Electronic Market Makers, Trader Anonymity and Market Fragility

by

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Abstract

We investigate empirically the impact of electronic market-makers on *the reliability and the consistency* with which financial markets provide transactional liquidity services. Our empirical analysis is based on proprietary intraday data from U.S. futures markets. We document results of considerable regulatory importance. We find strong evidence that, in sharp contrast to the erstwhile locals in futures pits, electronic market makers reduce their participation and their liquidity provision in periods of significantly high and persistent volatility, in periods of significantly high and persistent customer order imbalances, and in periods of significantly high and persistent bid ask spreads. Our results are consistent with trader anonymity in electronic markets' not being conducive to facile adjustment of severe information asymmetries. We also find that electronic market makers with longer trading horizons are much less susceptible to withdrawing from liquidity provision in periods of market stress. Overall, given that electronic market-makers represent the irreversible and inevitable progression of technology, our results raise the question whether exchanges and regulators should consider affirmative obligations for hitherto voluntary market makers.

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1. Background and Motivation

The quality of a financial market is determined by its ability to *continually and reliably* provide low-cost transaction services for large size trades at an efficient price. In this context, the economic agents who enable and supply this liquidity are often generically (and sometimes loosely) labeled as "market-makers". Such market makers perform the critically important role of providing 'predictable immediacy' in financial markets by standing ready and waiting to trade with the incoming buy and sell orders of those who demand immediate execution of their orders (Demsetz, 1968). They are willing to bear the cost and the risk of carrying unbalanced inventory exposures of the traded asset (Grossman and Miller, 1988), and are economically rewarded with the premium for doing so.

Trading has increasingly moved to electronic platforms over the last two decades. With innovations in trading technology, a new market maker category has emerged and increasingly dominated liquidity supply in U.S. markets in recent years. This category is that of the electronic market makers (hereafter sometimes abbreviated as "EMM"). An electronic market maker can be characterized as a professional trader acting in a proprietary capacity, and engaged in trading strategies primarily directed at harvesting bid-offer spread revenues by net supply of liquidity, often through computer-based electronic trading decisions and automated computer-based trade executions. Electronic market maker profits are driven by buying and selling financial securities, often without human trade-by-trade interaction or the making of pre-meditated directional bets, but instead participating on both sides of the book, turning over inventory as often as is optimal and often a large number of times during the day, thereby potentially generating a relatively high amount of trading volume with minimal capital investment.[1] Electronic market makers are very important since they collectively account for well over half of the trading volume in U.S. financial markets. The aim of this paper is to empirically investigate the impact of electronic market-makers on *the reliability and the consistency* with which financial markets provide transactional liquidity services.

In this context, it is important to note that market makers in traditional equity markets, like the specialists on the New York Stock Exchange and the competing market makers on NASDAQ, have typically been obligated, through affirmative obligations, to always stand ready to supply liquidity and to maintain orderly markets. On the other hand, market makers in U.S. futures markets, like the "Locals" in futures pits, have always been "voluntary market makers", being essentially traders with exchange membership engaged in liquidity supply activities to generate revenues and earn profits as part of their normal trading business, but without any formal affirmative obligations to maintain liquid and orderly markets.

In spite of the move to electronic markets, of the increasing ability of public traders to contribute to liquidity supply, and of the deregulation that has taken place over the past two decades, market maker affirmative obligations in equity markets still exist through designated market-makers – though the ambit and effective impact of these affirmative obligations have significantly declined. In equity markets, we had very effective affirmative obligations before, and the market microstructure environment has changed to reduce but not eliminate the need or the effect of affirmative obligations. Hence, it is difficult to isolate the effect of electronic market-makers through an empirical analysis of equity markets. Also, because of the continued

[1] EMM trading strategies can potentially generate a large number of trades over a very short period. However, the focus of this paper is on EMMs, not on high frequency traders *per se*.

availability of designated market-makers with affirmative obligations, the absence of continual and reliable liquidity services from electronic market-makers is arguably likely to have less of an adverse impact on the functioning of the market. On the other hand, the U.S. futures markets have always functioned through voluntary market makers without affirmative obligations, and they still function through voluntary market makers without affirmative obligations – albeit with one important change: the new electronic trading platform, and the presence of electronic market-makers rather than scalping locals in the trading pits. In the absence of any liquidity suppliers with affirmative obligations, the reliability of the liquidity supply – and hence the fragility of these markets – is critically dependent on the reliability with which liquidity is provided by voluntary electronic market-makers. The U.S. futures markets therefore provide the ideal laboratory to empirically investigate the impact of electronic market-making on market fragility. This is what this paper sets out to do.

Our motivation for investigating the impact of electronic market-making on market fragility arises from two perspectives. First, from an academic perspective, on the basis of extant theoretical models in finance, we argue that, even in a trading environment in which all market-making is voluntary (like it is in the U.S. futures markets), voluntary electronic market makers, often trading through computerized decision-making and automated trade execution, would be more likely than other voluntary market makers (like "locals" in futures markets) to exit the market and reduce their contribution to overall liquidity during periods of market stress. This is because the new electronic market-makers operate in an anonymous trading environment with greater sensitivity to perceived information asymmetry than in the traditional floor/pit trading environment where reputational considerations can potentially be relevant; and also because the electronic platform enables them to reduce their holding period of the asset. We comprehensively formulate several questions and test several hypotheses in this context.

