Block Trades in Options Markets

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Abstract

This paper documents the evolution of block trading in the crude oil options market and examines how it may have affected trading in the downstairs market. While sparse prior to the reduction of the minimum permissible block size threshold in October 2012, block trading currently accounts for about 30% of the trading volume in WTI crude oil options. We compare the execution costs of large/block orders across trading venues before and after the October 2012 rule change, in order to gain a better understanding of the factors behind the recent increase in block trading. We find that while block orders share similar characteristics with those routed to the pit, they have lower information content and face higher execution costs, which can be linked to high search and negotiation costs. However, when we condition for the choice of placing such orders as blocks, we find that block orders would have been costlier to execute at the pit, which may have contributed to the eventual demise of the energy options pits.

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Block Trades in Options Markets

I. Introduction

When the Dodd Frank swap rules were introduced in October 2012, energy traders, who have been trading swaps for decades, diverted their order flow to the futures market[1]. This switch was facilitated by both the Intercontinental Exchange (ICE) and the Chicago Mercantile Exchange: they introduced new futures contracts similar to existing swaps and reduced the minimum block threshold for many futures and options. The reduction of the minimum block threshold became effective on October 15th 2012, in an attempt to retain the order flow associated with the execution of Exchange for Related Positions (EFRPs)[2], a type of privately negotiated transactions also affected by the new swap rules[3]. However, while the reduction in block sizes has been associated with the so-called futurization phenomenon, what might been missed in the popular press is that the fact that block trading might also have had an impact on the energy options market structure, as market participants with relatively small order sizes gained access to block trading.

The reduction in the block trade threshold was intended to preserve market participants' ability to engage in non-competitive, privately negotiated transactions. Block trades, which are likewise privately negotiated transactions executed away from the public auction market, are subject to minimum transaction size requirements and have been traditionally used by market participants to execute large orders for which the centralized ("downstairs") market[4] might be unable to provide sufficient liquidity without commanding a significant liquidity premium. Similar to EFRPs, block orders are routed to the "upstairs market"[5], an off-exchange network of broker/dealers and large institutional investors, who negotiate transactions privately primarily over the phone. Table 1 presents the reduction in the block sizes for major CME energy contracts. Noticeably, the minimum permissible block trade threshold for WTI crude oil options dropped from a thousand to a hundred contracts. This dramatic reduction could potentially allow market participants to

[1] Philips, M., (2013, January 24). Traders take their swaps trades to futures exchanges. *Bloomberg Business.* Retrieved from http://www.bloomberg.com/news/articles/2013-01-24/traders-take-their-swaps-deals-to-futures-exchanges.

[2] Exchange for Related Positions refer to privately negotiated transactions, executed over the counter, which consist of two positions: a transaction in the organized exchange and a corresponding related OTC position, i.e. cash, OTC swap and OTC derivative. These are exchange transactions for bona fide business.

[3] The OTC leg of the transaction would subject market participants to CFTC swap regulation, while transitory exchange for related positions are prohibited based on rule 538.

[4] The "downstairs" market refers to trading in the centralized market which includes the electronic order book and the pit (floor trading), which was active in the time frame examined.

[5] The "upstairs" market refers to all trades negotiated off-exchange and in the case of energy futures it includes EFRPs and block trades.

divert order flow from the floor and/or the electronic order book to the upstairs market, potentially raising concerns over reduced market transparency and liquidity. To wit, Hranaiova, Haigh & Overdahl (2004) report that many market participants a decade ago viewed block trades as order flow diverted from the floor. On the contrary, advocates of block trading argue that such trading does not necessarily take business away from the centralized market, but instead can increase liquidity as participants entering the market using block trades might subsequently trade in the centralized market to either hedge or offset their positions.

The objective of the present paper is to assess how the reduction in the minimum threshold for block trades may have affected liquidity and overall market quality. We focus on WTI options contracts, for which the minimum block order threshold was reduced from thousand to hundred contracts. Block trading in WTI crude oil options, which was very limited before October 2012, increased substantially thereafter, currently representing about 30% of the total volume. The increase in block trading volume could reflect solely the transition of EFRPs to blocks. However, it is also possible, that the lower minimum block thresholds have attracted additional order flow to the upstairs market; such order flow might have otherwise never have reached the market, but it might also represent trades that would otherwise have been directed in the electronic market and/or the pit. In this context, we explore the characteristics of orders executed as blocks. We investigate whether block trading is more popular for relatively less liquid orders, such as option trading strategies, and if so, whether block trading allows market participants to achieve lower execution costs compared to those offered in the electronic market and the pit. Interestingly, the execution difficulty associated with the complexity of option trading strategies is also commonly considered the primary reason for the relatively slow transition of options trading from the pit to the electronic market, which supports the claims on the importance of human intermediation in reducing search costs and raises concerns over the potential migration of order flow from the floor to the less transparent block trading.

We find that block orders differ from EFRPs in that they have a higher information content (although still low) and in that block trading is more popular with option trading strategies, compared to outrights. While the block outright volume appears to subside over time, the proportion of option trading strategies trading as blocks increases right after the rule change remains stable close to 30%. At the same time, pit orders, which are predominantly option trading strategies gradually decline from about 30% to about 10% towards the end of our sample. We also find that block and pit orders share similar characteristics and face higher execution costs than electronic orders. Block orders face the highest effective half spread, which can be attributed to high search and negotiation costs, as the information content of those orders is lower than the orders executed at the pit and the electronic platform. However, these orders benefit from block trading, as they might have faced higher execution costs had they been executed in the downstairs market, especially the pit. On the contrary, pit orders, do not seem to benefit from the decision to execute the specific orders at the pit. Large electronic orders involving option trading strategies appear to enjoy the

lowest execution costs, but their size is relatively smaller than orders executed as blocks and at the pit. Our results suggest that the reduction in the minimum permissible block threshold, combined with the technological improvements accommodating the execution of option trading strategies on the electronic platform may have led to the break down of the options market at the pit, which led to its shut down in December 2016. Our results, also, highlight the importance of human intermediation for some types of orders, which may explain the reasons behind the introduction of the Box Options Exchange,[6] a new open outcry venue for options, in the era of electronic trading.

Our work, which is the first study to investigate the dynamics of block trading in the options market, complements the existing academic literature on block trading in the equity market. Glosten (1994) highlights the advantages of pooling liquidity, and predicts that the upstairs market could not survive. However, Seppi (1990) suggests that a separating equilibrium could arise where uninformed traders prefer the upstairs market and enjoy lower execution costs by certifying that they are uninformed and implicitly committing not to trade right after the block. Moreover, Grossman (1992) asserts that upstairs brokers are able to offer lower execution costs by tapping into unexpressed liquidity. Madhavan & Cheng (1997) examine empirically execution costs for large equity trades; while they document lower execution costs for large trades executed in the upstairs markets, they find this difference to be economically small. They find upstairs trades to have only a temporary impact on prices, indicating that they are primarily liquidity motivated, which supports the Seppi's (1990) theoretical prediction. Bessembinder and Venkataraman (2004) also present evidence that upstairs brokers are able to offer lower execution costs by tapping into unexpressed liquditiy. Similar results are presented in Smith, Turnbull & White (2001), who study block trades in the Toronto Exchange, and in Rose (2014), who studies block trading in the Australian Stock Exchange. According to Keim & Madhavan (1996), the temporary impact of a block trade is positively related to the order size, the cost of locating counterparties, the degree of risk aversion and the variance of the risky asset's return. Fong, Madhavan & Swan (2004) compare the upstairs market, a crossing network and the downstairs electronic order book in the Australian Stock Exchange and find evidence against the filtering/certification hypothesis. Their results suggest that upstairs markets have no harmful effect on downstairs markets, as the permanent impact for large trades does not appear to be higher in the upstairs market. These authors highlight the search role of dealers in the upstairs market and argue that both markets can coexist as they offer various complementary ways to search for counterparties. The literature has also documented the asymmetry in the price impact following block trades: the price impact appears to be

[6] Bullock, N., (2017, August 2). Chicago open-outcry trading floor launch wins approval. Financial Times. Retrieved from https://www.ft.com/content/fc1ebbca-77cb-11e7-90c0-90a9d1bc9691.

temporary when one examines aggressive sell trades but permanent for aggressive buy trades (Kraus & Stoll, 1972, Anderson, Cooper & Prevost, 2006).

Our study also relates to Hranaiova, J. *et al.* (2004), who are the first to study block trades in the derivatives market. They focus on block trades on FTSE 100 index futures and options on futures on the three month Euribor contract, both trading on the Euronext – London International Financial Futures Exchange (LIFFE). They note that the use of block trades in futures and options is very different from equity markets and should be studied with a different light. Interestingly, they do not find block trading to increase with volatility, which is when one would expect human intermediation to result in lower execution costs. Futures block trades, which account for 10% of the volume in futures, concentrate on rollover hedging strategies. Options block trades account for 40% of the volume in their sample and comprise primarily of speculative trading strategies. Their study concentrates primarily on FTSE 100 futures, where they do not find an increase in volume after the execution of block trades. Moreover, block trade prices appear to be very close to prices in the centralized markets. These findings indicate that the order flow in the upstairs market is two sided and robust and block trades do not result in a significant market impact. Therefore, consistent to the literature in the equity market, they find block trades on FTSE 100 futures to be liquidity driven. However, their analysis concentrated primarily on futures. Our study focuses on the options market, and uses the specific event of the reduction in the permissible block threshold to study to investigate the dynamics of block trading for crude oil options.

