to-maturity futures contract. Contracts exist on a monthly basis. Contract month expiry and roll over occurs at the end of the first business day preceding the 15th calendar day before the start of the next contract month. Finally, we acquire the daily Dated Brent fixing results from Platts Singapore. The Platts data contain daily Dated Brent prices published at 16:30 London time.

Over time, Platts amended its Dated Brent assessment methodology several times. For example the oil grade basket was expanded to include not only Brent but also other North Sea crude oil grades such as Forties and Oseberg and later Ekofisk, and the oil delivery period window was continuously widened from, initially, 7-15 days, to 10-25 days (early 2012) and, most recently (early 2015), even to 10-30 days ahead[12]. Our sample period starts on Monday 9th January 2012 after the enlargement of the delivery period window (implemented on Friday, 06.01.2012) in order to work with a sample of Dated Brent benchmark prices that is large enough and nevertheless determined by a majorly uniform methodology. A trading day, on which a Platts benchmark assessment occurs and during which the futures contracts are traded, is denoted *d*. The holiday schedule is received from Platts and days on which the services of the London office are affected are excluded from our analysis (see Platts (2016)). The total number of trading days is defined as *D*. Our full period of investigation comprises observations from 9th January 2012 until 24th September 2015 inclusive, some 921 trading days.

INSERT TABLE 1 ABOUT HERE

[12] Please refer to 'Evolution of Dated Brent – a brief history of major changes' by Platts (http://www.platts.com/price-assessments/oil/dated-brent) for further explanations on the changes to the Platts Dated Brent benchmark assessment.

III Empirical Analysis, Results and Discussions

A The Event Study Window

We begin our analysis by specifying our period of interest within the trading day (see also Table 1). Our focus encapsulates the 1-minute intervals characterizing the start and end of the Platts window at 16:00 and 16:30 respectively; 16:30 coincides with the publication of the daily Dated Brent benchmark price. The publication of the fixing results at 16:30 London time is referred to as the event time. The 120-minute window of investigation covers an hour before the event time (starting 15:30) and an hour after the event time (ending 17:30) for each trading day *d*. The 1-minute intervals within the window of investigation are indexed relative to the 1-minute event time of the Dated Brent benchmark publication at t_0 = 16:30; that is 15:30-17:29 inclusive or $-60 \leq t \leq 59$. In summary, the total window of investigation is configured so as to cover 30 minutes before the start of the event window (t_{-60} = 15:30 to t_{-31} = 15:59 inclusive) known as the estimation window, the 30 minutes of the price fixing referred to as the Platts or event window (t_{-30} = 16:00 to t_{-1} = 16:29 inclusive) and 60 minutes after the event time (t_0 = 16:30 to t_{+59} = 17:29 inclusive), that is, the post-event window.

The Thomson Reuters Tick History timestamps indicate interval start times. The event time, t_0 = 16:30 London local time, relates to the start of the interval covering the Platts Dated Brent price publication. The window always finishes at the end of the interval t_{-1} = 16:29 and Platts publishes its daily Dated Brent price precisely at 16:30:00.999, covered by the interval t_0 = 16:30. The interval t_{-30} = 16:00 indicates the Platts window start time and t_{-31} = 15:59 is the 1-minute

trading interval immediately prior to the window; the latter is used to determine the fixing direction as illustrated in Figure 1[13].

INSERT FIGURE 1 ABOUT HERE

B Relative Volume, Volatility and Trade Size Evolution Around the Dated Brent Benchmark Publication

In order to determine the implications of the Dated Brent benchmark assessment on the trading activity in the ICE Brent Crude futures market, we scrutinize the trading volume during the window of investigation. The benchmark assessment outcome is expected to convey new information to the financial market and thus we expect momentary heightened trading volume. Aspris et al. (2015) assume that the fixing concentrates a lot of information in a short window of time and that the price discovery process will lead to increased volumes. Intraday volume data are retrievable for the derivative contracts, but no volume data are available for the spot instruments. We compute the relative volume for each interval *t* during the window of investigation and then average across all sample trading days *D*. In order to do so, the log volume per interval is calculated relative to a reference volume, which is the average log volume of the 30-minute estimation

[13] All time specifications are in London local time. For consistency, care needs to be taken with differences in daylight savings. During summer time, London local time corresponds to British Summer Time (BST = GMT + 1), whereas during the winter, London local time corresponds to GMT. The ICE Brent Crude futures and Platts Dated Brent observations are timestamped at London local time and no adjustments need to be made. The intraday data for the Brent crude oil spot (BFO-) are timestamped at GMT and thus during the summer the time is incremented by one hour such that 15:30 GMT equals 16:30 BST. BST begins at 01:00 GMT on the last Sunday of March and ends at 01:00 GMT on the last Sunday of October.

window (t_{-60} = 15:30 to t_{-31} = 15:59) on any given day *d*, prior to the event window start (t_{-30} = 16:00). This 30-minute reference volume should reflect the average trading level on *d*, being unbiased by the benchmark assessment process (Aspris et al. (2015)). Consistent with Caminschi and Heaney (2014), $VM_{t,d}$ is defined as the total trading volume during any given 1-minute interval *t* and day *d*. The relative average volume per interval *t* is computed as follows:

$$VMref_d = \frac{1}{30} \sum_{t=-60}^{-31} \ln\left(VM_{t,d}\right) \quad (1)$$

$$\overline{VM_t} = \frac{1}{D} \sum_{d \in D} \frac{\left(\ln\left(VM_{t,d}\right) - VMref_d\right)}{VMref_d} \quad (2)$$

The relative volume $\overline{VM_t}$ is the averaged (by total number of sample days *D*) difference between the log volume of the 1-minute interval *t* and the reference volume on day *d*, scaled by the reference volume on *d* such that it yields the percentage volume increase or decrease relative to the estimation window. The issue of zero volume log transformations is accounted for by adjusting observations with a value of 0 to 1 (Caminschi and Heaney (2014)). The log transformation normalizes the data and mitigates the skewness effect caused by the zero bound on volume and improves the robustness of the subsequent *t*-tests (Caminschi and Heaney (2014), Aspris et al. (2015)). The manipulation of the zero volume observations has no material implications on our results. We also compute the relative trade size ($\overline{TS_t}$), as the log value of the division of trading volume by the number of trades in interval, *t*, following the above approach.

We define the relative volatility $\bar{V}_t$ as the averaged (by total number of sample days *D*) difference between the volatility of the 1-minute interval *t* and the reference level on day *d*, scaled by the reference volatility on *d* such that it yields the percentage volatility increase or decrease relative to the estimation window. In order to measure price volatility for each interval *t* of the window of investigation, the Garman and Klass (1980) volatility estimator is applied. $H_{t,d}$, $L_{t,d}$,

$O_{t,d}$, $C_{t,d}$ refer to high, low, open and close prices for the interval t on day d respectively. Volatility per interval $V_{t,d}$, reference volatility $Vref_d$ and relative volatility $\bar{V}_t$ are defined as:

$$V_{t,d} = \sqrt{\frac{1}{2}\left(\ln\left(\frac{H_{t,d}}{L_{t,d}}\right)\right)^2 - (2\ln(2) - 1)\left(\ln\left(\frac{C_{t,d}}{O_{t,d}}\right)\right)^2} \quad (3)$$

$$Vref_d = \frac{1}{30}\sum_{t=-60}^{-31} V_{t,d} \quad (4)$$

$$\bar{V}_t = \frac{1}{D}\sum_{d\in D}\frac{(V_{t,d} - Vref_d)}{Vref_d} \quad (5)$$

INSERT FIGURE 2 ABOUT HERE

The results for the relative trading volume, the relative volatility and the relative trade size during the window of investigation, comprising the Dated Brent fixing event by Platts, are reported in Table 2. The three metrics are computed relative to the average reference value of the estimation period (t_{-60} = 15:30 to t_{-31} = 15:59) thirty minutes prior to the start of the Platts fixing (t_{-30} = 16:00). $\overline{VM_t}$, $\bar{V}_t$ and $\overline{TS_t}$ are scaled by their reference value such that it yields the average percentage increase or decrease in interval t relative to the estimation window. A value of zero of the percentage measure represents an average relative trading volume, volatility or trade size equal to its respective reference level over the estimation window. Significance for each trading measure is established via a one sample t-test on $\overline{VM_t}$ ($\bar{V}_t$, $\overline{TS_t}$) = 0. For parsimony, we only report a 41-minute sub-window (t_{-35} = 15:55 to t_{+5} = 16:35) of the full 120-minute window of investigation in Table 2, covering 5 minutes before the fixing start and 5 minutes after the price publication, which does not result in a loss of critical information. Figure 2 illustrates the development of the three metrics over the full window of investigation.

INSERT TABLE 2 ABOUT HERE

Relative volume, as well as relative volatility and relative trade size, all show enhanced values in the run-up to the Platts Dated Brent price publication at 16:30 (t_0). These findings are in contrast to other short-lived private information studies. For example, Lucca and Moench (2015) report abnormally low volume and volatility during the pre-FOMC announcement window, an effect already documented in earlier studies as the 'calm before the storm' (see Jones, Lamont and Lumsdaine (1998), Bomfim (2003)), with both measures only experiencing a significant spike with the release of the policy decision itself. For $\overline{VM_t}$ in Panel A of Table 2 and Figure 2, the trading intensification commences exactly with the start of the Platts window (t_{-30} = 16:00) and drops sharply thereafter (t_{+1} = 16:31). The average relative volume jumps by approximately 7% at the fixing start and gradually rises to nearly 40% above the estimation level, with the highest trading volume recorded immediately prior to the price publication (t_{-1} = 16:29). This is consistent with the findings of Bernile et al. (2015), who report concentrated trading activity during the lockup period immediately before FOMC announcements. After the fixing end, $\overline{VM_t}$ gradually reverts back to pre-event levels, only exceeding it by 4% five minutes after publication (t_{+5} = 16:35). The increase in trading volume relative to the reference volume is majorly statistically significant at the 1% level and persists for 30 minutes. Analyzing Panel B in Table 2 and Figure 2, $\bar{V}_t$ shows a slightly different behaviour. Relative volatility increases significantly, by 95%, immediately after the fixing start with the effect only lasting for 2 minutes. Thereafter, relative volatility escalates even more abruptly, peaking at 236% above estimation levels (although not statistically significant) and reaching a significant top of 165% at 16:29 relative to the estimation period,

directly before the actual Dated Brent price publication at 16:30. The observed volatility inflations are largely statistically significant. Again, we observe a sharp decline in volatility at the fixing end relative to the estimation period, reaching non-significant levels (68.17%) within the first minute (t_{+1} = 16:31) after the Dated Brent publication and approaching zero only 4 minutes thereafter (3% at t_{+4} = 16:34). As shown in Panel B of Figure 2, subsequent volatility levels remain low at all times during the post-event window.

Lastly, in Panel C of Table 2 and Figure 2, the relative trade size $\overline{TS}_t$ gradually increases during the 30-minute Platts window, up to a maximum of nearly 43% above the reference level, and more gently reverts to its previous levels at the end of the price fixing. Almost all $\overline{TS}_t$ during the event window are statistically significant at the 1% level. Moreover, the moderate reversion in trade size leads to equal levels of significance in the post-event window, even if the average size of trades remains well below its earlier peak (see Panel C of Figure 2).

Although all three measures experience different patterns, the overall picture shows significantly enhanced values during the Dated Brent price assessment window. The results for the intervals during the 30-minute Platts window from 16:00 (t_{-30}) to 16:29 (t_{-1}) are for the most part statistically significant for all three measures. The sharp decline in the levels of the three measures following the fixing end allows us to conclude that there is no corresponding spike in trading activity of the ICE Brent Crude futures, relative to the reference level, with the publication of the fixing results. We expected an elevated level of trading activity around the announcement of the fixing price, however trading activity already peaks before the publication of the Dated Brent price at t_{-1} as indicated by both $\overline{VM}_t$ and $\bar{V}_t$ and at t_{-11} for $\overline{TS}_t$. It is also important to note the general reversion in trading activity following the fixing end, reaching levels close to its reference values. The continuous significant negative levels of $\overline{VM}_t$ and $\bar{V}_t$ roughly 10 minutes after the Dated Brent

publication ($t > 10$), up to an hour thereafter, demonstrate an extended decline in futures market activity relative to the reference level (Figure 2, Panel A and B). We attribute this effect to the futures market adjusting to leaking information well in advance of the fixing end, rather than the fact that the Dated Brent price publication is also considered to be the closing of the European physical oil market[14]. The closing of the physical market should not prevent the financial market to effectively continue its price discovery, in case the Dated Brent publication still carries new information, as the ICE Brent Crude futures market only closes at 23:00. $\overline{TS}_t$ is the exception, experiencing significantly heightened positive trade sizes, even though at a quickly declining magnitude (see Panel C, Figure 2), relative to the reference trade size up to 30 minutes after the Dated Brent publication. The higher than usual trade sizes may be caused by futures traders actively closing their positions or trading an expected price reversal. Overall, the identified trading activity patterns are consistent with our hypothesis that information leaks into the market prior to the publication of the Dated Brent benchmark.

Collectively, these findings are in opposition to an expected market reaction at, or instantly after, the actual publication of the daily Dated Brent at 16:30 (t_0) London time. Intuitively, one would expect an abrupt response at the announcement time by the Brent futures to the supposedly new information received with the publication of the fixing results. On the contrary, the results of the simple trading activity tests suggest a preliminary confirmation of our leakage hypothesis, as the reaction of the ICE Brent Crude futures precedes the Platts Dated Brent announcement.

[14] This is due to the Market on Close (MOC) process defined by Platts, which allows participants to submit bids and offers for consideration in the price fixing procedure until the end of the Platts window at 16:30. The MOC aims to ensure that the Dated Brent price reflects the last available useful price of the day.

C Returns Analysis around the Dated Brent Benchmark Publication

In order to test our hypotheses of information leakage and anticipatory trading, we need to identify the returns available to 'uninformed' and 'informed' traders. We do this by computing the means of 'unadjusted' and 'adjusted' returns available to 'uninformed' and 'informed' participants respectively. The adjusted returns are a measure of hypothetical returns available to a trader who has an informational advantage over the general market. In our case, the informational advantage is assumed to stem from ex ante knowledge of the direction of the daily Dated Brent benchmark assessment.

Unadjusted Returns

Unadjusted returns are the returns available to a long only investor. Unadjusted returns for interval t on any trading day d are computed based on 1-minute close prices $C_{t,d}$:

(6) $$UR_{t,d} = \ln\left(\frac{C_{t,d}}{C_{t-1,d}}\right)$$

(7) $$\overline{UR_t} = \frac{1}{D}\sum_{d\in D} UR_{t,d}$$

(8) $$CUR_t = \sum_{t=-60}^{t} \overline{UR_t} - \sum_{t=-60}^{-31} \overline{UR_t}$$

The cumulative unadjusted returns CUR_t are calculated based on the average unadjusted returns $\overline{UR_t}$. The term on the right hand side of Equation 8 is an adjustment factor used to offset average unadjusted returns such that $CUR_{-31} = 0$ (Caminschi and Heaney (2014)). This has the effect that the cumulative return equals zero for the interval immediately preceding the start of the Platts window (t_{-31}), making it easier to determine the evolution of returns during the benchmark assessment process (t_{-30} to t_{-1}), up to the publication at t_0.

Adjusted Returns

In order to determine adjusted returns, we follow both Ederington and Lee (1995) and Caminschi and Heaney (2014). The fixing direction parameter captures informational advantages of an informed trader on the direction of the daily Dated Brent benchmark assessment. Consequently, the fixing direction parameter adjusts the unadjusted ICE Brent Crude futures returns by the forthcoming Dated Brent price direction. Thus the adjustment factor takes the value of one if the published Platts Dated Brent price (t_0) on day *d* is higher than the price of the crude oil spot on *d* immediately prior to the start of the window (t_{-31}), assuming that the informed trader takes a long position. When the difference is negative, the adjustment factor adopts the value minus one to reflect a short position of an informed trader (see Figure 1). It is crucial to note that the adjusted return measure is hypothetical in the sense that it does not give the value of actual realized returns. According to Caminschi and Heaney (2014), directional foresight is defined as the anticipation of the final benchmark price being higher or lower relative to the pre-window spot price. The informed trader is unlikely to have knowledge of the exact published price. The portion of the cumulative adjusted returns that an informed trader can get hold of, and thus his profits, are largely determined by the point in time at which he gains the critical intelligence allowing him to decide on a long or short position. The decision needs to be made before the final price publication. The adjusted returns are the product of the fixing direction and the unadjusted returns of the 1-minute interval *t*. The cumulative adjusted returns are based on directional foresight and represent the gain attainable through anticipatory trading during the event window. Equations 11 and 12 follow the same rationale as described in the previous section on unadjusted returns.