Second, from the perspective of market participants, there have been extensive concerns articulated by regulators and policymakers that, while electronic market-making improves overall liquidity, it also generates greater potential for periodic episodic illiquidity. The issue came to the forefront with the Flash Crash of May 6, 2010 in one of the most liquid markets in world. In July 2011, a report by the International Organization of Securities Commissions (IOSCO), an international body of securities regulators, concluded that while "*algorithms…. have been used by market participants to manage their trading and risk, their usage was also clearly a contributing factor in the flash crash event of May 6, 2010.*" [2] Regulators have specifically questioned the stability of the liquidity provided by electronic market-makers in modern electronic markets, though their major concerns have been specifically in relation to high frequency trading rather than electronic market makers more generally.[3,4] Consequently, regulatory proposals endeavor to impose affirmative obligations to mandate market makers to 'make' markets even during periods of stress. For example, the European Commission's final

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[2] Earlier, a joint SEC/CFTC official report had concluded on September 30, 2010 that *"HFTs initially provided liquidity to the large sell order that was identified as the cause of the crash. But after fundamental buyers withdrew from the market, HFTs, and all liquidity providers, also stopped trading and providing competitive quotes."* Although Kirilenko, Kyle, Samadi and Tuzun (2014) find no evidence to link the flash crash to HFTs, they document that HFTs exacerbated volatility during the 'Flash Crash'.

[3] For example, speaking in the specific context of high frequency trading ("HFT") rather than the broader context of electronic market-making, Andrew Haldane, Executive Director for Financial Stability at the Bank of England, and Member of the Interim Financial Policy Committee in his speech 'Race to Zero' (July, 2011), said: "*Far from solving the liquidity problem in situations of stress, high-frequency trading firms appear to have added to it. And far from mitigating market stress, high-frequency trading appears to have amplified it. High-frequency trader liquidity, evident in sharply lower peacetime bid-ask spreads, may be illusory. In wartime, it disappears. This disappearing act, and the resulting liquidity void, is widely believed to have amplified the price discontinuities evident during the Flash Crash. High-frequency trader liquidity proved fickle under stress, as flood turned to drought*".

[4] In the same vein, Senator Charles Schumer, in a September 2010 letter to the SEC writes: *"I have come to believe that high frequency traders provide less of the benefits to our markets than its adherents claim, and does so at a greater cost to long term investors…. The SEC should identify market participants who frequently engage in these practices, and require exchanges and other trading venues to slow down those market participants [in times of stress]…. The Commission should consider imposing a minimum quote duration, so that orders could not be sent and cancelled within a fraction of a second".*

draft proposals for the revised Markets in Financial Instruments Directive (MiFID II) along with a related regulation (MiFIR) were published on October 20, 2011; and included affirmative obligations requiring Electronic market makers to *"be in continuous operation during the trading hours of the trading venue to which it sends orders or through the systems of which it executes transactions'* and also required that *"the trading parameters or limits of an electronic trading strategy shall ensure that the strategy posts firm quotes at competitive prices with the result of providing liquidity on a regular and ongoing basis to these trading venues at all times, regardless of prevailing market conditions."* Regulatory proposals have also aimed at constraining electronic market-makers through fees and rules.[5]

In the context of the extensive regulatory concerns summarized above, and the associated proposals for affirmative obligations and fees, it is important to empirically test, in as clinically controlled testing environment as possible, whether electronic market makers are just the "fair weather friends" they have been conjectured to be, or if their contribution to liquidity supply is as reliable and stable as that of other voluntary market makers even at times of market stress. Extant empirical research has been confined to high-frequency trading rather than been on electronic market-making *per se*; and, even for high frequency trading, existing research has focused mostly on "normal" market conditions.[6,7]

[5] There have been proposals (e.g., House Resolution 1068) to impose a per-trade tax of .25%. Other suggestions include implementing fees when the number of canceled orders by a market participant exceeds a certain level, limiting the number of canceled orders, or requiring quotes to have a minimum life before they can be canceled or revised. The European Commission has also proposed a financial trading tax of 0.1% on trading of shares and bonds and 0.01% on trading of derivative contracts within the 27 member states of the European Union by 2014.

[6] A recent exception is Brogaard, Hendershott and Riordan (2014) who conclude, based on 2008-2009 data on trades executed against liquidity on the NASDAQ exchange (excluding trades executed on other stock markets), that HFTs do not reduce their liquidity supply on high volatility days. Their data, unlike ours, do not identify each HFT individually, so their results rely on an artificial "aggregate" HFT – see also Carrion (2013) and Chordia (2013). A further advantage of our dataset is that it allows us to compare liquidity provision at the trader level in electronic (2008, 2011) *vs*. non-electronic (2006) market environments.

[7] Hendershott and Riordan (2013) find that high frequency traders play a positive role in price efficiency through their marketable orders. Hasbrouk and Saar (2013) find that low-latency activity improves traditional market quality

Despite extensive regulatory concerns, almost all extant studies examine the impact on market quality only under normal or average market conditions, rather than on any periods of stress; and extant studies do not tell us how market-makers in electronic markets differ in their trading behavior in this context from market-makers in the erstwhile face-to-face futures pits. They do not examine if and how the trading of electronic market makers exacerbates liquidity problems in situations of market stress. Do they continue to intermediate trades during periods of market stress? Do they 'lean against the wind'? Are electronic market makers, who intermediate more than half the trading volume, averse to taking positions when volatility and/or informed trading is high? Are they more sensitive to market conditions than other voluntary liquidity providers? How did they trade during the 2008 financial crisis? How reliable or valuable is the liquidity electronic market makers supply? Are they only fair-weather friends who run for the exits when their liquidity provision is most needed? These important questions are the focus of our study.

We investigate crude oil futures markets. Our results are based on comparing two periods: a three-month period in 2006 in which trading was entirely in futures pits and market making was done by locals, and a three-month period in 2011 in which trading was largely on the electronic platform and intermediated largely by electronic market makers. Our focus is on "stressful" periods where stress is measured by high and persistent volatility, and/or high and persistent customer order imbalances, and/or high and persistent bid-ask spreads. We also consider the trading behavior of electronic market makers over a three-month period at the time of the 2008 financial crisis as being representative of a major "stressful" period. In a later

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measures such as short-term volatility, spreads, and displayed depth in the limit order book. Brogaard (2010) also finds that high-frequency traders provide liquidity and correct mispricing of securities. Hendershott, Jones, and Menkveld (2011) find that the introduction of auto-quote on the NYSE improves liquidity and enhances the informativeness of quotes. Raman, Robe and Yadav (2012) document that the introduction of electronic trading by the New York Mercantile Exchange (NYMEX) in 2006 leads to a big increase in trading by financial institutions which improves several measures of market quality.

version, we also propose to analyze from this perspective two essentially equivalent assets, i.e., two derivative contracts – a futures contract and an options contract – on the same asset (i.e., crude oil) traded at the same time, but in different systems, one an anonymous electronic system and the other a traditional face-to-face pit/floor trading environment where reputational considerations are potentially relevant.