The rest of this paper is organized as follows. Section II discusses block trading rules for WTI crude oil futures and options, while section III describes the data. Section IV presents descriptive statistics, while section V set up our methology for studying execution costs across various trading venues. Sections VI and VII present our results. Section VI concludes the paper.

II. The upstairs market (EFRPs and Block trades) in the futures and options markets

The upstairs derivatives markets handle privately negotiated transactions, which include exchange for related positions and block trades. Both types of transactions are executed away from the centralized market place and must be reported to the exchange within a certain time frame. However, only block trades have a minimum quantity threshold.

Exchange for related positions

An Exchange for related position (EFRP) transaction allows futures contracts to be exchanged with an economically offsetting position in a related cash commodity or OTC derivative position. They include exchange for physical or cash commodities (EFP), exchange for swap (EFS), an exchange of over the counter options for exchange traded options (EOO) or an exchange for risk (EFR).

EFRPs were developed to allow flexibility for commercial users to make or take delivery outside of the standardized exchange delivery system. Their use had increased remarkably the past few decades (Dunsky, 2014). Their proliferation intensified in the early 2000s, when NYMEX started allowing the clearing of energy OTC swaps through EFS or EOO transactions, which would become exchange traded futures and options EFRPs were often used to allow transactions in illiquid or newly launched products until liquidity had become sufficient. However, with the implementation of the Dodd Frank Act, the swap leg of the EFRP would be subject to various new regulations. Moreover, transitory EFRPs and EOOs were prohibited in 2014 for all CME products. [7]

Block Trades

In derivatives markets, block trades are large privately negotiated transactions between eligible market participants[8] that are executed away from the public auction market[9]. While market participants may use communication technologies to bilaterally request block quotes, the actual execution of block trades has to be completed through human intermediation, because electronic matching is not allowed.

Block trades must meet some minimum quantity thresholds. The latter were revised downwards in October 2012, as discussed further below, in order to allow block trades to replace exchange for related positions (EFRPs), which were practically banned at around the same time (Dusnky, 2014). The newly set minimum threshold was determined by exchanges based on volume, transaction and order information and market participants' input in 2011. Commodity trading advisors are allowed to pool smaller customer orders in order to place a consolidated block order that meets the threshold for a particular contract, but the customer must have specified that he or she wishes to have it executed it as a block.

Block trades may be executed at any time during the day and must be transacted at prices that are "fair and reasonable" depending on the size of the order, the prices in other relevant markets, the circumstances of the markets and the market participants. However, contrary to the equity market, there is no explicit requirement for CME block trades to be executed at a price that falls within the contemporaneous bid - ask spread in the centralized market. Also, the trade price has to be consistent with the minimum tick

[7] "Transitory EFRPs are EFRPs in which the execution of an EFRP is contingent upon the execution of another EFRP or related position transaction between the parties and where the transactions result in the offset of the related positions without the incurrence of market risk that is material in the context of the related position transactions". CME Group, June 27 2014, Market Regulation Advisory Notice RA1311-5RR, Retrieved from http://www.cmegroup.com/rulebook/files/ra1311-5rr-rule538.pdf

[8] Eligible participants for block trades generally include exchange members and member firms, broker/dealers, government entities, pension funds, commodity pools, corporations, investment companies, insurance companies, depository institutions and high net worth individuals.

[9] CME Group, Retrieved from http://www.cmegroup.com/clearing/trading-practices/block-trades.html

increment for the market in question and every outright transaction or leg of any block eligible spread or combination trade must be executed at a single price[10].

Block trades must be reported to exchange within a certain timeframe after their execution, typically within five and fifteen minutes depending on the product. In a brokered transaction the reporting obligation is the broker's responsibility whereas in other cases it is the responsibility of the seller unless otherwise agreed to by the participants involved in the trade.

Block trade information is disseminated to the market, but prices are published separately from transactions in the regular market. Block trade information is also reported on the futures exchanges' website and displayed on the trading floor, where such floor exists. Market participants involved in the solicitation or negotiation of block trades must keep the related information confidential. Although anticipatory hedging is not allowed[11], parties in a block trade are allowed to hedge or offset the risk associated with the block trade during the period preceding to the public reporting of the block trade.

The upstairs market for WTI Crude Oil derivatives

On October 15th 2012, the minimum quantity threshold for WTI crude oil futures blocks was reduced from hundred to fifty contracts, while the minimum quantity threshold for WTI crude oil option outrights was reduced from thousand to hundred contracts. For all intra-commodity WTI futures or option spreads and combinations, the sum of the quantities of the legs of the transaction must meet the minimum block quantity threshold. For all inter-commodity futures or option spreads and combinations the sum of the quantities of the legs of the transaction must meet the larger of the threshold requirements for the individual contracts involved. Finally for spread trades involving both futures and options, the options component of the spread must meet the minimum quantity threshold for the outright option or option combination while the quantity of futures executed must be consistent with the delta of the options component of the spread.

The reporting timeframe for WTI crude oil futures is five minutes and for WTI crude oil options is fifteen minutes. If a block trade involves a spread or combination where at least one leg of the transaction falls in the fifteen minute requirement, the whole trade should be reported within that fifteen minute requirement. Like other NYMEX products, WTI futures and options can be reported to the exchange through CME Clearport, CME Direct and the floor.

[10] CME Group, November 8 2013, Market Regulation Advisory Notice, Rule 526, Retrieved from https://www.cmegroup.com/rulebook/files/cme-cbot-ra1313-3-block-trades.pdf

[11] CME Group, November 8 2013, Market Regulation Advisory Notice, Rule 526, Retrieved from https://www.cmegroup.com/rulebook/files/cme-cbot-ra1313-3-block-trades.pdf

III. Data

This study uses the specific event of the reduction in the minimum permissible block size in WTI crude oil options, which occurred in response to the introduction of the Dodd Frank swap rules, to identifythe attractive features of block trading in the options market, while gaining a better understanding of the options market structure.

The dataset

The dataset includes trade data on WTI crude oil options during the time period extending from January 1st 2012 to December 31st 2014. The dataset, constructed using the TSS database of the U.S. Commodity Futures Trading Commission (CFTC), includes the order id (CTR card order number for pit and block trades and EFRPs), which allows us to group executed trades belonging in the same order. Therefore, we can estimate the execution costs associated with all filled orders, even those having resulted in multiple trades; a common phenomenon for electronic orders. It also includes detailed transaction information, including the customer accounts and the traders involved in every leg of the trade, the trade prices and quantities, and whether the particular trade was part of an option trading strategy.

Definition of large orders

We focus most of our analysis on large orders that could have potentially been executed at any of the available trading venues: the trading floor (pit), the electronic platform and off-exchange trades (blocks and EFRPs). Therefore, we define "large orders" as those orders that are either filled as blocks or are large enough to meet the post October 2012 minimum size criterion of one hundred contracts for trading as blocks even though they are in practice executed in the pit or on the electronic market. Our definition is arguably conservative as we do not take into account unexecuted orders. Moreover, if a trader places multiple orders to fulfill a single large order, the original order could escape our definition of a large order or its size might be underestimated. Even with these limitations, large orders comprise about 65% of the daily trading volume during our sample period before October 15th 2012, the day when the minimum threshold for block trades was reduced from a thousand to a hundred contracts. They comprise about 59% of the daily trading volume during our sample period following October 15th 2012. Each order often contains more than one contract (i.e. they are part of option trading strategies). As the dataset contains information that allows us to distinguish outright trades from those trades that were part of an option trading strategy, We also separate orders by contract and examine the differences in the execution of large outright and spread orders.

Trade initiation

In order to estimate execution costs, we need to determine if each trade is buyer or seller initiated. Our dataset provides an "aggressor" indicator for all electronic trades. In contrast, we do not have the same information for trades executed either in the pit or in the upstairs market. Since we only have access to trade data, we estimate trade initiation using the tick test, where the benchmark or reference price is the last electronic trade. When the previous electronic trade is at the same price as the volume weighted average price of the executed portion of the order (which we consider as the price of the order), our benchmark is the trade before the previous trade. If the price of the latter trade is also equal to the price of the original trade, we use the trade before that one. Beyond this point, if the prices of three consecutive trades are constant, we exclude the order.[12]

Order initiation

Our data set contains large orders, which are on opposite sides of the same trade. We focus just on the "aggressive" (i.e. liquidity demanding) side of each trade. We find that pit and upstairs trades typically involve a relatively limited number of trading counterparties for each large order[13]. Moreover, in most cases both sides of the trade are large orders. Our study focuses on aggressive orders. However, disentangling the aggressive side of large electronic trades can be challenging, as a large order can often be executed against many other smaller orders or against a fraction of other large electronic orders or even a combination of the two. We keep the order on the side of the trade with the largest executed quantity and we consider it a buyer (seller) initiated order if the executed price is higher (lower) than the last electronic trade in the specific option contract. In identifying the aggressive side of each large electronic trade, we keep those orders with at least fifty percent of the executed quantity designated as aggressive. When both sides of an order are deemed aggressive based on the fifty percent criterion[14], we keep the order with the largest executed quantity.