(9) $$FIXDIR_d = \begin{cases} +1, & PDB_{0,d} > CS_{-31,d} \\ -1, & PDB_{0,d} < CS_{-31,d} \\ 0, & PDB_{0,d} = CS_{-31,d} \end{cases}$$

(10) $$AR_{t,d} = FIXDIR_d \times \ln\left(\frac{C_{t,d}}{C_{t-1,d}}\right)$$

(11) $$\overline{AR_t} = \frac{1}{D}\sum_{d\in D} AR_{t,d}$$

(12) $$CAR_t = \sum_{t=-60}^{t} \overline{AR_t} - \sum_{t=-60}^{-31} \overline{AR_t}$$

Difference in Returns

The difference in returns quantifies the value of directional foresight and is computed as the difference between adjusted and unadjusted returns. The metric yields the excess returns of an informed trader over an uninformed trader. Equations 14 and 15 follow the same rationale as described for the unadjusted returns.

(13) $$DR_{t,d} = AR_{t,d} - UR_{t,d}$$

(14) $$\overline{DR_t} = \frac{1}{D}\sum_{d\in D} DR_{t,d}$$

(15) $$CDR_t = \sum_{t=-60}^{t} \overline{DR_t} - \sum_{t=-60}^{-31} \overline{DR_t}$$

The differencing brings with it the advantage of cancelling out long-term bull or bear market trend effects (Caminschi and Heaney (2014)).

INSERT TABLE 3 ABOUT HERE

Table 3 reports the results for average unadjusted returns, adjusted returns and difference in returns by intervals for the ICE Brent Crude futures. While the unadjusted returns accrue to an uninformed long-only investor, the adjusted returns reflect the position of an informed investor, with educated directional foresight, anticipating the Dated Brent fixing direction and adapting his

exposure accordingly. In case the results of our adjusted return measure corroborate our anticipation hypothesis, we have evidence in support of futures market participants front-running the Dated Brent price publication, allowing us to suggest that the trading activity in Brent futures during the event window reflects private information on the fixing direction. The difference in returns is the differential between the adjusted returns and the unadjusted returns, and represents the value of private information; i.e. the value of anticipating the fixing direction. The unadjusted returns $\overline{UR_t}$, the adjusted returns $\overline{AR_t}$, and difference in returns $\overline{DR_t}$ describe the returns for interval *t* averaged across trading days *D*. Significance is established via a one sample t-test on $\overline{UR_t}$ = 0, $\overline{AR_t}$ = 0 and $\overline{DR_t}$ = $\overline{AR_t}$ - $\overline{UR_t}$ = 0 respectively. The cumulative return measures (CUR_t, CAR_t and CDR_t) offset the average returns ($\overline{UR_t}$, $\overline{AR_t}$, and $\overline{DR_t}$ respectively) by an adjustment factor such that the cumulative returns equal zero for the interval immediately preceding the start of the Platts window (t_{-31}), making it easier to determine the evolution of returns during the Dated Brent fixing (t_{-30} to t_0). CUR_t, CAR_t and CDR_t contrast the cumulative returns available to an uninformed investor, an informed investor and the difference between the two respectively. The ratios of the CUR_t, CAR_t and CDR_t illustrate the proportion of the respective cumulative returns in relation to its maximum; the peak of the cumulative returns during the window of investigation is set to 100%. We only report a 41-minute sub-window (t_{-55} = 15:55 to t_{+5} = 16:35) of the full 120-minute window of investigation in Table 3, covering 5 minutes before the fixing start and 5 minutes after the price publication[15]. Figure 3 illustrates the behavior of the three metrics during the full window of investigation.

[15] This reporting approach is for parsimony and does not leave out any critical return evolution information; furthermore, minute-by-minute results for the full 120-minute investigation are available on request.

INSERT FIGURE 3 ABOUT HERE

On the one hand, contemplating the unadjusted returns for Brent futures in Panel A of Table 3, only a few intervals show significant unadjusted returns, some shortly before the fixing start, several during the Platts window, and some after the fixing end. The significant return intervals seem randomly distributed, although a sequence appears to develop from t_{-23} to t_{-21}. Nevertheless, we argue that the significance in unadjusted returns is not attributable to the benchmark assessment. Intuitively, in the absence of information leakage and foreknowledge of early-informed traders, the return distribution should be random and non-predictable. As evidenced in Panel A of Table 3 and illustrated by the graphical representation of the mean unadjusted returns in Panel B of Figure 3, no pattern is discernible.

On the other hand, the adjusted returns in Panel B of Table 3 depict a completely different picture. The adjusted returns capture trading in the ICE Brent futures based on informational advantages of an informed trader with regards to the direction of the daily Dated Brent benchmark assessment. The informed trader has an educated foreknowledge of the final Dated Brent price (t_0) being higher or lower relative to the pre-event window crude oil spot price (t_{-31}), allowing him to capture price movements in the ICE Brent futures market. In case some market participants actually possess directional foresight, this should reflect in the adjusted returns as, in order for the price (and thus the returns) to move in the direction of the assessment outcome, fixing direction-aligned transactions need to be made well in advance of the daily Dated Brent price announcement. The graphical representation of the mean adjusted returns in Panel C of Figure 3 yield a first indication of anticipatory trading during the 30-minute Platts window, as the $\overline{AR_t}$, which are now adjusted by the fixing direction, allow a pattern to emerge.

As reported in Panel B of Table 3, immediately with the fixing start at t_{-30}, the mean adjusted returns are statistically significant at the 1% level ($\overline{AR_t}$ = 1.44). Overall, during the event window (t_{-30} to t_0), the mean adjusted returns of 21 out of the 30 intervals are significantly different to zero. Remarkably, the $\overline{AR_t}$ intervals that capture the different phases of the Platts window (as described in the background section in Appendix 1) are all statistically significant at either the 1% or 5% level, suggesting a gradual introduction of new private information to the futures market with the progression of the fixing process. The intervals are: the fixing start interval at 16:00 (t_{-30}), the end of submission of bids and offers for the grade differential assessment at 16:10 (t_{-20}) (although changes to bids/offers are allowed until 16:25), the start and end of the assessment of CFD prices 16:15 (t_{-15}) and 16:25 (t_{-5}) respectively, and the final assessment of forward Brent prices from 16:25 (t_{-5}) onwards. This pattern corresponds to heightened trading activity consistent with leaking information ahead of official benchmark announcements (cf. Bernile et al. (2015)). This also indicates that informed market participants seek to reduce the risk of interference by other unexpected events whilst front-running the physical oil fixing direction. They therefore only begin building up their position in the futures market right after the fixing start as new information becomes available to them, gradually expand their position as the fixing progresses, and finally close their positions with the Dated Brent price announcement. The mean adjusted returns in the last minute of the event window are not significantly different from zero (t_{-1} = 16:29). Crucially, the $\overline{AR_t}$, for the interval of the Dated Brent publication itself at 16:30 (t_0), are not statistically significant either, but already indicate a reversal ($\overline{AR_t}$ = -0.3). Lastly, significant negative adjusted returns ($\overline{AR_t}$ = -0.5) are discernible immediately after the fixing end (t_{+1}), possibly due to an earlier market overreaction in the run-up to the Dated Brent publication (cf. Brunnermeier (2005)).

The cumulative adjusted returns in Panel B of Table 3 are based on directional foresight and represent the cumulative gain attainable through anticipatory trading in the ICE Brent futures during the Platts window. The observed pattern accentuates commonalities with the tipping concept, in the sense that some selected market participants with access to private information on the progression of the Dated Brent benchmark assessment, are able to front-run the market at large (cf. Irvine et al. (2007), Christophe et al. (2010)). As depicted in Panel A of Figure 3, there is an important and steep run-up in CAR_t instantly after the fixing start and prior to the fixing end. The clear and continuous trend in adjusted futures returns during the event window suggests that market participants anticipate the fixing direction on a regular basis. For example, fixing members could use their superior information of the fixing progression, or other participants might decide to purchase access to the *Global Alert* service, in order to draw inferences from the spot oil order flow during the benchmark assessment. The increase in cumulative adjusted returns reaches an interim high (ratio of 88%) of almost 21 bps at 16:29 (t_{-1}) shortly prior to the publication of the daily Dated Brent price (cf. Bernile et al. (2015)), with a 4-minute return reversal thereafter, from 16:30 to 16:33 inclusive (t_0 to t_{+3}), possibly due to a previous overshooting by the market. The described pattern coincides with the double private information exploitation elaborated by Brunnermeier (2005). As predicted in the theoretical work of the former, early-informed traders make the majority of their profits by trading aggressively prior to the public announcement and can potentially realize additional, but smaller, gains by reversing their position thereafter. Subsequently, we observe a slight but steady positive trend, leading to the peak in CAR_t (ratio = 100%), 54 minutes after the Dated Brent publication (t_{+54}). However, the adjusted returns in the post-event window are only randomly significant. These findings possibly suggest that the Dated Brent fixing continues to impact the ICE Brent Crude futures market up to an hour after the Dated

Brent publication, although to a much lesser extent. The on-going market reaction suggests that not all market participants are aware of the information contained in the Dated Brent price until its actual publication (cf. Irvine et al. (2007)). The continuous price effect resembles what is commonly referred to as "post-earnings announcement drift" (Vega (2006)) in corporate finance.

Overall, the abrupt accrual in cumulative adjusted returns instantly after the fixing start, combined with the largely continuous significant adjusted returns during the event window, affirms not only more active trading ahead of the Dated Brent announcement (see volume, volatility and trade size results above), but the pattern also coincides with informed trading in the ICE Brent Crude futures market based on foreknowledge of the upcoming Dated Brent direction (cf. Irvine et al. (2007)). The findings show that an informed trader, taking a fixing direction-aligned futures position immediately at the fixing start (t_{-30}) and liquidating it before the fixing end (t_{-1}), is able to realize a daily average abnormal profit of 21 bps over the 30-minute Platts window.

In Panel C of Table 3, the difference between the adjusted and the unadjusted returns constitutes the gains accruing to an informed Brent futures trader, and thus represents the value of private information such as foresight of the fixing direction. The results of both the $\overline{DR_t}$ and the CDR_t mainly mirror the findings of the $\overline{AR_t}$ and the CAR_t. Likewise, the difference in returns per interval is largely significant during the Platts window. The post-event return reversal ensuing from the overshooting of the ICE Brent Crude futures (cf. Brunnermeier (2005)) is more pronounced, with the mean difference in returns being statistically different in t_0 and t_{+1} at the 10% and 5% levels respectively. However, the most important distinction is that there is no positive trend continuation in the cumulative difference in returns after the fixing end (compare cumulative adjusted returns and cumulative difference in returns in Panel A of Figure 3). With a value of about 27 bps, CDR_t peaks at t_{-1}, as shown by the ratio of 100% in Panel C. We therefore reason that the

trend in the CAR_t is driven mainly by the unadjusted returns, as observed by the slight upwards trend in CUR_t in Figure 3. As in the calculation of the cumulative difference in returns, the adjusted returns are corrected for the effect of the unadjusted returns; the CDR_t measure does not experience an upward tendency. Hence, we discredit our aforementioned interpretation of a post-earnings announcement drift, which suggested that the announcement of the Dated Brent price continues to impact the futures contracts up to an hour after the fixing end. At the time of the Dated Brent price publication, the respective information seems to have previously been revealed to the market by the pre-release trading activities of informed traders (see Easley and O'Hara (1992)). This is consistent with the arrival of a high level of informed traders, as comprehensive and concentrated information, irrespective of whether it is public or private, translates into small post-event return drifts (Vega (2006)).

In order to provide a more clear-cut picture of the implications of the Dated Brent price assessment on ICE Brent Crude futures returns, we re-conduct our analysis portioning the trading day into pooled batches of 5 and 10 minutes (Section A and Section B, Table 4). The defined batches cover the full window of investigation from 15:30 to 17:29 inclusive. The results for the mean adjusted returns and difference in returns by batches are reported in Panel A and B of Table 4. As above, both measures are statistically significant at the 1% level immediately after the fixing start, for both the 5-minute and 10-minute batches. The mean returns of all batches during the event window are positive and significantly different from zero at the 1% level. Moreover, the difference in returns of the 5-minute and 10-minute batch instantly after the fixing end (Panel B of Section A and Section B) indicates a post-event reversal of -2.10 and -2.60 at the 1% and 5% significance level respectively (cf. Brunnermeier (2005)). Overall, our results are consistent with

informed investors exploiting informational advantages in relation to the fixing direction ahead of the public announcement by Platts.

INSERT TABLE 4 ABOUT HERE

According to Grossman and Stiglitz (1980), if markets are strongly efficient (that is, always in equilibrium where prices fully and instantly reflect all information), there will be no compensation for the generation of costly private information. It may be argued that the benchmark system by Platts, allowing fixing members and subscribers to follow the course of trading and order flow in real time against payment of a fee, needs to grant the information acquirer the possibility to trade on the gained knowledge. Any limitation on anticipatory trading would discourage beneficiaries to pay for the superior information, thereby reducing the commission and thus incentive of the information provider (e.g. Platts) to offer the benchmark administration infrastructure, and to conduct research in terms of interpreting market talk, providing news analysis by market specialists, and editorial coverage of market developments (cf. Irvine et al. (2007)). The arrangement allows for customer relationship management and the revenues from the information sale serve as compensation for generating energy market intelligence (cf. Irvine et al. (2007)), which Platts is not trading on itself. The outcome would be less research effort, resulting in less transparency between cash and paper oil and arguably less efficient markets. However, in this instance, uninformed investors continuously suffer an unfair information disadvantage.

D Price Discovery and Order Imbalance around the Dated Brent Benchmark Publication

For consistency, in the preceding section we largely use the methodology as employed by previous studies (see as an example Caminschi and Heaney (2014)), aimed at identifying informed anticipatory trading in the futures market around the Dated Brent price fixing event. We now supplement this approach by analyzing the arrival of private information into the ICE Brent Crude futures market around the event window. This allows us to draw more robust conclusions on informed trading behavior before, during and after the Platts window. Given approximately 93% of the trades in the Brent futures, and all important events such as the open and close of the European and American markets, fall in the period from 08:00 to 19:29 London time inclusive, we focus on this time span for the computation of price discovery measures.

Price Contribution

The Price Contribution (PC) measure is applied to investigate the intraday price discovery process of a typical trading day. The PC estimates the ratio of interval returns relative to the close-to-close return across the trading day. We follow Barclay, Litzenberger and Warner (1990), Barclay and Warner (1993), Cao, Ghysels and Hatheway (2000), Barclay and Hendershott (2004), van Bommel (2011), Ibikunle, Gregoriou and Pandit (2013), and Ibikunle (2015a) to measure the developments of interval-by-interval price discovery. The price contribution (PC) is computed daily for each interval *t*, as shown by Equation 16. We also compute the price contribution per trade (PCT) (Equation 17).

(16) $$PC_{t,d} = \frac{UR_{t,d}}{UR_{cc,d}}$$

(17) $$PCT_{t,d} = \frac{\frac{UR_{t,d}}{UR_{cc,d}}}{\frac{TR_{t,d}}{TR_{cc,d}}}$$

$UR_{t,d}$ refers to the log return of the ICE Brent Crude futures for interval t on trading day d, while $UR_{cc,d}$ refers to the log close-to-close return on day d. $TR_{t,d}$ sums the Brent futures transactions in interval t on trading day d, and $TR_{cc,d}$ is the total sum of $TR_{t,d}$. The interval length is defined as shown in Table 5. The ratio $UR_{t,d}/UR_{cc,d}$ measures the proportion of the interval return relative to the daily return of the Brent futures. The PCT scales the normal PC measure by the ratio $TR_{t,d}/TR_{cc,d}$, which captures the number of trades during interval t relative to the total sum of trades on day d. The PCT should be near 100%, if each trade contains approximately the same level of information (Ibikunle (2015b)). These tests give us a first idea of the informativeness of futures trading during the event window.

Order Imbalance

In order to link the trading activity and return measures and the price discovery measures, we apply the order imbalance framework, with the aim of understanding the dynamics of informed trading behavior around the Dated Brent benchmark assessment by Platts. The order imbalance provides insight into the proportion of buyer- versus seller-initiated transactions. We apply the order imbalance methodology to tick-by-tick transactions over the full window of investigation. We follow Lee and Ready (1991) in order to determine trade initiation. The algorithm classifies trades above the prevailing midpoint as buys, and those below the prevailing midpoint as sells[16].