We document results of considerable academic and regulatory importance. We find strong empirical evidence that, in sharp contrast to the erstwhile locals in futures pits, electronic market makers reduce their participation and their liquidity provision in periods or significantly high and persistent volatility, in periods of significantly high and persistent customer order imbalances, and in periods of significantly high and persistent bid ask spreads. Our results are consistent with trader anonymity in electronic markets' not being conducive to facile adjustment of severe information asymmetries. We also find that electronic market makers with longer trading horizons are much less susceptible to withdrawing from liquidity provision in periods of market stress. Finally, our results are also fully consistent with the changes we observe in liquidity provision around the 2008 financial crisis. Overall, insofar as electronic market-makers represent the irreversible and inevitable progression of technology, our results raise the question whether exchanges and regulators might usefully consider affirmative obligations for hitherto voluntary market makers.

The remainder of this paper is organized as follows. Section 2 explains the motivation and delineates the questions that are addressed in this paper. Section 3 describes the data. Section 4 documents the empirical results. Section 5 summarizes our findings and offers concluding remarks.

2. Questions Addressed and Testable Hypotheses

The trading of electronic market makers is expected to be different from other market-makers (voluntary or obligatory) during periods of stress mostly due to at least two reasons: first, they trade in electronic markets where traders are anonymous rather than in markets in which trader reputations can influence trading; and second, they trade with very short horizons. The questions we address in this paper largely flow from these two reasons.

2.1 Trader anonymity and informed trading

Benveniste, Marcus and Wilhelm (1992) show, on the basis of their theoretical modeling framework, that, in an exchange where traders are not anonymous, longstanding relationships between market participants can mitigate the effects of asymmetric information. A floor broker with a reputation of being informed, invariably pays higher spreads than others irrespective of the 'informedness' of the current trade. Due to lack of anonymity, reputation of a floor broker or market-maker plays an important role. These authors argue that, if a broker/trader is identified as having traded on private information, then the broker/trader will face long-term 'sanctions' whose costs will outweigh the benefits of concealing the private information. Consequently, floor traders/market-makers can separate informed and uninformed traders more efficiently than their counterparts in an electronic exchange, and the resulting separating equilibrium dominates the pooling equilibrium obtained in anonymous electronic exchanges. Since electronic market makers trade in markets where traders are anonymous, their trading strategies are significantly more sensitive to informed trading then the strategies often voluntary market makers in markets where market participants are not anonymous, for example, the locals in futures pits.

Supporting the above contention, Franke and Hess (2000), using data from DTB and LIFFE, show that in periods of low information intensity, the insight into the order book of the electronic trading system provides more valuable information than floor trading, but in periods of high information intensity, this is not the case. Similarly, Easley, Prado and O'Hara (2011) show that order flow 'toxicity' peaked around the flash crash. And importantly, Zigrand, Cliff and Hendershott (2011) argue that high-frequency traders rely on automated risk management algorithms to mitigate the disadvantage arising from the fact that they have no way of knowing their counterparties information level : these algorithms tend to limit high-frequency trader participation and liquidity provision at the first hint of a spike in informed trading.

Consequently, electronic market maker strategies should arguably be very sensitive to the probability of informed trading. Electronic market makers should be more averse to taking positions and to providing liquidity during periods of market stress than other voluntary market-makers operating in a Floor Trading type system in which traders are not anonymous. In this context, we first compare the trading activity of locals and electronic market makers during periods of market stress using two different sample periods with similar characteristics. Like electronic market makers, locals are voluntary market-makers, have inventories with similar half-lives, and also tend not to carry overnight inventories (Manaster and Mann, 1996). Second, we note that, according to Benveniste, Marcus and Wilhelm (1992), "the benefits of a floor exchange mechanism will be greatest when the potential for privately informed trading is greatest and when liquidity traders are most sensitive to transaction costs". Hence, the greater the persistence of extreme market conditions, the greater the differences we would expect to find between the trading of locals and electronic market makers.

2.2 Short-horizon trading

Electronic market makers are the prototypical 'short-horizon' traders in De Long, Shleifer, Summers and Waldmann (1990) who bear position risks only when they expect to profitably offload their positions within their trading horizon. The trading advantage of Electronic Market Makers stems from their ability to trade in and out of positions faster than others (Javanovic and Menkveld, 2010). Such agility is hindered when capital is locked-up in a single position. Therefore, the lower the chances of profitable inventory rebalancing in a short period of time, the greater the reluctance to take a position and, conditional on participation, the smaller the position undertaken.

These observations yield several testable implications. First, the factors that lower the chances of a profitable rebalancing of inventory in a short period of time are the underlying volatility (informational and liquidity related), the informed ('Toxic') order-flow, and the pre-existing inventory position. As a corollary, electronic market makers are more likely to offload their inventory when the aforementioned variables increase; and consequently, more likely to demand liquidity than provide it when volatility, informed trading or pre-existing inventory positions increase. Second, electronic market makers with shorter trading horizons (proxied by rate of inventory mean-reversion) should arguably be more sensitive to the aforementioned variables than those with longer trading horizons. Third, by extension, electronic market makers should be more severely averse to trading and providing liquidity when both market conditions are severe and capital costs are high (which reduce trading horizons). Finally, trading and liquidity provision should be significantly lower during the 2008 financial crisis.