Reporting time

Trades executed in the pit or on the electronic markets are reported in real time to market participants. This is not the case for upstairs trades. Block trades in WTI crude oil options have to be reported within fifteen minutes. While our dataset includes the execution time for all trades, reporting times are not available. (i)

[12] For electronic trades we provide results using the aggressor indicator using both the tick test and the actual aggressor indicator for robustness. We use the aggressor indicator based on the tick test to compare execution costs across venues, with the rational that the implicit bias affecting the estimation of execution costs is similar across at various trading venues. The tick test trade initiator coincides with the aggressor indicator for 60% of all the large aggressive electronic orders and 77% of the large aggressive electronic outrights.

[13] Most frequently there is just one trading counterparty for each large order.

[14] It is possible for both sides to be aggressive when the orders are *not* executed against each other in their entirety (i.e. in a one-to-one execution).

After November 2013, our dataset contains the clearing time, which coincides with the reporting time for blocks entered in Globex. For these orders, we use the clearing time as reporting time. For all other block trades, we assume that the reporting time is equal to the maximum fifteen minutes after the reported execution time. (ii) EFRPs have to be reported for clearing within one hour of the transaction time when the transaction occurs between 7am and 4:45pm. EFRPs taking place outside of this window have to be reported the next day before 8 am. We estimate execution costs only for exchange for related position transactions that take place between 7am and 4:45pm, which constitute 98% of the sample. We estimate our price impact measures for exchange for related positions by adding the maximum one hour to the recorded transaction time.

IV. Descriptive statistics: Trading activity in upstairs and downstairs markets

Figure 1 presents the daily share in the total volume in WTI crude oil options for EFRPs and blocks trades during our sample period. EFRP and block trading volume proportions are reported in separate graphs. We also examine separately volume proportions ofoption outrights and option trading strategies ("spreads"), executed as EFRPs and block trades . We observe that EFRPs, which account for about twenty percent of the daily trading volume in option outrights and option trading strategies at the beginning of our sample decline rapidly after the rule change and finally become virtually extinct. At the same time, trading volume in block trades, which was negligible, increases after the rule change. Block trading in outright options increases sharply right after the October 15th, 2012 rule change, but subsequently declines steadily to levels close to ten percent of the total daily volume. The increase in block trading is especially notable for option trading strategies, whichgenerally accounts for about forty percent of the total daily volume in crude oil options. These patterns together suggest that the order flow increase in block trades may not be solely attributed to the substitution of EFRPs with block trades. These finding raise the question ofwhether the increased volume in block option trading strategies represents order flow that has been attracted away from the floor, where option trading strategies have been traditionally traded.

Figure 2 shows that the reduction in the minimum threshold does not seem to have affected in a similar way the activity of block trading in the WTI crude oil futures market, where block trades account for less than 8% of the daily trading volume. This could be the result of the relative simplicity of trading and related execution strategies for futures contracts that require less human intermediation. It could also be the result of the fact that the volume of EFRPs in the WTI crude oil futures market has been limited: the daily average was lower than four percent before the rule change and declined to less than 1.5% of the volume thereafter.

Figure 3 exhibits the daily proportion of trading in the pit and the electronic market during the time period examined. As in Figure 1, we present trading volume for option outrights and trading strategies

separately. Trading volume in the pit is negligible for outrights in the entire sample period. In contrast, trading in option trading strategies which accounted for over forty percent of the total trading volume of crude options in 2011, has been declining steadily to levels lower than ten percent. Notably, we find no abrupt decline around the time of the reduction of the minimum block threshold. Rather, the share of electronic trading for both option outrights and option trading strategies increases steadily from 2011 to 2015. The proportion of trading volume in electronic option trading strategies often surpasses twenty percent of the daily trading volume, especially towards the end of our sample.

We revisit the trading activity by venue focusing on large orders, in order to understand the driving forces behind the choice of trading venue. We define large orders as orders larger than the minimum post October 2012 block threshold of hundred contracts. Table 2 presents the activity of large trades on each venue before and after October 15th 2012, when the minimum threshold for block trades was reduced. Panel A of Table 2 shows that the average size of block orders is substantially lower after the decline of the minimum threshold on October 15th 2012.These smaller block orders might be orders which would have traded as EFRPs had the rule not changed. However, it is also possible that some of these orders represent orders that would have traded in the downstairs market, or even orders that may have never reached the market had the rule not changed. At the same time the average size of large pit and electronic orders has slightly increased. As expected, EFRPs, which accounted for half of large orders prior to the rule change, comprises just five percent of the volume of large trades after the change. Similarly, we observe a jump in the trading volume of block trades from just 7 percent of volume prior to the rule change to 52 percent thereafter. Interestingly, large electronic orders become more common, accounting for 27 percent of the large order volume, up from 11 percent prior to the rule change. The volume of large pit trades drops from thirty percent to seventeen percent.

Next, we examine outrights and option trading strategies (separately). Panel B of Table 2 presents the relevant summary statistics. Our dataset differentiates option outrights from option trading strategies (spreads). While the volume of EFRPs is evenly distributed between outrights and option trading strategies prior to the rule change, we find that block trades are more frequently used to execute option trading strategies (accounting for 37 percent of large orders) than outrights (which represent just 14% of the daily trading volume of large trades). Moreover, most pit orders represent option trading strategies prior to the rule change. At the same time, the volume proportion of such large pit trades appears to have declinedfrom 25% to 16%, which could potentially indicate that some of the trading volume in option trading strategies has migrated from the pit to blocks. Electronic large orders increase symmetrically for outrights and spreads. The lower minimum threshold has encouraged more large trades in block option trading strategies, which cannot be explained just by the substitution of EFRPs with block trades. Similarly, the increase in the volume of block outrights is not sufficient to explain the reduction of EFRP volume. Therefore, it is

possible that the increase of the block trade volume reflects only partly the transition of EFRPs to block trades. Another possible explanation is that the block trading has drawn order flow from the pit after the minimum threshold for blocks was reduced, contributing to its declining trading volume and the eventual close of options energy pits in December 2016

V. Methodology: Execution Costs

We explore one of the possible driving forces for the choice of trading venue, execution costs. Similar to the literature (Bessembinder, 2003), we proxy execution cost using the effective half spread, which we estimated as:

$$Effective\ half\ spread = 100 * Di\ * (\log(\mathrm{P}_{t_b}) - \log(\mathrm{P}_{t_0})),$$

where *log* represents the natural logarithm, P_{t_b} is the price of the volume weighted average price of the large order, P_{t_0} is an appropriate benchmark price. For the latter, we use the price of the previous electronic transaction in the corresponding contract. The variable D_i is a trade direction indicator where D_i= 1 trade for a buyer initiated trade and D_i= - 1 for a seller initiated trade. For pit trades we use Lee and Ready (1991) "tick test" to sign trades[15].

We are also interested in decomposing the effective half spread into a temporary and permanent components. Following Kraus (1972), we have:

$$Temporary\ spread = 100 * D_i * (\log(P_{t_b}) - \log(P_{t_1}))\ ,$$

and

$$Permanent\ spread = \ D_i * (\log(P_{t_1}) - \log(P_{t_0}))$$

where P_{t_1} is the price of the tenth electronic trade after the reporting time of the block/large trade. The temporary spread represents compensation for search and negotiation costs, while the permanent spread represents the permanent price impact. Similar to the literature, we consider orders informed (liquidity driven) when the permanent spread constitutes a high (low) proportion of the effective half spread. Our results include only those options for which the previous trade executes up to four hours prior to the large

[15] For electronic orders, we could also use the actual aggressor indicator provided in our dataset. Preliminary tests, not reported here for brevity, show that while the patterns in electronic execution costs are similar, estimates of execution costs using the tick-test based aggressor indicator are typically overstated. Therefore for comparative purposes across all trading venues, we use the aggressive indicator estimated using the tick test.

trade we are considering, while the tenth subsequent trade executes within four hours of the reported block trade. We do this, so that our results are not driven by illiquid option contracts, for which the tenth trade takes place substantially later. In this case the subsequent trade price could be driven by a number of other factors beyond the impact of the large trade we are considering.[16]

In the analysis that follows, we explore differences in execution costs across all available trading venues (the electronic order book, the pit and upstairs market) during the period of 2012-2014, accounting for how these have changed after the reduction of the minimum permissible block threshold on October 15th 2012. Since execution costs are observed conditional on the self-selection of a trading venue, we employ Lee's (1983) two stage model to estimate unconditional execution costs across trading venues. In the first stage, the trade initiator's choice is modeled with a multinomial logit. We also control for order characteristics (order size, moneyness, time to expiration, whether the order includes a trading strategy or not), implied volatility which proxies market conditions and finally, a dummy, which is equal to zero before the reduction of the minimum block threshold and one afterwards. The second stage is an OLS regression correcting for selection bias. The second stage regression controls for order characteristics (order size, moneyness, time to expiration and whether the order is part of trading strategy or not) and implied volatility.

VI. Execution Costs: Univariate results

In this section, we present the average effective half spread, the temporary and permanent spread of all large aggressive option orders. Table 3 compares execution costs of large orders across all trading venues. Panel A presents execution costs prior to October 15th, 2012, while Panel B presents execution costs after the minimum block threshold was reduced. Prior to the rule change (Panel A), both the average effective half spread and the permanent spread are lower for large outright pit trades compared to electronic trades. For large pit strategy trades the effective half spread is higher than the electronic market. The permanent spread is also higher for pit trades, but this could be potentially attributed to the considerably larger size of pit orders. During this period, there is a small number of outright block orders with an effective half spread slightly higher and a permanent spread lower than the ones in the electronic order book. Given the substantially larger size of these orders, the execution costs seem competitive. During this period, upstairs orders are dominated by EFRPs, which have an effective half spread higher than any other type of trade and practically no permanent price impact. These results are intuitive, given the nature of EFRPs. Finally,

[16] As a robustness test, we also estimate execution costs limiting our sample to options for which the previous trade takes place after the previous open and the subsequent tenth trade occurs prior to the next closing. Results are very similar and have been omitted.

there is no obvious difference in the average option characteristics (i.e. time to expiration, implied volatility and moneyness[17]) across different venues.

