Exploring price impact liquidity for December 2016 NYMEX energy contracts

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This paper proposes a new daily price impact assessment for futures contracts, LL_d*, while investigating four December 2016 energy contracts listed on NYMEX: CL (crude oil); NG (natural gas); HO (diesel); and RB (gasoline). The paper uses transaction prices in nearby futures contract prices to update stale prices. By making this adjustment, the author improves the liquidity assessments. Farther out the curve, trading in spread transactions is more predominant than in outright transactions. The computations suggest that a market participant could have achieved, in general, a smaller price impact than trading in an outright December transaction by first entering into a December-to-December spread transaction in CL and then exiting out of the new December position with one year shorter time to expiration with a corresponding outright trade. The lower price impact may be due to substantial liquidity that may result from market participants using the spread transactions to increase the time to expiration of their CL positions. This result, however, fails to hold for the other three energy contracts.*

1. INTRODUCTION

The author proposes a new daily liquidity assessment, $\mathrm{LL_d}$.[2] The paper examines the liquidity of the December 2016 contracts on NYMEX for light sweet crude oil[3] (CL), Henry Hub natural gas[4] (NG), New York Harbor ULSD[5] (HO), and RBOB gasoline[6] (RB). Over the lifetime of the contracts, generally, the price impacts are less than 1.0% of the contract price.

2. LIQUIDITY ASSESSMENT

LL_d is the volume-weighted average price impact of trades involving a futures contract over a trading day.[7] It focuses on trades that may affect changes to open interest at the end of the trading day and not just the immediate ability to trade with a counterparty which has been the traditional focus of liquidity assessments that are designed for market making.[8] LL_d does not use limit order book quotes, because quotes do not represent consummated trades. Further, some of the liquidity in the limit order book is fleeting and cannot be traded against. In addition, the limit

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[2] See Leon (2012) for a discussion on the importance of liquidity risk management for financial institutions and their supervisory regulators.

[3] The underlying is West Texas Intermediate crude oil that may be delivered in Cushing, OK. See http://www.cmegroup.com/trading/energy/crude-oil/light-sweet-crude_contract_specifications.html.

[4] Henry Hub is located in Erath, LA. See http://www.cmegroup.com/trading/energy/natural-gas/natural-gas_contract_specifications.html.

[5] ULSD stands for ultra-low-sulfur diesel. This contract used to be called heating oil. The contract specification was changed slightly by NYMEX, but the contract still retained its HO symbol. See http://www.cmegroup.com/trading/energy/refined-products/heating-oil_contract_specifications.html.

[6] RBOB stands for Reformulated Blendstock for Oxygenate Blending. This is gasoline before it is blended with denatured fuel ethanol. The delivery location is New York harbor. See http://www.cmegroup.com/trading/energy/refined-products/rbob-gasoline_contract_specifications.html.

[7] The paper defines a trading day to include all traded contracts that are cleared on the same date.

[8] See Fett *et al* (2016) and Marshall *et al* (2012) for literature reviews of liquidity assessments in futures markets. See Kervel *et al* (2016) for a liquidity discussion concerning large institutional orders in a low latency environment.

order book may not replenish quickly. Finally, the act of offloading a position may induce market makers to increase their ask price or reduce their bid price or both (i.e., widen their bid-ask spread) to protect themselves against the adverse selection risk that is inherent in market making, causing the market price to move against a trader (Kyle (1985)).

The author anticipated that LL_d for a contract would tend to be slightly higher, i.e., less liquid, near the inception of the contract and improve, but far from monotonically, as the time to expiration decreases. When a contract enters the spot month,[9] the author anticipated that the contract would become slightly less liquid, too. This is because the author thought that LL_d would be similar to other more traditional assessments of liquidity, namely, open interest and trading volume. As such, the liquidity assessments far out the curve (longer time to expiration of the futures contract) came as a surprise.

LL_d gives equal weight to the price impact involved for each futures contract traded. This volume-weighting is more appropriate with futures data, because open interest[10] is not fixed.[11] Moreover, volume-weighting is better suited to account for market participants electing

[9] For the four energy contracts considered in this paper, the spot "month" is the last three trading days of the physical-delivery contract (This is the convention we have of calling a period a month even when we're only talking about a few days). Long and short positions held to the close of trading on the last trading day, and not offset by an exchange-for-related-position (EFRP) transaction, are matched by the clearinghouse and delivery occurs after the last trading day. This feature (delivery only after the last trading day) is different from agricultural futures contracts, where delivery generally takes place during the spot month. See termination of trading provisions in NYMEX Rulebook chapters 151, 191, 200, and 220, available at http://www.cmegroup.com/rulebook/NYMEX/1a/150.pdf, http://www.cmegroup.com/rulebook/NYMEX/1a/191.pdf, http://www.cmegroup.com/rulebook/NYMEX/2/200.pdf, and http://www.cmegroup.com/rulebook/NYMEX/2/220.pdf.

[10] Open interest is the number of futures contracts outstanding on the long side of a futures contract.

[11] The number of securities outstanding is generally fixed but may change with an initial public offering or a secondary offering. In addition, short sellers are restricted by their ability to borrow a security. Nevertheless, there is no legal restriction on the number of times a security may trade during a day.

to shred their orders, i.e., to break up their orders into smaller trades, because volume-weighting accounts for the total amount of a large transaction that is shredded.[12] Otherwise, shredded orders might be given too much influence in a liquidity assessment, because without volume-weighting each shredded trade in the overall transaction would be treated separately. LL_d assesses the price impact of larger quantity trades with commensurately larger weight. Since volume-weighting applies the proportion of contracts traded relative to total volume, it is more suitable for clearing applications that seek to estimate the liquidation costs to offload positons in a contract month than liquidity assessments that treat each trade equally. In this manner, LL_d is distinguished from immediacy liquidity that is more relevant in the context of market making.

LL_d uses the first trade of the day to initialize the assessment, so the summation for LL_d begins at 2 and not at 1. LL_d is defined as follows:

Let P_i= the price of trade i.

Let P_i^* = the proxy for the current market price. This might be P_{i-1} or something else.

Let Q_i = quantity traded, the number of futures contracts traded) in trade i.

Let N_d = the number of trades on day d.

Let TV_d = Total notional volume during a trading day d except for the first trade, that is $\sum_{i=2}^{N_d} Q_i$.

$$LL_d = \sum_{i=2}^{N_d} \frac{Q_i}{TV_d} \; |P_i - P_i^*|$$

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[12] For a discussion on how to assess the cost of rebalancing a portfolio, see Perold (1988). Specifically, an implementation shortfall calculation might use LL_d in imputing benchmark prices for a portfolio rebalancing.

$|P_i - P_i^*|$ is measured in U.S. dollars. TV_d is measured in quantity traded. The coefficient $\frac{Q_i}{TV_d}$ is without units because it is quantity traded/ quantity traded. Thus the units of LL_d are $s.

The paper's data set includes block trades that have timestamps,[13] because the investigation seeks liquidity that might be needed to liquidate a large position, as may be the case if a DCO[14] instructs a clearing member to offload some or all of a market position.[15] Such liquidity demand may ultimately induce market participants, not necessarily the other side of the trade, to maintain open interest at the end of the trading day.

Determining when a block trade occurred is difficult. NYMEX does not require reporting of the time when a block trade occurred. NYMEX reports a block trade only after it is reported to them. After engaging in a block transaction, NYMEX grants participants a five minute period to report their trades to them. This allows time for the parties to transact without the immediate worry of other market participants learning about the large trade and deciding to trade in front of their anticipated trades, leading to worse price executions. In the calculations that follow, the paper presumes that block trade participants will take the full five minutes to

[13] Block trades are trades that are negotiated away from the exchange, usually bilaterally, and then are to be reported to the exchange within the allowed time delay. Unfortunately, many block trades do not have timestamps. The author removed all trades without timestamps from the analysis because the author does not know where to place such trades in the time series.

[14] A DCO has authority to take action with respect to a clearing member. See CFTC regulation 39.13(h)(6). It would be the clearing member that takes action with respect to a FCM when the clearing member is not the FCM. The FCM is the party that takes action with respect to an FCM's customer's position.

[15] For some applications, an investigator might be interested in only the liquidity emanating from the matching engine and elect to exclude block transactions from the computation. Block trades that have timestamps are included in this paper because they represent liquidity that a market participant might exploit to exit out of a position.

report their trades to NYMEX. So the computations move block trades back five minutes in the time series. LL_d is sensitive to where block trades are placed in the time series as this affects the choice of the proxy for the market price. Further, LL_d is weighted by the relative volume of the trade to the total trading volume that happens over a trading day so block trades are given more weight in LL_d. As a sensitivity test, the author computed LL_d assuming no time delay, and results were qualitatively similar.

LL_d includes all outright-to-outright transactions.[16] Since the exchange matching engine has functionality that allows outrights to trade against spreads, LL_d also includes outright-versus-spread transactions.[17] LL_d is sensitive to including outrights-versus-spread trades because these transactions generally improve liquidity, i.e., lower LL_d, especially far out the curve.

LL_d does not include spread-versus-spread transactions because a market participant cannot use a spread transaction directly to liquidate an outright position that is one side of the market.[18] A trader can liquidate a spread position, however, if the position is the legs of the spread.

LL_d is a proxy for liquidity that is computed using price changes. There are price changes that are not due to the liquidity needs of traders, however. Prices may move when there

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[16] An outright-versus-outright transaction means that both sides of the transaction assume positions only in same calendar month contract.

[17] A spread transaction is a transaction in which a trader takes positions in at least two different calendar month contracts. For example, a trader might take a short position in a December 2016 contract and simultaneously take a long position in a December 2015 contract.

[18] The paper does consider the ability of market participants to use spread transaction indirectly. Specifically, a market participant first engages in a December 2016/December 2015 spread transaction and then exists out of the December 2015 position with an outright transaction where there is better liquidity. The author acknowledges that this is an area warranting future research because the provision of spread versus spread trading may play an important role in trading deferred contract months.

are new pre- and post-trade disclosures or other information disclosures or subsequent analyses involving these disclosures arriving to the market. Further, prices may move if market participants actively disagree about the price formation implications of market fundamentals. Consequently, a contract market may be more liquid than LL_d assesses it to be on a given day. If there is substantial trading volume, the overestimate of the price impact of trading may be reduced substantially, but not eliminated entirely.

3. AMIHUD-LIKE ASSESSMENT

As a sensitivity test, this paper considers another liquidity assessment that employs consummated trades:

$$A_d = \frac{1}{(N_d - 1)} \sum_{i=2}^{N_d} \quad |P_i - P_i^*| \ / \ Q_i$$

A_d is an Amihud-like price impact ($/quantity traded). The two assessments are different, but they have the same sum (except for units), if Q_i is equal to 1 for all i, namely, $\frac{1}{(N_d-1)} \sum_{i=2}^{N_d} \quad |P_i - P_i^*|$. The author compares LL_d and $A_d$to by assuming one contract is traded in A_d.

Weighting larger quantity trades more heavily is appropriate in determining the cost to liquidate a position in a calendar month because we are interested in the average cost to trade a contract and not the average cost of individual trades. A_d gives less weight to large quantity trades whereas LL_d gives more weight to larger quantities traded. Absent different price executions for different order sizes, A_d is still affected by how an order is shredded, but LL_d is invariant to how an order was broken up because LL_d gives the overall trading the same weighting in the assessment.

For contrast purposes and because there is no "correct" assessment *per se*, the graphs of LL_d and A_d are presented for all the energy commodities considered. Even though there are theoretical reasons to select LL_d over A_d for an initial margin surcharge application, there are not strong empirical reasons for the contracts examined. When performing two-sample t-tests with unequal variances for the energy contracts considered in this paper, the distributions of LL_d and A_d are not statistically significantly different from each other at the alpha=0.05 level. Most trades consummated by the matching engine are for only one contract. Further, many large volume block trades failed to have timestamps. These facts combined with the similarity in the price impact between larger volume trades and smaller volume trades help to explain the lack of statistical significance between the different liquidity assessments.

4. STALE PRICES

The computation of LL_d or any assessment based on consummated trades is less reliable as a proxy very far out the curve, because of infrequent trading. First, LL_d cannot be computed when there are less than two trades. Second, P_{i-1}, as a proxy for the current market price, P_i^*, is suspect when there are just a few trades, because tick-by-tick price changes are more likely to be due to other reasons than liquidity demands. This makes LL_d a weaker proxy for liquidation liquidity near the inception of trading of a futures contract when there is a longer time until the expiration of the contract, i.e., far out the curve.

In an attempt to address the second concern, the paper constructs a more sophisticated proxy for the current market price, P_i^*, than P_{i-1}. The proxy exploits the frequent trading in contract months in the same commodity near expiration. The paper uses $P_i^{\wedge}$, the price of the last non-block outright-to-outright traded contract in a close-to-expiration contract month, while assuming that the implied spread of between the calendar month and a close-to-expiration contract month is constant (i.e., using $\hat{\tilde{P}}_{i-1}$, the most recent trade price in the near-to-expiration contract before trade i in the far-to-expiration contract , and P_{i-1}, the most current trade in the far-to-expiration before the recent trade i in the far-to expiration contract, and computes the implied spread, (P_{i-1} - $\hat{\tilde{P}}_{i-1}$) which is assumed to be constant while there is no trading in the far-to-expiration contract.[19]

Specifically, the paper uses the most current difference in the price between the last traded contract in (1) the calendar month in the far-to-expiration contract and (2) the close to expiration contract month, that has a timestamp less than or equal to the timestamp of the last trade in the far-to-expiration contract for the implied spread. If there are equal timestamps, then the method sorts on the exchange match-id to determine which trade occurred first. The paper then adds the price of the close-to-expiration contract with the implied spread, which is assumed to be constant. However, if there are no trades in the near-to-expiration contract directly after the last trade in the far to expiration contract month, then the computation uses the previous price in the far-to-expiration contract, P_{i-1}, for the current market price. That is:

$$P_i^* = \{ \hat{P}_i + (P_{i-1} - \hat{\tilde{P}}_{i-1}) \quad \text{if the last trade in time is in near-to-expiration contract, or}$$
$$P_{i-1} \quad \text{otherwise.} \}$$

Since CL terminates trading three business days before the 25th of the month, the author chose to use the contract for the calendar month of the cleared date plus 1 month at or before the

[19] The implied spread between far away contracts months might have less volatility than the price of a contract in a far-away contract month, because the spread might not be so sensitive to information disclosures or analyses that concern the spread and not the entire term structure of crude oil. Nevertheless, implied spreads may be sensitive to supply interruptions, demand shocks, and storage activity that involve the relevant time interval, among other things.

15th of the month and the cleared date plus 2 months after the 15th of the month for the near-to-expiration contract. This was done to approximately obtain the contract month with the highest trading frequency, avoid the spot month, and to be computationally straightforward.

The definition of the near-to-expiration contract was modified for HO and RB because the highest trading volume occurs in contract months other than those closest to expiration. Instead, the computations use one month later for the near-to-expiration contract for both HO and RB.

5. SPREADS

Many traders used spread transactions to extend the time until expiration of their futures contracts. In offloading an outright position far out the curve, a market participant might have preferred spread transactions involving the December 2016 contract, because it may have been cheaper to use spreads and a closer to expiration outright contract than using an outright transaction in the December 2016 contract. The author considered a December 2015-December 2016 spread transaction because it is had the highest trading volume of all spreads with the December 2016 contract in crude oil over the lifetime of the December 2016 contract by a substantial margin. In particular this spread transaction had highest trading volume far out the curve. There was substantial trading volume in CL for the June 2016 spread to December 2016 that a DCO might utilize, too. The remaining energy contracts December-to-December spreads are less liquid.[20] This made it impractical to engage in a spread trade to the contract that is one

[20] The largest trading volume calendar spread transaction in NG is the April/May spread in the same year. The price of the spread which is long April and short May will be larger if there is a cold winter in the United States, all else being equal. This is because the amount of natural gas in storage will be drawn down to heat building and for other uses, but by May the demand for natural gas will have subsided and the replenishing of storage of natural gas will be underway. Thus, the price of the spread which is long

year closer to expiration because it appears that it would have been cheaper to trade out of a position directly with an outright contract.