3. Data and Variables Analyzed

The data employed in this study consist of intraday transaction records of all WTI Crude Oil futures on the New York Mercantile Exchange (NYMEX) from three different time periods: January and March, 2006; April and December, 2008; and January and March, 2011. These data are obtained from the Commodity Futures Trading Commission (CFTC). In the electronic trading period, post September, 2008, the crude oil futures market trades around the clock (except between 5:15 pm and 6 pm, EST). Prior to September, 2008, during the pit trading period, the markets trade only between 9am and 2.30pm. In order to ensure a "fair" comparison between the pre-electronic and post-electronic periods, we only study trading between 9am and 2.30pm.[8] This dataset provides details such as the commodity and delivery month, the quantity, the price, and the date and time of the transaction. Moreover, buyer and seller identity codes are also provided.[9] Further, traders are classified into one of four customer types via a Customer Type Indicator (CTI), which ranges from 1 to 4 as follows:

- CTI 1 traders are the individual members of the exchange, also known as 'Locals'.
- CTI 2 traders are the institutional members of the exchange.
- CTI 3 traders are member traders trading on behalf of other member traders.
- CTI 4 are the customers of the exchange or external traders

Identification of Electronic Market-Makers

Electronic market-makers (EMMs) are identified in the 2011 and 2008 samples. We identify EMMs based on two criteria. One, they are relatively active (greater than 2,000 trades a day). Two, their end-of-day positions are tiny compared to their daily trading volume (less than 5%). Based on these criteria, we identify 52 traders as the *de facto* EMMs. Descriptive statistics relating to their trading are provided in Table 1, Panel A. Various important points are made in the panel. First, those 52 traders (0.35% of all trading accounts) account for about 50% of the overall trading volume in the world's most heavily traded commodity - median Trades per day is

[8] Even in the electronic trading period, most of the trading (~90%) occurs between 9am and 2.30pm (EST). Account-level data are aggregated across several dozen or hundreds of accounts in order to protect the confidentiality of individual traders' underlying position(s) and trade secrets or strategies.
[9] These identities are coded by the CFTC so as to conceal the actual identities of the market participants.

4,372.73. Second, as expected, electronic market-makers' trade size is less than the average market trade size. Third, consistent with our selection criteria, EMMs carry very little of their daily trading overnight - Mean Closing Ratio (End-of-Day Inventory/Total Trading) is ~ 0.00%.

Identification of Locals

Locals are identified in the pre-electronic trading, 2006 sample. It should be noted that all the trading in this period happens in the Pits – there are no EMMs. As in Manaster and Mann (1996), CTI 1 traders are identified as locals. There are 941 CTI 1 traders, so that considering all these traders would be computationally costly. For this reason, we focus on those that trade more than 25 times a day - 941 CTI 1 traders account for 50.39% of the total trading volume and the selected 200 Locals account for 41.39% of trading volume. Descriptive statistics relating to their trading are provided in Table 1, Panel B. Similar to EMMs, Locals' trade size is less than the average market trade size and they a tend to go-home 'flat' (Mean Closing Ratio is ~ 0.00%).

Variable Definitions

All market variables are calculated as 60 minute moving averages of 1 minute estimations. For example, Volatility of returns is calculated every minute and a moving average of the last 60 observations is reported. Also, all market variables are volume weighted averages across different maturities. Returns, Volatility of Returns, Volume and Bid-Ask spreads are calculated as done in the prior literature. We also calculate Customer Demand Imbalance (CD Imbalance, i.e., CTI 4 (Customers) Buy *minus* CTI 4 (Customers) Sell Volume) to indicate the direction and magnitude of the liquidity demanded by the customers of the exchange.

Table 1, Panels A and B provide descriptive statistics of the different market variables in the two time periods. This comparison yields the following observations. One, Volatility (of Returns) is not significantly different between the two periods. If anything, the 2006 sample exhibits higher Kurtosis. Two, Bid-Ask Spreads are higher in 2006 – clearly Pit trading was more profitable for liquidity providers than electronic trading is for EMMs. Three, CD Imbalance is more volatile in 2006. Finally, as expected, Volume is much higher in the 2011 sample. In sum, the market variables are either similar across the time-periods, or the market conditions and deviations in market conditions are worse in the 2006 sample.

4. Empirical Results

4.1 Overview of methodology

Market-makers are clearly expected to be reluctant to trade and provide liquidity during market crashes: for example, Floor Traders on the NYSE and Dealers in NASDAQ had both closed shop on 'Black Monday' October 19, 1987. But, Electronic market makers, because of the inherent disadvantage in dealing with information asymmetry arising from electronic trading, and because of their objective to maximize their trading with minimal capital investment, could be extremely sensitive to even minor deviations from 'normal' conditions. It might not take a market-wide crash for electronic market makers to withdraw from the market: even small perturbations have the potential to instigate a withdrawal. In view of this conjecture, we examine the trading and liquidity provision of electronic market makers and locals when market conditions deviate from the mean by greater than two standard deviations.

In all our univariate and multivariate analyses, we examine the trading of locals and of electronic market makers via two approaches. Our first approach is from the perspective of how intermediaries (both EMMs' and Locals) trade with respect to the customers of the exchange?

Demsetz (1968) argues that the true measure of liquidity is the cost of transactions for the customers of the exchange, not the intermediaries. Our dataset allows us to *ex ante* identify customers of the exchange (CTI-4 traders, see Manaster and Mann (1996)). So, we test how the trading propensity of EMMs and Locals relates to demand imbalance (Buy-Sells) of CTI-4 traders, which is also a proxy for order flow ‘toxicity’ (See Easley, Prado and O’Hara, 2010). And, conditional on trading, how the trading of EMMs and Locals is related to CTI-4 demand imbalance. For example, if EMM net trading volume is negatively related to CTI4 demand imbalance, then we can infer that EMMs performed the prescribed role of a liquidity supplier.