After the minimum block threshold is reduced (Panel B), the permanent spread increases for electronic large outrights, whereas execution costs for electronic spreads remain unchanged. Effective half spread for pit outrights, which is lower compared to the electronic market, decreases further after the change of the block minimum threshold. In contrast, pit spread trades appear to face a higher effective half spread than in the electronic market, which could indicate that search costs associated with option spreads are higher resulting in liquidity providers commanding a higher compensation. However, it could also be the result of the larger average trade size, since the average trade size for option contracts belonging to a spread is 493 contracts at the pit and just 65 in the electronic order book. After the rule change, the effective half spread for block trades increases to a level substantially higher than effective half spread of large orders in the electronic market. This preliminary result is inconsistent with the findings of the academic literature in equity market (Madhavan & Cheng, 1997), where block trading is associated with lower effective spreads. The substantially higher effective half spread in options block trading could potentially be explained by the larger size of block orders. However, it could also be associated with high search and negotiation costs arising from the specifics of option orders. At the same time, the permanent spread for both outrights and spreads constitutes a small fraction of the execution cost, which is consistent with the certification hypothesis (Seppi 1990), according to which brokers are able to distinguish liquidity driven trades, which are facilitated in the upstairs market and have minimal price impact in the downstairs market[18]. Finally, EFRPs, which decline dramatically following the regulatory change, face even higher execution costs than in the previous period.

Since blocks and large pit orders are substantially larger than electronic large orders we also explore to replicate our analysis by separating all orders into four size bins. Table 4 presents the execution costs of outrights across all venues before (Panel A) and after the rule change (Panel B). Table 5 presents the execution costs of option trading strategies across all venues before (Panel A) and after the rule change (Panel B).

Panel A of Table 4 shows the differences in effective half spreads between various trading venues before the rule change, aggregated by order size. When comparing large orders of similar size, we observe that large pit orders have the lowest effective half spread. Moreover, although the permanent spread for pit orders is lower than the corresponding ones in the electronic market, permanent spreads constitute more

[17] Moneyness is measured by the absolute value of WTI Futures Price/Strike price - 1. A very small number indicates that the underlying price is close to the strike price, where as a larger number indicates that the underlying price is far from the strike price.

[18] Seppi (1990) does not distinguish between the pit and electronic market, since the electronic market was not popular at the time the paper was written.

than fifty percent of the total execution cost, they are at least partly information driven. This pattern appears to be even stronger after October 15th, 2012 (Panel B). Consistent with the academic literature on block trading (Madhavan & Cheng, 1997), block outright trades prior to the rule change represent orders of substantial size. They exhibit a similar effective half spread, but a lower permanent spread compared to the downstairs market, indicating that they represent a lower information content than orders executed in the downstairs market. After October 15th 2012 only larger block orders have a lower effective half spread than the electronic market (Panel B). However, the permanent spread is consistently lower than all other trading venues irrespective of the order size, suggesting that outright block orders are more likely to be liquidity driven. The cost structure of exchange for related positions appears to be different from block trades. Exchange for related positions exhibit much higher effective half spread and a practically zero permanent spread. On the contrary, block trades have a lower effective half spread and permanent spread while small constitutes a measureable portion of the execution cost.

Table 5 presents the execution costs of option trading strategies when size is considered. Prior to the rule change (Panel A) there are very few electronic spread orders in our sample, which are relatively small. For these small size trades (below 200 contracts), electronic spread orders have the lowest effective half spread compared to all other trading venues. Pit trades appear to be the dominant trading venue for option spreads and there are no spread orders trades as blocks. In the second part of our sample (Panel B), the frequency of smaller electronic option trading strategies increases while their effective half spread remains the lowest across all trading venues. The effective half spread for pit trades increases a little whereas the permanent component decreases. The effective half spread for block trades is higher than all other trading venues irrespective of size, which suggests that brokers providing liquidity command a large premium for search and negotiations costs. Finally, exchange for related positions both before and after the rule change exhibit higher total execution costs than all other trading venues.

VII. Execution costs: Multivariate results

We first model the execution costs (effective half spread, temporary spread and permanent spread) for each order i in each trading venue using the following regression model:

$$y_i = a_0 + a_1 order\ size_i + a_2 spread\ dummy_i + a_3 rule\ change\ dummy_i + a_4 implied\ volatility_i + a_5\ moneyness_i + a_6\ time\ to\ expiration_i + \varepsilon_i$$

where y_i = measure of execution costs (effective half spread, temporary spread, permanent spread),
order size = the number of contracts included in a given order i,
spread dummy = a dummy, which is equal to one if the order is part of a trading strategy and zero otherwise,

rule change dummy = a dummy, which is equal to one if the order was placed after October 15th 2012, and zero otherwise,

implied volatility = the implied volatility of the traded optio

moneyness = the absolute logarithmic difference of the WTI Futures Price and the Strike price,

time to expiration = the number of days between the date of the order and the expiration of the option contract in the order.

The results are presented in table 6. The first three columns refer to the upstairs market (EFRPS & block orders), the following three to pit orders and the last three columns refer to larger orders placed in the electronic market. The standard errors have been corrected for autocorrelation and heteroscedasticity using Newey-West and the corresponding t-statistics are reported in italics below the parameters. The intercept for the effective half spread, which proxies for the effective half spread after controlling for order characteristics and market conditions, is the positive for the upstairs market market and the pit, and insignificant for the electronic market. Consistent to the univariate results, the intercept for the temporary spread in the upstairs market is positive and statistically significant, while the intercept of the permanent spread is not statistically different from zero. This suggests that upstairs orders are generally liquidity driven. However, the coefficient of the rule change dummy is positive and significant for the effective half spread and the permanent spread, indicating that the appearance of some informed orders after the minimum block threshold was reduced. They could be representing informed orders migrating to the upstairs market from the downstairs market. Pit orders seem to be associated with a significant permanent spread, as indicated by the positive intercept. Moreover the coefficients for the rule change dummy in the effective half spread and temporary spread regressions are positive and statistically significant suggesting that pit orders became harder to execute after the minimum block threshold was reduced. The rule change dummy is also positive and significant for the effective half spread for electronic orders. The coefficients for order size suggest that larger orders tend to receive better pricing in the upstairs market and the pit and worse pricing in the electronic market. Contrary to the upstairs market and the pit, trading strategies enjoy a lower effective half spread than other electronic orders. Implied volatility appears to increase the execution costs for upstairs and pit orders, while we do not find a significant effect in the electronic market. Finally, moneyness is associated with higher execution costs and time to expiration with lower execution costs irrespective of the trading venue.

The above results do not take into account the fact that traders self-select the venue accounting for the expected trade cost of each venue for their orders. Therefore, to account for self selection, we use Lee's (1983) two stage model. The probability of choosing each s alternative venue out of the total M alternatives (i.e. three venues in our case) for each order i is given by:

$$P_{s,i} = \frac{e^{\beta_s{}' X_i}}{\sum_{j=1}^{M} e^{\beta_s{}' X_i}}$$

where X_i is a vector of explanatory variables which include order characteristics (order size, spread dummy, moneynesss, days to expiration), implied volatility which serves as a proxy for market conditions and the rule change dummy.

In the second stage, we model the execution costs across venues accounting for the selection of the venue. The conditional execution costs (effective half spread, temporary spread and permanent spread) for alternative s is given by :

$$y_{s,i} = \gamma_s{}' Z_i - \sigma_s \rho_s \varphi(\frac{\Phi^{-1} P_{s,i}}{P_{s,i}}) + u_{s,i}$$

where $y_{s,i}$ represents the execution cost of the venue chosen, $E(u_{s,i}, s) = 0$, φ is the standard normal density function, σ_s is the standard deviation of the original disturbance term of the execution cost equation and ρ_s is the correlation of this error term with the error term from the choice equation. Finally, Z_i includes all the explanatory variables included in the choice function except the rule change dummy. Following Lee (1983) we estimate this equation using OLS. The OLS coefficienet corresponds to $\sigma_s \rho_s$ and its sign indicates whether the selection of the particular trading venue actually results in lower execution costs.

We first use a multinomial logistic regression to model the choice of the trading venue, which we normalize with respect to the choice of the electronic venue. The results appear in Table 7. Our results indicate that orders placed as blocks and at the pit have similar characteristics: they tend to be larger, they are often part of a trading strategy, they include options with lower moneyness as short time until expiration. We also note that orders are more likely to be placed as blocks than to be directed at the pit if they are larger, whereas pit seems to be favored for trading strategies. Block and pit orders are also more likely when volatility is high. Finally, we note that the coefficient for the rule change dummy is positive and significant for block orders and negative and significant for pit orders which could be indicative orders migrating from the pit to the upstairs market after the reduction in the minimum block size in October 2012.