[16] According to Chordia, Roll and Subrahmanyam (2008) it is generally accepted that reporting errors have declined drastically over recent years and thus it is sensible to take the quote midpoint immediately prior to the trade as the comparison quote. In case the trade was executed exactly at the midpoint, we determine the direction based on the

Order imbalance by number of trades (OIB#) for the ICE Brent Crude futures is computed as the aggregated number of buyer-initiated transactions in the 1-minute interval *t*, minus the aggregated number of seller-initiated transactions in the 1-minute interval *t*, divided by the sum of buyer-initiated and seller-initiated transactions in the 1-minute interval *t* (Chordia et al. (2008)). The order imbalance dollar value (OIB$) replicates the above-described measure with the slight difference of using the monetary value of the transactions instead of the number of trades (Chordia et al. (2008)). In addition, so as to facilitate the interpretation of the OIB# and OIB$ measures, the order imbalance for each interval *t* is adjusted by the fixing direction of that day *d*, as described above for the adjusted returns. This has the advantage of facilitating the identification of trading behavior based on the foreknowledge of the Dated Brent fixing direction, as the adjusted order imbalance (AOIB) measures always adopt positive values if the majority of transactions in interval *t* have been aligned with the direction of the upcoming daily price publication. The fixing direction adjusted order imbalance by number of trades for each time interval *t* on trading day *d* is calculated as follows:

$$AOIB\#_{t,d} = FIXDIR_d \times \left(\frac{\#B_{t,d} - \#S_{t,d}}{\#B_{t,d} + \#S_{t,d}}\right) \tag{18}$$

and the adjusted order imbalance dollar value for each time interval *t* on trading day *d* equals:

$$AOIB\$_{t,d} = FIXDIR_d \times \left(\frac{\$B_{t,d} - \$S_{t,d}}{\$B_{t,d} + \$S_{t,d}}\right) \tag{19}$$

first preceding transaction which was executed at a different price; a practice also called tick test (Lee and Ready (1991)). Lee and Ready (1991) attest their algorithm 90% accuracy in classifying trades. Aitken and Frino (1996), Ellis, Michaely and O'Hara (2000), Lee and Radhakrishna (2000), and Odders-White (2000) confirm the accuracy of the Lee and Ready (1991, LR) algorithm as lying between 74% and 93%. In a recent work, Holden and Jacobsen (2014) demonstrate that the LR trade classification algorithm is reasonably accurate (88%) in today's context of fast markets as well.

FIXDIR$_d$ is as earlier defined, thus adjusting the order imbalances by the forthcoming Dated Brent price direction[17].

INSERT TABLE 5 ABOUT HERE

For the price discovery analysis, we are mostly concerned with the twelve 10-minute trading periods as shown in Table 5. The $\overline{PC_t}$ and $\overline{PCT_t}$ describe the values for interval *t* averaged across all trading days *D*. Significance is established via a one sample t-test on $\overline{PC_t}$ = 0 and $\overline{PCT_t}$ = 0. Of specific interest to our study is the contribution to price discovery of the three trading periods constituting the Dated Brent assessment window (t_{-30} to t_{-1}) preceding the price publication (t_0). Considering the findings in the previous sections we suspect that, during the assessment window, transactions in the ICE Brent Crude futures significantly contribute to price discovery and have particularly important implications on the price development of the futures market. The results are reported in Table 5. As shown in Panel A, the 10-minute period immediately ahead of the Platts price publication (t_{-10} to t_{-1}) significantly contributes to the price discovery in the ICE Brent Crude futures market, an indication that a substantial amount of information enters the market during the pre-announcement period. Remarkably, the last third of the 30-minute Platts Dated Brent assessment window is on average responsible for roughly 15% of the close-to-close price

[17] The adjustment factor takes the value of one if the published Platts Dated Brent price (t_0) on day *d* is higher than the price of the crude oil spot on *d* immediately prior to the start of the window (t_{-31}), assuming that the informed trader takes a long position. When the difference is negative, the adjustment factor adopts the value minus one to reflect a short position of an informed trader. In case both prices are the same the adjustment factor is zero (see Figure 1).

contribution. The result is significant at the 5% cut-off level. Quite surprisingly, in the post-event window, the 10-minute period instantly after the publication of the fixing results (t_0 to t_{+9}) does not significantly contribute to the Brent futures price discovery. If the daily Dated Brent price announcement conveys new information to the market that has not yet been incorporated into the futures price, we would expect a noticeable market reaction after 16:30. The results in Panel B present the average price contribution per trade during the window of investigation and support the hypothesis of informed trading prior to the Dated Brent fixing end. Again, with a value of 368%, the 10-minute period prior to the announcement is significantly different from zero at the 5% cut-off level. These findings strongly support the preceding results obtained in previous sections of this paper.

INSERT FIGURE 4 ABOUT HERE

The results for the adjusted order imbalance by number of trades (*AOIB#*) and the adjusted order imbalance dollar value (*AOIB$*) are presented in Table 6. The adjusted OIB facilitates the identification of trading behavior based on the foreknowledge of the Dated Brent fixing direction, as the measures always adopt positive values if the majority of transactions in interval *t* have been aligned with the direction of the upcoming daily Platts price publication. Thus the *AOIB#* and *AOIB$* take a value greater than zero if market participants 'trade in the right direction' during the half hourly assessment period prior to the daily Dated Brent price announcement. A continuous positive non-zero value of the OIB measures would indicate front-running in the ICE Brent Crude futures based on foreknowledge of the daily Dated Brent fixing direction. The $\overline{AOIB\#_t}$ and $\overline{AOIB\$_t}$ describe the values for interval *t* averaged across all trading days *D*. Significance is

established via a one sample t-test on $\overline{AOIB\#_t} = 0$ and $\overline{AOIB\$_t} = 0$. For reasons of space, we only report a 41-minute sub-window (t_{-35} = 15:55 to t_{+5} = 16:35) of the full 120-minute window of investigation in Table 6, covering 5 minutes before the fixing start and 5 minutes after the price publication, which does not result in a loss of information. Figure 4 illustrates the development of the three metrics over the full window of investigation.

Overall, at first glance, the results of this additional analysis largely mirror our earlier adjusted return findings in Table 3, and support our aforementioned line of reasoning. The $\overline{AOIB\#_t}$ and $\overline{AOIB\$_t}$ values, in Panel A and Panel B of Table 6 respectively, are typically statistically insignificant for intervals outside of the event window but show significant positive non-zero values during the 30-minute Dated Brent price fixing by Platts. These findings are also depicted in Figure 4, suggesting that ICE Brent Crude futures participants, on average, trade in the right direction ahead of the Dated Brent price announcement; i.e. they front-run the assessment end by taking fixing direction-aligned futures positions well in advance. With an average value of 3.44% at t_{-6} for the OIB by number of trades and 4.48% at t_{-11} for the OIB dollar value, trades in the right direction outweigh trades in the wrong direction by several percentage points at their peak. In general, the abnormal order imbalances gradually increase from 16:05 (1.99%) to 16:20 (3.11%), followed by 3 minutes of balanced market activity (16:21 to 16:23) and then surge again during the final minutes of the event window (16:24 to 16:28). The absence of similar trading behavior outside of the event window allows us to reasonably conclude that the adjusted order imbalance evolution from 16:00 to 16:30 is caused by informed market participants trading already in the futures market based on their superior information on the fixing direction. In addition, again confirming earlier findings, immediately after the Dated Brent fixing end $\overline{AOIB\#_t}$ displays a value of -1.84% (t_0, 5% significance level) and -2.81 (t_{+1}, 1% significance level) and $\overline{AOIB\$_t}$ shows a

value of -1.96% (t_0, 10% significance level), indicating an order submission pattern in the opposite direction of the published fixing price. Hence, the pattern provides affirmation for the reversal of positions due to a price overshooting in the run-up of the announcement (cf. Brunnermeier (2005)). This could also be the consequence of the crowding out of informed traders by noise/uninformed traders, as the former reduce their trading activity levels following their earning of abnormal returns at the fixing close. Our conclusion remains the same irrespective of whether we consider the order imbalance by trades or by dollar value.

INSERT TABLE 6 ABOUT HERE

In order to assure that the observed behavior is unique to the 30-minute Platts window, we show in Table 7 that no similar anomaly can be observed ex ante or ex post of the event window. We also replicate our analysis using 5-minute and 10-minute batches. In Section A, the values of $\overline{AOIB\#_t}$ and $\overline{AOIB\$_t}$ are continuously positive and significant at the 1% or 5% level, for each 5-minute period during the 30-minute assessment window. Apart from this, only two batches outside of the event window are significantly different from zero (t_{-60} to t_{-56} and t_{+50} to t_{+54}). In Section B, the pooling of AOIB into 10-minute batches allows for even clearer conclusions with solely the periods between 16:00 and 16:30, in Panel A and Panel B, displaying positive non-zero values at the 1% significance level.

INSERT TABLE 7 ABOUT HERE

Along with the return measures and the price contribution test results, these findings support our second proposition, namely the anticipation hypothesis that informed investors (e.g. physical oil market participants), with private information on the fixing progression and thus some foreknowledge on the upcoming price direction, 'trade the trend' in the ICE Brent Crude futures instantly after the fixing start and prior to the Dated Brent fixing end. Thereby, by front-running the market at large, they are able to realize abnormal profits in the Brent futures market over the 30-minute benchmark assessment window prior to the price publication by Platts.

E Multivariate Regression Analysis

We now move to identify differences in trading behavior around the time of the Dated Brent price publication by Platts within a multivariate framework, and also to test for the consistency of our findings across several scenarios. In order to better determine varying trading behavior around the benchmark publication, we first divide the total window of investigation [15:30,17:29] into four sub-periods: the estimation window [15:30,15:59], the event window [16:00,16:29], the publication time [16:30] and the post-event window [16:31,17:29]. Secondly, we run two sets of regressions on the intervals of each period individually. The first set uses adjusted returns of the Brent futures as the dependent variable, and the second set uses the adjusted order imbalances. We define seven independent control variables to assure consistency and determine divergences in the trading behavior in the futures market ex ante, during and ex post of the Dated Brent price fixing. Both sets of regression models are as outlined in Equations 20 and 21 below:

$$AR_{t,d} = \alpha + \beta_{SUR}SUR_{t,d} + \beta_{SENT}SENT_{t,d} + \beta_{SUR*SENT}SUR * SENT_{t,d} + \beta_{SCAN}SCAN_{t,d} + \beta_{POSTSCAN}POSTSCAN_{t,d} + \beta_{EXP}EXP_{t,d} + \beta_{EIA}EIA_{t,d} + \varepsilon_{t,d} \quad (20)$$

$$AOIB\#(\$)_{t,d} = \alpha + \beta_{SUR}SUR_{t,d} + \beta_{SENT}SENT_{t,d} + \beta_{SUR*SENT}SUR * SENT_{t,d} + \beta_{SCAN}SCAN_{t,d} + \beta_{POSTSCAN}POSTSCAN_{t,d} + \beta_{EXP}EXP_{t,d} + \beta_{EIA}EIA_{t,d} + \varepsilon_{t,d} \quad (21)$$

The *SUR* indicator is designed to capture differences in the futures market on days with surprise Dated Brent price announcements, and adopts the value one accordingly and zero otherwise. A surprise announcement is defined as a daily difference belonging to the top 9th or bottom 1st decile of all differences between the published Dated Brent price and the pre-event window spot price. The sentiment indicator (*SENT*) adopts the value one on days with a positive fixing direction, and zero on days with no change or a negative fixing direction[18]. The sample contains 442 positive fixing days, 471 negative fixing days and 8 flat days. The *SUR*SENT* dummy variable distinguishes positive surprise days (*SUR* = 1 and *SENT* = 1) from negative surprise days (*SUR* = 1 and *SENT* = 0) and average days (*SUR* = 0 and *SENT* = 1 or 0). The scandal dummy (*SCAN*) adopts the value zero, but the value one for the period from 14th May 2013 to 30th November 2013, at the beginning of which the European Commission and the EFTA Surveillance Authority conducted unanticipated searches of the offices of several crude oil market participants on suspicion of collusion and price distortion during the Dated Brent benchmark assessment process operated by Platts. After 30th November 2013, the news coverage about these supposedly illegal practices and manipulation of the Dated Brent benchmark died down. The *POSTSCAN* indicator simply accounts for the period after the controversy surrounding the Dated Brent benchmark assessment became public, and takes the value one after the 30th November 2013 and

[18] The fixing direction on day *d* is positive when the published Platts Dated Brent price (t_0) on day *d* is higher than the price of the crude oil spot on *d* immediately prior to the start of the window (t_{-31}), assuming that the informed trader takes a long position. When the difference is negative, the adjustment factor adopts the value minus one to reflect a short position of an informed trader. If both prices are the same, the adjustment factor is zero (see Figure 1).

zero otherwise. The post-scandal dummy controls for a potential weakening of anticipatory trading behavior in the futures market after the questionable practices were uncovered. The *EXP* dummy adopts the value one on ICE Brent Crude futures expiry days and zero otherwise. Finally, the *EIA* indicator adopts the value one on days on which the U.S. Energy Information Administration (EIA) releases its 'Weekly Petroleum Status Report' and zero otherwise. The EIA dummy variable is included to identify whether the anticipatory trading behavior is more pronounced on days when other market-sensitive news items are released.

INSERT TABLE 8 ABOUT HERE

Results of the regression of adjusted returns on the control variables (Equation 20) are reported in Table 8. The period of highest interest is the 30-minute Platts assessment window (Panel B). The findings indicate that, during the event window, the interval-by-interval adjusted returns on surprise Dated Brent announcement days are on average 1.04% higher than for non-surprise announcements (1% significance level). This is not surprising, considering that the profit potential of early-informed traders front-running the market is substantially higher on surprise announcement days (cf. Irvine et al. (2007), Bernile et al. (2015)). Panel A of Figure 5 shows that surprise Dated Brent price announcements more than double the daily potential gain to an average of nearly 45 bps over the 30-minute assessment window, compared to an average of roughly 21 bps for all sample days. Additionally, the *SENT* dummy variable shows that the adjusted futures returns on days with a positive Dated Brent fixing direction behave differently from days with no change or a negative fixing direction. On average, interval-by-interval adjusted returns on days with a positive fixing direction are 0.39% lower at the 1% level, compared to no change/negative

fixing days. This is consistent with the general acceptance of a stronger market reaction to negative news (Michaelides et al. (2015)). The cumulative adjusted returns in Panel B of Figure 5 show that the profit potential on negative sentiment days is approximately 26 bps and only 16 bps on positive sentiment days. Furthermore, in the post-event window (Panel D, Table 8) negative fixing days are characterized by a more pronounced and lasting price reversal in the order of magnitude of several bps, whereas positive fixing days experience a marked and continuous post-announcement drift in excess of 5 bps (compare CAR for positive and negative announcements in Panel B of Figure 5). The noticeable post-announcement drift on positive fixing days is also reflected in the positive and significant (0.16% at the 1% level) sentiment measure (SENT) in the post-event window. According to Daniel et al. (1998) and Vega (2006), this contrast indicates that negative fixings carry more private information (smaller drift and larger reversal) than positive fixings (larger drift and smaller reversal).

INSERT FIGURE 5 ABOUT HERE

For robustness, we also control for the effects of certain time periods or sets of days on our findings. For the event window, we speculated that anticipatory trading behavior during the period of the publication of the Dated Brent controversy (*SCAN*) would be somewhat less pronounced, possibly due to the primary beneficiaries of front-running keeping a low profile. Nonetheless, we are unable to find any significant evidence suggesting that public attention notably changes trading behavior during the window of investigation. Interestingly, after the media attention on the Dated Brent assessment procedure by Platts lessened, from December 2013 onwards (*POSTSCAN*), the front-running of the Dated Brent announcement in the ICE Brent Crude futures market appears to

have intensified. During the Platts assessment window (Panel B, Table 8), the daily average interval-by-interval adjusted returns are 0.39% higher (1% significance level).

The *EXP* dummy and the *EIA* dummy are not significantly different from zero. Hence, the profitability of anticipatory trading from 16:00 to 16:30 is not affected by this specific set of days, during which other factors have most likely influenced the price development of the ICE Brent Crude futures as well. Interestingly, on expiry days (*EXP*), the average adjusted return of the Brent futures at the time of publication (Panel C) of the Dated Brent price (t_0 = 16:30) is 2.43% higher (10% significance level) compared to normal trading days. Crucially, however, apart from this, our control variables indicate that the majority of the developments take place during the Platts price fixing, well in advance of the actual Dated Brent price publication, and hardly any development can be observed at the time of the official release.