In our second approach, we examine how market-maker liquidity provision, both by EMMs’ and by Locals, depends on different market conditions. The greater the proportion of trading volume for which market makers are passive traders providing liquidity, the better the contribution to liquidity provision. In this context, one can proceed in two ways. First, extant work uses the textbook perspective on liquidity provision: a trader is deemed to be supplying liquidity when s/he is posting a standing limit order and demanding liquidity when s/he is “picking” an existing limit order through a market order or a marketable limit order. However, this perspective is not the only perspective that should be taken to liquidity provision. Market makers supplying liquidity engage in active inventory management, and have to occasionally demand liquidity to rebalance their inventory. With electronic market makers, this ratio can be much higher - up to 40% - as against 15 to 20% in conventional dealer markets (Sofianos, 1995). A second way to measure the extent of liquidity provision by a market maker is to estimate the extent to which “customer order flow” finds EMM counterparties to consummate their trades. Our data allows us to measure the extent to which EMMs offset customer order-flow, and we use this as a second measure of liquidity provision by the market maker.

4.2 *Market maker trading activity in different market conditions: Univariate analysis*

This subsection provides the results of the univariate analysis of the trading activity in different market conditions of both electronic market makers and locals during the relevant sample periods, 2011 and 2006 respectively.

Table 2 provides a univariate picture of the trading activity of electronic market makers in normal market conditions and during periods of market stress. Periods of market stress are defined in terms of high volatility, high order imbalances, the presence of both high volatility and high order imbalances, and high bid ask spreads; where "high" is defined in terms of two standard deviations away from the mean. When volatility and/or the order imbalance is greater than two standard deviations, it means that the average of the one-minute volatility values or the average of the one-minute order imbalances over the past one hour have been abnormally high.

Table 2 provides strong and statistically significant conclusions. First, when volatility is persistently and significantly high, electronic market makers reduce their participation significantly. They also service significantly fewer customer trades, their overall liquidity provision in terms of posting of standing limit orders falls significantly, and their liquidity provision to customers also falls significantly. Second, when order imbalance is significantly and persistently high, the results are very similar to the volatility-related conclusions above. The more toxic the order flow, the lower is the extent of participation and liquidity provision by electronic market makers, both in general and specifically to customers. Not surprisingly, when both volatility and order imbalances are persistently and significantly high, the participation and liquidity provision of electronic market makers drops even more dramatically. Finally, when bid-ask spreads are significantly and persistently high, while the changes in electronic market maker participation liquidity provision is of a sign similar to that for volatility and order imbalances, the results are not statistically significant. Overall, the univariate analysis clearly indicates that electronic market makers tend to withdraw and provide less liquidity during stressful periods.

There is, to our knowledge, no extant empirical analysis about the behavior of voluntary market makers during periods of market stress. Hence, on the basis of table 2, one may be tempted to conclude that voluntary market makers tend to withdraw and cut liquidity provision during periods of market stress. However, Table 3 provides a corresponding analysis of the behavior of locals, and the results are in complete contrast from the results reported in table 2 for each and every stress indicator. First, when volatility is persistently and significantly high, the participation of locals *increases* significantly, they also service significantly *greater* customer trades, their overall liquidity provision in terms of posting of standing limit orders *increases* significantly, and their liquidity provision to customers also *increases* significantly. Second, when order imbalance is significantly and persistently high, the results are again very similar to the volatility-related conclusions above. The more toxic the order flow, the *greater* is the extent of participation and liquidity provision by locals, both in general and specifically to customers. Not surprisingly, when both volatility and order imbalances are persistently and significantly high, the participation and liquidity provision of locals *increases* even more dramatically. Finally, when bid ask spreads are significantly and persistently high, the changes in the participation and liquidity provision of locals is this time not only of a sign similar to that for volatility and order imbalances, the results are also statistically significant. Overall, the univariate analysis clearly indicates that locals tend to increase their participation and provide more liquidity during stressful periods.

The difference in results between locals and electronic market makers is unlikely to arise because of a difference in sample characteristics: as shown in the descriptive tables, the two periods are quite comparable – if anything, the 2006 sample appears to be more volatile in terms of order imbalances. There could be two reasons why the results for different. First, locals could be better informed about price and liquidity schedules relative to electronic market makers because pits are expected to provide more information due to human interaction than what is feasible in anonymously traded electronic markets. Second, locals could be less averse to taking positions during stressful periods because they have longer trading horizons. We test these hypotheses in the next subsection.

4.3 Market maker trading activity in different market conditions: Multivariate Analysis

Unlike obligated market-makers, EMMs (being voluntary market-makers/dealers) have the option of not participating in trades. Hence, we model EMM trading as a 2-stage process. In Stage 1, we model the EMMs' decision to trade. In Stage 2, we model the direction and magnitude of the EMMs' trading, conditional on trading. To this effect, we employ the Heckman two-stage regression methodology. In Stage 1, we use a Probit framework to determine the probability of a change in an EMM's inventory. In Stage 2, we use ordinary least squares regressions to determine the direction and magnitude of change in an EMM's inventory. Our results are in table 4.