6. APPLICATION: INITIAL MARGIN SURCHARGE

Derivative clearing organizations (DCOs)[21] require clearing members[22] and futures commission merchants (FCMs)[23] to post margin to limit exposure to potential losses from defaults. In calculating initial margin,[24] DCOs consider historical price movements of the futures price, but this is not their only consideration. DCOs and FCMs may require an additional surcharge of initial margin for illiquid futures contracts because a trader who wishes to unwind a position may induce an impact on the market price;[25] That is, the market price of the futures

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April and short May during a cold winter will be high because natural gas is under higher demand than during a mild winter.

[21] DCOs clear financial contracts by becoming the counterparty to a trade through a process called novation. They mitigate their credit loss exposure by having their counterparties (clearing members) post collateral to them called margin.

[22] A clearing member may carry positions on behalf of itself or others. A position for "itself" generally means a position in a "house account." And "others" includes clearing member's customers –that is, each customer origin, who may be (1) customers of the clearing member's FCM, or (2) customers of another FCM who is not a clearing member. See the definition of clearing member in CFTC regulation 1.3(c) and more generally, CFTC regulation 39.13 for more details. DCOs require clearing members to post margin for open positions to limit exposure to potential losses from defaults its clearing members. See CFTC regulation 39.13(f).

[23] Generally, a customer has no direct relationship with a DCO. An FCM intermediates contracts between the DCO and its customers and thereby guarantee the performance of its customers.

[24] Many FCMs are clearing members. Initial margin serves as the first source of collateral in absorbing a trader's losses. Initial margin is posted by the clearing member to the DCO to protect against adverse price movements in a customer's portfolio. In addition, FCMs may collect extra initial margin from its customers which it not required to post to the DCO.

[25] See CFTC Regulation 39.13(g)(13). "A derivatives clearing organization shall apply appropriate limitations or charges on the concentration of assets posted as initial margin, as necessary, in order to ensure its ability to liquidate such assets quickly with minimal adverse price effects, and shall evaluate the appropriateness of any such concentration limits or charges, on at least a monthly basis."
At a minimum, FCMs charge the amount of initial margin required by the relevant DCO. An FCM may impose an initial margin surcharge for reasons other than an illiquid contract.

contracts moves against the trader due to a lack of liquidity. This illiquidity makes it more costly to offload a positon.

DCOs and FCMs may use a bid-ask spread at the close of trading for a contract as a transaction cost assessment of offloading a position, that is, a liquidity surcharge.[26] For a particular contract month, a liquidity surcharge might be estimated by:[27]

(bid-ask spread) * (Quantity to offload).

This paper offers an alternative to the bid-ask spread; namely:[28]

LL_d * (Quantity to offload).

These estimates of the cost of liquidation are independent of the correlation in the positions in the underlying portfolio.[29]

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[26] See https://www.theice.com/publicdocs/clear_credit/ICE_CDS_Margin_Calculator_Presentation.pdf.

[27] A DCO might seek to port healthy customers with sufficient initial margin to protect the DCO to a healthy FCM without hedging their positions. Nevertheless, a DCO would likely approximately hedge, use liquid contracts but allow some residual basis risk, a defaulted "house account" or a defaulted FCM's customer's position. By doing so, the DCO would have more time to offload positons, since there is less price risk in the approximately hedged positions. Engaging in additional hedging will increase the transaction costs for a DCO beyond pure price impact costs, however.

[28] LL_d may be modified in various ways. For instance, a DCO might use the 90th percentile of LL_d over a relevant historical time interval to compute a liquidity surcharge for a related contract month.

[29] A trader might be able to offload a more balanced portfolio more slowly, and with potentially a lower price impact, because a balanced portfolio may have less price risk associated with it. Moreover, it's likely to be more costly to offload a larger position, all else being equal, but the liquidity assessments discussed in this paper make no adjustments for the size of the underlying portfolio. If the quantity to be offloaded is a large percentage of average daily trading volume, then the price impact may be super-linear in quantity to offload and greater than these estimates. For instance, Robert Taylor of CME states "Typical value-at-risk ("VaR") models scale linearly with portfolio size, however, it is well-known that the cost of liquidation increases super-linearly with size. CCP's models, therefore, are required to apply a form of additional margins on large portfolios of even the most liquid products, and also during times of market crisis which would require significantly higher collateral." on page 5 of his comment letter dated December 2, 2014 with respect to the margin for uncleared swaps proposed rulemaking.

There are two basic types of margin: variation and initial. Variation margin resets a customer's trading losses or gains on their portfolio to zero. Variation margin is posted to settle up using the current prices, often closing prices, for positions. This settling up occurs after the close of the trading on the exchange. There can also be calls for variation margin by a DCO during the trading day if there are extreme price movements, but these events are infrequent.

Initial margin is the amount of margin required by a DCO and any additional collateral required to be held at an FCM[30] that is posted by the customer to insure against most adverse future price movements affecting a participant's positions. A DCO must use at least a 99% confidence interval[31] to cover adverse price movements in the underlying futures contracts over the margin period of risk.[32] For a futures contract, the margin period of risk is often one trading day. If a contract is more illiquid, however, the appropriate minimum liquidation time for the margin period of risk may be longer than one day, because it may take longer to offload a participant's

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The author leaves the super-linear modeling to future research. Such estimates are complicated by the use of spread transactions to transform positions into potentially more liquid outright positions and the subsequently exit out of the more liquid outright contracts.

[30] A FCM might demand additional initial margin, because the FCM wants to protect itself from default by its customers, because an FCM guarantees the performance of its customers to the DCO. Further, a customer may desire to have extra margin at an FCM. Extra margin allows a customer to respond more easily to calls for additional margin as conditions change over time – especially if it is relatively costly or inconvenient to transfer collateral to the FCM through wire transfer or automated clearing house transaction.

[31] The actual coverage of the initial margin must meet an established confidence level of at least 99 percent, based on data from an appropriate historic time period, that is, an *ex post* time period. See, CFTC Regulation 39.13(g)(2). See CFTC Regulation 39.13(g)(2). For instance, on page 2 of a commenter letter dated December 2, 2014, Robert Taylor of CME states "CME calibrates its initial margin requirements for its over-the-counter ("OTC") interest rate swaps using a 99.7% confidence level sampling to meet a 99% coverage standard."

[32] Regarding spread and portfolio margins, a DCO may allow reductions in initial margin requirements for related positions if the price risks are significantly and reliably correlated. See CFTC Regulation 39.13(g)(4). This paper discusses cross-margining benefits with holding offsetting contracts in different calendar months for the same commodity.

position, especially to avoid a significant price impact if a large amount of open interest needs to be liquidated.[33]

The types of assets posted as initial margin need not be cash, but may be other high quality instruments such as U.S. Treasury and high-grade corporate debt that a DCO or FCM has deemed acceptable. See CFTC Regulation 39.13(g)(10). A DCO may apply a haircut to high-grade corporate debt (for instance, a 5% hair cut would only count 95% of the current market value of a debt instrument towards initial margin), because it is less likely to retain its value and ability to be converted into cash in times of market stress, in comparison to a U.S. Treasury security. See CFTC Regulation 39.13(g)(12).

Initial margin can be a misnomer in practice. That is because many practitioners and this paper use the term not just for the amount of margin that is initially required to be placed at the DCO and FCM, but also for the amount of margin that is required to be maintained at the DCO and FCM, sometimes called maintenance margin. The amount of initial margin required may also increase or decrease if the volatility of the underlying contracts increases or decreases, respectively, as this will likely affect the confidence interval over the look back period used to compute the confidence interval.

Cross-margining benefits should substantially reduce the initial margin required of a customer's portfolio that takes offsetting positions in different calendar months in the same

[33] Assessing the liquidity in a contract may also be helpful to an exchange in setting and in determining whether to grant an exemption to one of its position limits. An exchange would likely want to deter a market participant from trading in a manner that causes sudden or unreasonable price impacts on a contract market; such price impacts may cause financial harm to market participants, or even reputational risk or economic disadvantage to the exchange. In such circumstances, an exchange would likely elect not to grant an exemption or to instruct a market participant to establish or liquidate his or her desired position gradually, in an orderly manner.

commodity relative to a stand-alone portfolio containing positions on the same side of the market in each contract month. In the offsetting case, the portfolio is exposed to the basis risk between the two calendar contracts but not the price risk of the commodity overall. For instance, the price movements of a relevant spread position tend to be substantially less than the daily price movements of a particular contract month. Consequently, an offsetting spread position would likely require holding substantially less initial margin than stand-alone portfolios.[34]

A DCO may face a trade-off when imposing a liquidity surcharge. This is because a futures exchange tends to be vertically integrated with its DCO. Since requiring more margin increases the cost of trading, a DCO would prefer not to reduce the revenue of its exchange; however, a DCO would also prefer to have more initial margin posted to protect its clearing members, the default fund, and ultimately itself from defaulted positions.

A position defaulted to a DCO[35] might be liquidated by an auction where the clearing members of the DCO have an affirmative obligation to bid to assume the defaulted positions. The ability to auction defaulted position mitigates to some extent liquidity issues for DCOs, but the ability to auction does not completely eliminate price concession losses to a DCO.

As the first bearer of losses, a customer needs to be aware of potential liquidity cost losses from having his or her positions offloaded at a substantial discount and might elect to maintain extra margin, prophylactically. FCMs, who guarantee customer positions and bear

[34] This may be one reason why market makers may be willing to make markets in spreads farther out the curve than in outright contracts. Market maker might not have to post as much margin when its proprietary portfolio does not net out to zero, because the portfolio is substantially hedged by each leg of a spread being offset by one of the other legs in a spread transaction.

[35] For a position to be defaulted to a DCO, a customer or house account, a customer's or house account's FCM, and the corresponding clearing member (if the clearing member is different than the FCM) would all have had to default.

losses after a customer defaults and who may execute trades in order to reduce a customer's position, may also seek extra initial margin from customers. This extra margin protects their customers and the FCM itself from price concession trading losses as well as other loss exposures from the customer to the FCM.

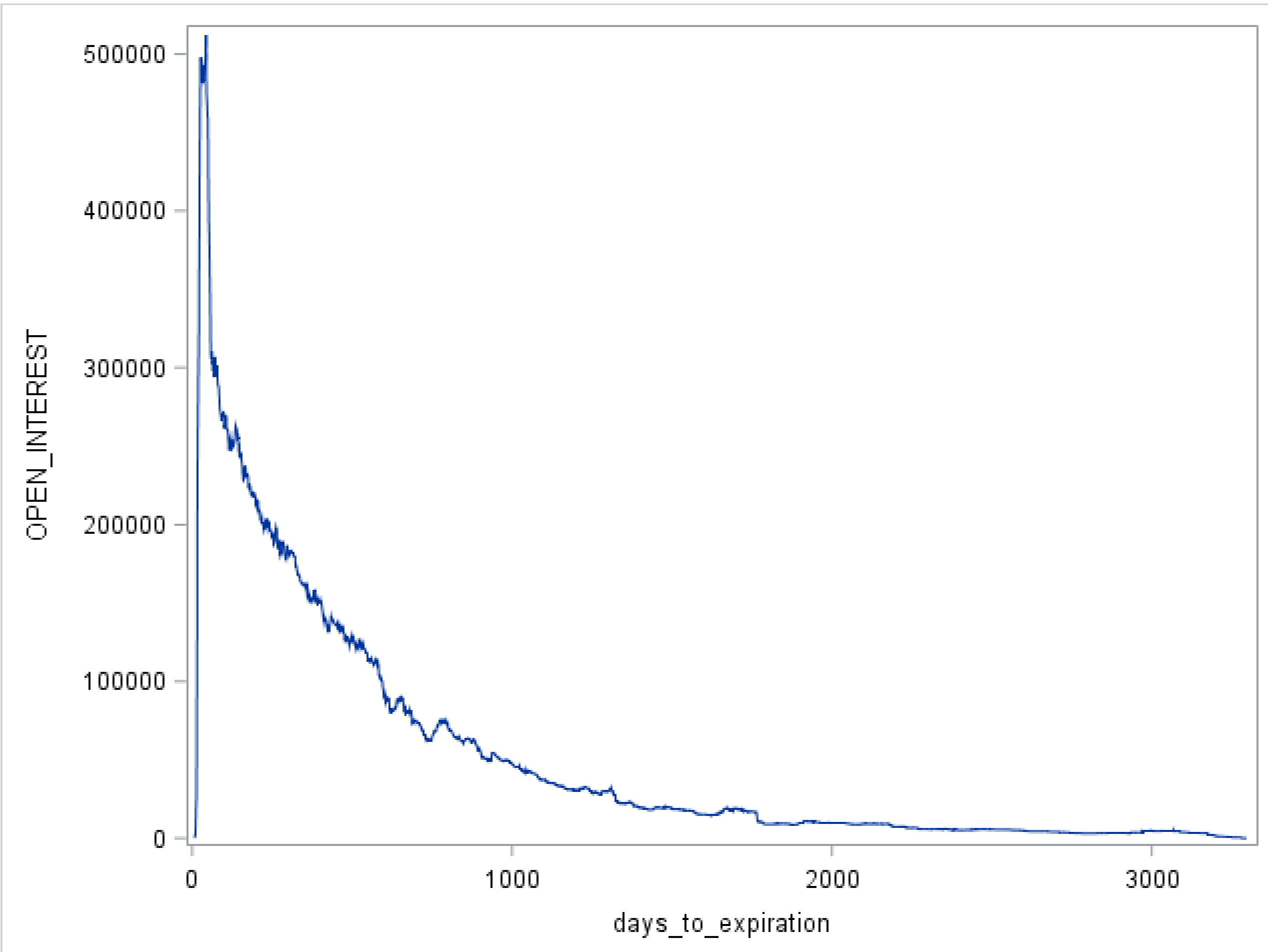
6. CONCLUSIONS

The liquidity costs were generally less than 1.0% of the contract price for NYMEX's December 2016 CL, NG, HO, and RB. The low liquidity cost was anticipated close to expiration because these contracts are some of the oldest and most established futures contracts, but liquidity costs remained low far out the curve, too.

The computation for CL suggests that a trader could have accessed even better liquidity very far out the curve by first engaging in a December 2015-to-December 2016 spread transaction and then trading out of the new position with an outright December 2015 transaction. This result, however, failed to hold true for the other three energy contracts, because either the December-to-December spread transactions were illiquid or because there was not a substantial liquidity advantage in executing an outright transaction in the December 2015 versus the December 2016 contract.