INSERT TABLE 9 ABOUT HERE

The results from regressing the adjusted order imbalance measures on the control variables (Equation 21) are presented in Table 9. We replicate the regression analysis using both the adjusted order imbalance by number of trades (*AOIB#*) and the adjusted order imbalance dollar value (*AOIB$*), and do so for each of the four sub-periods individually. The latter order imbalance measure encapsulates the economic significance of the imbalances in the order flow. The results obtained largely confirm our findings from the adjusted return regressions. The surprise indicator and the sentiment indicator are both significant at the 1% cut-off level during the Dated Brent price fixing (Table 9, Panel B). Both the interval-by-interval *AOIB#* and *AOIB$* are on average about 3% higher on surprise announcement days (cf. Bernile et al. (2015)). Figure 4 already shows that

ICE Brent Crude futures participants, on average, trade in the direction of the Dated Brent fixing during the 30-minute pre-publication window (16:00 to 16:30). The *SUR* coefficient now indicates that on surprise announcement days, Brent futures traders are even more likely to trade in the right direction during the event window (Panel A, Figure 6); that is, the ratio of fixing direction-initiated transactions minus opposite direction-initiated transactions over total transaction is even more imbalanced.

Furthermore, linking to the concept of overreaction to bad news, on positive sentiment days both interval-by-interval adjusted order imbalances during the Dated Brent fixing window are, on average, approximately 18-20% lower than on negative sentiment days (Table 9, Panel B). Hence, upon inversion of the argument, the fixing-direction aligned abnormal order imbalance is, on average, roughly 20% higher on days with a negative Dated Brent fixing direction (Panel B, Figure 6). Even on positive surprise announcements days (*SUR*SENT*), the minute-by-minute *AOIB#* is significantly lower (-2.71% at 1% significance level) compared to other trading days. Strangely enough, whereas we expected positive adjusted order imbalances, the *AOIB#* and *AOIB$* are negative on days with a positive fixing direction, even throughout the event window (Panel B, Figure 6). We attribute the fact that the AOIB measures are continuously negative on positive fixing days to the fact that our full sample period (9th January 2012 to 24th September 2015) does not cover a bullish oil market, and is characterized by a steady sideways movement and a later, unchecked, plunge in oil prices. On this basis it is reasonable that, averaged across all trading days *D*, seller-initiated transactions outweigh buyer-initiated transactions, perhaps even on days with a positive fixing direction. The aforementioned line of reasoning is also supported by the overbalance of negative fixing days (471 vs. 442) and seller-initiated transactions (55.66% vs. 44.34%). For example, even on fixing days with a positive price trend, the majority of market

participants could use the opportunity of climbing futures prices to unwind their positions at a more favorable price. However, this shortcoming is partly accounted for by the previously discussed adjusted return measure, which sufficiently indicates that front-running exists for both positive and negative Dated Brent fixing directions (see Panel B, Figure 5). Furthermore, the difference in returns measure also cancels out the effects of bull or bear markets by subtracting the unadjusted returns from the adjusted returns and thus provides a picture, which is unbiased by the long-term market trend.

INSERT FIGURE 6 ABOUT HERE

Other time periods or sets of days that we control for also fail to yield any statistically significant estimates. For example, we do not find evidence that the period of controversy concerning the Dated Brent assessment procedure by Platts (14th May 2013 to 30th November 2013) had an altering impact on the ICE Brent futures trading during the event window. However, the period after the media attention died down seems to be characterized by slightly higher *AOIB#* (0.78% at the 10% significance level) and *AOIB$* (1.27% at the 5% significance level). Differing from our earlier results, the expiry days seem to have implications on the Brent futures market during the event window, with the order asymmetry being more than 2% larger compared to normal trading days (5% and 10% significance level for the *AOIB#* and *AOIB$* respectively). This positive order overbalance seems to be corrected for during the post-event window (see Panel D, Table 9), immediately after the publication of the Dated Brent price, as shown by a negative *EXP* coefficient (-3.07% for *AOIB#* and -3.70 for *AOIB$* at the 1% cut-off level). The EIA 'Weekly

Petroleum Status Report' also does not appear to influence the futures trading during the Platts window.

The sentiment dichotomy of the order imbalance measures can be observed throughout the four sub-periods of the window of investigation, including the publication time (see Panel C, Table 9) and is significantly different from zero at the 1% level. Apart from this, hardly any development can be observed at the time of publication. The Brent futures market reaction seems to have mainly occurred during the 30-minute benchmark assessment ahead of the actual Dated Brent release.

IV Conclusion

This paper is the first to scrutinize the observed behavior of Brent futures around the Dated Brent assessment operated by the price reporting agency Platts, at a time when the regulatory status of commodity benchmarks shifts back into focus with the proposed *EU Benchmark Regulation* increasingly taking shape. Our results are consistent with information leakage and anticipatory trading in the crude oil futures market ahead of the daily Dated Brent price announcement.

Our dataset consists of about four years of daily Dated Brent prices assessed by the price reporting agency Platts and intraday ICE Brent Crude futures data. We provide the first set of evidence suggesting information leakage through informed anticipatory trading in the Brent futures market during the Dated Brent price fixing from 16:00 to 16:30 London time. We find significantly enhanced trading activity, as measured by trading volume, trade size and price volatility, in the ICE Brent futures immediately after the start and prior to the end of the physical oil benchmark assessment. Informed futures traders are able to realize statistically significant average abnormal returns, amounting to 27 bps in excess of uninformed traders, during the 30-minute Platts assessment window. The marked price run-up in the ICE Brent Crude futures begins

instantly after the fixing start and precedes the fixing end at 16:30. Immediately after the Dated Brent publication, the Brent futures contracts experience a price reversal, possibly correcting an earlier price overshooting. There is no abrupt response by the futures market to the supposedly new information received with the publication of the Dated Brent fixing results. The findings are thus consistent with our leakage hypothesis.

Additionally, a second set of measures, based on the concept of order imbalances, produces significant evidence of informed trading and thereby supports our anticipation hypothesis. The adjusted order imbalance measures show that ahead of the Dated Brent price announcement, fixing direction-aligned Brent futures positions significantly outweigh positions in the opposite direction, a strong indicator of informed trading. In other words, during the 30-minute fixing window ICE Brent Crude futures traders, on average, anticipate the right direction and front-run the Dated Brent assessment end in order to exploit abnormal profit opportunities. A significant adjusted order asymmetry is not identified in the pre-assessment period, nor at the time of publication or in the post-publication period. The results allow us to reasonably assert that the abnormal order pattern in the Brent futures, from 16:00 to 16:30, is caused by the trading activities of early-informed market participants based on their superior information on the Dated Brent fixing evolution.

Lastly, we show that informed anticipatory trading during the 30-minute Platts assessment window is more pronounced for surprise Dated Brent price fixings, which is not surprising considering the greater profit potential. Moreover, front-running in the ICE Brent Crude futures is more intense ahead of negative Dated Brent fixings relative to positive Dated Brent fixings, possibly due to an overreaction to negative news or higher private information content. This would also explain the marked and enduring price reversal after the publication on negative fixing days. The described effects are consistent across adjusted return and order imbalance measures.

Decisively, all results from the univariate and multivariate analyses overwhelmingly indicate that the Brent futures market mainly reacts when the Platts price fixing is still fully in progress, and hardly any development could be observed at the time of the official Dated Brent price release. The incorporation of the private information from the Dated Brent fixing into the Brent futures price appears to precede the official Platts publication. The daily 30-minute Platts window presents an important profit opportunity for informed market participants who are able to forecast the direction of the Dated Brent price announcement. Presumably, informed traders such as Dated Brent fixing members, with private information on the fixing process, participate in the ICE Brent Crude futures market and front-run Platts' Dated Brent fixing end.

On a controversial note, as demonstrated by numerous studies in the energy finance literature, oil futures incorporate expectations in their prices and therefore often lead reactions in the underlying spot instrument in advance of the actual developments (see Schwarz and Szakmary (1994), Silvapulle and Moosa (1999), Elder et al. (2014), Inci and Seyhun (2014), Liu et al. (2015)). It may therefore be speculated that the heightened activity in the ICE Brent Crude futures, instantly after the fixing start by Platts is a normal reaction, caused by the fact that the futures contracts are the primary source of price discovery, as opposed to an abnormal reaction indicating information leakage during the fixing process. Adding to this, Brent futures prices are easily observable by traders nearly 24/7, whereas the Platts Dated Brent is difficult to monitor and is largely assessed once a day during a 30-minute window. Thus it may be sensible to assume that the futures already incorporate all available information. This issue of interpretation has also been raised by Caminschi and Heaney (2014), who question whether the 'leakage interpretation' or 'market push interpretation' is more probable; i.e. does the on-exchange futures trading of fixing members ahead of the fixing result announcement leak information, or are the public markets

pushing derivative prices during the fixing process in order to influence the fixing outcome? While there is certainly a bi-directional relationship between the financial and physical market with a changing lead-lag price discovery pattern, based on the findings of this event study we judge the leakage interpretation to be more plausible. An inspection of Platts' assessment process and an investigation of the Dated Brent fixing components reveals that all three assessment variables are traded OTC, determined only by the actions of a few participants in an overall opaque and illiquid physical crude oil market. After all, the existence and importance of Platts as a price reporting agency originates from the fact that the physical market activities are difficult to monitor by the general market.

Certainly, price reporting agencies such as Platts play a fundamental role in fostering transparency and bring many benefits to the global energy markets. Platts started off as a market observer and its journalists made calls to cash oil participants to get a feel for the physical market price at the end of the trading day, and subsequently published the daily price at market close. However, Platts gradually developed from a simple information provider into a benchmark administrator, the products of which are nowadays of international importance, but still operates outside regulatory supervision to the present day. The industry leadership and market power enables Platts to grant participation in the Dated Brent fixing process to selected fixing members, and subsequently only supplies oil market intelligence to clients against payment of a substantial fee. The efficient market hypothesis suggests that, in a perfect world, security prices will at all times reflect the entire available information (see Fama (1970)) and thus each investor should obtain information instantly and at the same time (see Hirshleifer et al. (1994), Brunnermeier (2005)). However, the nature of the international oil market, with its division between the paper and cash dimensions, an integral part of which is the daily Dated Brent assessment by Platts,

creates a lasting information imbalance between oil market participants, who are active simultaneously in both the physical oil market and the financial oil market, and those who only operate in the latter. This division manifests itself most distinctively during the Dated Brent assessment. The consequences for the latter 'uninformed' traders could be economically significant; this scenario could be compared to the practice of tipping preferred clients ahead of analyst recommendations (see Irvine et al. (2007), Christophe et al. (2010)) or pre-releasing macroeconomic decisions to selected press representatives, even under lockup conditions (see Bernile et al. (2015)). The current benchmark architecture gives an unfair advantage to market actors that participate in the Platts fixing or pay for information on the fixing progression. Platts' Dated Brent assessment has far reaching consequences, penetrating every layer of the crude oil market, driving not only the pricing of cash oil but also of paper oil. Our findings have structural financial policy implications, emphasizing the influence of unregulated physical commodity price benchmarks on regulated exchange-traded financial products.

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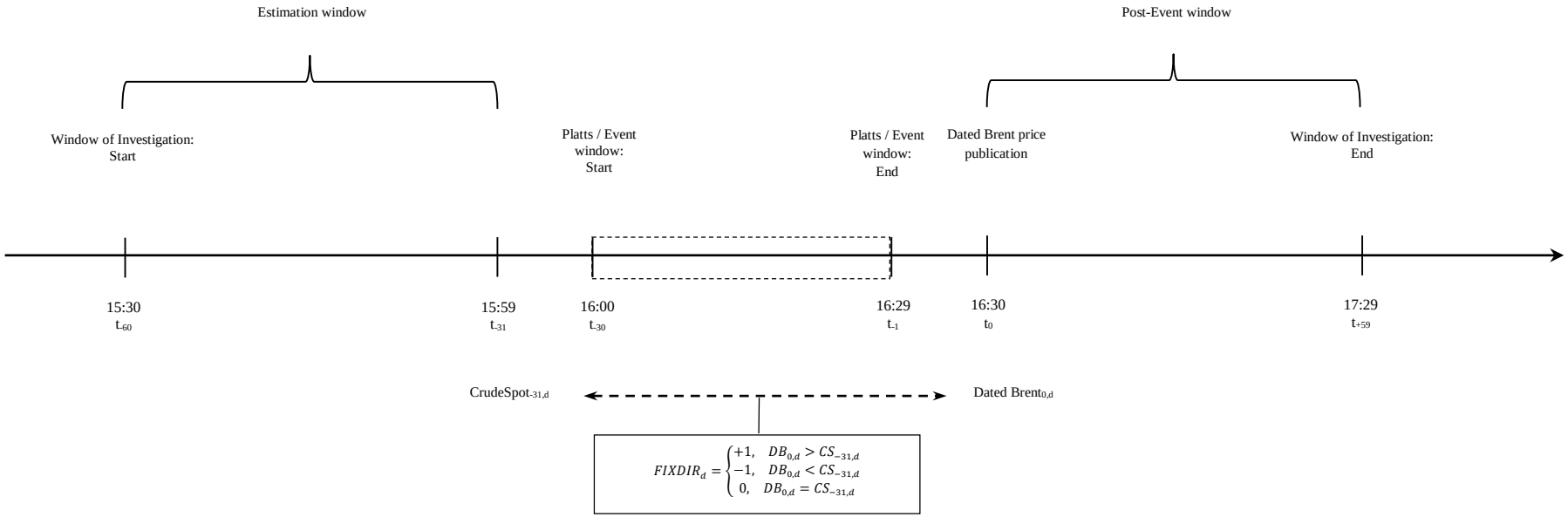
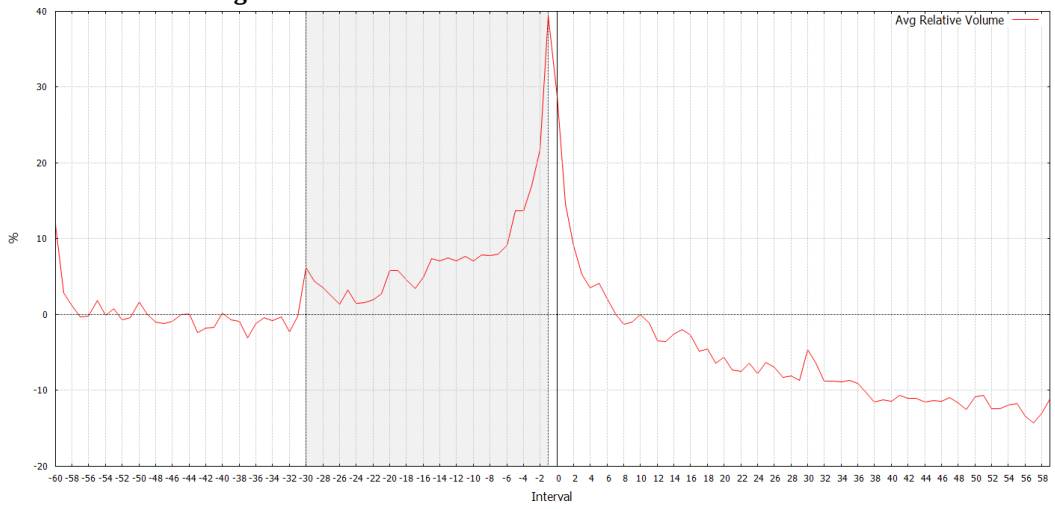
Figure 1: Window of Investigation



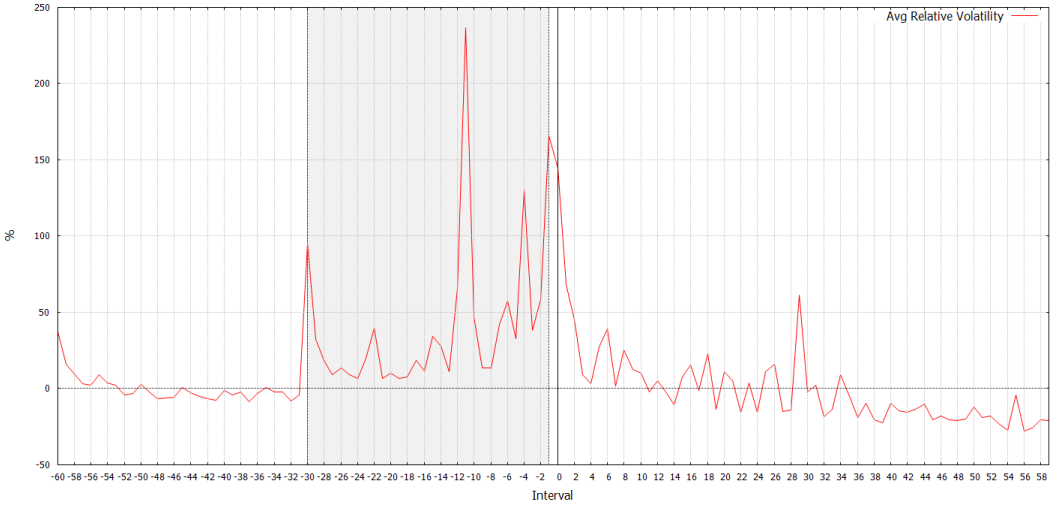
Notes: This figure illustrates the event study design applied to analyze trading behavior surrounding the Platts Dated Brent price publication. Timestamps represent interval start times. The estimation window covers interval t_{-60} to t_{-31} [15:30:00,15:59:59]. The event window covers t_{-30} to t_{-1} [16:00:00,16:29:59]. The publication interval t_0 covers [16:30:00,16:30:59]. The post-event window includes the publication time and covers t_0 to t_{+59} [16:30:00,17:29:59].