First, in regard to inventory, consistent with dealer inventory models, inventory not only affects the propensity to trade of the electronic market maker, it also affects the magnitude and the direction of new trades. A one-standard deviation increase in absolute inventory raises the propensity to trade of the electronic market maker by 81.2%. Also, when electronic market makers trade, they rebalance their inventory positions. Second, in regard to volatility, the propensity to trade of electronic market makers reduces significantly when volatility increases significantly. When volatility is high, they maintain higher spreads that reduce the probability of trades. Third, in regard to trading revenues, electronic market makers are more likely to trade after losses, but only to reduce their inventories; and they tend to unwind positions after significant losses. Fourth, in regard to returns, electronic market makers are, on average, contrarian traders. However, importantly, when the magnitude of returns is significantly high, i.e. greater or less than two standard deviations away from the mean, these electronic market makers trade with the customer order flow: this pattern is completely consistent with the claims made by numerous regulators and commentators that electronic market makers demand rather than provide liquidity during such periods. Fifth, in regard to the absolute value of customer order imbalances, the trading propensity of electronic market makers reduces significantly when the absolute value of order imbalances is high; and the incremental effect of high absolute order imbalances on liquidity provision is also significantly negative. Clearly, electronic market makers are extremely reluctant to take positions when order flow is toxic. Sixth, in regard to order imbalances, it is again clear that, in normal conditions, electronic market makers trade against customers of the exchange – as they should. However, when order imbalances are abnormally and persistently high in magnitude, they trade *alongside* their customers: this behavior is consistent with the claim that, during periods of market stress, EMMs start demanding liquidity instead of providing it. Finally, in regard to bid ask spreads, on average, Electronic market makers trade more when spreads are high as they should; however, persistent and large bid ask spreads significantly reduce their participation. Overall, these results provide strong confirmation that electronic market makers significantly reduce their contribution to liquidity provision in periods of market stress.

The corresponding results for locals are in table 5. First, not surprisingly, the results for inventory for locals are very similar to those for Electronic market makers; and even the half-lives of these inventories is very similar. For returns, the results are also similar. However, the results for other attributes are, as expected, different. For volatility, the propensity of locals to trade also drops significantly amid increases in volatility – but, in contrast to electronic market makers, there is measurable nonlinearity in the negative relationship: the participation of locals is negatively related to volatility only when the volatility is greater than two standard deviations. For trading revenues, locals do not reduce their inventories after significant losses – unlike electronic market makers. And the propensity to trade is significantly and positively related to absolute order imbalances: the trading of locals increases with demand imbalances, although at a lower rate in extreme conditions. Consistent with this finding, customer order imbalances are negatively related to inventory changes. Unlike the case of electronic market makers, even when customer order imbalances our abnormally and persistently high in magnitude, locals continue to trade against customers and continue to provide liquidity to customers. This provides evidence supporting the argument that pits may have been better suited to solve the problems associated with extreme levels of information asymmetry. Finally, again unlike electronic market makers, even persistent and abnormally large bid ask spreads do not reduce the participation of locals.

Table 6 provides results for the trading behavior of electronic market makers and locals in extreme conditions that have not necessarily persisted for a relatively long time. In this table, we classify periods as "extreme" when the market variables have been greater than two standard deviations for one minute (instead of one hour).

Our results show that the effect of 60 minutes of extreme conditions on the trading of locals is similar to the effect of a single minute of extreme conditions on the trading behavior of electronic market makers. Table 6 shows that, as the persistent of toxic order flows goes from one minute to 60 minutes, electronic market makers go from providing liquidity to demanding liquidity. Their participation is positively related to demand imbalances overall, but the relationship in less positive when demand imbalances are greater than two standard deviations. They continue to fulfill customer order flow even in these one minute extreme conditions, but their behavior in relation to other variables a similar to their behavior in the case of persistent extreme conditions. Clearly, the informational disadvantages of electronic market makers with respect to locals appear to be greater when periods of market stress are more prolonged.

Next, Table 7 reports the results of examining the trading behavior of the subset of electronic market makers who have a relatively long trading horizon. We measure the trading horizon based on the mean reversion of inventories. Those in the lowest quartile of mean reversion are classified as "longer-term traders". Market stress is determined on the basis of a one-minute interval, as in Table 6. There are several notable results. First, mean-reversion takes place only when the inventory goes beyond two standard deviations, otherwise it drifts along. Second, electronic market makers do not liquidate after significant intraday losses. Third, they are not sensitive to returns. Fourth, and most importantly, their propensity to participate is positively and significantly related to volatility; this relationship holds even when the volatility is greater than two standard deviations. Overall, these results show that toxic order flows do not hinder participation or liquidity provision of longer-term horizon market makers.

In Tables 8A and 8B, we present results similar to those in Table 4 and 5 but based on measuring liquidity provision according to the conventional approach of whether the market maker in question provided liquidity through posting of standing limit orders *versus* demanded liquidity by picking an existing limit order. For electronic market makers, liquidity provision by all measures decreases with volatility, and the incremental effect of extreme volatility is negative; liquidity provision by all measures also decreases significantly with the absolute value off customer order imbalance and the incremental effect of extreme values is always negative and significant; but liquidity provision increases when spreads increase. Still, overall the results are largely similar to those obtained from the early analysis, and the bottom-line conclusion continues to be that electronic market makers provide significantly less liquidity in periods of market stress. On the other hand, locals are less sensitive to extreme levels of volatility and the starkest difference emerges as before in respect of the impact of customer order imbalances. Overall, our findings support the claim that electronic market makers are significantly more sensitive and averse to toxic order flow than locals are.

4.4 Electronic market makers and the 2008 Financial Crisis

In this subsection, we investigate our central proposition - the significant reduction in the participation of and liquidity provision by electronic market makers in periods of market stress - in the specific context of the 2008 financial crisis. To this end, we analyze data from April 2008 to December 2008. We divide the time period from April, 2008 to December, 2008 as follows. The *pre-Lehman period* is from April to September 14, 2008. *Crisis Period 1* is from September 15 (Lehman Bankruptcy) to October 14, 2008. *Crisis Period 2* is from October 15 (when retail sales hit a 3-year low and the Chairman of the Fed said that recovery will be slow) to November 30, 2008. *Crisis Period 3* is from December 1 (when the NBER confirmed that the United States had entered into a recession and U.S. manufacturing activity hit a 26-year low) to December 31, 2008.

The results of our univariate analysis are in Table 9. Clearly, electronic market maker trading and liquidity provision dropped dramatically during the crisis periods, with drops as large as 50%. The trading is affected only after October 15. The results strongly confirm our previous results about the aversion of electronic market makers to volatility and customer order imbalances.