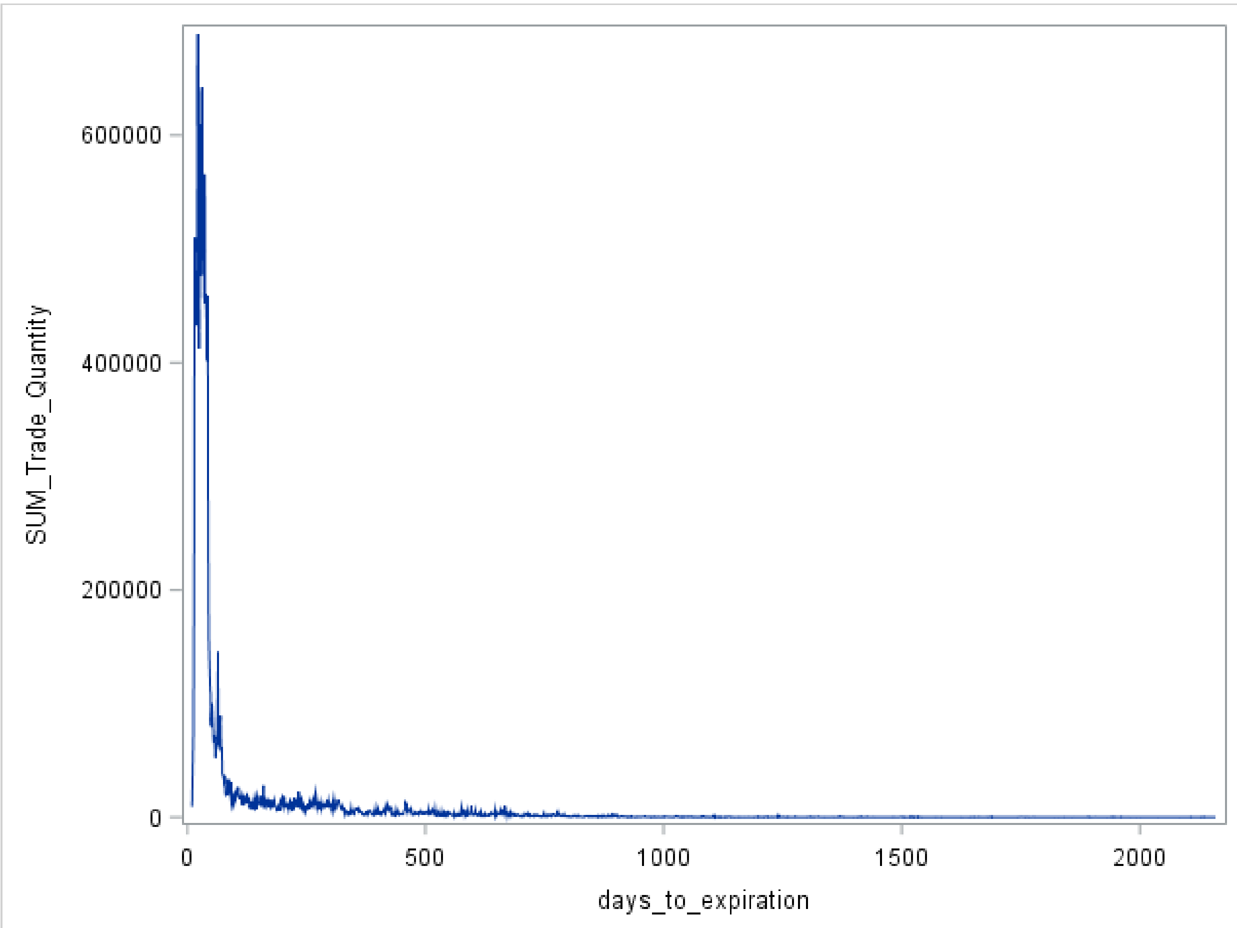
7. GRAPHS

Open Interest versus Days to Expiration December 2016 CL



When first listed by NYMEX, the December crude oil contract had nine years to expiration. As is typical for a futures contract, open interest builds slowly. Open interest increased drastically in the months close to expiration before declining sharply just before the spot month when exchange position limits in the physical-delivery contract restrict speculative positions. This suggests that there were many market participants that wanted financial exposure to crude oil, but did not want to make or take actual delivery of the underlying commodity. NYMEX provided the open interest data to the CFTC.

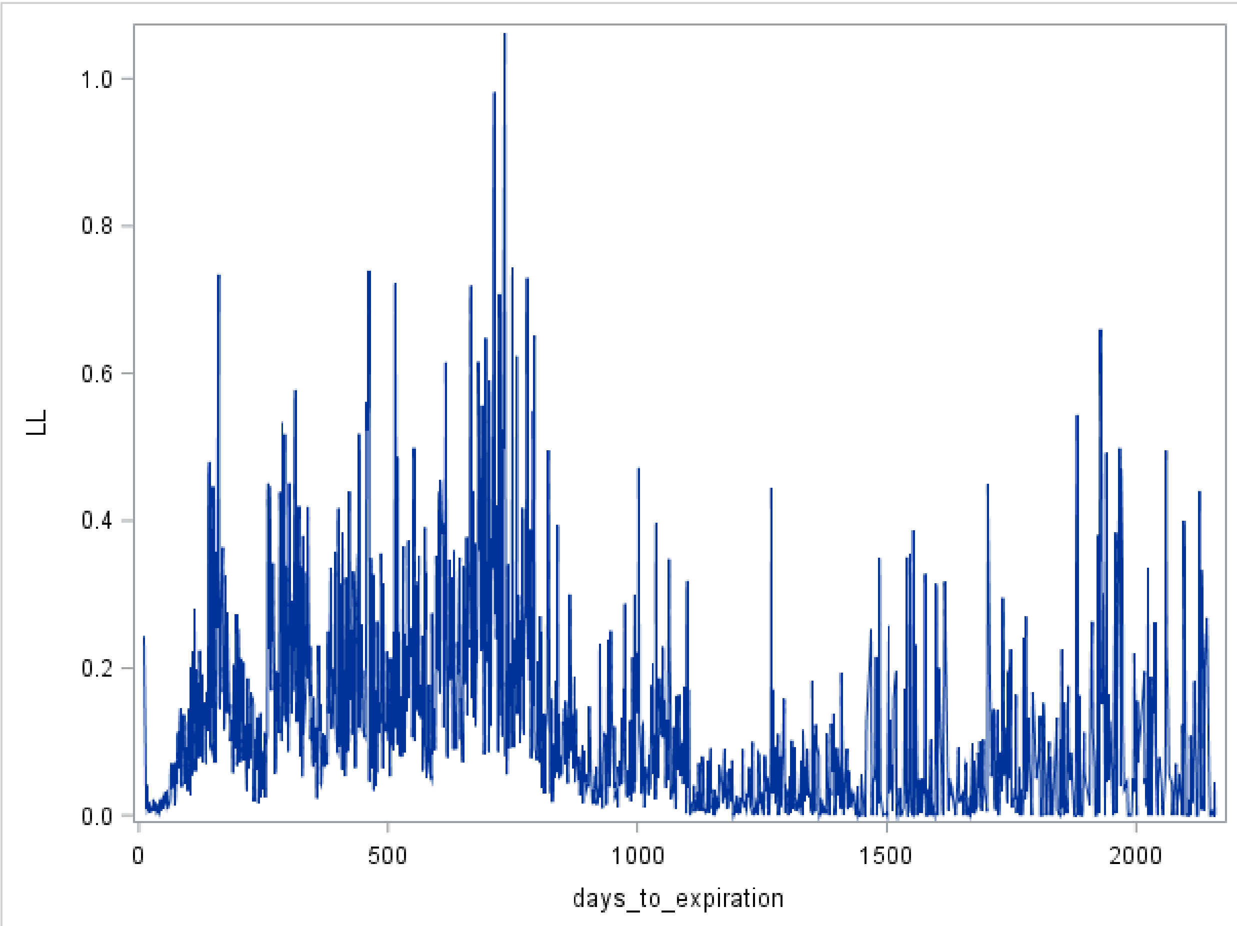
Trading Volume without the First Trade against Days to Expiration for December 2016 CL



Note: The CFTC has only stored transaction data back until 2011.

The shape of the trading volume graph is similar to the open interest graph but is more jagged. It is more peaked near the expiration of the contract, too.

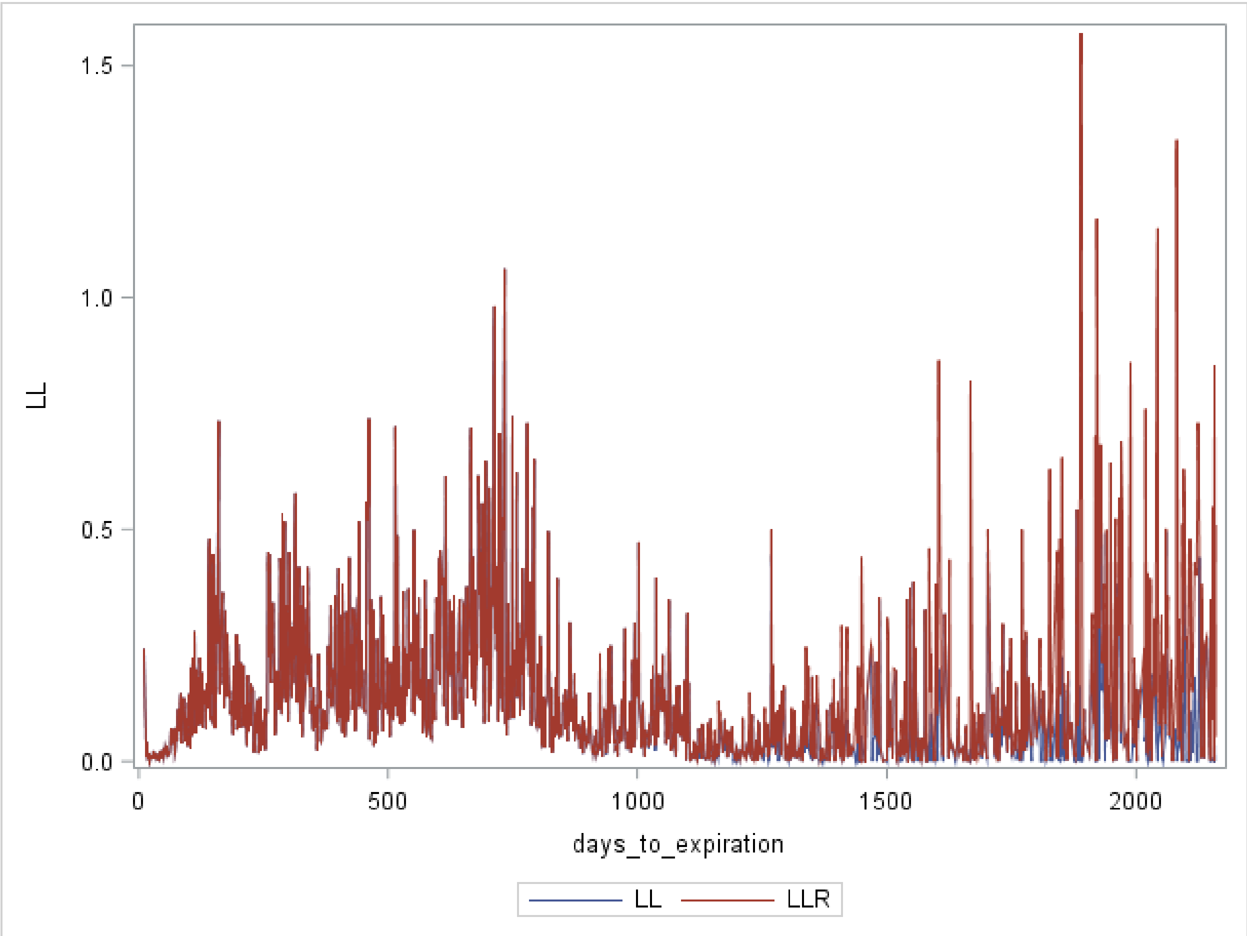
Liquidation Liquidity versus Days to Expiration for CL December 2016



Note: The CFTC has stored the transaction data only back to 2011.

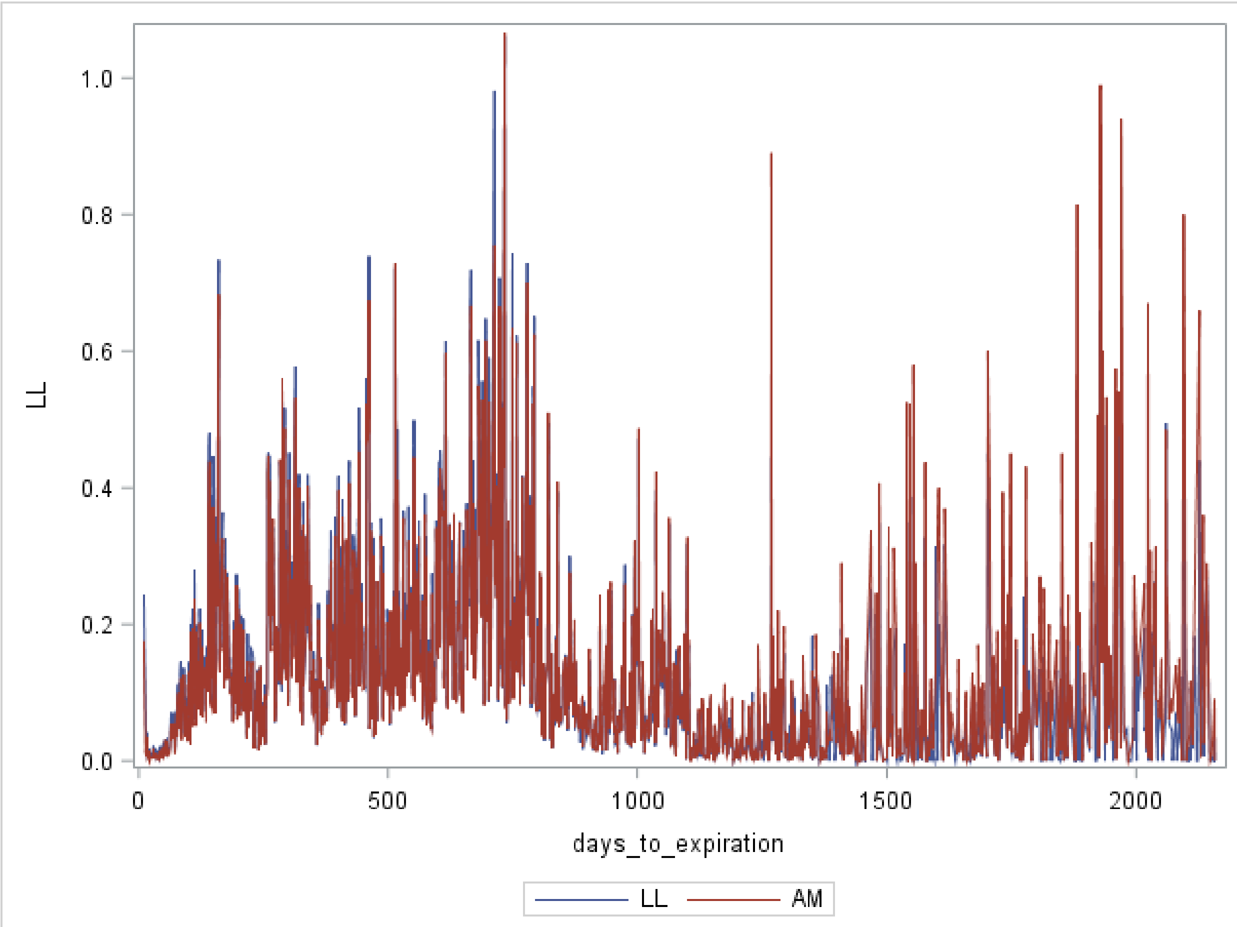
The liquidity for December 2016 CL varies from day to day. The tick size is $0.01 per barrel with one contract unit being 1,000 barrels. The block size is 50 contracts for the outright and 5 for the year-to-year spread. LL_d equal to 0.2 suggests a $200 price impact to trade one contract. At $50 per barrel, one long futures contract would sell for $50,000. $200/$50,000 is 0.4%. It appears that liquidity is not appreciably worse -- even appreciably better -- far out the curve even though open interest and trading volumes are substantially less there.