Figure 2: Average Trading Activity in ICE Brent Crude Futures

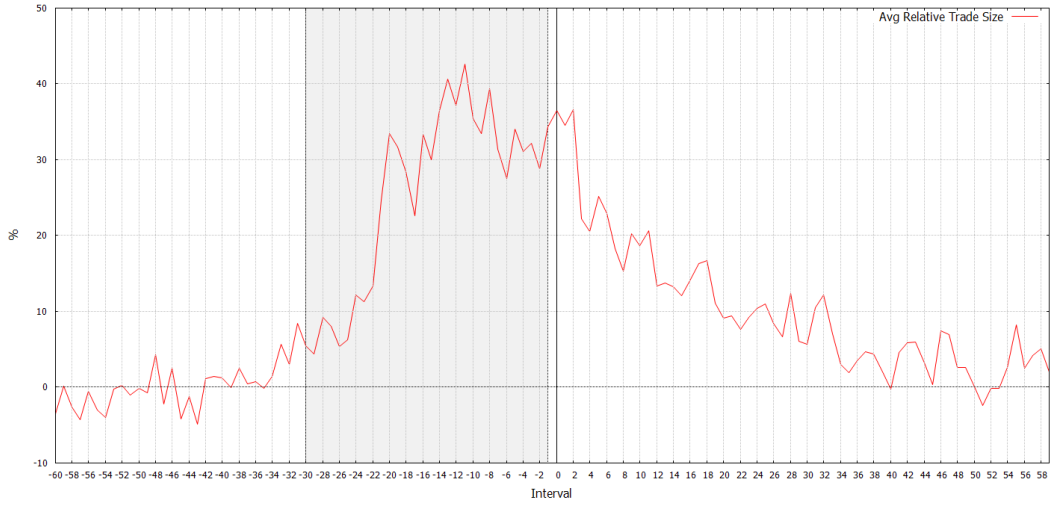
Panel A: Average Relative Volume



Panel B: Average Relative Volatility



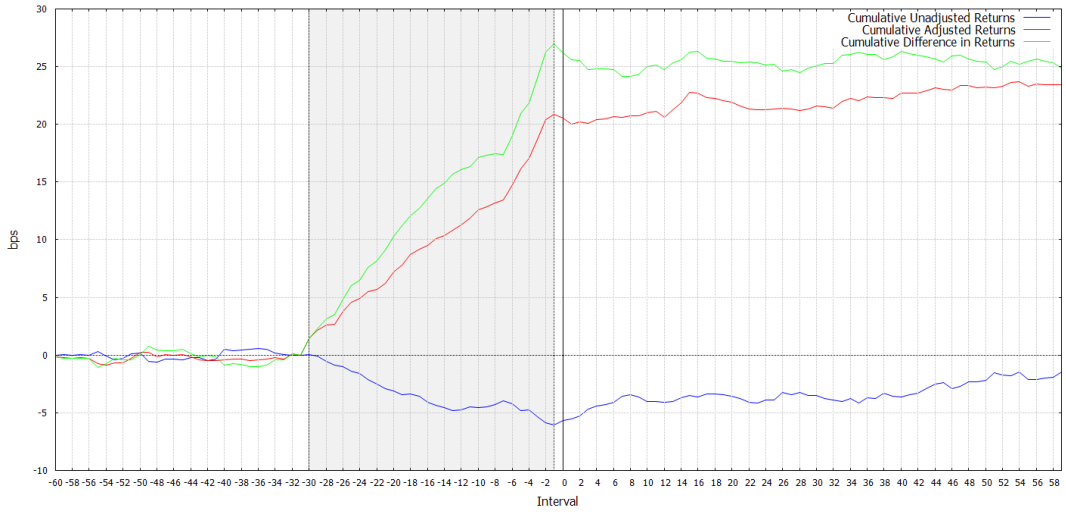
Panel C: Average Trade Size



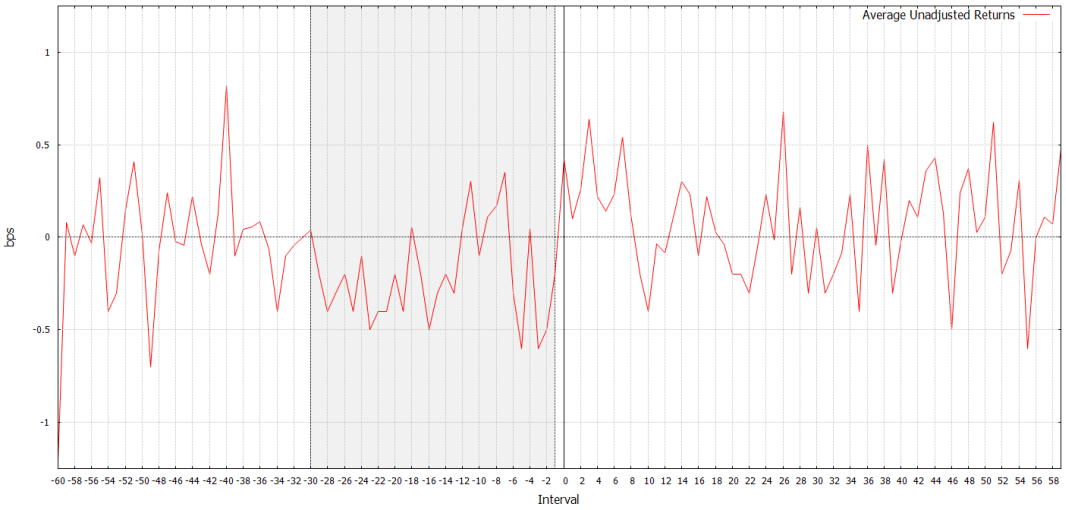
Notes: Panels A, B and C show the average relative volume, volatility and trade size respectively. All measures are reported in percentage terms (%). The shaded area indicates the event window from fixing start (t_{-30}) to fixing end (t_{-1}) [16:00:00,16:29:59]. The vertical black line marks the Platts Dated Brent publication interval t_0 [16:30:00,16:30:59].

Figure 3: Cumulative Returns for ICE Brent Crude Futures

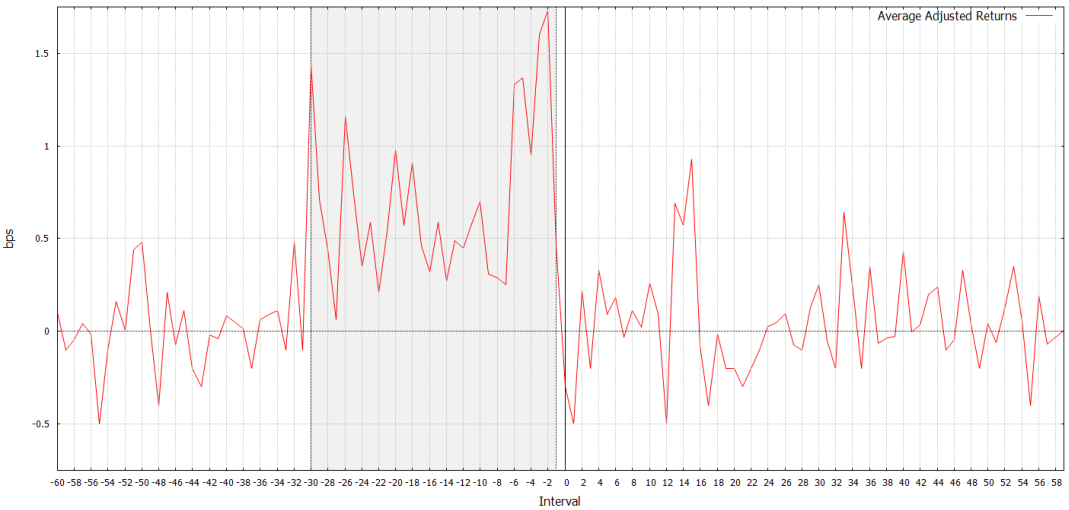
Panel A: Cumulative Returns



Panel B: Average Unadjusted Returns



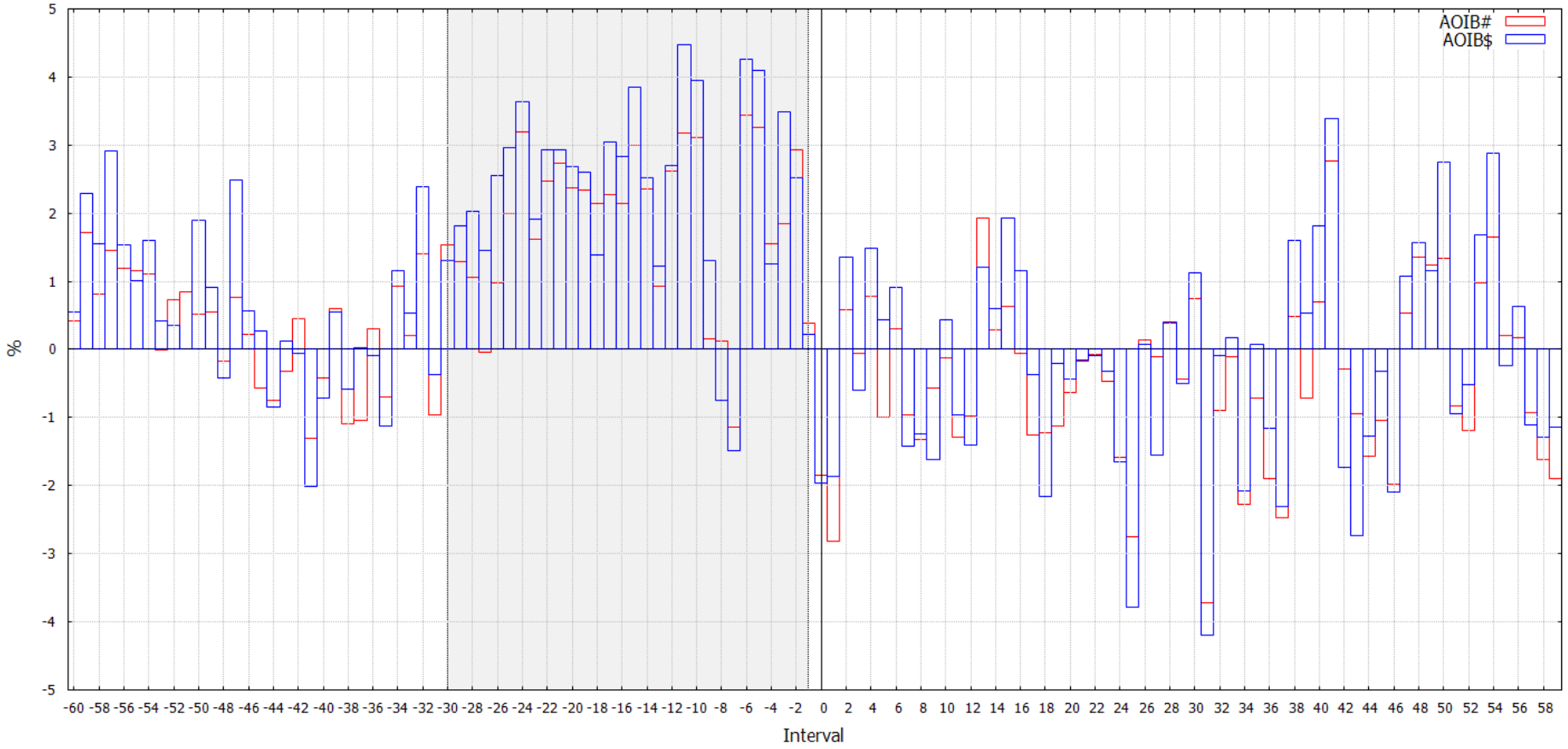
Panel C: Average Adjusted Returns



Notes: Panels A, B and C show cumulative adjusted return measures, average unadjusted returns and average adjusted returns respectively. All return measures are multiplied by 10,000 and reported in bps (1 bps = 0.01%). The shaded area indicates the event window from fixing start (t_{-30}) to fixing end (t_{-1}) [16:00:00,16:29:59]. The vertical black line marks the Platts Dated Brent publication interval t_0 [16:30:00,16:30:59].

Figure 4: Adjusted Order Imbalance for ICE Brent Crude Futures

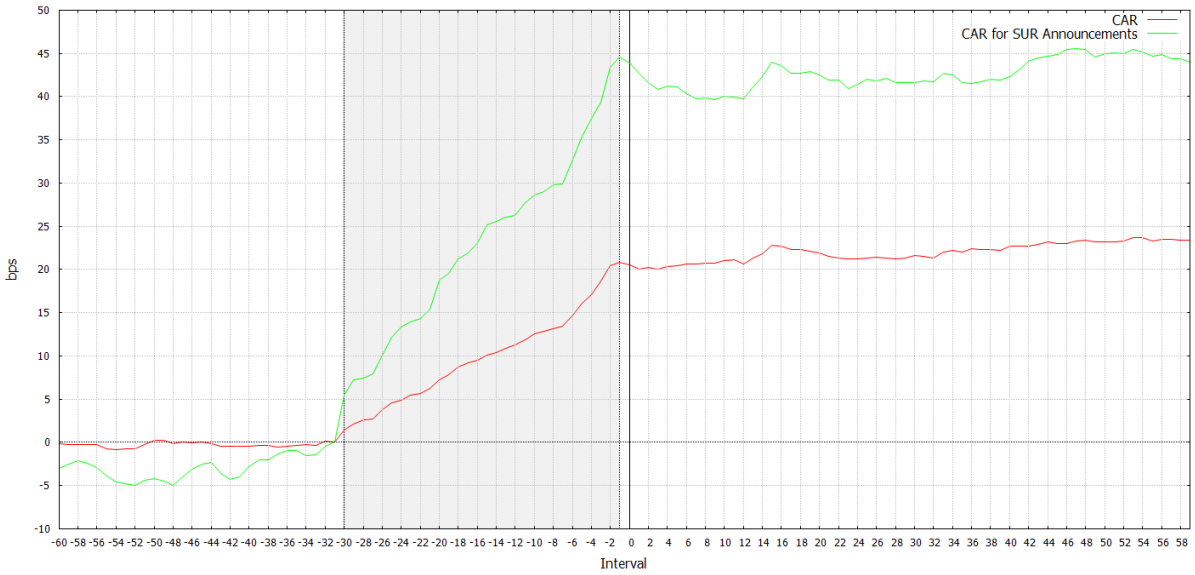
Adjusted Order Imbalance by Number of Trades (*AOIB#*) and by Dollar Value (*AOIB$*)



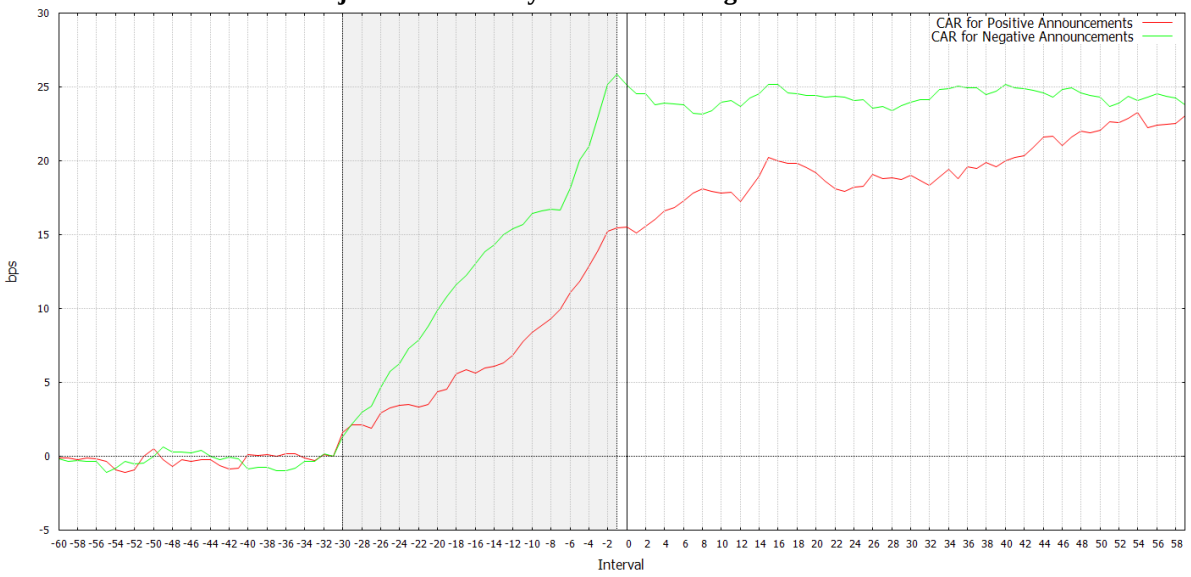
Notes: Panel A shows the average adjusted order imbalance by number of trades (*AOIB#*) and the average adjusted order imbalance dollar value (*AOIB$*). All measures are reported in percentage terms (%). The shaded area indicates the event window from fixing start (t_{-30}) to fixing end (t_{-1}) [16:00:00,16:29:59]. The vertical black line marks the Platts Dated Brent publication interval t_0 [16:30:00,16:30:59].