The results of our multivariate analysis are presented in Table 10. This table is based on the following procedure. We use the three exogenous shocks to the crude oil market to examine the relation between the liquidity provision of electronic market makers and market variables of interest. In the first stage, we extract the components of market variables that are exogenous to the trading of electronic market makers: these are the predicted components from the regression. In the second stage, different measures of liquidity provision are regressed on the extracted exogenous components of market variables. This methodology is similar to the one employed by Hendershot *et al.* (2011). Our results again show that, during this period of extreme market stress, the participation and the liquidity provision of electronic market makers is inversely related to volatility, customer order imbalances, and bid ask spreads.

5. Concluding Remarks

The liquidity and pricing efficiency of financial markets is critically dependent on the market makers who provide liquidity in these markets. With the move to electronic trading, and changes in trading technology, the nature of the market-makers supplying liquidity has changed significantly. Traders in electronic markets trade anonymously and face potentially greater information asymmetries than in markets with floor or pit traders. Electronic markets also allow market makers to have considerably shorter trading horizons. In these contexts, the aim of this paper is to empirically investigate the impact of electronic market-makers on *the reliability and the consistency* with which financial markets now provide transactional liquidity services.

Our empirical analysis is based on proprietary intraday data from U.S. futures markets.

Market making in these markets has always been voluntary. Earlier, trading was in futures pits and locals were the voluntary market makers. Now, trading is electronic, and the new electronic market makers continue to be voluntary. Markets where market-making is voluntary are also more susceptible to issues of reliability and stability in liquidity provision. Hence, these markets provide an ideal laboratory for our investigation.

We document results of considerable academic and regulatory importance. We find strong evidence that, in sharp contrast to the erstwhile locals in futures pits, electronic market makers reduce their participation and their liquidity provision in periods or significantly high and persistent volatility, in periods of significantly high and persistent customer order imbalances, and in periods of significantly high and persistent bid ask spreads. Our results are consistent with trader anonymity in electronic markets' not being conducive to facile adjustment of severe information asymmetries. We also find that electronic market makers with longer trading horizons are much less susceptible to withdrawing from liquidity provision in periods of market stress. Finally, our results are also fully consistent with the changes we observe in liquidity provision around the 2008 financial crisis. Overall, given that electronic market-makers represent the irreversible and inevitable progression of technology, our results raise the question of whether exchanges and regulators should consider affirmative obligations for hitherto voluntary market makers.

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Table 1 –Sample Description

This table presents characteristics of two data periods. Panel A presents market characteristics for the time-period January to March, 2011 and the trading characteristics of Electronic Market-Makers (*EMMs*). *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. Panel B presents market characteristics for the time-period January to March, 2006 and the trading characteristics of *Locals*. *Locals* are traders who trade more than 25 trades a day and are categorized under CTI (Customer Type Indicator) 1 category. All market variables are calculated as 60 minute moving averages of 1 minute estimations and are volume weighted averages across different maturities. *Returns*, *Volatility*, *Volume* and (Bid-Ask) *Spread* are calculated as done in the literature. *CD Imbalance Ratio* (Customer Demand Imbalance Ratio) is the ratio of the difference between CTI 4 (Customers) Buy and Sell and trading volume.

Panel A: January to March, 2011

	Volatility	*Return*	*Spread*	*CD Imbalance*	*Volume*	*CD Imbalance Ratio*
Mean	0.35%	0.00%	0.01%	1.83	488.45	0.28%
Median	0.24%	0.00%	0.01%	-0.07	343.22	0.22%
Std	0.35%	0.11%	0.07%	75.49	538.12	2.53%
Min	0.00%	-1.50%	-0.98%	-890.25	3.67	-9.28%
P25	0.11%	-0.05%	-0.01%	-18.81	183.35	-1.33%
P75	0.46%	0.05%	0.02%	18.48	604.02	1.84%
Max	3.48%	1.50%	0.88%	2130.06	13388.23	12.84%

Number of Traders	*Number of EMMs*	*EMM Proportion (% Total Traders)*	*EMM Trades (% Total Trades)*	*EMM Volume (% Total Volume)*	*Median EMM Closing Ratio*	*Median Number of EMM Trades(Daily)*
14984	52	0.35%	52.55%	47.46%	0.00%	4372.73

Panel B: January to March, 2006

	Volatility	*Return*	*Spread*	*CD Imbalance*	*Volume*	*CD Imbalance Ratio*
Mean	0.29%	0.00%	0.35%	0.87	256.12	0.16%
Median	0.20%	0.00%	0.25%	0.00	179.84	0.19%
Std	1.51%	0.24%	0.39%	87.85	325.01	6.11%
Min	0.00%	-9.25%	-0.99%	-1928.00	1.00	-52.91%
P25	0.05%	-0.06%	0.10%	-14.38	63.11	-2.58%
P75	0.40%	0.06%	0.47%	15.00	344.30	3.09%
Max	163.64%	16.41%	26.48%	2674.98	6905.14	100.00%

Number of Traders	*Number of Locals*	*Local Proportion (% Total Traders)*	*Local Trades (% Total Trades)*	*Local Volume (% Total Volume)*	*Median Local Closing Ratio*	*Median Number of Local Trades(Daily)*
13622	200	1.47%	44.97%	41.39%	0.00%	59.13

Table 2 – EMMs' Trading Activity by Market Conditions: Univariate Analysis

This table presents univariate analysis of Electronic Market-Makers' (EMMs) trading during periods of market stress- periods when market conditions (Eg: *Volatility* or *CD Imbalance*) are abnormally high (greater than 2 std. deviations) for prolonged period of time. For example, when *Volatility-High* is when 1-min *Volatility* (and/or *CD Imbalance*) over the past 1 hour has been greater than twice its standard deviation over the sample period. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. *Customers* are traders who are classified under the CTI (Customer Type Indicator) 4 categories in the dataset. *EMM -Customer Volume* is the sum of all trades during the minute where *EMMs* traded against *Customers*. *EMM Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity. *EMM -Customer Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity to *Customers.* The analysis is conducted over using data from the time-period January to March, 2011.Two tailed *p-values* are also reported.