LL with LLR (using the last trade) against Days to Expiration for CL December 2016



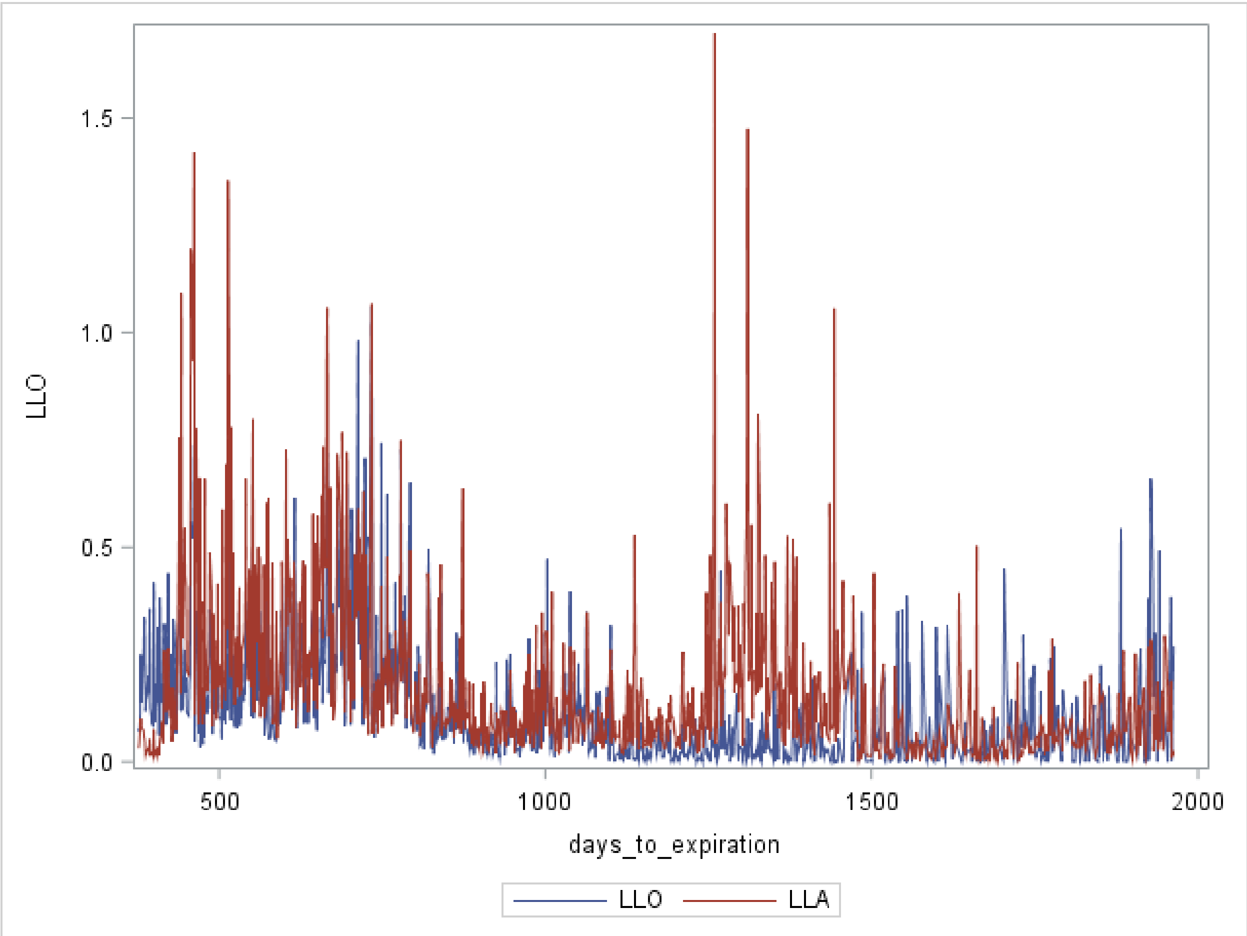
This graph displays LL with the more sophisticated proxy for the current market price with LLR which employs the last price as a proxy for the current market The more sophisticated proxy reduces some of the overestimate of the liquidity costs that is due to stale prices. This is especially true far out the curve, where the contract is assessed to be substantially more liquid. The p-value for the two-sample t-test with unequal variances is 3.42E-05. This p-value gives strong evidence to the alternative hypothesis that the distribution of LL is different than LLR.

A_d with LL_d against Days to Expiration CL December 2016



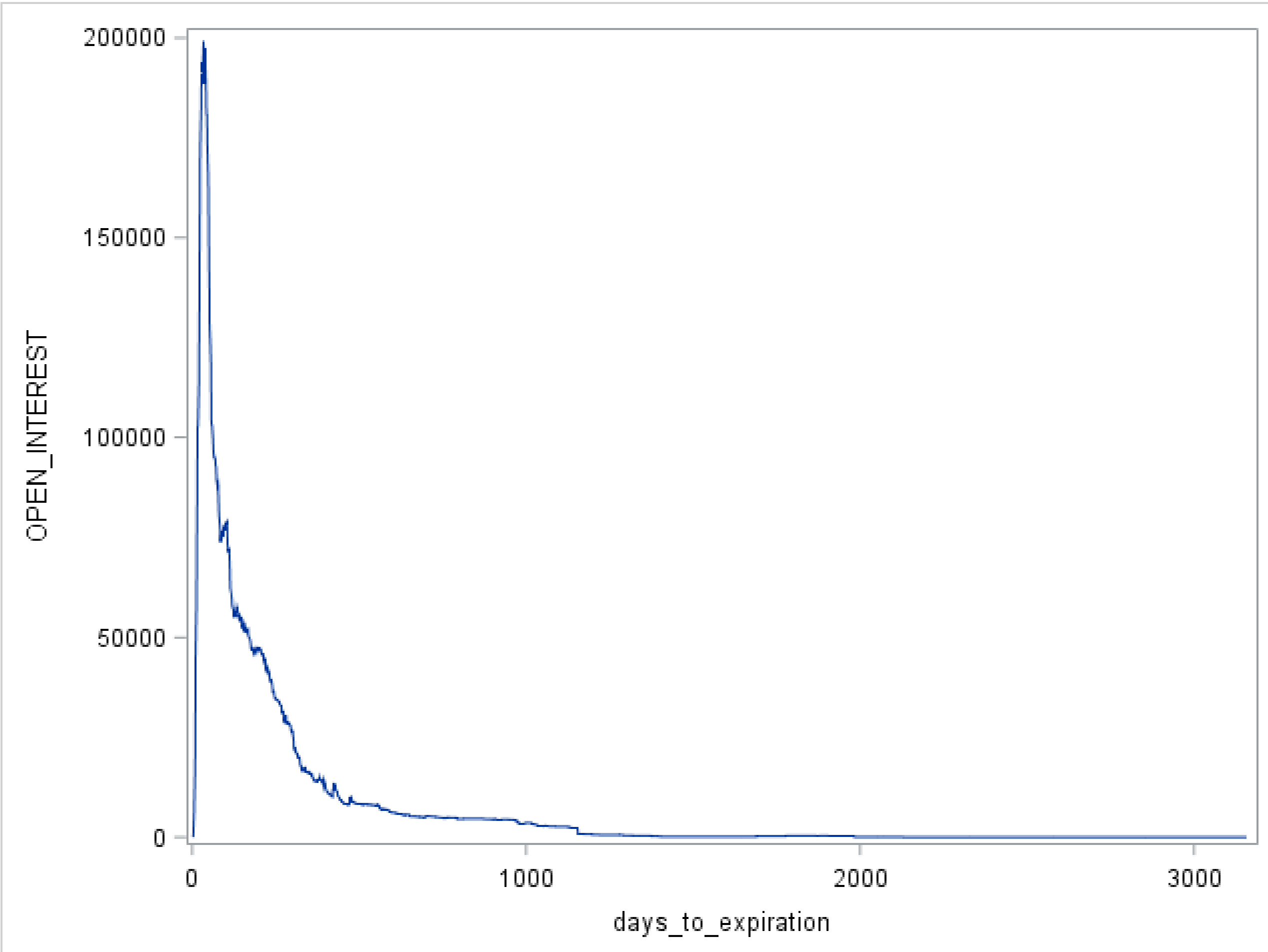
As discussed above, the author prefers LL_d over A_d for theoretical reasons. Even though A_d and LL_d assess differently, they are appear to be qualitatively similar. The p-value for the two-sample t-test with unequal variance is 0.077227. Given the large sample sizes of the non-missing observations, 1249, the p-value gives weak evidence for the alternative hypothesis that the two samples are different. For instance, at an alpha =0.05 level, we fail to reject the null hypothesis that the two samples are the same.

Outright Liquidity for December 2016 with December 2015-2016 December Spread plus 2015 Outright Liquidity for CL



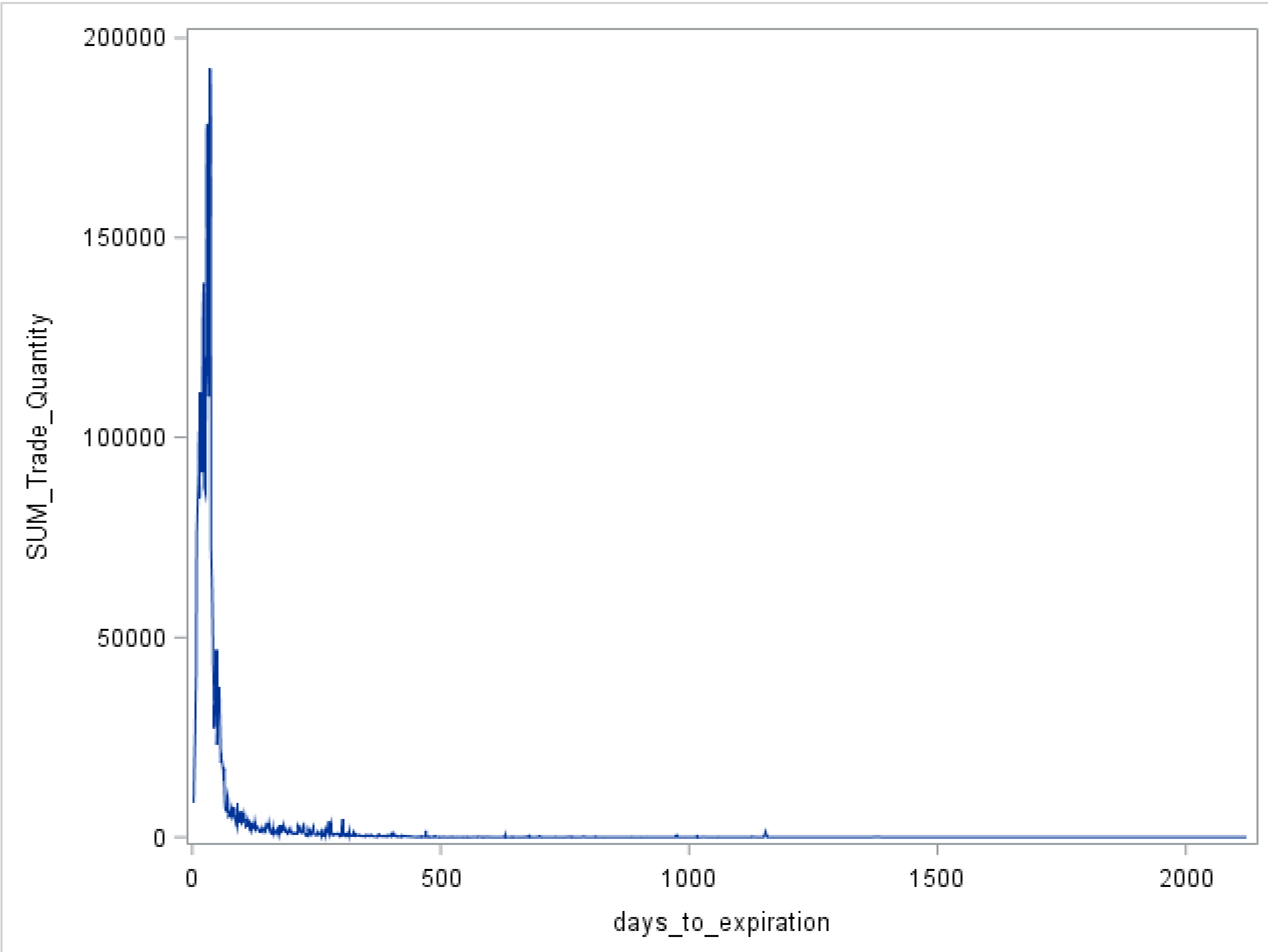
The LL of CL December 2016, LLO, tends to be below LLA, the LL of the previous calendar year outright plus the LLR of the December 2015 / December2016 calendar spread, except for, generally, far out the curve (> 1600 days to expiration) and when the December 2015 contract was near expiration (365 < days to expiration < 430 for the December 2016 contract). The graphs suggests that a market participant might have been able to offload a portion of a trader's position more cheaply with a December 2016-2015 spread and outright for December 2015 instead of a straightforward December 2016 outright far out the curve. In the energy contracts examined in this paper, crude oil is the only contract that exhibits this behavior. There were a substantial number of traders who got exposure farther out the curve by using spread transactions to roll their position.

Open Interest versus Days to Expiration for December 2016 NG



The natural gas contract had a nine year time to expiration when it was first listed by NYMEX. Open interest grew more slowly for natural gas, but it also follows the same typical pattern common to all the energy contracts in this paper.

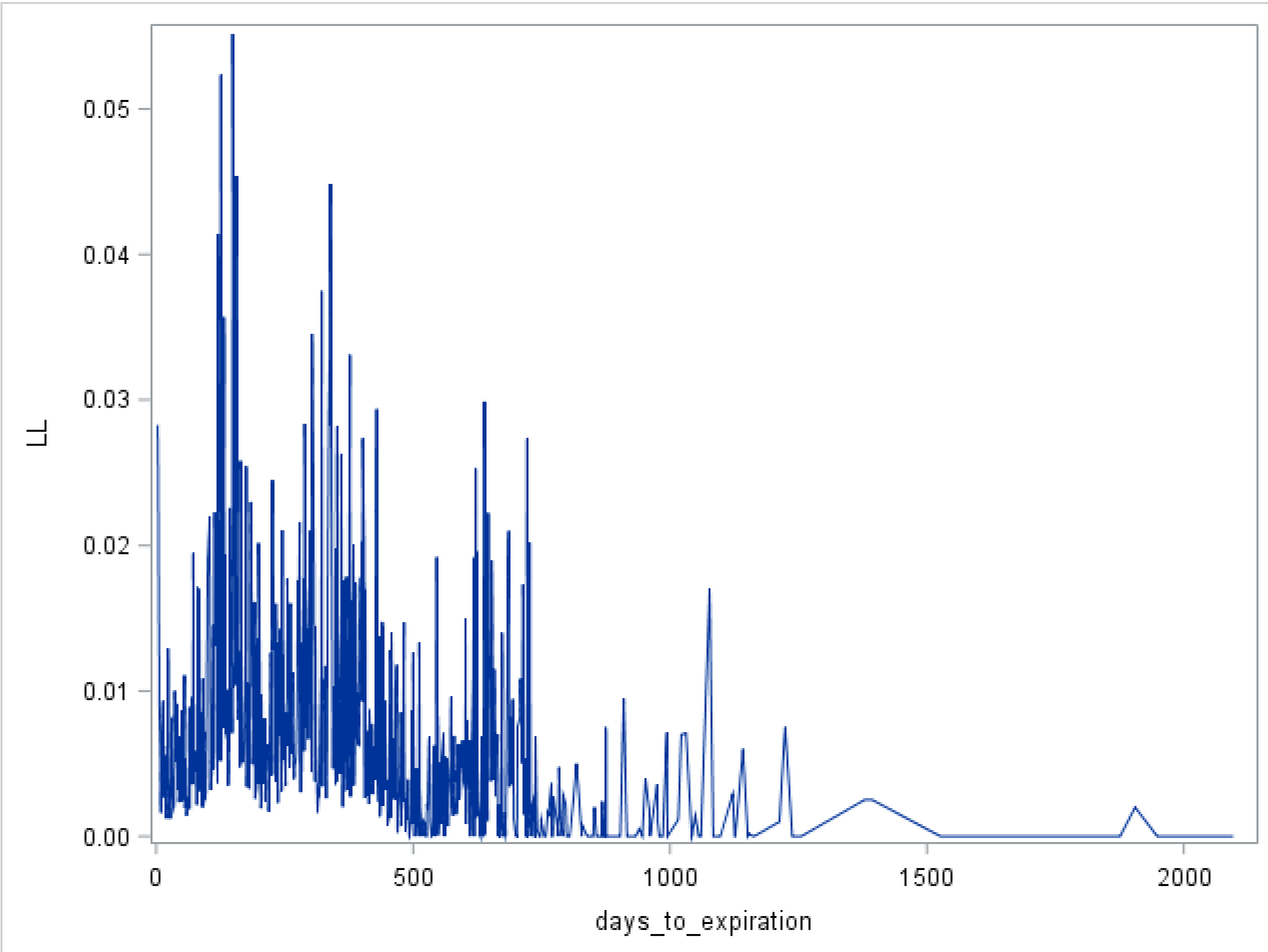
Trading Volume without the first trade against Days to Expiration for NG 2016



Note: The CFTC has stored the transaction data only back to 2011.