In the second stage, we use OLS to estimate the execution costs of each venue conditional on the traders' choice of venue. The results are presented in Table 8. The intercept of the effective half spread equations reflect the unconditional average effective half spread for every venue. Our results reveal that the total execution costs of orders placed as blocks are higher than those placed at the pit and the electronic market, which can be attributed to higher temporary spread, which suggests that block orders are generally

liquidity driven. We also note that execution costs for trading strategies are higher in the pit compared to block orders which could have potentially led to a migration of orders from the pit to the block market. The selection correction terms are significant in all three regressions. However, the coefficient of the selection correction term is negative just for electronic market, indicating that the choice of placing large orders in the electronic market leads indeed to lower execution costs.

Finally, we estimate the unconditional execution costs across all trading venues by estimating the following OLS regression:

$$y_i = \delta' Z_i - \theta_1 Block\ dummy_i + \theta_2 Pit\ dummy_i + \theta_3 Block\ dummy\ select_{block,i} + \theta_4\ Pit\ dummy_i\ select_{pit,i} + (1 - Pit\ dummy_i - Block\ dummy_i)\ select_{electronic,i}$$

where y_i represents execution costs, the block (pit) dummy takes the value one if the order was placed as a block (at the pit), and the remaining terms are interecation terms of the venue dummies the selection correction terms for each venue, estimated using the results of the first stage multinomial logistic regression.

Table 9 presents the results. The block dummy is positive and statistically significant, while the pit dummy is negative and statistically significant, providing further evidence that block orders have the highest execution cost. Results are similar for the temporary spread, indicating that block orders are mostly liquidity driven, which is consistent with the notion that orders routed as blocks have high search costs. Moreover, blocks have a lower permanent spread. When we look at the interaction terms, we note that the interaction terms with the corresponding selection correction terms are negative and significant for the block and electronic orders and positive for pit orders, which indicates that those selecting to trade in the block market or the electronic order book get lower costs.

Our results suggest that the pit is the least attractive trading venue, which combined with our finding that orders routed at the pit and the upstairs market share similar characteristics, indicates that the reduction in the minimum threshold for block trades could have drawn liquidity from the pit. This is also consistent with the decline of the popularity of the energy options pit, which led to its eventual closure in December 2012. At the same time, the surge in trading activity in block trades, which can offer competitive execution costs for certain orders, suggests that there that human intermediation might still be valuable for the execution of illiquid financial instruments, such as option trading strategies. This is an interesting finding in light of the recent approval of BOX Options Exchange, a Chicago based open outcry trading venue.

VIII. Conclusion

We use a comprehensive dataset of trades in the crude oil option market between 2011 and 2014 to investigate large trades executing in the downstairs market (pit and electronic market) as well as EFRPs

and blocks. We document that block trading has increased substantially after a reduction in the legal minimum block threshold in October 2012. Block trades have lower effective half spread than the corresponding effective half spread of exchange for related positions prior to the rule change. At the same time, while the permanent component of the EFRP spread is statistically insignificant, we find evidence that blocks have a higher permanent spread than EFRPs. However, the permanent spread constitutes a small portion of the total execution costs, which suggests that while block trades reflect some information content, they are primarily liquidity driven. The high temporary component of the effective half spread for blocks could be interpreted as compensation for search and negotiation costs. Moreover, block trading appears to attract option trading strategies, which, combined with the beforementioned difference in the cost structure of blocks and EFRPs, suggests that the block trading volume after the rule change cannot be solely attributed to the migration of EFRPs to blocks.

The proliferation of block orders involving option trading strategies raises questions on whether the reduction of the minimum block threshold may have led to the migration of pit orders, often option trading strategies, to the upstairs market. We indeed find that both the pit and block trading attract orders with similar characteristics and that the relative popularity of blocks has increased while that of the pit has declined. Moreover, the choice to execute an order at the pit appears to be associated with higher execution costs compared to block trading and the electronic market. At the same time, the choice to trade in the electronic market is also associated with lower exectution costs. Morever, we observe that the execution costs of electronic option trading strategies are low compared to other trading venues and the volume of such trades in the electronic market increases. Still, electronic option spread trades are small compared to pit and block trades. These findings suggest that the electronic market provides a cost efficient trading venue for executing relatively large orders linked to option trading strategies. However, it is mostly able to absorb relatively smaller "large orders".

Our results suggest that the reduction of the minimum threshold for block trading in the WTI options market, has attracted order flow with low information content from the pit to the upstairs market, which combined with the increased ability of the electronic order book to offer a cost effective execution for some option trading strategies may has facilitated the break down of the options market at the pit, which was eventually shut down in December 2016. Our findings also highlight the need of human intermediation for the execution of certain types of orders; an interesting finding in light of the continuous electronification of trading and the recent approval of the Box Options Exchange, a new open outrcry trading venue.

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Table 1: The reduction in block trade thresholds in energy contracts.

This table describes the reduction in the minimum threshold for block trades in the energy market, which was introduced in October 2012. It shows the old and the revised block minimum threshold for eight prominent energy contracts trading at NYMEX.

Contract	Commodity Code	Old block threshold	New block threshold
Light Sweet Crude Oil futures	CL	100 contracts	50 contracts
Light Sweet Crude Oil options	LO	1000 contracts	100 contracts
Brent Crude Oil Last Day Financial Futures	BZ	100 contracts	25 contracts
Henry Hub Natural Gas futures	NG	100 contracts	50 contracts
Henry Hub Natural Gas options	ON	1,600 contracts	100 contracts
New York Harbor ULSD Heating Oil futures	HO	50 contracts	25 contracts
RBOB Gasoline futures	RB	50 contracts	25 contracts
Henry Hub Natural Gas Look-Alike options	LN	550 contracts	15 contracts

Source: CME Group. (2012, September 27). Certification Rule, Submission 12-292R, Retrieved from http://www.cmegroup.com/market-regulation/files/12-301_FINAL.pdf.

Table 2: Summary statistics for large orders

This table presents the activity of large orders on each venue before and after October 15th 2012, when the minimum threshold for block trades was reduced. We define large orders as those WTI Crude oil options trades that would meet the post October 2012 minimum block order threshold. Panel A presents summary statistics on all such orders during the period extending from January 1st 2012 to December 31st 2014. The sample is separated in orders placed and executed before and after October 15, 2012, which is when the minimum block trade threshold was reduced. Panel B separates these orders in outrights and option trading strategies.

Panel A: Summary statistics for large orders in WTI Crude oil options

	Before Oct 15 2012				After October 15 2012			
	Average Order Size	Average Daily Order Number	Average Daily Volume	Volume Percentage of Large Orders	Average Order Size	Average Daily Order Number	Average Daily Volume	Volume Percentage of Large Orders
EFRPS	404.28	222.38	89,905.44	0.52	410.96	15.99	6,570.14	0.05
Blocks	4331.29	2.80	12,109.93	0.07	735.72	101.41	74,612.79	0.52
Electronic	143.70	131.85	18,946.47	0.11	162.03	237.39	38,463.57	0.27
Pit	321.33	158.10	50,800.54	0.30	368.51	67.39	24,833.38	0.17

Panel B: Summary statistics for large orders in WTI Crude oil options – Outrights vs. Trading Strategies

		Before Oct 15 2012				After Oct 15 2012			
	Spread Dummy	Average Order Size	Average Daily Order Number	Average Daily Volume	Volume Percentage of Large Orders	Average Order Size	Average Daily Order Number	Average Daily Volume	Volume Percentage of Large Orders
EFRPs	1	323.42	135.27	43,748.05	0.25	256.17	11.05	2,830.14	0.02
Blocks	1	4,326.80	2.82	12,204.55	0.07	1,055.31	18.86	19,903.69	0.14
Electronic	1	140.76	122.58	17,254.07	0.10	150.01	165.41	24,812.30	0.17
Pit	1	224.08	25.63	5,742.22	0.03	230.09	8.94	2,057.35	0.01
EFRPs	2	529.84	87.12	46,157.39	0.26	557.87	10.45	5,830.59	0.04
Blocks	2	5,250.00	1	5,250.00	0.03	663.67	82.76	54,923.12	0.37
Electronic	2	182.51	10.43	1,903.95	0.01	189.65	72.47	13,743.04	0.09
Pit	2	340.14	132.47	45,058.32	0.25	385.62	59.97	23,127.55	0.16

Table 3 – Execution costs in all trading venues

Table 3 compares execution costs (effective half spread, temporary impact, price impact) of large orders across all trading venues. We define large orders as those WTI Crude oil options trades that would meet the post October 2012 minimum block order threshold. Our dataset extends from January 1st 2012 to December 31st 2014. Orders are separated in outrights and option trading strategies. Panel A presents execution costs prior to October 15th, 2012, while Panel B presents execution costs after the minimum block threshold was reduced.