Figure 5: Conditional Cumulative Adjusted Returns

Panel A: Cumulative Adjusted Returns for Surprise Announcements



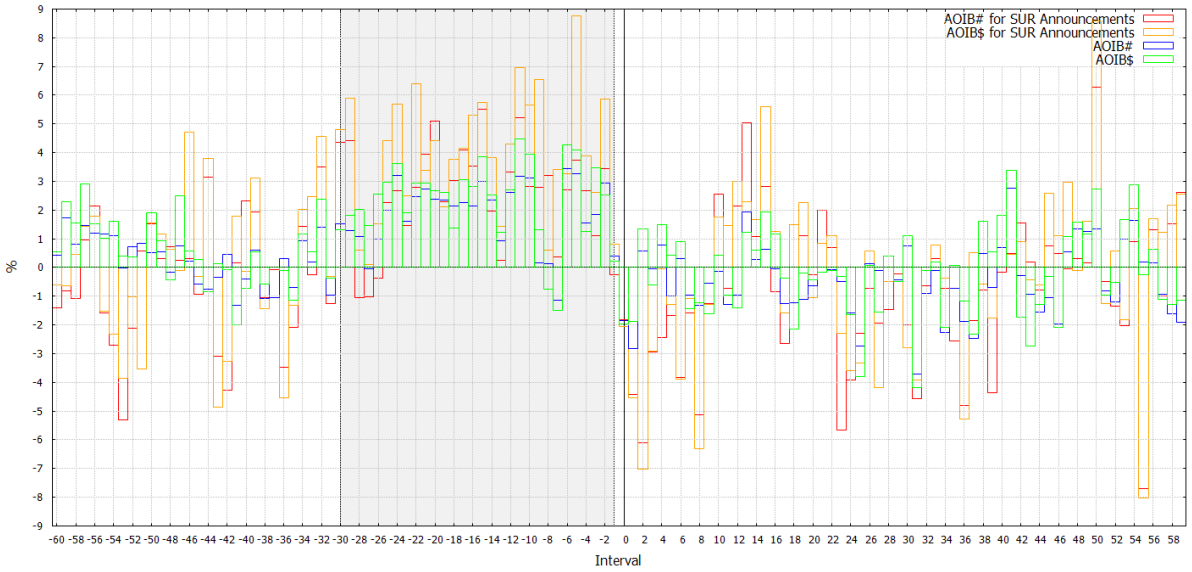
Panel B: Cumulative Adjusted Returns by Positive and Negative Announcements



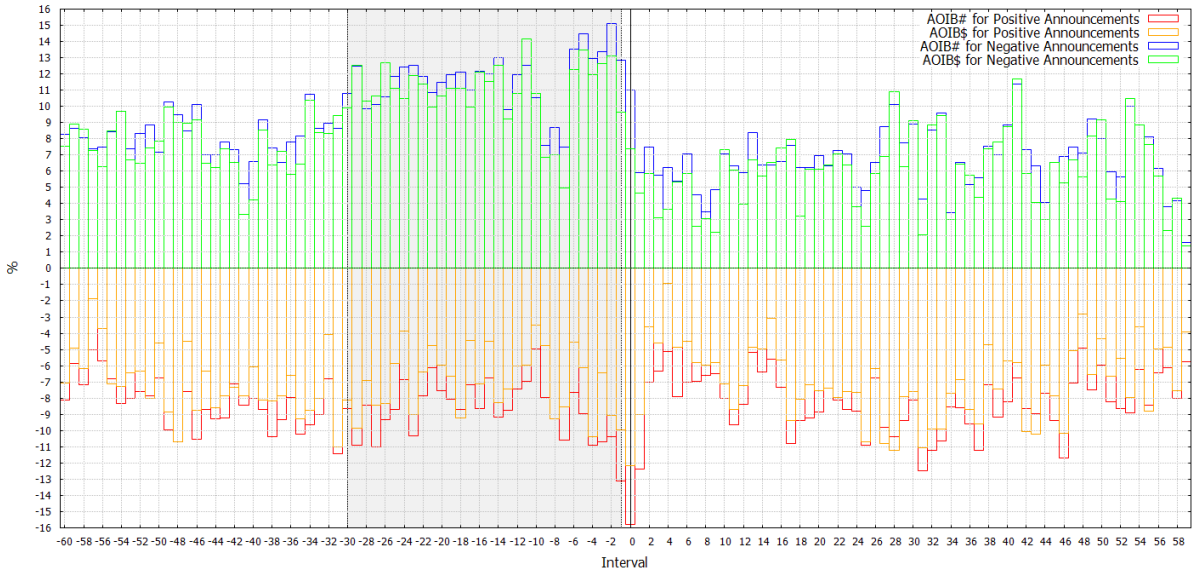
Notes: Panel A shows cumulative adjusted returns for days with surprise Dated Brent announcements (*SUR* = 1 vs. *SUR* = 0) versus all announcement days. Panel B contrasts cumulative adjusted returns on days with a positive sentiment (*SENT* = 1) with days with a negative or neutral sentiment (*SENT* = 0 or -1). All return measures are multiplied by 10,000 and reported in bps (1 bps = 0.01%). The shaded area indicates the event window from fixing start (t_{-30}) to fixing end (t_{-1}) [16:00:00,16:29:59]. The vertical black line marks the Platts Dated Brent publication interval t_0 [16:30:00,16:30:59].

Figure 6: Conditional Adjusted Order Imbalance Measures

Panel A: *AOIB#* and *AOIB$* for Surprise Announcements



Panel B: *AOIB#* and *AOIB$* by Positive and Negative Announcements



Notes: Panel A shows average *AOIB#* and average *AOIB$* for days with surprise Dated Brent announcements (*SUR* = 1 vs. *SUR* = 0) versus all announcement days. Panel B contrasts average *AOIB#* and average *AOIB$* on days with a positive sentiment (*SENT* = 1) with days with a negative or neutral sentiment (*SENT* = 0 or -1). All measures are reported in percentage terms (%). The shaded area indicates the event window from fixing start (t_{-30}) to fixing end (t_{-1}) [16:00:00,16:29:59]. The vertical black line marks the Platts Dated Brent publication interval t_0 [16:30:00,16:30:59].

Table 1: Summary of Sample Data

Description	Time	t_i	Platts Dated Brent	ICE Brent Crude Futures	Brent Crude Oil Spot
Identifier			PCAAS00	LCOc1	BFO-
Source			Direct Acquisition	Thomson Reuters Tick History	Thomson Reuters Tick History
Sample Period			09.01.2012 - 24.09.2015	09.01.2012 - 24.09.2015	09.01.2012 - 24.09.2015
Trade Days			943	1,161	1,354
Trade Days with all required Components			921	921	921
Intvl length			1 min	1 min	1 min
1-minute Intvls per Trade Day			1	120	1
Window of Investigation: # Intvls	[15:30,17:29]	t_{-60} to t_{+59}	120	120	120
Estimation Window: # Intvls	[15:30,15:59]	t_{-60} to t_{-31}	30	30	30
Platts / Event window: # Intvls	[16:00,16:29]	t_{-30} to t_{-1}	30	30	30
Post-Event Window: # Intvls	[16:30,17:29]	t_0 to t_{+59}	60	60	60

Notes: The table summarizes the sample data comprising the Platts Dated Brent, the ICE Brent Crude Futures and the Brent Crude Oil Spot.

Table 2: Average Trading Activity in ICE Brent Crude Futures

		Panel A			Panel B			Panel C		
		Avg Relative Volume			Avg Relative Volatility			Avg Relative Trade Size		
t_i	*Time*	$\overline{VM_t}$	*Sign*	*t-value*	$\overline{V_t}$	*Sign*	*t-value*	$\overline{TS_t}$	*Sign*	*t-value*
-35	*15:55*	-0.16		-0.2	0.59		0.26	-0.15		-0.06
-34	*15:56*	-0.56		-0.69	-2.12		-0.56	1.39		0.59
-33	*15:57*	-0.06		-0.07	-2.07		-0.72	5.67	**	2.43
-32	*15:58*	-2.06	***	-2.76	-8.24	***	-4.64	2.95		1.25
-31	*15:59*	0.11		0.12	-4.25	**	-2.15	8.46	***	3.19
-30	*16:00*	6.61	***	6.06	95.32	*	1.82	5.43	**	2.17
-29	*16:01*	4.85	***	4.96	32.11	***	2.73	4.42	*	1.8
-28	*16:02*	3.86	***	4.36	18.32	*	1.94	9.24	***	3.56
-27	*16:03*	2.73	***	2.75	9.04		1.47	8.02	***	2.81
-26	*16:04*	1.68	*	1.66	13.51	*	1.73	5.33	**	1.98
-25	*16:05*	3.51	***	3.72	8.99	***	2.61	6.26	**	2.32
-24	*16:06*	1.71	*	1.72	6.70		1.47	12.12	***	4.4
-23	*16:07*	1.90		1.56	19.98		1.6	11.29	***	3.85
-22	*16:08*	2.21	**	2.16	39.77		1.44	13.30	***	4.69
-21	*16:09*	2.98	***	2.6	6.47		1.4	24.67	***	7.06
-20	*16:10*	6.00	***	6.16	9.92	***	3.05	33.47	***	9.54
-19	*16:11*	6.06	***	6.1	6.40	**	2.22	31.65	***	8.11
-18	*16:12*	4.90	***	4.97	7.46	**	2.3	28.46	***	8.84
-17	*16:13*	3.68	***	4.08	18.60	*	1.91	22.64	***	7.82
-16	*16:14*	5.21	***	5.17	11.51	*	1.81	33.38	***	9.6
-15	*16:15*	7.70	***	6.9	34.20	*	1.66	30.00	***	9.5
-14	*16:16*	7.27	***	6.76	27.64		1.35	36.47	***	11.32
-13	*16:17*	7.75	***	8.22	10.86	**	2.58	40.62	***	12.44
-12	*16:18*	7.37	***	6.6	65.98		1.23	37.14	***	11.95
-11	*16:19*	7.98	***	6.4	236.59		1.03	42.64	***	12.34
-10	*16:20*	7.38	***	7.02	46.85		1.29	35.38	***	10.96
-9	*16:21*	8.13	***	8.65	13.59	***	3.32	33.43	***	11.16
-8	*16:22*	8.07	***	6.96	13.56	**	2.11	39.33	***	10.92
-7	*16:23*	8.31	***	6.73	42.25	*	1.84	31.34	***	10.02
-6	*16:24*	9.37	***	10.03	57.32		1.56	27.55	***	10.11
-5	*16:25*	14.11	***	14.46	32.78	***	5.46	34.01	***	11.01
-4	*16:26*	14.02	***	14.47	130.50		1.42	31.07	***	11.33
-3	*16:27*	17.40	***	21.11	37.97	***	12.05	32.18	***	11.71
-2	*16:28*	22.19	***	25.45	58.12	***	9.73	28.83	***	10.94
-1	*16:29*	39.89	***	35.62	165.50	***	3.39	34.32	***	17.03
0	*16:30*	29.27	***	24.53	144.38	***	2.59	36.50	***	14.5
+1	*16:31*	14.80	***	13.35	68.17		1.59	34.50	***	14.02
+2	*16:32*	9.28	***	9.28	45.10		1.5	36.56	***	13.15
+3	*16:33*	5.52	***	6.56	8.91	**	2.43	22.25	***	9.04
+4	*16:34*	3.74	***	4.55	3.20		1.13	20.56	***	8.08
+5	*16:35*	4.47	***	4.12	27.45		1.47	25.16	***	8.77

Notes: This table reports the results of the average relative trading activity measures. Panels A, B and C present the results for the average relative volume, the average relative volatility and the average relative trade size respectively. All three measures are reported in percentage terms (%). The t-value is the statistic of a one sample t-test of the mean being equal to zero. *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015. Timestamps represent interval start times. The two single horizontal black lines represent the Platts Dated Brent fixing start and fixing end. The Platts Dated Brent price publication falls in the 0 interval starting at 16:30 London local time.

Table 3: Return Measures for ICE Brent Crude Futures

		Panel A				Panel B					Panel C				
		Avg Unadjusted Returns				Avg Adjusted Returns					Avg Difference in Returns				
t_i	*Time*	$\overline{UR_t}$	*Sign*	*t-value*	CUR_t	$\overline{AR_t}$	*Sign*	*t-value*	*CARt*	*Ratio*	$\overline{DR_t}$	*Sign*	*t-value*	*CDRt*	*Ratio*
-35	*15:55*	-0.06		-0.28	0.51	0.09		0.42	-0.35	-1.46	0.16		0.51	-0.86	-3.19
-34	*15:56*	-0.40	*	-1.69	0.16	0.11		0.54	-0.23	-0.99	0.46		1.44	-0.39	-1.47
-33	*15:57*	-0.10		-0.54	0.05	-0.10		-0.51	-0.34	-1.44	0.01		0.02	-0.39	-1.44
-32	*15:58*	-0.04		-0.2	0.00	0.48	**	2.32	0.13	0.57	0.52	*	1.87	0.13	0.49
-31	*15:59*	0.00		-0.02	0.00	-0.10		-0.61	0.00	0.00	-0.10		-0.43	0.00	0.00
-30	*16:00*	0.04		0.11	0.04	1.44	***	4.26	1.44	6.09	1.40	***	3.1	1.40	5.21
-29	*16:01*	-0.20		-0.58	-0.11	0.71	***	2.73	2.15	9.08	0.86	**	2.5	2.26	8.40
-28	*16:02*	-0.40	*	-1.77	-0.53	0.44	*	1.89	2.59	10.95	0.86	**	2.51	3.13	11.60
-27	*16:03*	-0.30		-1.33	-0.86	0.06		0.25	2.66	11.21	0.39		1.23	3.52	13.06
-26	*16:04*	-0.20		-0.66	-1.03	1.16	***	4.74	3.81	16.10	1.32	***	3.57	4.84	17.97
-25	*16:05*	-0.40	*	-1.69	-1.43	0.74	***	3.13	4.56	19.23	1.15	***	3.55	5.99	22.22
-24	*16:06*	-0.10		-0.66	-1.58	0.35		1.54	4.91	20.71	0.50		1.54	6.49	24.07
-23	*16:07*	-0.50	**	-2.32	-2.10	0.59	***	2.64	5.50	23.20	1.11	***	3.56	7.60	28.20
-22	*16:08*	-0.40	*	-1.7	-2.50	0.21		0.89	5.71	24.08	0.61	*	1.77	8.20	30.45
-21	*16:09*	-0.40	*	-1.86	-2.90	0.54	**	2.54	6.25	26.36	0.94	***	3.14	9.14	33.92
-20	*16:10*	-0.20		-0.75	-3.08	0.98	***	4.07	7.22	30.49	1.16	***	3.29	10.30	38.22
-19	*16:11*	-0.40		-1.63	-3.44	0.57	**	2.55	7.80	32.91	0.94	***	2.95	11.24	41.71
-18	*16:12*	0.06		0.24	-3.39	0.91	***	3.95	8.71	36.74	0.85	***	2.64	12.09	44.88
-17	*16:13*	-0.20		-0.83	-3.58	0.46	**	2.01	9.16	38.67	0.65	**	2.05	12.74	47.28
-16	*16:14*	-0.50	**	-2.2	-4.08	0.32		1.42	9.49	40.04	0.82	**	2.51	13.56	50.33
-15	*16:15*	-0.30		-1.22	-4.37	0.59	**	2.5	10.07	42.52	0.88	***	2.87	14.44	53.59
-14	*16:16*	-0.20		-0.77	-4.53	0.27		1.26	10.35	43.66	0.43		1.46	14.88	55.20
-13	*16:17*	-0.30		-1.37	-4.81	0.49	**	2.44	10.84	45.74	0.77	***	2.65	15.65	58.06
-12	*16:18*	0.05		0.24	-4.76	0.45	**	2.16	11.29	47.65	0.40		1.37	16.05	59.55
-11	*16:19*	0.30		1.28	-4.46	0.58	**	2.52	11.87	50.10	0.28		0.92	16.33	60.60
-10	*16:20*	-0.10		-0.46	-4.57	0.70	***	2.93	12.57	53.03	0.81	**	2.37	17.14	63.59
-9	*16:21*	0.11		0.46	-4.46	0.31		1.34	12.88	54.36	0.21		0.62	17.34	64.36
-8	*16:22*	0.17		0.73	-4.29	0.29		1.28	13.17	55.61	0.13		0.39	17.47	64.82
-7	*16:23*	0.35	*	1.77	-3.94	0.25		1.28	13.43	56.67	-0.10		-0.36	17.37	64.46
-6	*16:24*	-0.30		-1.12	-4.24	1.33	***	5.18	14.76	62.29	1.63	***	4.65	19.00	70.49
-5	*16:25*	-0.60	**	-2.36	-4.83	1.37	***	5.58	16.12	68.05	1.95	***	5.46	20.95	77.74
-4	*16:26*	0.05		0.18	-4.78	0.95	***	3.78	17.08	72.08	0.91	**	2.52	21.86	81.11
-3	*16:27*	-0.60	**	-1.98	-5.34	1.60	***	5.79	18.68	78.83	2.16	***	5.41	24.02	89.11
-2	*16:28*	-0.50		-1.55	-5.85	1.73	***	5.37	20.40	86.11	2.23	***	4.8	26.25	97.40
-1	*16:29*	-0.20		-0.71	-6.09	0.46		1.34	20.86	88.04	0.70		1.53	26.95	100.00
0	*16:30*	0.42		1.54	-5.67	-0.30		-1.23	20.53	86.63	-0.80	*	-1.93	26.19	97.20
+1	*16:31*	0.10		0.48	-5.57	-0.50	**	-2.46	20.00	84.43	-0.60	**	-2.03	25.57	94.88
+2	*16:32*	0.26		1.15	-5.31	0.22		0.96	20.22	85.34	-0.04		-0.14	25.53	94.72
+3	*16:33*	0.64	***	2.63	-4.67	-0.20		-0.68	20.06	84.66	-0.80	**	-2.26	24.72	91.74
+4	*16:34*	0.22		0.94	-4.45	0.33		1.42	20.39	86.05	0.11		0.35	24.84	92.16
+5	*16:35*	0.14		0.65	-4.31	0.09		0.42	20.48	86.43	-0.05		-0.17	24.79	91.97