The shape of the trading volume graph is similar to the open interest graph, but slightly more peaked near the expiration of the contract. The lack of trading volume in the early years of the contract makes it more difficult to compute a reliable liquidity assessment based on transacted prices.

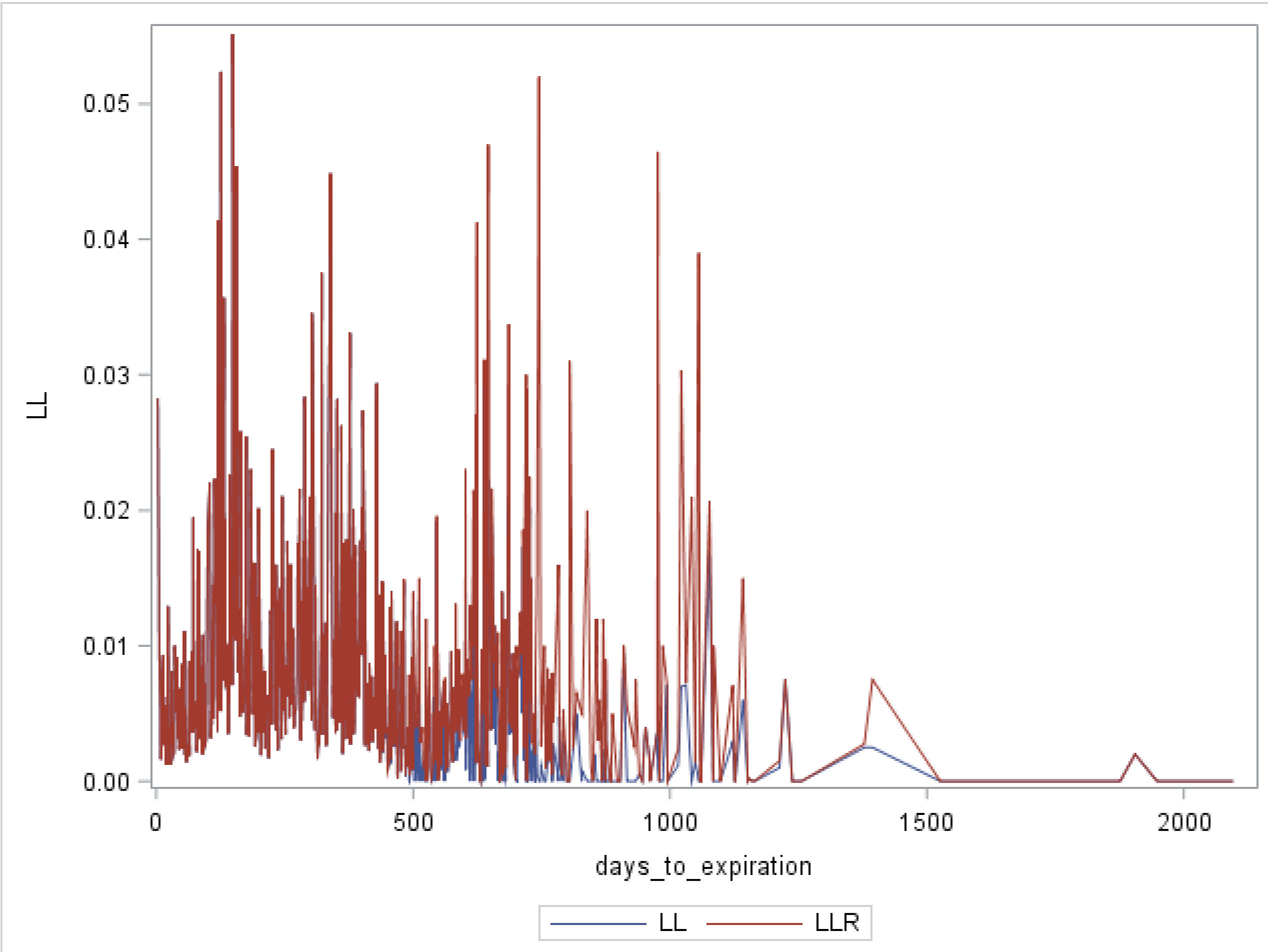
Liquidation Liquidity versus Days to Expiration for December 2016 NG



Note: The CFTC has stored the transaction data only back to 2011.

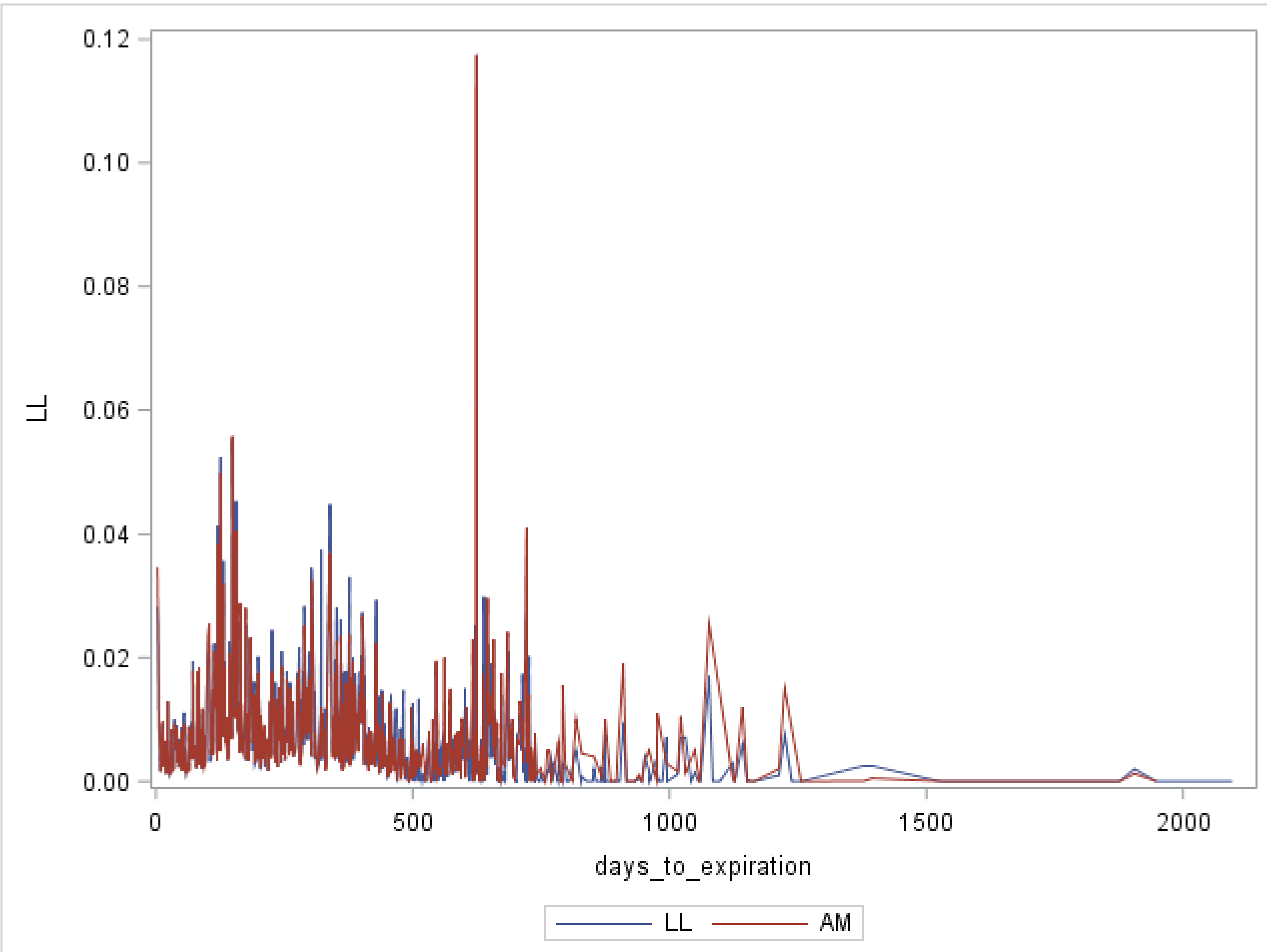
Although natural gas had less open interest as compared to crude oil, the contract had similar liquidity in outright trading. One contract is 10,000 million British Thermal Units (mmBtu). The tick size is $0.001 per mmBtu. The block size is 50 contracts for the outright and 15 contracts for the year-to-year spread. With LL_d equal to 0.01 the price impact is suggested be $100. At a price of $3.00 per mmBtu, one contract would sell for $30,000. $100/30,000 is approximately 0.333%.

LL with LLR (using the last trade) against Days to Expiration for 2016 NG



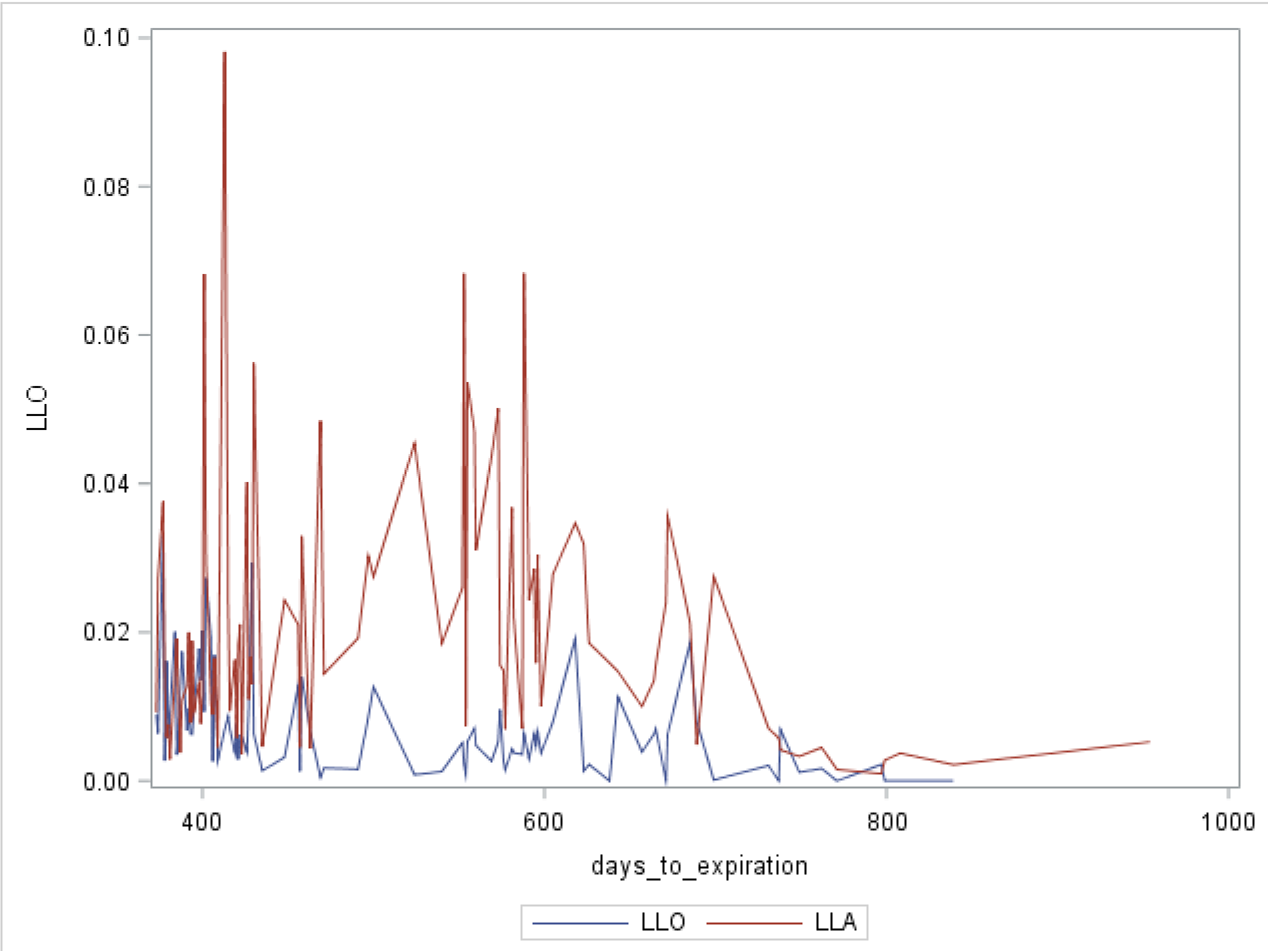
This graph displays LL with the more sophisticated proxy for the current market price with LLR which employs the last price as a proxy for the current market. The more sophisticated proxy reduces some of the overestimate of the liquidity costs that is due to stale prices. This is especially true far out the curve, where the contract is assessed to be substantially more liquid. The p-value for the two-sample t-test with unequal variances is 0.00116. With sample sizes of 595 for non-missing values, this p-value gives strong evidence to the alternative hypothesis that the distribution of LL is different than LLR.

A_d and LL_d against Days to Expiration for December 2016 NG



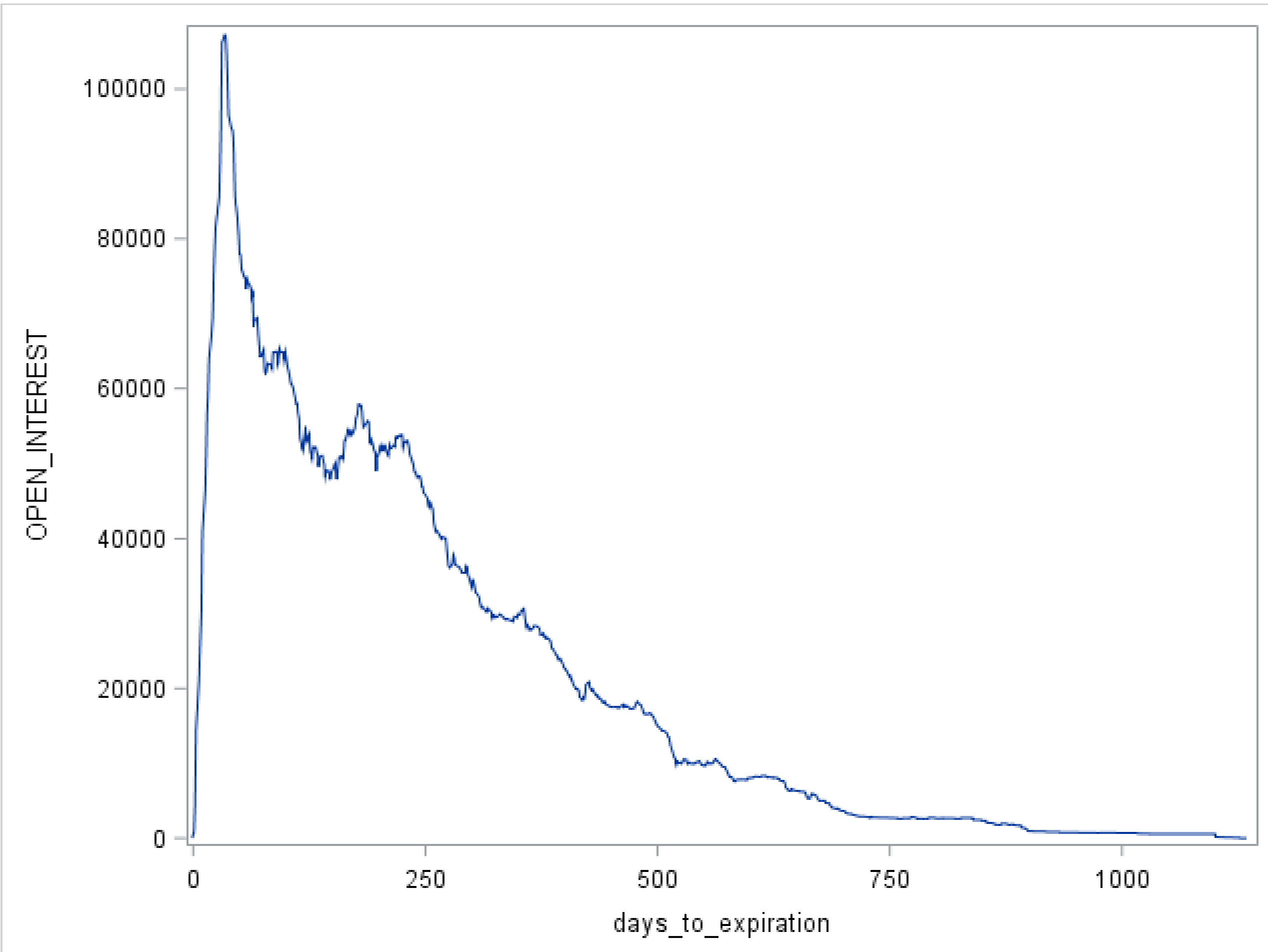
As discussed above, the author prefers LL_d over A_d for theoretical reasons. Even though A_d and LL_d assess differently, they appear to be qualitatively similar. The p-value for the two-sample t-test with unequal variance is 0.080472. Given the large sample sizes of the non-missing observations, 595, remember that we need two transactions in the contract to compute the liquidity assessments, the p-value gives weak evidence for the alternative hypothesis that the two samples are different. For instance, at an alpha =0.05 level, we fail to reject the null hypothesis that the two samples are the same.