Panel A: Execution costs in all trading venues before the rule change

Before October 15th, 2012												
	Type	Effective Half Spread	Temporary	Permanent	Temporary %	Permanent %	Average trade size per contract	Time to Expiration	Moneyness	Implied volatility	Obs	Number of accounts
Electronic	Outright	7.03	2.39	4.64	0.34	0.66	130	33	0.16	0.37	1559	192
	Spread	2.67	0.88	1.79	0.33	0.67	64	34	0.08	0.33	771	38
Pit	Outright	5.52	1.55	3.97	0.28	0.72	191	33	0.16	0.35	2082	146
	Spread	7.85	5.47	2.38	0.70	0.30	146	34	0.08	0.33	21525	322
Block	Outright	7.90	3.76	4.14	0.48	0.52	1381	20	0.13	0.36	406	16
	Spread											
EFRP	Outright	10.35	9.50	0.86	0.92	0.08	158	32	0.08	0.33	5098	306
	Spread	10.48	10.11	0.37	0.96	0.04	149	30	0.07	0.32	6390	228

Panel B: Execution costs in all trading venues after the rule change

After October 15th, 2012												
	Type	Effective Half Spread	Temporary	Permanent	Temporary %	Permanent %	Average trade size per contract	Time to Expiration	Moneyness	Implied volatility	Obs	Number of accounts
Electronic	Outright	6.88	1.53	5.35	0.22	0.78	130	48	0.09	0.25	5908	516
	Spread	2.95	1.19	1.76	0.40	0.60	65	74	0.06	0.22	16584	167
Pit	Outright	4.04	1.14	2.90	0.28	0.72	231	43	0.09	0.26	1352	151
	Spread	8.68	7.00	1.68	0.81	0.19	493	37	0.05	0.24	25163	386
Block	Outright	8.09	5.75	2.34	0.71	0.29	1570	438	0.07	0.26	6006	348
	Spread	9.16	8.14	1.02	0.89	0.11	767	189	0.05	0.23	30590	556
EFRP	Outright	18.34	18.12	0.22	0.99	0.01	138	25	0.07	0.30	547	114
	Spread	14.27	15.10	-0.84	1.06	-0.06	142	21	0.05	0.31	946	125

Table 4 – Execution costs for crude oil option outrights

Table 4 presents the execution costs (effective half spread, temporary impact, price impact) of WTI crude oil option outrights by size across all venues before (Panel A) and after the rule change (Panel B). Our sample consists of large option outright orders placed and executed during the period extending from January 1st 2012 to December 31st 2014. We define large orders as those WTI Crude oil options trades that would meet the post October 2012 minimum block order threshold. Orders are separated by size in four groups.

Panel A: Execution costs for crude oil option outrights by order size prior to the rule change

			Before October 15th, 2012										
			Outrights										
	Order Size Bin	Order Size	Effective Half Spread	Temporary	Permanent	Temporary %	Permanent %	Average trade size by contract	Time to Expiration	Moneyness	Implied volatility	Obs	Number of accounts
Electronic	1	0-200	6.49	2.42	4.07	0.37	0.63	108	32	0.15	0.37	1366	184
	2	200-400	10.17	2.38	7.79	0.23	0.77	227	30	0.19	0.40	159	44
	3	400-999	13.84	1.12	12.69	0.08	0.92	488	57	0.27	0.43	34	18
Pit	1	0-200	5.29	1.38	3.91	0.26	0.74	91	30	0.13	0.35	1366	113
	2	200-400	5.37	1.90	3.48	0.35	0.65	237	31	0.15	0.36	435	77
	3	400-600	6.33	1.88	4.46	0.30	0.70	469	28	0.16	0.3	195	39
	4	>=600	8.00	1.80	6.21	0.22	0.78	898	25	0.15	0.3	86	17
Block	1	0-200											
	2	200-400											
	3	400-600											
	4	>=600	7.90	3.76	4.14	0.48	0.52	1381	20	0.13	0.36	406	16
EFRP	1	0-200	10.08	9.40	0.69	0.93	0.07	77	29	0.07	0.32	3718	280
	2	200-400	10.46	8.99	1.47	0.86	0.14	230	33	0.09	0.34	980	139
	3	400-600	10.80	9.67	1.14	0.89	0.11	461	37	0.10	0.34	253	76
	4	>=600	15.75	15.09	0.66	0.96	0.04	1225	37	0.14	0.35	147	54

Panel B: Execution costs for crude oil outrights by order size after the rule change

			After October 15, 2012										
			Outrights										
	Order Size Bin	Order Size	Effective Spread	Temporary	Permanent	Temporary %	Permanent %	Average Order size	Time to Expiration	Moneyness	Implied volatility	Obs	Number of accounts
Electronic	1	0-200	6.36	1.44	4.92	0.23	0.77	109	48	0.08	0.25	5075	484
	2	200-400	9.29	2.28	7.01	0.25	0.75	227	49	0.11	0.25	729	166
	3	400-600	14.89	-0.54	15.42	-0.04	1.04	445	42	0.14	0.27	88	36
	4	>=600	17.57	8.67	8.90	0.49	0.51	760	42	0.21	0.33	16	9
Pit	1	0-200	3.80	1.18	2.62	0.31	0.69	90	42	0.08	0.25	915	114
	2	200-400	4.36	1.73	2.63	0.40	0.60	237	42	0.11	0.27	280	87
	3	400-600	4.29	-0.69	4.98	-0.16	1.16	473	52	0.11	0.27	106	38
	4	>=600	5.94	0.81	5.13	0.14	0.86	940	41	0.14	0.28	51	19
Block	1	0-200	7.95	5.38	2.57	0.68	0.32	106	47	0.06	0.25	2283	282
	2	200-400	7.80	6.16	1.63	0.79	0.21	239	51	0.07	0.25	1573	216
	3	400-600	8.56	6.31	2.25	0.74	0.26	480	36	0.09	0.26	970	125
	4	>=600	8.37	5.46	2.91	0.65	0.35	1310	36	0.10	0.27	1180	90
EFRP	1	0-200	20.30	20.40	-0.10	1.01	-0.01	50	24	0.05	0.29	446	111
	2	200-400	8.08	12.24	-4.16	1.52	-0.34	232	32	0.12	0.33	59	26
	3	400-600	10.54	5.59	4.95	0.53	0.89	476	29	0.13	0.35	19	13
	4	>=600	13.18	-0.71	13.89	-0.05	-19.48	1304	19	0.11	0.38	23	8

Table 5: Execution costs for crude oil option trading strategies

Table 5 presents the execution costs (effective half spread, temporary impact, price impact) of WTI crude oil option trading strategies by size across all venues before (Panel A) and after the rule change (Panel B). Our sample consists of large orders involving option trading strategies. These orders were placed and executed during the period extending from January 1st 2012 to December 31st 2014. We define large orders as those WTI Crude oil options trades that would meet the post October 2012 minimum block order threshold. Orders are separated by size in four groups.

Panel A: Execution costs for crude oil option trading strategies by order size prior to the rule change

			Before October 15th, 2012										
			Spreads										
	Order Size Bin	Order Size	Effective Half Spread	Temporary	Permanent	Temporary %	Permanent %	Average trade size by contract	Time to Expiration	Moneyness	Implied volatility	Obs	Number of accounts
Electroni	1	0-200	2.44	0.43	2.01	0.18	0.82	57	34	0.08	0.33	76	37
	2	200-400	8.37	11.98	-3.62	1.43	-0.43	241	25	0.09	0.33	10	6
	3	400-600											
	4	>=600											
Pit	1	0-200	8.11	5.82	2.29	0.72	0.28	74	24	0.06	0.32	16386	280
	2	200-400	7.00	4.47	2.53	0.64	0.36	233	29	0.09	0.33	3393	161
	3	400-600	6.76	4.22	2.54	0.62	0.38	465	27	0.10	0.34	1117	94
	4	>=600	7.53	4.10	3.43	0.54	0.46	970	25	0.11	0.35	629	63
Block	1	0-200											
	2	200-400											
	3	400-600											
	4	>=600											
EFRP	1	0-200	10.36	9.82	0.54	0.95	0.05	82	29	0.06	0.32	4534	219
	2	200-400	10.72	10.47	0.25	0.98	0.02	227	33	0.08	0.33	1394	133
	3	400-600	10.85	12.27	-1.42	1.13	-0.13	450	37	0.11	0.34	336	78
	4	>=600	11.08	10.78	0.30	0.97	0.03	899	37	0.12	0.34	126	41

Panel B: Execution costs for crude oil option trading strategies by order size after the rule change

			After October 15, 2012										
			Spreads										
	Order Size Bin	Order Size	Effective Spread	Temporary	Permanent	Temporary %	Permanent %	Average Order size	Time to Expiration	Moneyness	Implied volatility	Obs	Number of accounts
Electronic	1	0-200	2.91	1.14	1.77	0.39	0.61	60	74	0.05	0.22	16132	166
	2	200-400	4.12	2.83	1.28	0.69	0.31	226	76	0.08	0.23	409	39
	3	400-800	-0.94	-2.03	1.09	2.16	-1.16	452	69	0.09	0.26	43	15
Pit	1	0-200	9.03	7.36	1.67	0.81	0.19	75	35	0.04	0.24	18045	343
	2	200-400	8.00	6.18	1.82	0.77	0.23	237	41	0.06	0.24	4879	226
	3	400-600	7.03	5.56	1.47	0.79	0.21	458	44	0.07	0.24	1453	137
	4	>=600	8.07	6.70	1.38	0.83	0.17	910	50	0.09	0.25	786	95
Block	1	0-200	9.08	8.15	0.93	0.90	0.10	94	50	0.04	0.23	18951	477
	2	200-400	9.18	8.17	1.02	0.89	0.11	231	57	0.06	0.23	8394	361
	3	400-600	9.34	7.72	1.62	0.83	0.17	457	64	0.07	0.24	2172	221
	4	>=600	10.08	8.62	1.47	0.85	0.15	988	81	0.08	0.24	1073	140
EFRP	1	0-200	14.21	15.44	-1.24	1.09	-0.08	64	19	0.04	0.31	694	110
	2	200-400	14.30	14.79	-0.49	1.03	-0.03	240	22	0.07	0.32	179	62
	3	400-600	16.40	15.43	0.97	0.94	0.06	477	23	0.10	0.33	49	24
	4	>=600	11.46	6.93	4.53	0.60	0.65	988	35	0.10	0.35	24	15

Table 6: Execution costs across trading venues using multivariate regression

Table 6 presents the regression resuts of execution costs (effective half spread, temporary spread and permanent spread) on option characteristics (order size, spread dummy, moneyness and time to expiration), market conditions deteremined by the implied volatility and the rule change dummy, which takes the value one after October 15th 2012, when the minimum permissible block threshold was reduced, and zero otherwise. The first three columns refer to the upstairs market (EFRPS & block orders), the following three to pit orders and the last three columns refer to larger orders placed in the electronic market. The standard errors have been corrected for autocorrelation and heteroscedasticity using Newey-West and the corresponding t-statistics are reported in italics below the parameters. Significance at the 0.01, 0.05, 0.10 level is market by *, **, *** respectively.