Notes: This table reports the results of the average return measures. Panels A, B and C present the results for the average unadjusted returns, the average adjusted returns and the average difference in returns respectively. All return measures (normal and cumulative) are multiplied by 10,000 and reported in bps (1 bps = 0.01%). All ratios are expressed in percentage terms (%). The t-value is the statistic of a one sample t-test of the mean being equal to zero. *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015. Timestamps represent interval start times. The two single horizontal black lines represent the Platts Dated Brent fixing start and fixing end. The Platts Dated Brent price publication falls in the 0 interval starting at 16:30 London local time.

Table 4: Average Return Measures by Batches for ICE Brent Crude Futures

Section A				Panel A			Panel B		
5 mins				Avg Adjusted Returns			Avg Difference in Returns		
From (t_i)	*To (t_i)*	*From (Time)*	*To (Time)*	$\overline{AR_t}$	*Sign*	*t-value*	$\overline{DR_t}$	*Sign*	*t-value*
-60	*-56*	*15:30*	*15:34*	-0.02		-0.04	1.16		1.25
-55	*-51*	*15:35*	*15:39*	0.01		0.02	-0.10		-0.16
-50	*-46*	*15:40*	*15:44*	0.22		0.46	0.74		1.1
-45	*-41*	*15:45*	*15:49*	-0.50		-0.96	-0.50		-0.8
-40	*-36*	*15:50*	*15:54*	0.05		0.1	-0.90		-1.32
-35	*-31*	*15:55*	*15:59*	0.44		0.99	1.02		1.64
-30	*-26*	*16:00*	*16:04*	3.81	***	6.98	4.84	***	5.94
-25	*-21*	*16:05*	*16:09*	2.43	***	5.1	4.30	***	6.09
-20	*-16*	*16:10*	*16:14*	3.24	***	6.51	4.42	***	5.92
-15	*-11*	*16:15*	*16:19*	2.38	***	5.35	2.77	***	4.52
-10	*-6*	*16:20*	*16:24*	2.89	***	5.96	2.66	***	3.75
-5	*-1*	*16:25*	*16:29*	6.10	***	9.78	7.95	***	8.31
0	*+4*	*16:30*	*16:34*	-0.50		-0.85	-2.10	***	-2.6
+5	*+9*	*16:35*	*16:39*	0.37		0.76	-0.50		-0.66
+10	*+14*	*16:40*	*16:44*	1.11	**	2.36	1.21	*	1.74
+15	*+19*	*16:45*	*16:49*	0.20		0.48	-0.09		-0.16
+20	*+24*	*16:50*	*16:54*	-0.80	*	-1.83	-0.30		-0.5
+25	*+29*	*16:55*	*16:59*	0.08		0.18	-0.30		-0.45
+30	*+34*	*17:00*	*17:04*	0.91	**	2.17	1.16	*	1.87
+35	*+39*	*17:05*	*17:09*	0.00		0	-0.20		-0.34
+40	*+44*	*17:10*	*17:14*	0.90	**	2.33	-0.20		-0.31
+45	*+49*	*17:15*	*17:19*	0.03		0.08	-0.20		-0.32
+50	*+54*	*17:20*	*17:24*	0.51		1.25	-0.30		-0.52
+55	*+59*	*17:25*	*17:29*	-0.30		-0.72	-0.30		-0.56

Section B				Panel A			Panel B		
10 mins				Avg Adjusted Returns			Avg Difference in Returns		
From (t_i)	*To (t_i)*	*From (Time)*	*To (Time)*	$\overline{AR_t}$	*Sign*	*t-value*	$\overline{DR_t}$	*Sign*	*t-value*
-60	*-51*	*15:30*	*15:39*	-0.02		-0.02	1.03		0.8
-50	*-41*	*15:40*	*15:49*	-0.20		-0.35	0.23		0.25
-40	*-31*	*15:50*	*15:59*	0.49		0.75	0.16		0.19
-30	*-21*	*16:00*	*16:09*	6.25	***	9.05	9.14	***	8.56
-20	*-11*	*16:10*	*16:19*	5.62	***	8.7	7.19	***	7.67
-10	*-1*	*16:20*	*16:29*	8.99	***	11.65	10.60	***	8.92
0	*+9*	*16:30*	*16:39*	-0.10		-0.14	-2.60	**	-2.38
+10	*+19*	*16:40*	*16:49*	1.31	**	2.11	1.12		1.28
+20	*+29*	*16:50*	*16:59*	-0.70		-1.11	-0.60		-0.63
+30	*+39*	*17:00*	*17:09*	0.91	*	1.66	0.97		1.23
+40	*+49*	*17:10*	*17:19*	0.94	*	1.75	-0.40		-0.45
+50	*+59*	*17:20*	*17:29*	0.23		0.44	-0.60		-0.8

Notes: This table reports the results of the average return measures by 5-minute batches (Section A) and 10-minute batches (Section B). Panels A and B present the results for the average adjusted returns and the average difference in returns respectively. All return measures are multiplied by 10,000 and reported in bps (1 bps = 0.01%). The t-value is the statistic of a one sample t-test of the mean being equal to zero. *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015. 'From' and 'To' timestamps represent interval start times. The two single horizontal black lines represent the Platts Dated Brent fixing start and fixing end. The Platts Dated Brent price publication falls in the 0 interval starting at 16:30 London local time.

Table 5: Price Contribution of ICE Brent Crude Futures by Periods

				Panel A			Panel B		
				Avg Price Contribution			Avg Price Contribution per Trade		
From (t_i)	*To (t_i)*	*From (Time)*	*To (Time)*	$\overline{PC_t}$	*Sign*	*t-value*	$\overline{PCT_t}$	*Sign*	*t-value*
-60	*-51*	*15:30*	*15:39*	-1.31		-0.2	-211.31		-0.75
-50	*-41*	*15:40*	*15:49*	10.77	**	2.43	512.43	**	2.32
-40	*-31*	*15:50*	*15:59*	-1.09		-0.27	-9.15		-0.05
-30	*-21*	*16:00*	*16:09*	-4.12		-1.3	-62.70		-0.41
-20	*-11*	*16:10*	*16:19*	-4.69		-1.32	-276.98	*	-1.8
-10	*-1*	*16:20*	*16:29*	15.02	**	2.41	368.00	**	2.52
0	*+9*	*16:30*	*16:39*	-1.32		-0.29	8.11		0.03
+10	*+19*	*16:40*	*16:49*	0.93		0.3	-88.07		-0.38
+20	*+29*	*16:50*	*16:59*	-0.44		-0.16	-85.10		-0.35
+30	*+39*	*17:00*	*17:09*	-0.51		-0.11	-424.87		-0.78
+40	*+49*	*17:10*	*17:19*	-1.75		-0.37	-845.42		-0.9
+50	*+59*	*17:20*	*17:29*	2.94		1.42	765.25		1.29

Notes: This table reports the price contribution by trading period. Panels A and B present the results of the average price contribution and the average price contribution per trade respectively. All measures are expressed in percentage terms (%). The t-value is the statistic of a one sample t-test of the mean being equal to zero. *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015. 'From' and 'To' timestamps represent interval start times. The two single horizontal black lines comprise the Platts Dated Brent fixing start and fixing end. The Platts Dated Brent price publication falls in the period starting at 16:30 London local time.

Table 6: Order Imbalance Measures for ICE Brent Crude Futures

		Panel A			Panel B		
		Avg AOIB#			Avg AOIB$		
t_i	*Time*	$\overline{AOIB\#_t}$	*Sign*	*t-value*	$\overline{AOIB\$_t}$	*Sign*	*t-value*
-35	*15:55*	-0.69		-0.61	-1.13		-0.83
-34	*15:56*	0.92		0.81	1.16		0.87
-33	*15:57*	0.20		0.18	0.53		0.39
-32	*15:58*	1.41		1.24	2.39	*	1.76
-31	*15:59*	-0.97		-0.87	-0.37		-0.26
-30	*16:00*	1.53		1.4	1.31		0.98
-29	*16:01*	1.28		1.14	1.82		1.35
-28	*16:02*	1.06		0.99	2.02		1.53
-27	*16:03*	-0.05		-0.04	1.45		1.08
-26	*16:04*	0.98		0.9	2.55	*	1.92
-25	*16:05*	1.99	*	1.84	2.97	**	2.3
-24	*16:06*	3.20	***	2.9	3.63	***	2.69
-23	*16:07*	1.61		1.4	1.90		1.38
-22	*16:08*	2.47	**	2.1	2.93	**	2.06
-21	*16:09*	2.74	**	2.48	2.93	**	2.09
-20	*16:10*	2.38	**	2.03	2.68	*	1.82
-19	*16:11*	2.34	**	1.96	2.60	*	1.75
-18	*16:12*	2.14	*	1.94	1.38		0.97
-17	*16:13*	2.27	**	2.01	3.04	**	2.16
-16	*16:14*	2.15	*	1.88	2.83	*	1.93
-15	*16:15*	3.00	***	2.65	3.85	***	2.68
-14	*16:16*	2.35	**	2.07	2.52	*	1.75
-13	*16:17*	0.93		0.82	1.22		0.84
-12	*16:18*	2.61	**	2.28	2.71	*	1.86
-11	*16:19*	3.18	***	2.95	4.48	***	3.18
-10	*16:20*	3.11	***	2.83	3.95	***	2.8
-9	*16:21*	0.16		0.15	1.31		0.95
-8	*16:22*	0.12		0.11	-0.75		-0.52
-7	*16:23*	-1.14		-1.05	-1.48		-1.09
-6	*16:24*	3.44	***	3.15	4.27	***	3.14
-5	*16:25*	3.26	***	3.1	4.09	***	3.11
-4	*16:26*	1.55		1.49	1.26		0.95
-3	*16:27*	1.85	*	1.75	3.48	***	2.69
-2	*16:28*	2.93	***	3.02	2.51	**	2.15
-1	*16:29*	0.38		0.47	0.23		0.24
0	*16:30*	-1.84	**	-2.04	-1.96	*	-1.8
+1	*16:31*	-2.81	***	-2.88	-1.86		-1.52
+2	*16:32*	0.58		0.54	1.35		1.02
+3	*16:33*	-0.05		-0.05	-0.60		-0.46
+4	*16:34*	0.79		0.74	1.48		1.11
+5	*16:35*	-1.00		-0.9	0.44		0.32

Notes: This table reports the results of the average adjusted order imbalance (AOIB) measures. Panels A and B present the results for the average order imbalance by number of trades (*AOIB#*) and the average order imbalance dollar value (*AOIB$*) respectively. All OIB measures are expressed in percentage terms (%). The t-value is the statistic of a one sample t-test of the mean being equal to zero. *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015. Timestamps represent interval start times. The two single horizontal black lines represent the Platts Dated Brent fixing start and fixing end. The Platts Dated Brent price publication falls in the 0 interval starting at 16:30 London local time.

Table 7: Order Imbalance Measures by Batches for ICE Brent Crude Futures

Section A				Panel A			Panel B		
5 mins				Avg AOIB#			Avg AOIB$		
From (t_i)	*To (t_i)*	*From (Time)*	*To (Time)*	$\overline{AOIB\#_t}$	*Sign*	*t-value*	$\overline{AOIB\$_t}$	*Sign*	*t-value*
-60	*-56*	*15:30*	*15:34*	1.12		1.54	2.14	**	2.34
-55	*-51*	*15:35*	*15:39*	0.95		1.31	0.74		0.81
-50	*-46*	*15:40*	*15:44*	-0.05		-0.06	1.01		1.07
-45	*-41*	*15:45*	*15:49*	-0.46		-0.61	-0.47		-0.51
-40	*-36*	*15:50*	*15:54*	-0.01		-0.01	0.52		0.55
-35	*-31*	*15:55*	*15:59*	0.07		0.09	0.12		0.13
-30	*-26*	*16:00*	*16:04*	1.68	**	2.34	2.82	***	3.02
-25	*-21*	*16:05*	*16:09*	2.96	***	3.95	3.51	***	3.65
-20	*-16*	*16:10*	*16:14*	2.74	***	3.54	3.26	***	3.18
-15	*-11*	*16:15*	*16:19*	2.67	***	3.47	3.13	***	3.13
-10	*-6*	*16:20*	*16:24*	1.92	**	2.57	2.19	**	2.27
-5	*-1*	*16:25*	*16:29*	2.18	***	3.19	2.54	***	3.26
0	*+4*	*16:30*	*16:34*	-0.98		-1.5	-0.22		-0.27
+5	*+9*	*16:35*	*16:39*	-0.13		-0.18	0.37		0.38
+10	*+14*	*16:40*	*16:44*	0.18		0.24	0.24		0.24
+15	*+19*	*16:45*	*16:49*	-0.22		-0.27	0.28		0.28
+20	*+24*	*16:50*	*16:54*	-0.16		-0.2	-0.60		-0.58
+25	*+29*	*16:55*	*16:59*	-0.19		-0.22	-0.84		-0.8
+30	*+34*	*17:00*	*17:04*	-0.84		-1.01	-0.85		-0.82
+35	*+39*	*17:05*	*17:09*	-1.09		-1.28	0.00		0
+40	*+44*	*17:10*	*17:14*	0.97		1.17	0.37		0.35
+45	*+49*	*17:15*	*17:19*	0.33		0.38	0.81		0.78
+50	*+54*	*17:20*	*17:24*	0.79		0.91	2.22	**	2.05
+55	*+59*	*17:25*	*17:29*	-0.90		-1.08	-1.13		-1.07

Section B				Panel A			Panel B		
10 mins				Avg AOIB#			Avg AOIB$		
From (t_i)	*To (t_i)*	*From (Time)*	*To (Time)*	$\overline{AOIB\#_t}$	*Sign*	*t-value*	$\overline{AOIB\$_t}$	*Sign*	*t-value*
-60	*-51*	*15:30*	*15:39*	0.92		1.45	1.21		1.6
-50	*-41*	*15:40*	*15:49*	-0.29		-0.46	0.17		0.22
-40	*-31*	*15:50*	*15:59*	0.07		0.11	0.55		0.71
-30	*-21*	*16:00*	*16:09*	2.24	***	3.5	3.24	***	4
-20	*-11*	*16:10*	*16:19*	2.96	***	4.55	3.51	***	4.28
-10	*-1*	*16:20*	*16:29*	2.08	***	3.35	2.32	***	3.34
0	*+9*	*16:30*	*16:39*	-0.51		-0.86	0.08		0.12
+10	*+19*	*16:40*	*16:49*	0.26		0.38	0.13		0.16
+20	*+29*	*16:50*	*16:59*	-0.33		-0.48	-1.04		-1.21
+30	*+39*	*17:00*	*17:09*	-0.53		-0.73	-0.06		-0.06
+40	*+49*	*17:10*	*17:19*	0.41		0.58	-0.07		-0.08
+50	*+59*	*17:20*	*17:29*	-0.19		-0.27	0.06		0.07

Notes: This table reports the results of the average adjusted order imbalance (AOIB) measures by 5-minute batches (Section A) and 10-minute batches (Section B). Panels A and B present the results for the average order imbalance by number of trades (*AOIB#*) and the average order imbalance dollar value (*AOIB$*) respectively. All OIB measures are expressed in percentage terms (%). The t-value is the statistic of a one sample t-test of the mean being equal to zero. *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015. 'From' and 'To' timestamps represent interval start times. The two single horizontal black lines represent the Platts Dated Brent fixing start and fixing end. The Platts Dated Brent price publication falls in the 0 interval starting at 16:30 London local time.