Outright Liquidity for December 2016 with December 2015-2016 December Spread plus 2015 Outright Liquidity for NG



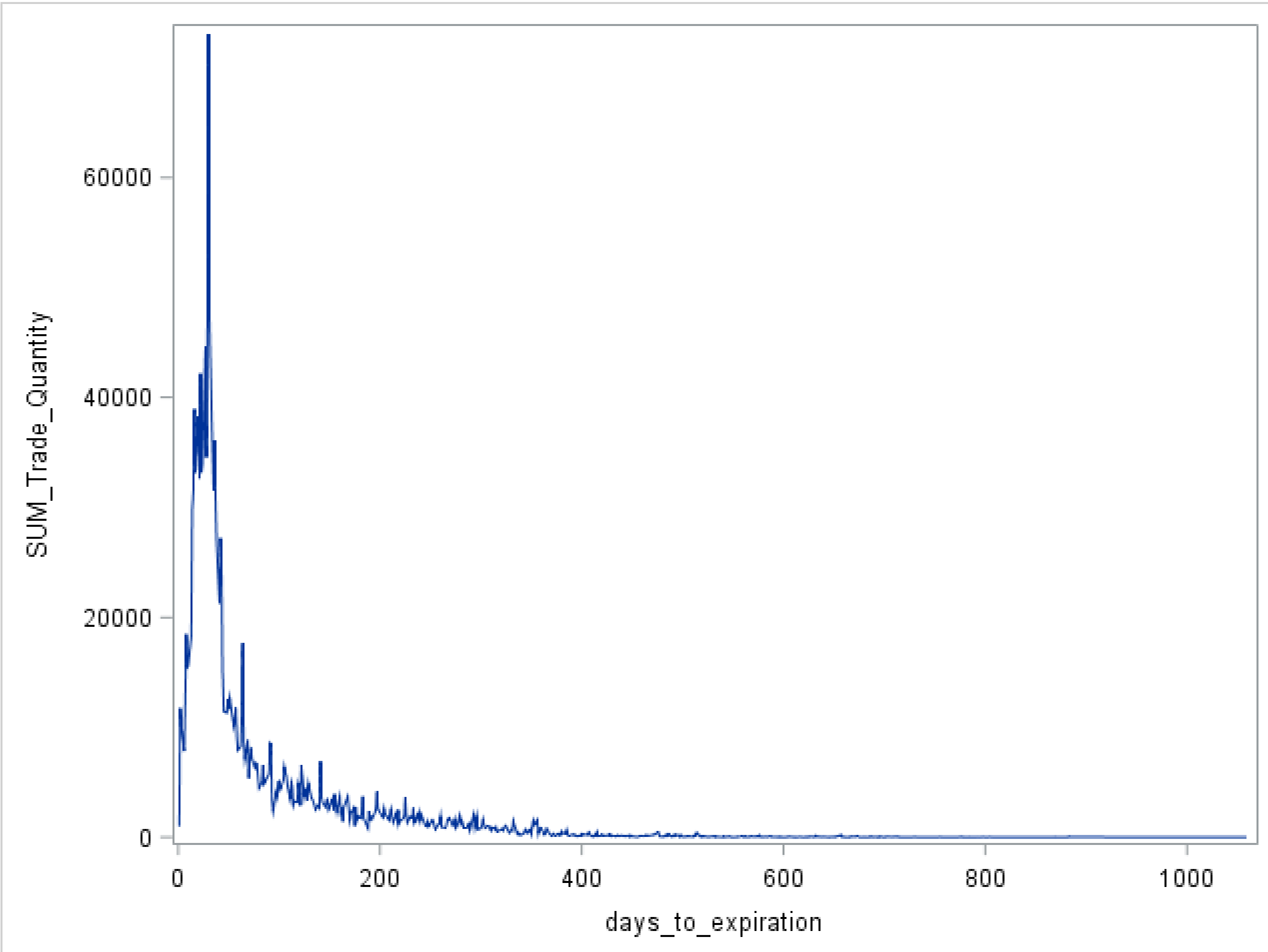
Generally, the LL of NG December 2016, LLO, tends to be below LLA, the LL of the previous calendar year outright plus the LLR of the December 2015 / December 2016 calendar spread. The graphs suggests that a market participant would not have been able to offload a portion of a trader's position more cheaply with a December 2016 / 2015 spread and outright for December 2015 instead of a straightforward December 2016 outright.

Open Interest versus Days to Expiration for December 2016 HO



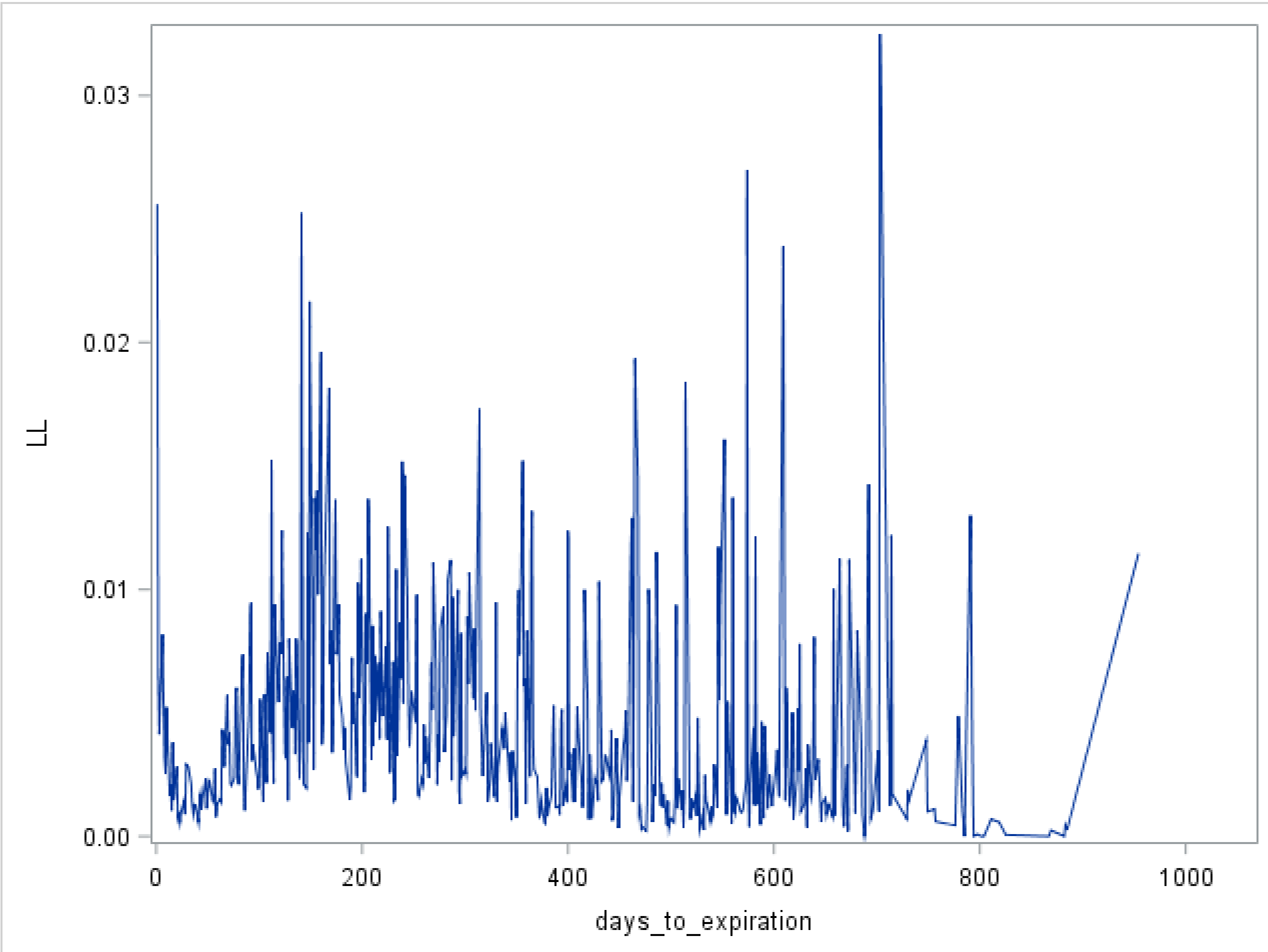
The diesel contract had less open interest compared to CL and NG, but it was still substantial. The open interest of this contract peeked earlier than just before the spot month. NYMEX lists the diesel contract for trading forward four years and one month until expiration.

Trading Volume without the first trade against Days to Expiration for HO 2016



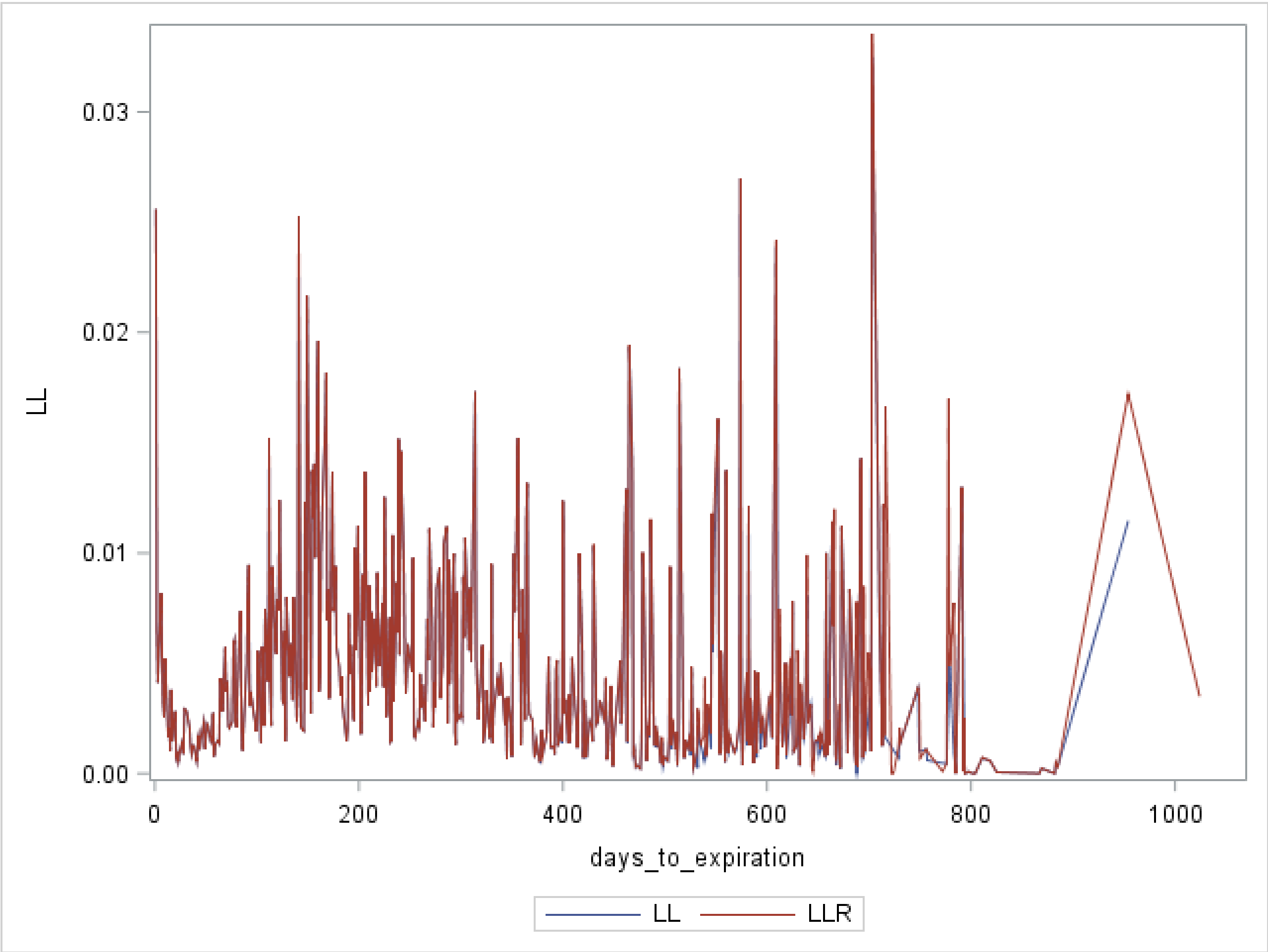
The shape of the trading volume graph is similar to the open interest graph. As with the open interest graph, the trading volume peaks earlier than just before the spot month. Consequently, the near-to-expiration contract month was chosen to be one month later in an attempt to capture, approximately, the highest volume.