	Upstairs Market			Pit			Electronic		
	Effective half spread	Temporary spread	Permanent spread	Effective half spread	Temporary spread	Permanent spread	Effective half spread	Temporary spread	Permanent spread
Intercept	9.4463***	9.9142***	-0.4679	3.3673***	1.5753	1.792**	-1.4531	-3.4874*	2.0343
	7.77	*6.26*	*-0.53*	*3*	*1.1*	*1.99*	*-1.18*	*-1.78*	*1.23*
Order size	-0.9356***	-1.2288***	0.2931***	-1.5987***	-1.661***	0.0624	1.1191***	0.5473**	0.5718***
	-5.08	*-5.63*	*2.69*	*-8.91*	*-8.53*	*0.82*	*5.52*	*2.05*	*2.6*
Spread	0.6129**	1.4401***	-0.8272***	4.2213***	5.6331***	-1.4118***	-2.4837***	0.3056	-2.7893***
dummy	*2.21*	*3.92*	*-3.36*	*17.62*	*16.89*	*-4.58*	*-10.33*	*0.98*	*-10.28*
Rule	0.6613*	-0.0519	0.7132**	3.4085***	3.5819***	-0.1734	1.1638***	0.5378	0.6261
change	*1.72*	*-0.11*	*2.37*	*9.47*	*8.19*	*-0.65*	*3.41*	*1.3*	*1.47*
Implied	12.8104***	12.8634***	-0.0531	21.1034***	14.9857***	6.1178**	3.8443	5.9814	-2.1371
Volatility	*4.94*	*3.73*	*-0.03*	*7.22*	*3.99*	*2.52*	*1.49*	*1.55*	*-0.69*
Moneyness	15.3021***	11.0137***	4.2883**	19.5946***	21.2964***	-1.7018	11.8699***	5.1621*	6.7078**
	5.42	*3.12*	*2.06*	*6.49*	*6.14*	*-0.9*	*5.37*	*1.73*	*2.55*
Days to	-0.0111***	-0.0095***	-0.0017	-0.029***	-0.0232***	-0.0058**	-0.0038***	-0.0002	-0.0036**
expiration	*-5.69*	*-4.03*	*-1.2*	*-8*	*-5.51*	*-2.55*	*-2.73*	*-0.12*	*-2.3*
N	49980	49980	49980	50117	50117	50117	24804	24804	24804
R-squared	0.0163	0.0091	0.0014	0.0355	0.0196	0.0024	0.0573	0.0042	0.0152

Table 7 : The choice of trading venue using a multinomial logistic regression

Table 7 presents the results of a multinomial logit regression, which models the choice of the trading venue, which we normalize with respect to the choice of the electronic venue. Independent variables include option characteristics (order size, spread dummy, moneyness and days to expiration), the option's implied volatility proxying for market conditions and the rule change dummy which takes the value one after October 15th 2012, when the minimum permissible block threshold was reduced, and zero otherwise. Corresponding p-values are reported below each coefficient. Significance at the 0.01, 0.05, 0.10 level is market by *, **, *** respectively.

The choice of trading venue: Multinomial Logit		
Parameter	Block orders	Pit orders
Intercept	-9.9053***	-3.087***
	<.0001	<.0001
Order size	1.5585***	0.7802***
	<.0001	<.0001
Spread dummy	1.3756***	2.8066***
	<.0001	<.0001
Implied volatility	1.4563***	1.4985***
	<.0001	<.0001
Moneyness	-5.6008***	-3.587***
	<.0001	<.0001
Days to expiration	-0.0007***	-0.0041***
	<.0001	<.0001
Rule change dummy	2.1164***	-2.5719***
	<.0001	<.0001
Test parameters coef=0	Chi-Square	Pr > ChiSq
Likelihood ratio	62198.2826	<.0001
Wald	29721.1889	<.0001

Table 8: Execution costs conditional on the choice of venue

Table 8 presents the second stage of Lee's (1983) two stage model. It represents an OLS regression, which models the conditional execution costs (effective half spread, temporary spread and permanent spread) for alternative trading venue (pit, electronic and block) s. The model is given by $y_{s,i} = \gamma_s{}' Z_i - \sigma_s \rho_s \varphi(\frac{\Phi^{-1} P_{s,i}}{P_{s,i}}) + u_s$ where $y_{s,i}$ represents the execution cost of the venue chosen, $E(u_s, s) = 0$, φ is the standard normal density function, σ_s is the standard deviation of the original disturbance term of the execution cost equation and ρ_s is the correlation of this error term with the error term from the choice equation. Finally, Z_i includes all the explanatory variables included in the choice function Following Lee (1983) we estimate this equation using OLS. The OLS coefficienet corresponds to $\sigma_s \rho_s$ and its sign indicates whether the selection of the particular trading venue actually results in lower execution costs. The corresponding t-statistics are reported below each coefficient. Significance at the 0.01, 0.05, 0.10 level is market by *, **, *** respectively.

	Block Market			Pit			Electronic		
	Effective half spread	Temporary spread	Permanent spread	Effective half spread	Temporary spread	Permanent spread	Effective half spread	Temporary spread	Permanent spread
Intercept	3.2920***	3.8213***	-0.52928	-0.9497**	-2.8736***	1.9239***	-2.4375***	-4.4004***	1.96287***
	3.69	3.18	-0.62	-2.54	-5.8	5.480	-5.28	-6.38	2.89
Order size	0.07	-0.3062*	0.3761***	-1.5287***	-1.5877***	0.059	1.7732***	0.987***	0.78623***
	0.57	-1.85	3.23	-38.52	-30.19	1.580	15.65	5.83	4.71
Spread dummy	1.8323***	2.8972***	-1.0648***	6.9286***	8.4546***	-1.5261***	-1.3528***	1.0431***	-2.39587***
	13.68	16.07	-8.38	40.3	37.11	-9.440	-8.11	4.19	-9.75
Implied volatility	9.1933***	10.0774***	-0.88412	24.0452***	17.9245***	6.1206***	4.3327***	6.5328***	-2.20009***
	13.41	10.92	-1.36	32	18	8.670	9.16	9.25	-3.16
Moneyness	16.7473***	10.4072***	6.3401***	18.1175***	19.7783***	-1.6608**	9.2142***	3.4396***	5.77456***
	16.07	7.42	6.41	22.54	18.57	-2.200	14.05	3.51	5.98
Days to expiration	-0.00752***	-0.0059***	-0.0016***	-0.0356***	-0.0301***	-0.0055***	-0.0050***	-0.001	-0.00399***
	-11.48	-6.67	-2.64	-34	-21.69	-5.59	-12.15	-1.61	-6.61
select_xpit	1.3498***	0.4729	0.8769***						
	4.36	1.13	2.98						
select_pit				4.157***	4.3302***	-0.1732*			
				43.79	34.42	-1.940			
select_electronic							-1.3433***	-0.91677***	-0.42651
							-7	-3.2	-1.51
N	110997	110997	110997	150351	150351	150351	74412	74412	74412
R-squared	0.0133	0.0069	0.0022	0.0398	0.0223	0.0025	0.057	0.0044	0.0153

Table 9: Execution costs across different trading venues

Table 9 models the unconditional execution costs across all trading venues by estimating the following OLS regression:

$$y_i = \delta' Z_i - \theta_1 Block\ dummy_i + \theta_2 Pit\ dummy_i + \theta_3 Block\ dummy\ select_{block,i} + \theta_4\ Pit\ dummy_i\ select_{pit,i} + (1 - Pit\ dummy_i - Block\ dummy_i)\ select_{electronic,i}$$

where y_i represents execution costs, the block (pit) dummy takes the value one if the order was placed as a block (at the pit), and the remaining terms are interecation terms of the venue dummies the selection correction terms for each venue, estimated using the results of the first stage multinomial logistic regression presented in Table 7. The corresponding t-statistics are reported below each coefficient. Significance at the 0.01, 0.05, 0.10 level is market by *, **, *** respectively.