Table 8: Regression of Adjusted Returns on Control Variables

Period	Panel A: Estimation Window [15:30,15:59]			Panel B: Event Window [16:00,16:29]			Panel C: Publication [16:30]			Panel D: Post-Event Window [16:31,17:29]		
Variable	*AR*	*Sign*	*t-value*	*AR*	*Sign*	*t-value*	*AR*	*Sign*	*t-value*	*AR*	*Sign*	*t-value*
Intercept	0.05		0.51	0.45	***	4.79	-0.22		-0.39	0.02		0.34
SUR	-0.08		-0.54	1.04	***	6.66	-0.22		-0.23	-0.07		-0.76
SENT	-0.18	*	-1.80	-0.39	***	-3.86	0.99		1.61	0.16	***	2.64
*SUR*SENT*	0.42	*	1.94	-0.04		-0.19	-0.47		-0.35	0.01		0.07
SCAN	0.08		0.59	0.16		1.12	-0.76		-0.91	-0.04		-0.52
POSTSCAN	0.01		0.11	0.39	***	3.97	-0.78		-1.29	0.00		0.02
EXP	-0.04		-0.21	-0.15		-0.74	2.43	*	1.93	-0.07		-0.56
EIA	0.02		0.22	0.07		0.67	-0.56		-0.83	-0.11	*	-1.69

Notes: This table reports the results of a simple OLS regression of the adjusted returns on several control variables across four sub-periods of the total window of investigation. Panels A, B, C and D present the regression results for the estimation window, the event window, the publication time and the post-event window respectively. The dependent variable AR is the adjusted return measure as described in the methodology. The independent variables account for different effects: *SUR* adopts the value 1 for surprise Dated Brent fixings defined as being in the top 9th or bottom 1st decile and 0 otherwise; *SENT* is an indicator adopting the value 1 for days with a positive fixing direction and 0 for days with no change or a negative fixing direction; *SUR*SENT* distinguishes positive surprise days (1) from other days (0); *SCAN* adopts the value 1 for the period [14.05.2013-30.11.2013] and 0 otherwise; *POSTSCAN* adopts the value 1 after the 30.11.2013 and zero otherwise; *EXP* adopts the value 1 on ICE Brent Crude futures expiry days and 0 otherwise; *EIA* adopts the value 1 on publication days of the 'Weekly Petroleum Status Report' and 0 otherwise. All coefficients are multiplied by 10,000 and reported in bps (1 bps = 0.01%). *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015.

Table 9: Regression of Order Imbalance on Control Variables

Period	Panel A: Estimation Window [15:30,15:59]						Panel B: Event Window [16:00,16:29]						Panel C: Publication [16:30]						Panel D: Post-Event Window [16:31,17:29]					
Variable	***AOIB #***	*Sign*	*t-value*	***AOIB $***	*Sign*	*t-value*	***AOIB #***	*Sign*	*t-value*	***AOIB $***	*Sign*	*t-value*	***AOIB #***	*Sign*	*t-value*	***AOIB $***	*Sign*	*t-value*	***AOIB #***	*Sign*	*t-value*	***AOIB $***	*Sign*	*t-value*
Intercept	8.09	** *	19.66	7.37	** *	14.70	10.72	** *	27.09	9.57	** *	18.90	11.62	** *	7.09	7.33	** *	3.38	6.48	** *	19.61	5.63	** *	14.20
SUR	-0.15		-0.21	-0.20		-0.23	2.83	** *	4.28	3.07	** *	3.62	2.27		0.83	1.32		0.36	1.30	** **	2.34	1.59	** **	2.40
SENT	-16.39	** *	-36.47	-14.60	** *	-26.64	-19.83	** ** *	-45.87	-17.89	** *	-32.36	-25.84	** *	-14.45	-19.09	** *	8.07	-14.27	** ** *	-39.49	-12.26	** ** *	-28.29
*SUR*SENT*	-0.50		-0.51	-0.24		-0.20	-2.71	** *	-2.88	-0.84		-0.70	-3.31		-0.85	-1.89		-0.37	-2.76	** *	-3.52	-2.60	** *	-2.76
SCAN	-0.67		-1.08	-0.70		-0.93	-0.27		-0.46	0.56		0.74	-2.67		-1.09	0.06		0.02	-0.35		-0.71	0.13		0.22
POSTSCAN	0.57		1.30	0.78		1.45	0.78	*	1.84	1.27	**	2.34	-0.69		-0.39	0.06		0.03	0.14		0.41	0.19		0.45
EXP	-1.16		-1.09	-0.77		-0.60	2.44	**	2.48	2.11	*	1.68	-5.91		-1.58	-6.09		-1.23	-3.07	** *	-3.29	-3.70	** *	-3.31
EIA	-0.17		-0.35	-0.05		-0.08	-0.56		-1.19	-0.14		-0.23	-0.98		-0.50	0.09		0.03	-0.13		-0.32	-0.29		-0.60

Notes: This table reports the results of a simple OLS regression of the AOIB measures on several control variables across four sub-periods of the total window of investigation. Panels A, B, C and D present the regression results for the estimation window, the event window, the publication time and the post-event window respectively. The dependent variable AR is the adjusted return measure as described in the methodology. The independent variables account for different effects: *SUR* adopts the value 1 for surprise Dated Brent fixings defined as being in the top 9th or bottom 1st decile and 0 otherwise; *SENT* is an indicator adopting the value 1 for days with a positive fixing direction and 0 for days with no change or a negative fixing direction; *SUR*SENT* distinguishes positive surprise days (1) from other days (0); *SCAN* adopts the value 1 for the period [14.05.2013-30.11.2013] and 0 otherwise; *POSTSCAN* adopts the value 1 after the 30.11.2013 and zero otherwise; *EXP* adopts the value 1 on ICE Brent Crude futures expiry days and 0 otherwise; *EIA* adopts the value 1 on publication days of the 'Weekly Petroleum Status Report' and 0 otherwise. All coefficients are expressed in percentage terms (%). *, ** and *** correspond to statistical significance at 10%, 5% and 1% levels respectively. Sample period is 09.01.2012–24.09.2015.

Appendix 1: Background

The Oil Market

Over the years, the on-exchange financial derivatives market has gained the upper hand over the physical OTC market in terms of value and volume traded. The financial instruments linked to oil, also called the paper market, is characterized by high liquidity and the involvement of numerous participants ranging from commercial hedgers to financial speculators. For 2015, with an average daily volume of 729,576 and an open interest of 2,030,972 contracts (ICE (2016)), the ICE Brent Crude futures are among the most actively traded crude oil derivative contracts worldwide, going head-to-head against the WTI futures (see Nguyen (2012), Meyer (2015)). In general, financial instruments such as futures contracts, have the advantage of being standardized, easier to trade and settle, thereby facilitating hedging and speculative behavior. In comparison, the physical or cash market is highly illiquid, specialized and opaque with the participation of only very few energy conglomerates, commodity traders or financial multinationals fulfilling the special requirements and obligations entailed by physical oil trading[1]. Nonetheless, the value of physical oil transactions is roughly two times that of gas and coal, four-and-a-half that of rice, wheat and corn combined and twenty-three times that of gold (Excelian (2013)). Notwithstanding the distinctions, both markets are highly interlinked. Particularly, the interdependencies between paper and cash oil arise from physical contracts (spot or forward) being priced against major crude oil grades that are assessed with the help of physical benchmarks, and which underlie financial derivatives such as futures, options, CFD and Exchange Futures for Physical (EFP). Hence, the physical oil benchmarks are of crucial importance, as their daily price levels are used for the

[1] Requirements include factors such as financial solvency and operational and logistical abilities (e.g. physical oil delivery and acceptance).

settlement of thousands of spot and derivative deals worth billions of dollars. For example, at settlement, the ICE Brent Crude futures' price tends to converge toward the price of forward Brent (Barret (2012a)) as the futures are settled against the ICE Brent Index, which is calculated based on the forward market activity. The interdependencies are further intensified, as *"Cash or Forward (BFOE) Brent is both the immediate underlier for the ICE Brent futures contract, and the parent of Dated Brent until it acquires a vessel, loading dates and cargo number."* (Davis (2012), p. 15).

Platts and its Dated Brent Benchmark

Platts is a division of McGraw Hill Financial, a publicly traded financial information corporation specializing in ratings, indices, benchmarks and other analytics. Platts is a global information provider for commodity markets assessing price references and benchmarks for, amongst others, the energy market. One of its flagship benchmarks is the Dated Brent.

The Dated Brent or Dated BFOE is the key marker for physical crude oil pricing worldwide, and Platts' daily benchmark price is the most frequently used by industry participants (Barret (2012a)). The benchmark has emerged as the most influential global oil price reference, as it is less constrained by logistical limitations or legal and political concerns (Montepeque (2012)).[2] Dated Brent is the value of crude oil on the date of publication for loading in a month's time; i.e.

[2] There are many international physical benchmarks, the importance of which is largely defined by the oil quality, mode of transportation, trading structure and trading terms. Grade quality varies depending on viscosity and sulphur content as these two characteristics define the refining effort required and the amount of consumable oil extracted. Sulphur is a highly pollutive component and thus the higher the sulphur content the more refining is needed. Moreover seaborne oil is distinguished from onshore oil as shipping experiences less capacity restrictions than pipeline transportation. Brent is considered a seaborne high quality light sweet crude oil. Long-term supply contracts are typically priced on a spread relative to the benchmark grade (=grade differential).

a physical cargo of North Sea BFOE crude oil that has been assigned a loading date for shipping (has become wet). Since its launch in Europe in 2002, the daily price of Dated Brent is assessed in a process called Market on Close (MOC). The trading platform *eWindow* allows core market participants to directly submit bids and offers for consideration in the price fixing procedure (Barret (2012a)). On top of that, transactions, bids and offers can be communicated to Platts via phone or online instant messenger, which Platts then instantly puts on *eWindow*, granting the main participants prompt knowledge of new developments (Barret (2012a)). During the 'window', a thirty minute time frame from 16:00 to 16:30 London local time, which is a central element to the overall MOC process, Platts determines the Dated Brent price based on a combination of data received for three OTC variables; grade differentials[3], forward Brent (also called cash BFOE) and CFD (the difference between Dated Brent and forward Brent). Based on these variables, Platts calculates the Dated Brent Strip[4] and combines it with the grade differentials to determine a price for each grade (Brent, Forties, Oseberg, Ekofisk), with the most competitive grade setting the daily Dated Brent price. It is important to note that the window is merely a part of the whole MOC price setting process, and Platts monitors the physical market throughout the trading day as well[5]. The MOC methodology has the advantage of promoting liquidity, in a rather illiquid market, as it leads to a natural concentration of activity in a short period at the end of the day (Barret (2012a)).

[3] Grade differentials are assessed relative to Dated Brent and/or forward Brent: e.g. Sept 20-25 Forties at Dtd. +70cts or Oct 18-20 Brent at Dtd. -40cts or Oct 16-18 Forties at Nov Cash BFOE (i.e. Forward Brent) +100cts (all figures depicted are fictional values).

[4] Anticipated Dated Brent or average price of Dated Brent that can be guaranteed today for delivery in 10-25 days.

[5] For more information please refer to: https://www.platts.com/IM.Platts.Content/aboutplatts/mediacenter/PDF/intromocoil.pdf

Typically, the window therefore experiences the highest participant activity. The window itself can be divided into different phases defined by the three assessed OTC variables. During the first phase from 16:00 to 16:10, market participants are required to submit their bid and offers on a differential to Dated Brent or to Forward Brent, although existing submissions for physical grades can be altered until 16:25. The value of CFD contracts is assessed in the second phase from 16:15 to 16:25. The third and last phase, from 16:25 to 16:30, judged to be of critical importance and described as particularly stressful for both Platts and the physical market participants, consists of the forward Brent (cash BFOE) valuation. Although, the OTC physical oil market is theoretically open 24/7, the price publication at 16:30 London time reflects the most useful price for the day at the 'close' of the physical market.

The minimum trade size for BFOE is a partial cargo of 100,000 barrels, and a full cargo corresponds to 600,000 barrels. The minimum shipment size acts as barrier-to-entry to the physical oil market such that, typically, during the Platts window only a handful of participants contribute to the price assessment at any given time, and of those even less account for roughly half of the total trading activity (Fattouh (2011a), Barret (2012a)). The participating companies are mostly major oil multinationals or large commodity traders, and thus amongst the best informed in the physical market.

In the absence of another oil benchmark regime, Platts fulfils an essential role in creating price transparency by capturing, summarizing and disseminating the information of the opaque and illiquid physical oil market. According to most practitioners in the oil industry, the Platts benchmark is at present indispensable to pricing in the physical oil market (Mackey and Lawler (2013)) Nevertheless, numerous issues related to the unregulated Platts process give rise to concern. The main criticism emphasizes that the level of liquidity during the Platts window is often

deficient, allowing the price assessment to be dominated by few participants and thereby hampering the price discovery process (Fattouh (2011a)). It is up to the participating companies' own interest to communicate their trading activity to Platts, and they do not have any obligation to report all of their transactions, bids and offers, even though they have an incentive to do so if they want their trading activity to be reflected in the final price. Platts endeavors to verify the submitted transactional information, yet dishonest behavior of fixing participants cannot be ruled out. Although, Platts applies rigorous internal procedures to verify the veracity of the reported transactions, their guidelines, such as rules for the admission of participants, are self-imposed and enforced, and not subject to regulatory supervision.

The Intercontinental Exchange and the ICE Brent Crude Futures

The Intercontinental Exchange (ICE) is a worldwide electronic exchange and clearing house operator focusing on the trade and clearance of financial and commodity derivative contracts. Specifically focusing on energy derivatives, the ICE Brent complex is one of their key products. From 2012 until 2015, the ICE Brent Crude futures contract has been the world's largest futures contract measured by trading volume and open interest (see Nguyen (2012), Meyer (2015)).

The contract is traded from Sunday to Friday between the hours of 01:00 and 23:00 on the London-based ICE Futures Europe electronic platform. Commercial hedgers such as energy producers, users, processors and merchants form the largest participant category; in all, there are hundreds of participants involved in the futures trading. Hence, the ICE Brent Crude futures are important hedging instruments for physical oil market participants. One contract of the ICE Brent Crude futures corresponds to a size of 1,000 barrels, is denominated in U.S. dollars and is cash settled against the ICE Brent Index with an option for physical delivery through EFP. The Brent

Crude futures are listed in consecutive months up to 7 years forward. The nearby futures contract is typically the most liquid whereas the longer-dated contracts are predominantly thinly traded. For our study, we only focus on the front month contract as it is usually the most liquid and most important, Granger-causing the other higher maturity contracts (see Inci and Seyhun (2014)). Thus, for the most part, price innovations should first occur in the closest-to-maturity contract.