Liquidation Liquidity versus Days to Expiration for December 2016 HO



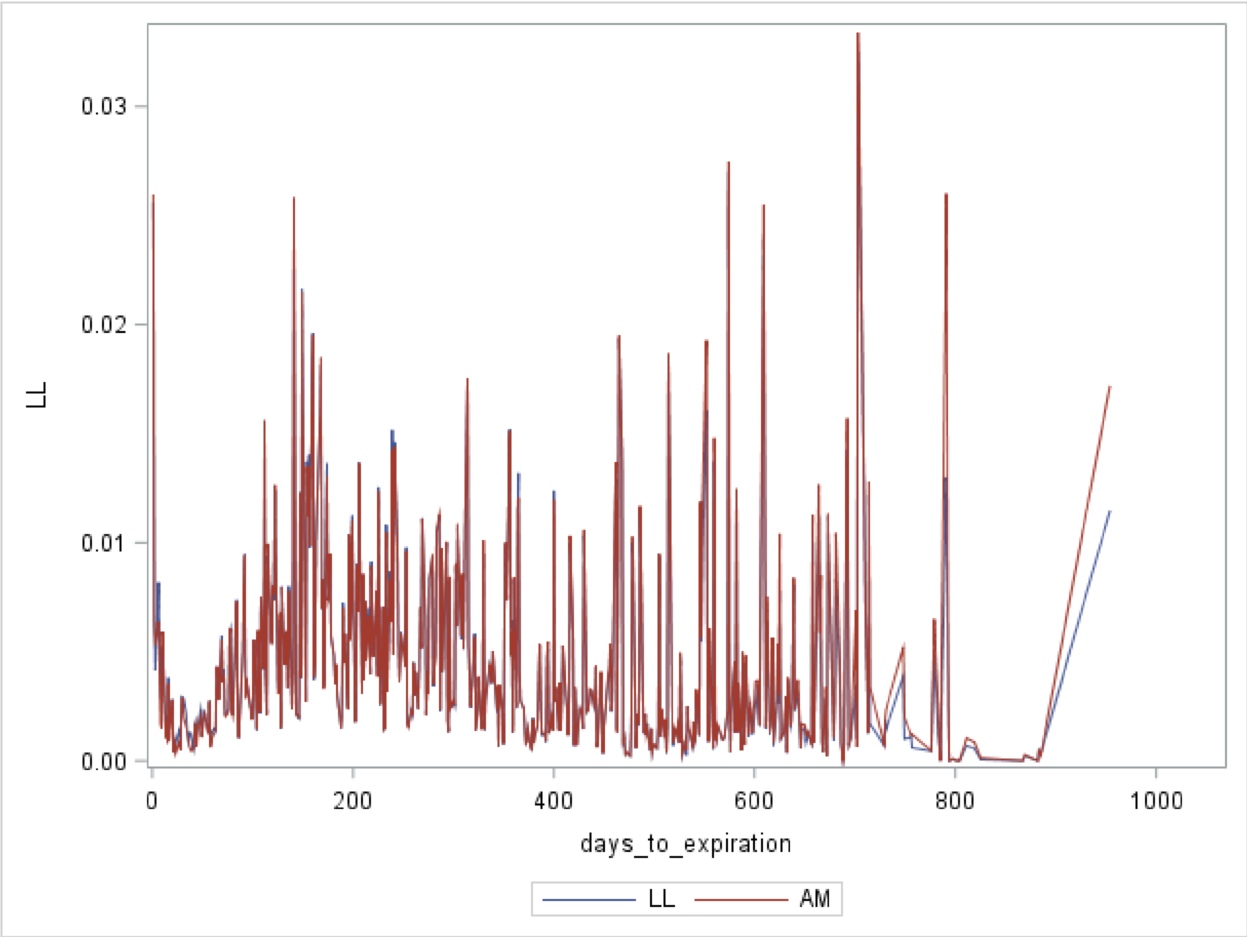
The diesel contract was liquid in the outright contract. The tick size is $0.0001. One contract is 42,000 gallons or 1,000 US barrels. The block size is 25 contracts for the outright and 10 for the December-to-December spread. With LL_d equal to 0.001 the price impact is suggested to be $420. At a price of $1.65 per gallon, one contract would sell for $69,300. $420/69,300 is approximately 0.606%.

LL with LLR (using the last trade) against Days to Expiration for 2016 HO



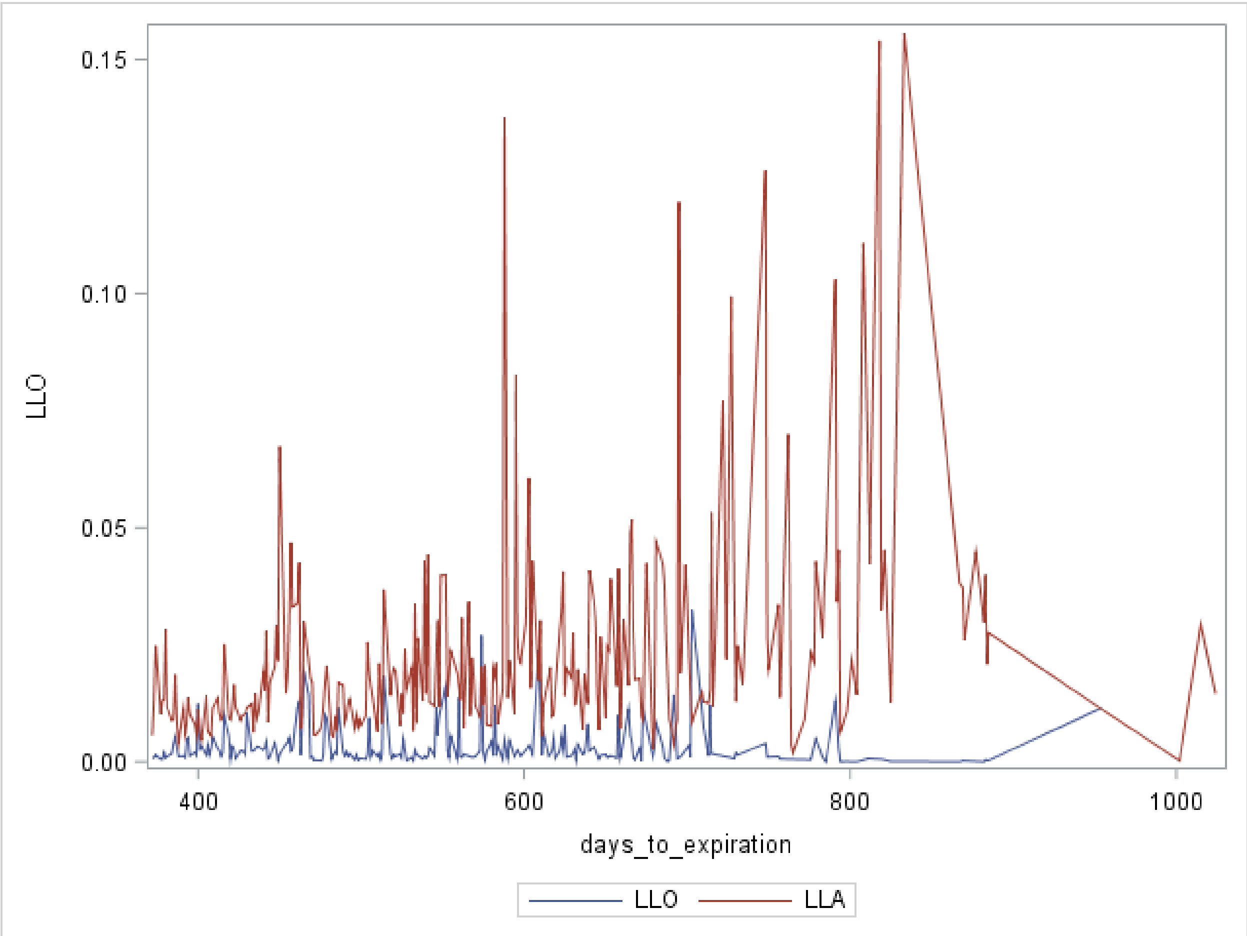
This graph displays LL with the more sophisticated proxy for the current market price with LLR which employs the last price as a proxy for the current market. The p-value for the two-sample t-test with unequal variances is 0.334751. With sample size of 519 for non-missing values, this p-value gives little evidence for the alternative hypothesis that the distribution of LL is different than LLR. For this contract, updating prices with the more sophisticated proxy had less influence than with the other contracts.

A_d and LL_d against Days to Expiration for December 2016 HO



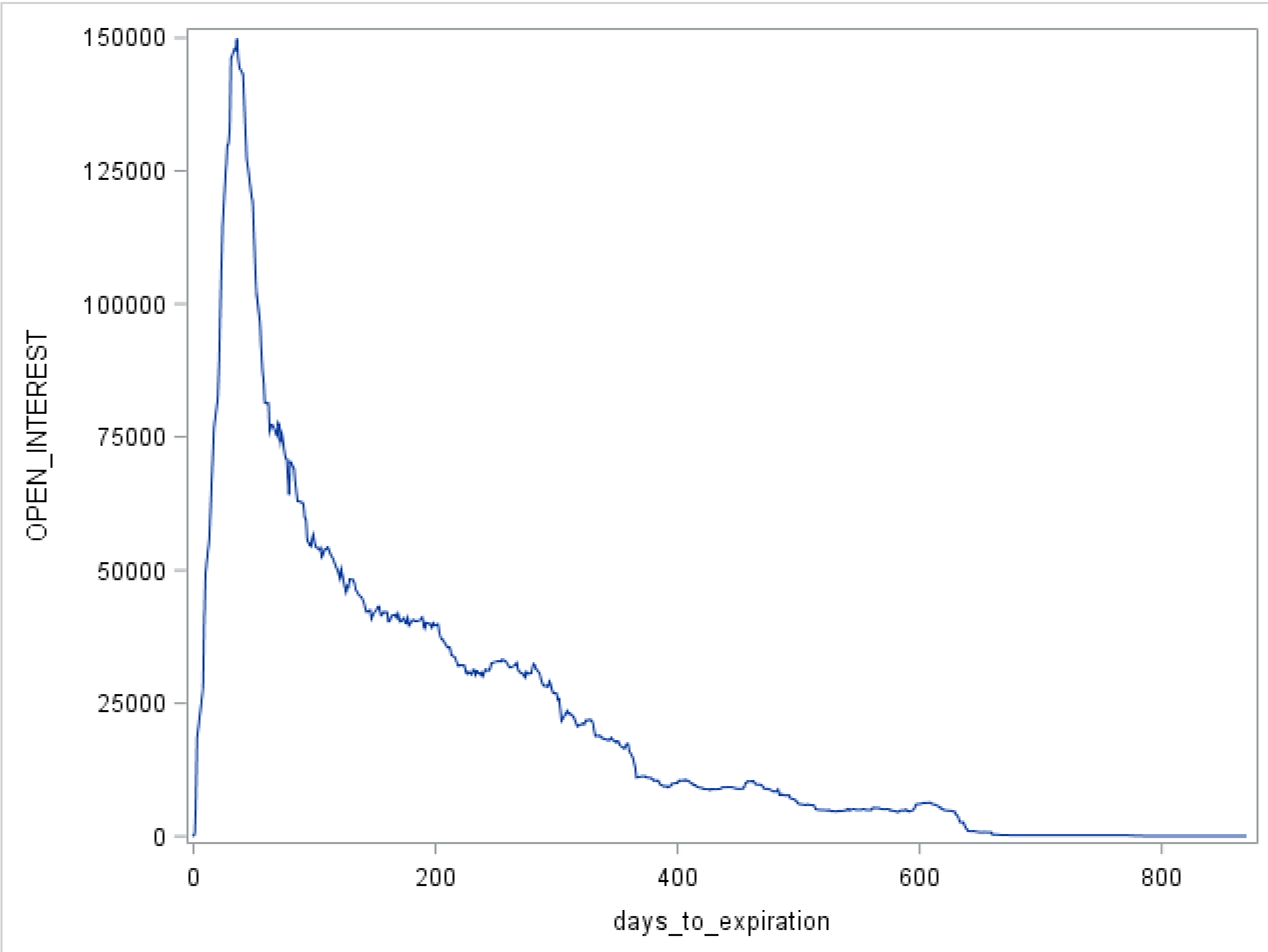
As discussed above, the author prefers LL_d over A_d for theoretical reasons. Even though A_d and LL_d assess differently, they appear to be qualitatively similar. The p-value for the two-sample t-test with unequal variance is 0.34512. Given the large sample size of the non-missing observations, 519, remember that we need two transactions in the contract to compute the liquidity assessments, the p-value gives little evidence for the alternative hypothesis that the two samples are different. For instance, at an alpha =0.05 level, we fail to reject the null hypothesis that the two samples are the same.

Outright Liquidity for December 2016 with 2015/2016 December Spread plus 2015 Outright Liquidity HO



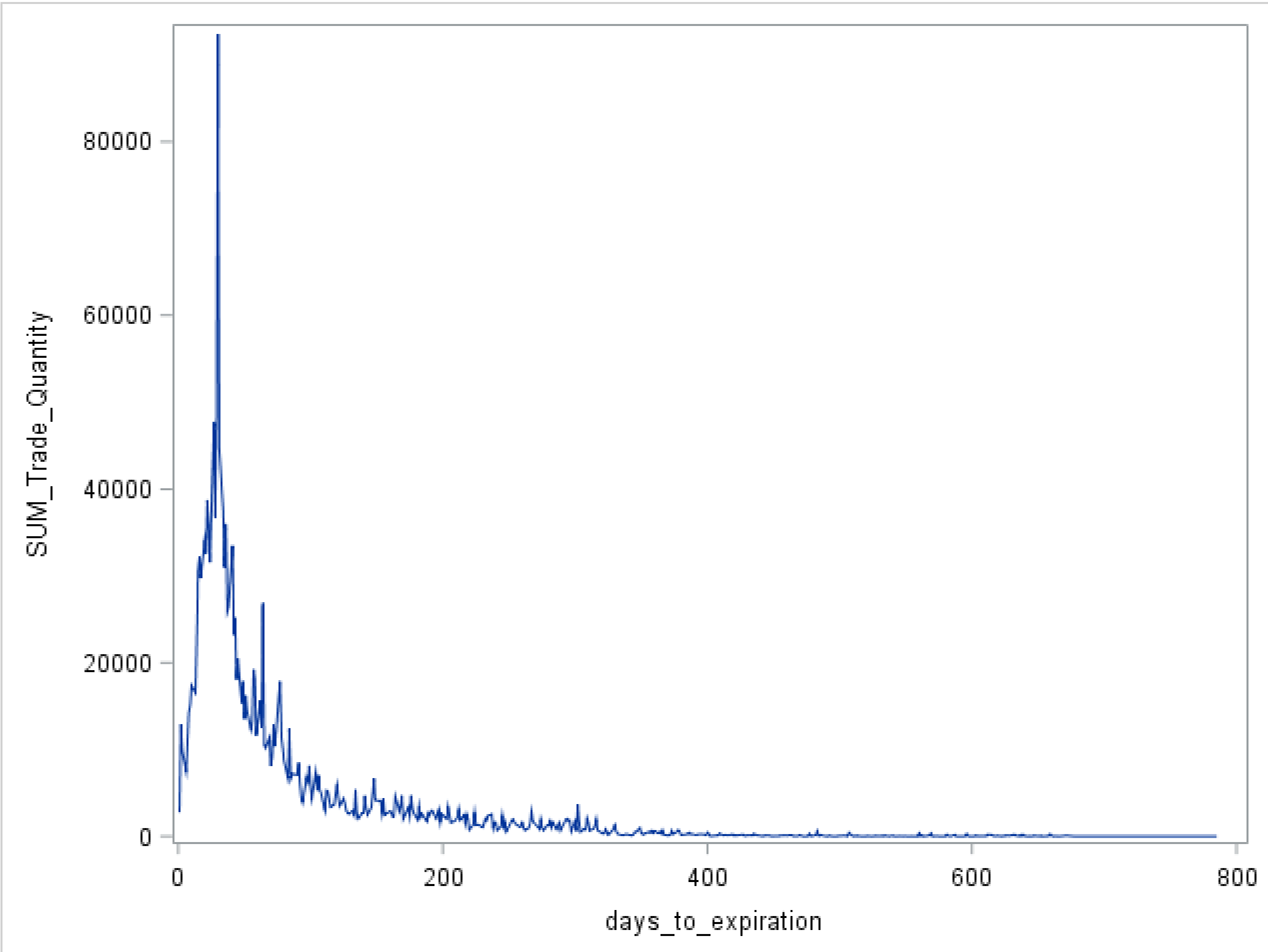
As the red graph is predominately above the blue graph, this suggests that a trader would have done better to exit a position in the December 2016 directly with an outright trade than first using a December 2015/2016 spread and exiting out with a December 2015 outright.