	Effective half spread	Temporary spread	Permanent spread
Intercept	6.90171***	2.97662***	3.92509***
	30.74	9.87	17.54
Order size	-0.92733***	-1.09386***	0.16652***
	-27.54	-24.19	4.96
Spread dummy	0.88388***	2.78115***	-1.89727***
	11.03	25.84	-23.76
Implied volatility	11.31645***	10.38367***	0.93278**
	29.15	19.92	2.41
Moneyness	14.54672***	11.59486***	2.95185***
	30.04	17.83	6.12
Days to Expiration	-0.01047***	-0.00763***	-0.00283***
	-26.89	-14.6	-7.31
Block dummy	3.77636***	6.33606***	-2.5597***
	15.78	19.72	-10.73
Pit dummy	-0.44437**	0.30767	-0.75203***
	-2.19	1.13	-3.73
Block dummy *	-0.84257***	-1.32052***	0.47796***
Select_Block	-5.27	-6.16	3
Pit dummy * Select_Pit	1.87886***	2.50686***	-0.628***
	25.26	25.1	-8.47
(1 - Block dummy - Pit	-2.44407***	-1.71475***	-0.72932***
dummy)* Select_Elect.	-15.45	-8.07	-4.63
N	335760	335760	335760
R-squared	0.0328	0.0237	0.0055

Figure 1: The Upstairs WTI options market

Figure 1 presents the share in the total volume in WTI crude oil options for EFRPs and blocks trades during our the period extending from September 2011 to December 2014.. EFRP and block trading volumes are reported in separate graphs. We also examine option outrights and option trading strategies ("spreads") separately.

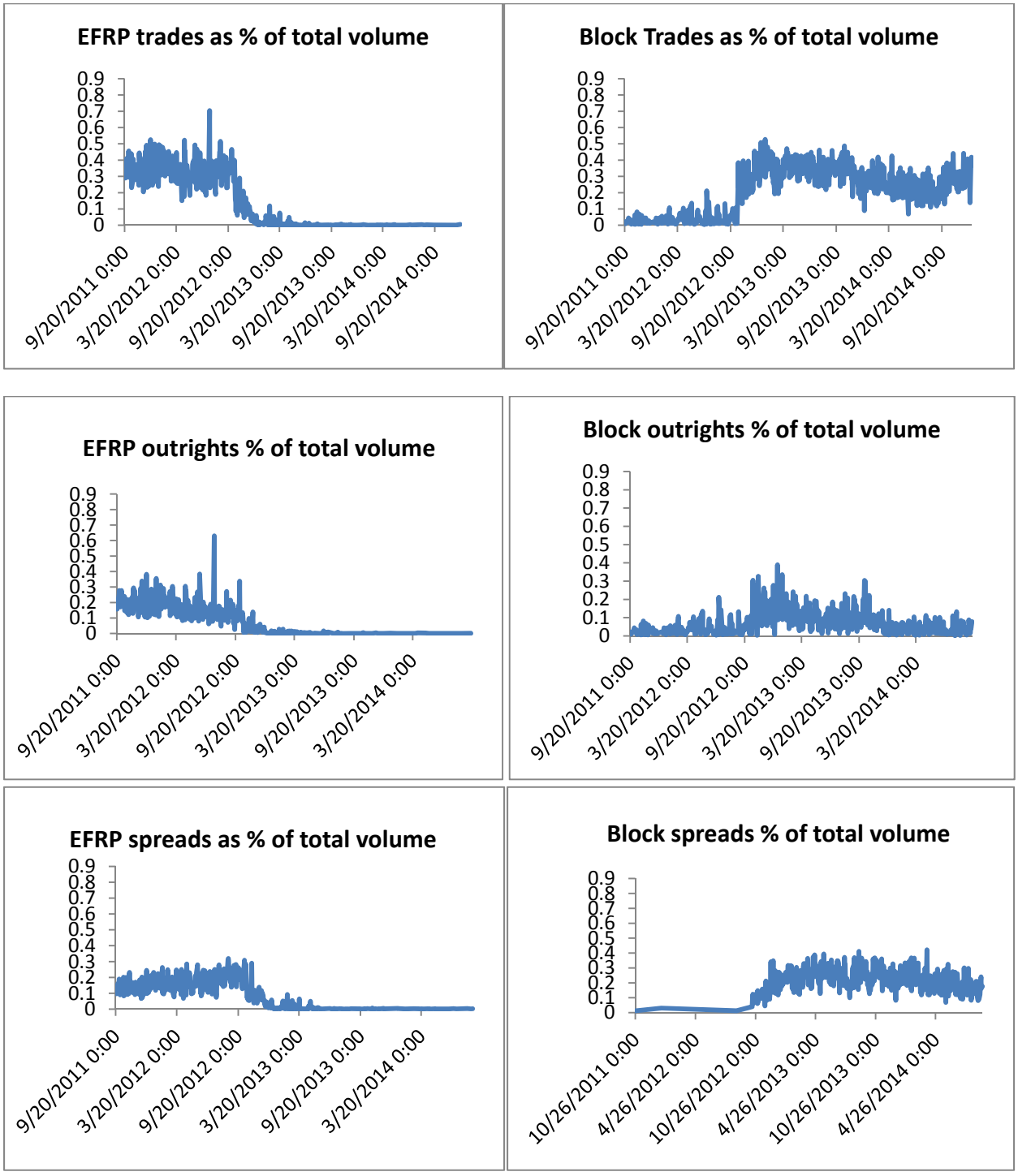

Figure 2: The WTI Futures market

Figure 2 exhibits the daily proportion of futures trading in the four venues (the pit, the electronic market, block trades and EFRPs) during the time period extending from September 2011 to December 2014.

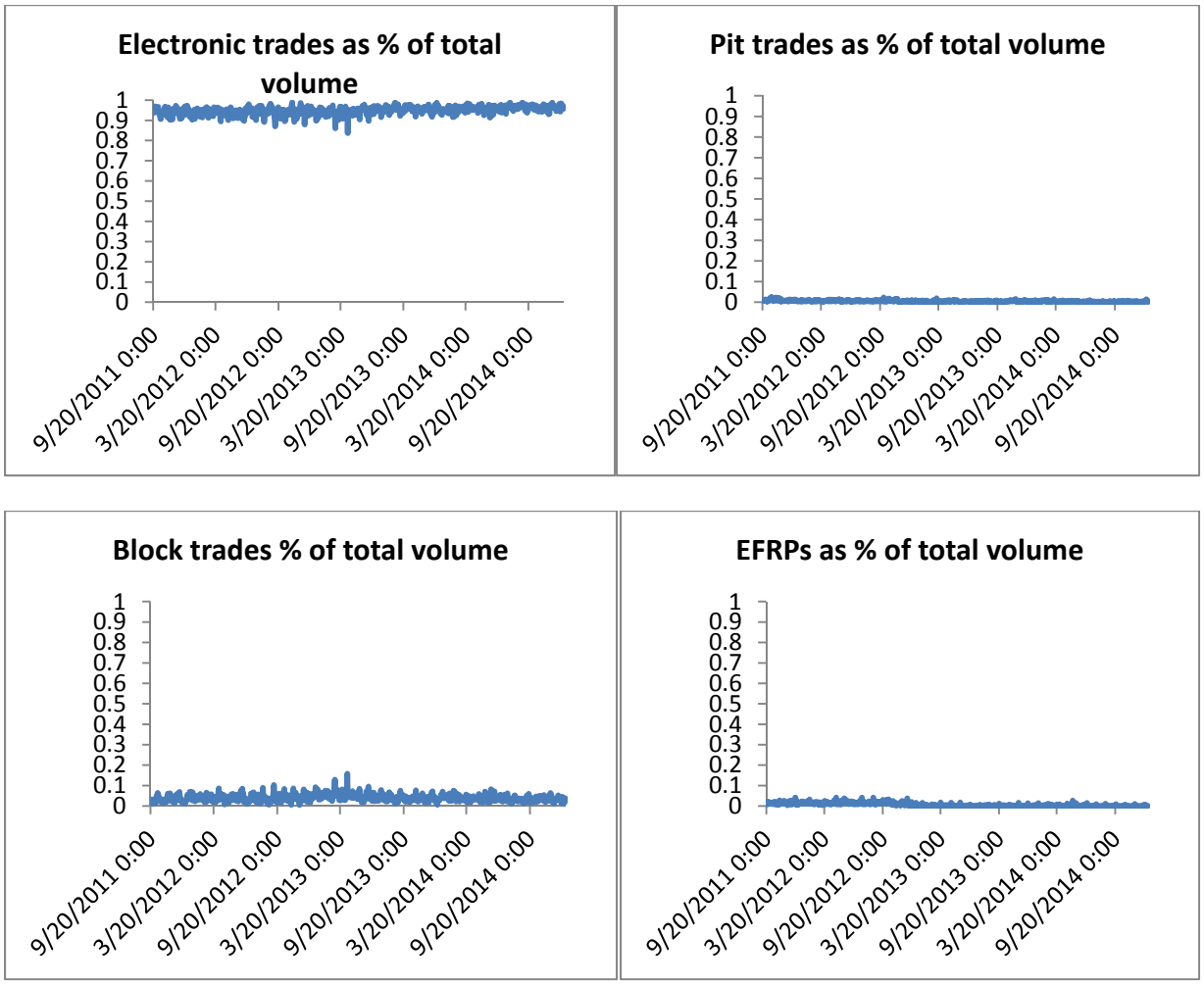

Figure 3: The downstairs WTI options market

Figure 3 exhibits the daily proportion of trading in the pit and the electronic market during the time period extending from September 2011 to December 2014. We present trading volume for option outrights and trading strategies separately.