Open Interest versus Days to Expiration for December 2016 RB



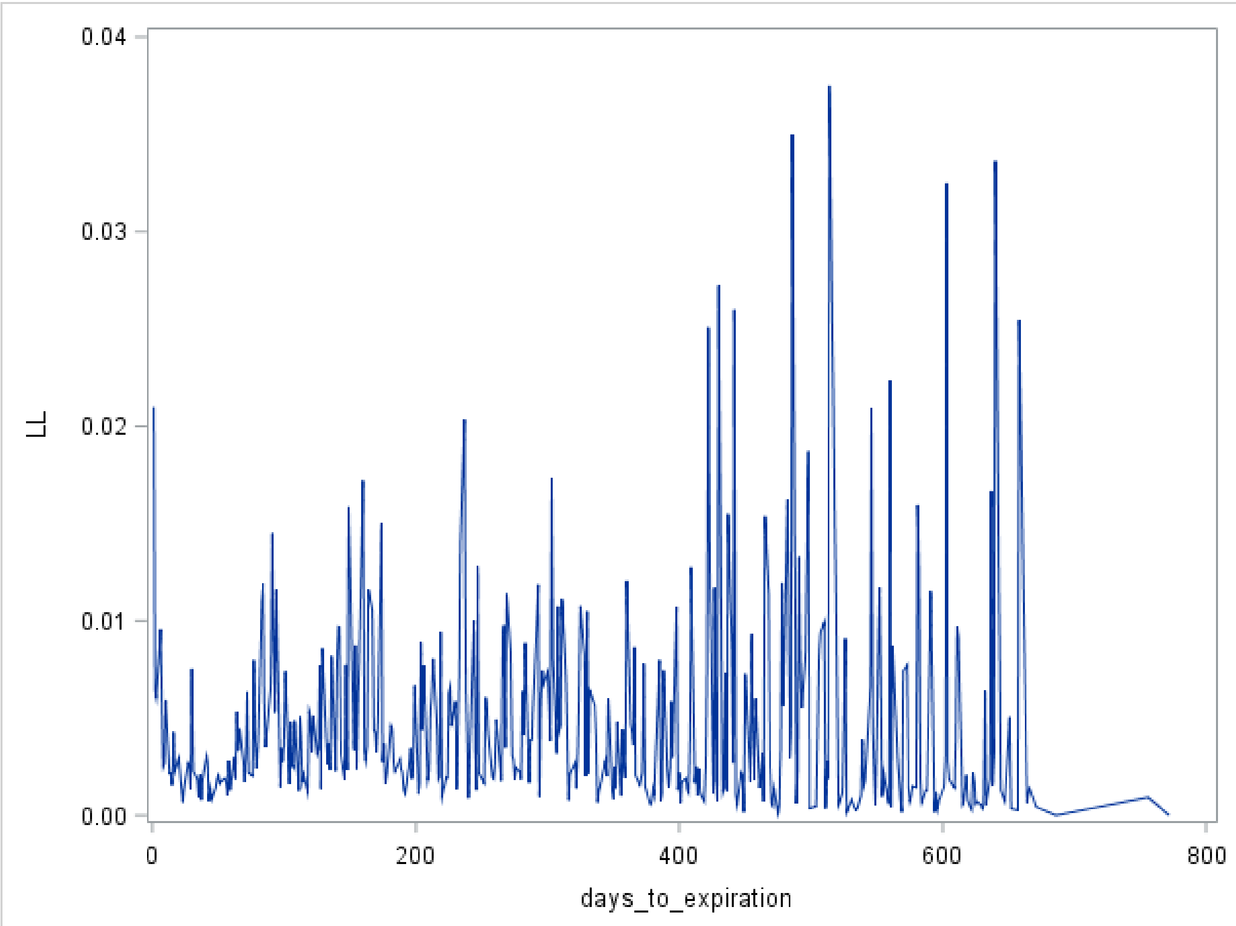
The final contract considered is RBOB gasoline. NYMEX lists the contract for three years. Open interest follows the typical pattern for futures contracts except that open interest peeked sooner and declined before the prompt month.

Trading Volume without the first trade against Days to Expiration for RB 2016



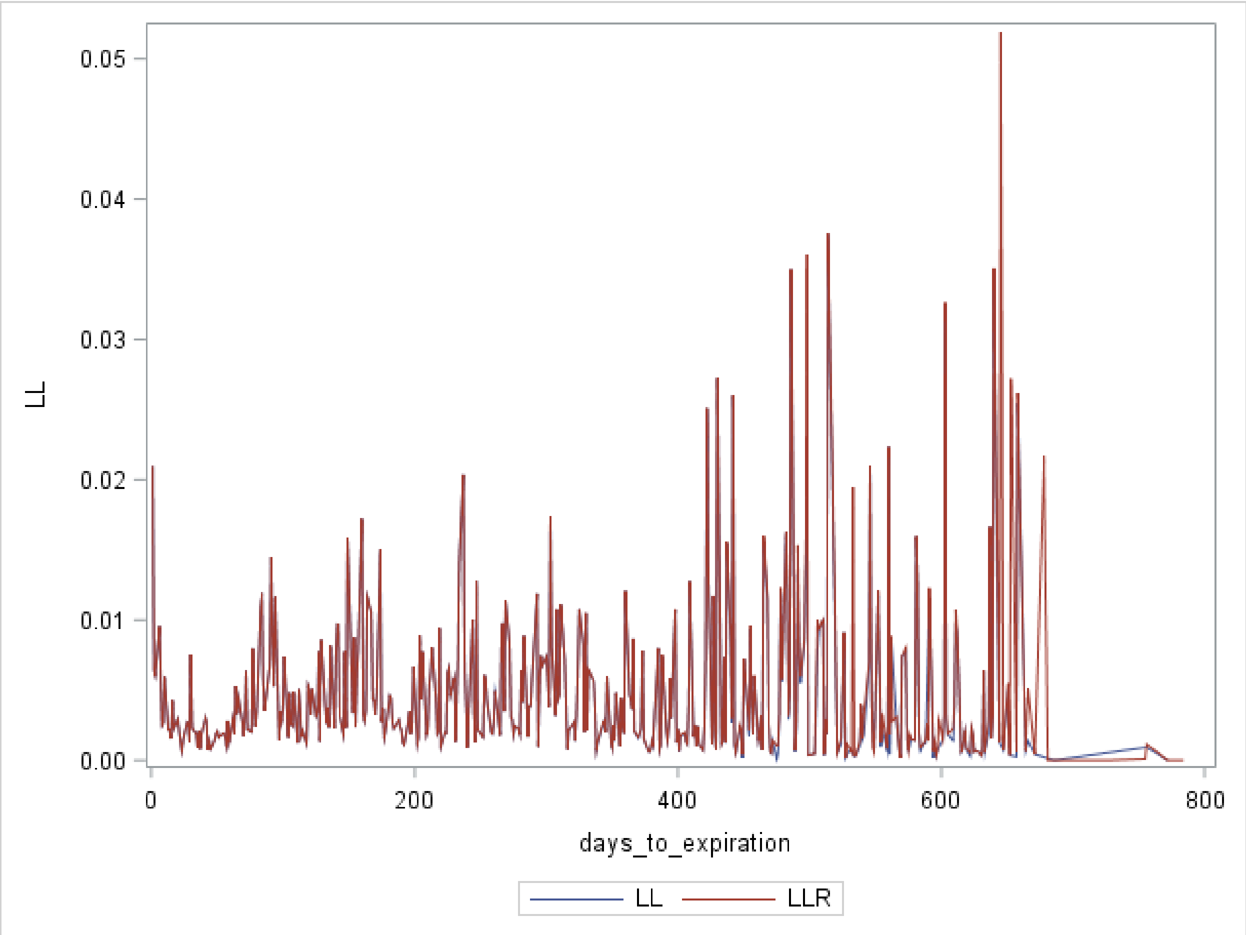
The shape of the trading volume graph is similar to the open interest graph. As with the open interest graph, the trading volume peaks earlier than just before the spot month. Consequently, the near-to-expiration contract month was chosen to be one month later in an attempt to capture, approximately, the highest volume.

Liquidation Liquidity versus Days to Expiration for December 2016 RB



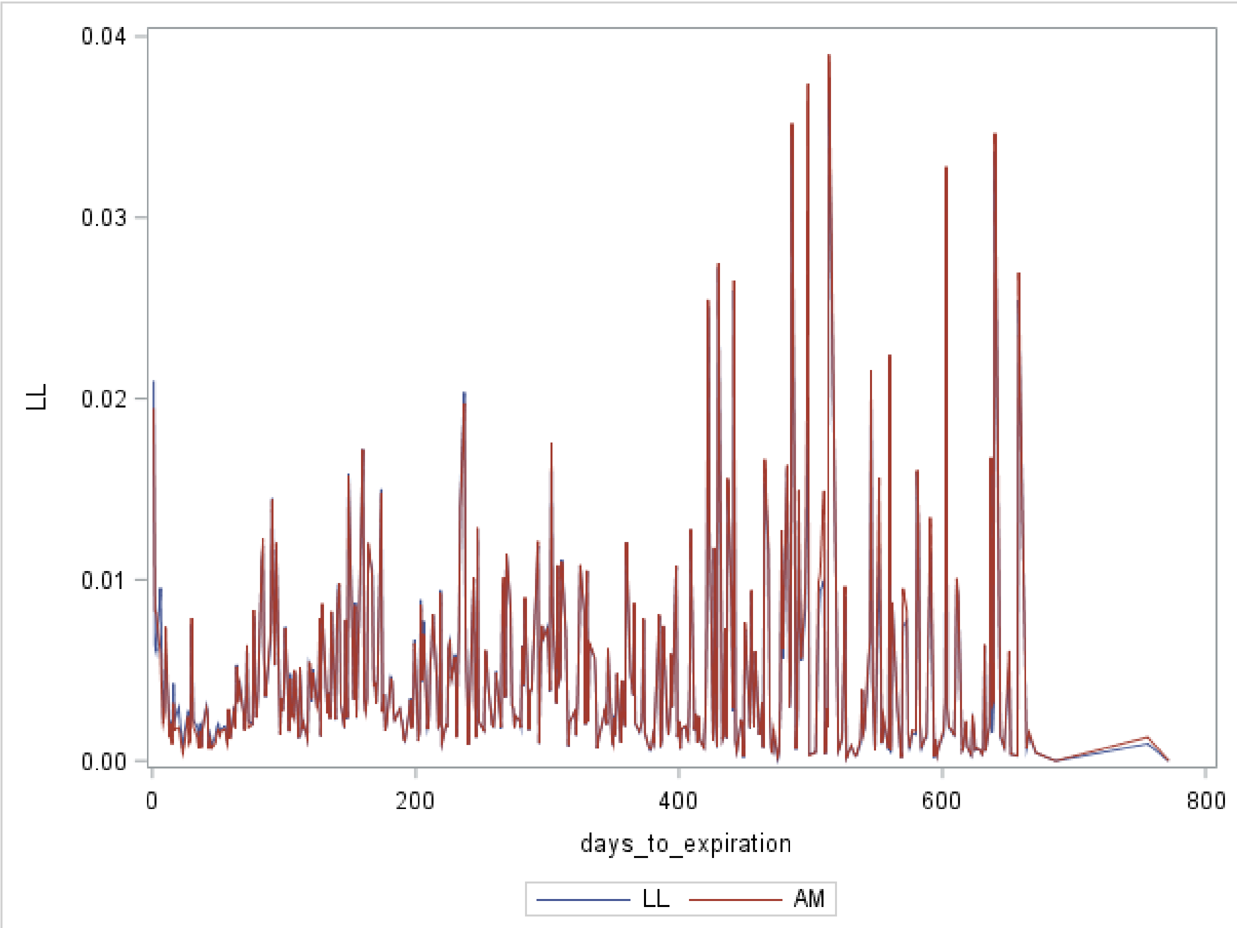
One contract is 42,000 gallons. The tick size is $0.0001. The block size is 25 contracts for the outright and the author presumes it is 10 for the year-to-year spread, but could not find that information explicitly on the CME's web page. With LL_d equal to 0.01, a price impact of $420 is suggested. At a price of $1.55 per gallon, one contract would sell for $65,100. $420/$65,100 is approximately 0.645%.

LL with LLR (using the last trade) against Days to Expiration for 2016 RB



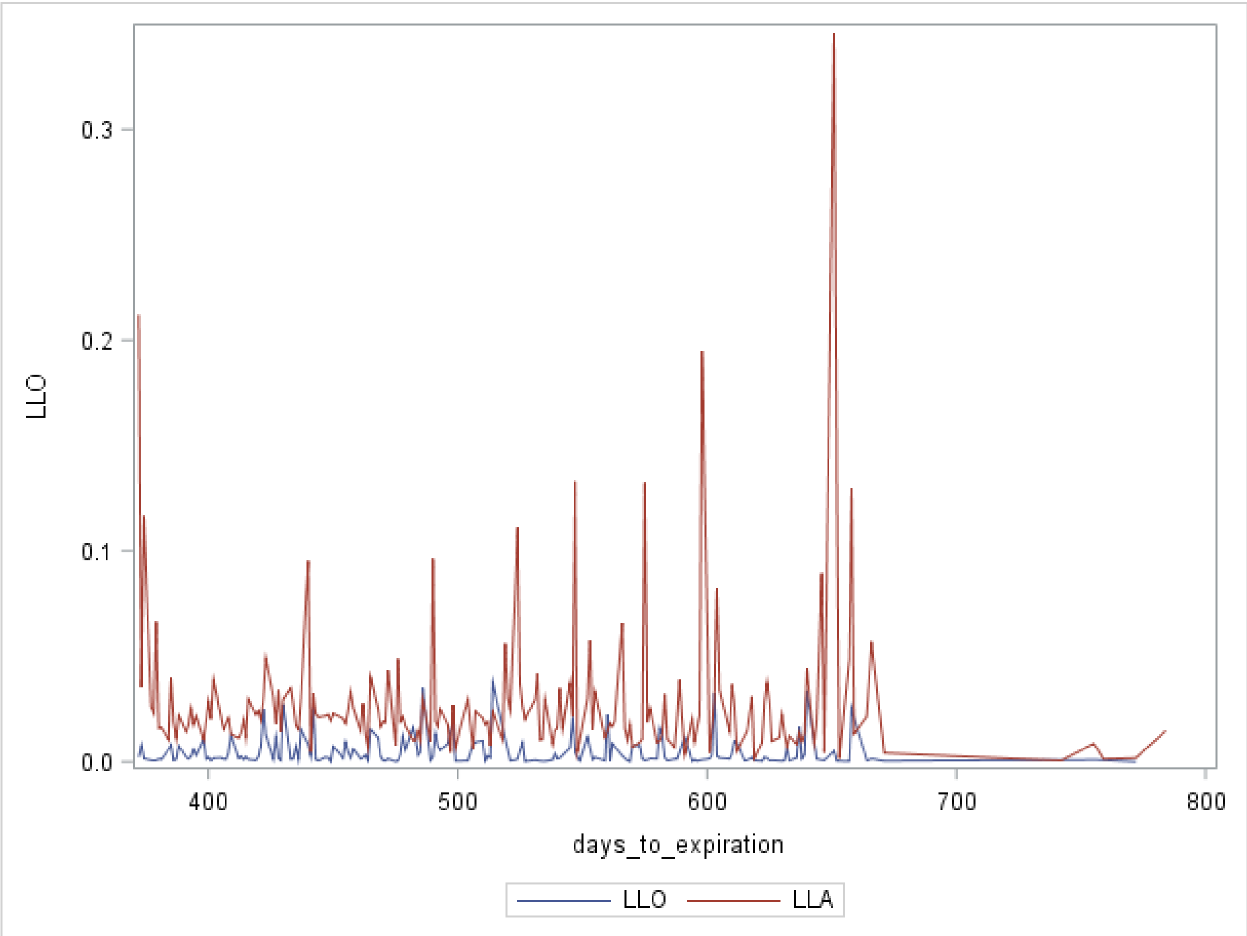
This graph displays LL with the more sophisticated proxy for the current market price with LLR which employs the last price as a proxy for the current market. The p-value for the two-sample t-test with unequal variances is 0.223258. With sample size of 456 for non-missing values, this p-value gives weak evidence for the alternative hypothesis that the distribution of LL is different than LLR. For this contract, updating prices with the more sophisticated proxy had less influence than with the CL and NG contracts.

A_d and LL_d against Days to Expiration for December 2016 RB



As discussed above, the author prefers LL_d over A_d for theoretical reasons. Even though A_d and LL_d assess differently, they appear to be qualitatively similar. The p-value for the two-sample t-test with unequal variance is 0.376875. Given the large sample size of the non-missing observations, 456, remember that we need two transactions in the contract to compute the liquidity assessments, the p-value gives little evidence for the alternative hypothesis that the two samples are different. For instance, at an alpha =0.05 level, we fail to reject the null hypothesis that the two samples are the same.

Outright Liquidity for December 2016 with 2015/2016 December Spread plus 2015 Outright Liquidity RB



The red graph is predominately above the blue graph suggesting that trading in the December-to-December spread and more prompt outright would have been more expensive than simply trading in the outright contract.

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