	N	Non-EMM Volume / Total Volume	EMM - Customer Volume / Customer Volume	EMM Liquidity Provision Volume / Total Volume	EMM - Customer Liquidity Provision Volume / Customer Volume
Volatility-High	1232	30.92%	51.50%	40.14%	23.99%
Volatility-Otherwise	23010	27.97%	55.83%	44.22%	27.27%
Difference		2.96%	-4.33%	-4.08%	-3.27%
Percentage Difference		10.57%	-7.75%	-9.23%	-12.01%
p-value		*<0.001*	*<0.001*	*<0.001*	*<0.001*
CD Imbalance-High	1366	30.30%	53.51%	43.35%	26.33%
CD Imbalance-Otherwise	22876	27.99%	55.73%	44.05%	27.15%
Difference		2.31%	-2.23%	-0.70%	-0.82%
Percentage Difference		8.27%	-4.00%	-1.59%	-3.01%
p-value		*<0.001*	*<0.001*	*0.05*	*0.018*
(Volatility*CD Imbalance) - High	217	33.88%	49.37%	38.28%	22.53%
(Volatility*CD Imbalance) -Otherwise	24025	28.07%	55.67%	44.07%	27.14%
Difference		5.81%	-6.29%	-5.79%	-4.61%
Percentage Difference		20.71%	-11.30%	-13.14%	-16.99%
p-value		*<0.001*	*<0.001*	*<0.001*	*<0.001*
BidAsk Spreads -High	771	28.57%	54.06%	43.45%	26.89%
BidAsk Spreads - Otherwise	23471	28.10%	55.66%	44.03%	27.11%
Difference		0.46%	-1.60%	-0.58%	-0.22%
Percentage Difference		1.64%	-2.88%	-1.32%	-0.80%
p-value		*0.32*	*0.003*	*0.208*	*0.631*

Table 3 – Locals' Trading Activity by Market Conditions: Univariate Analysis

This table presents univariate analysis of *Locals* trading during periods of market stress- periods when market conditions (Eg: *Volatility* or *CD Imbalance*) are abnormally high (greater than 2 std. deviations) for prolonged period of time. For example, when *Volatility-High* is when 1-min *Volatility* (and/or *CD Imbalance*) over the past 1 hour has been greater than twice its standard deviation over the sample period. *Locals* are traders who trade more than 25 trades a day and are categorized under CTI (Customer Type Indicator) 1 category. *Customers* are traders who are classified under the CTI (Customer Type Indicator) 4 categories in the dataset. *Local -Customer Volume* is the sum of all trades during the minute where *Locals* traded against *Customers*. *Local Liquidity Provision Volume* is the sum of all trades during the minute where *Locals* provided liquidity. *Local - Customer Liquidity Provision Volume* is the sum of all trades during the minute where *Locals* provided liquidity to *Customers.* The analysis is conducted over using data from the time-period January to March, 2011. Two tailed *p-values* are also reported.

	N	Non-Local Volume / Total Volume	Local-Customer Volume / Customer Volume	Local Liquidity Provision Volume / Total Volume	Local - Customer Liquidity Provision Volume / Customer Volume
Volatility-High	315	14.37%	77.73%	53.75%	41.90%
Volatility-Otherwise	21445	24.56%	68.64%	47.23%	36.33%
Difference		-10.19%	9.08%	6.53%	5.57%
Percentage Difference		-41.50%	13.23%	13.82%	15.33%
p-value		*<0.001*	*<0.001*	*<0.001*	*<0.001*
CD Imbalance-High	1256	18.74%	75.21%	50.20%	38.82%
CD Imbalance-Otherwise	20504	24.76%	68.37%	47.14%	36.26%
Difference		-6.02%	6.84%	3.06%	2.56%
Percentage Difference		-24.31%	10.00%	6.49%	7.06%
p-value		*<0.001*	*<0.001*	*<0.001*	*0.001*
(Volatility*CD Imbalance) - High	7	23.66%	66.49%	47.22%	37.95%
(Volatility*CD Imbalance) -Otherwise	21753	24.41%	68.77%	47.32%	36.41%
Difference		-0.75%	-2.29%	-0.10%	1.54%
Percentage Difference		-3.06%	-3.32%	-0.21%	4.24%
p-value		*0.945*	*0.853*	*0.991*	*0.873*
BidAsk Spreads -High	1175	15.69%	77.19%	52.63%	41.32%
BidAsk Spreads - Otherwise	20585	24.91%	68.29%	47.02%	36.13%
Difference		-9.22%	8.91%	5.61%	5.19%
Percentage Difference		-37.02%	13.04%	11.93%	14.36%
p-value		*<0.001*	*<0.001*	*<0.001*	*<0.001*

Table 4 – EMMs' Trading Activity by Market Conditions: Multivariate Analysis

This table presents a (Heckman) 2-stage regression analysis of Electronic Market-Makers' (EMMs) trading during periods of market stress. The first stage models the probability of an *EMM* trading during the minute. The second stage models the direction and magnitude of the *EMM*'s trading, conditional on trading. The analysis is conducted over using data from the time-period January to March, 2011. Periods of market stress are identified as periods when market conditions (Eg: *Volatility* or *CD Imbalance*) are abnormally high (greater than 2 std. deviations) for prolonged period of time. For example *Volatility-High* is a binary variable equal to 1when 1-min *Volatility* (and/or *CD Imbalance*) over the past 1 hour has been greater than twice its standard deviation over the sample period. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. Two tailed *p-values* are also reported.

Parameter	Model 1		Model 2	
	Selection Equation	Delta Inv	Selection Equation	Delta Inv
Intercept	-1.059	-0.094	-1.085	-0.125
	<0.001	*<0.001*	*<0.001*	*<0.001*
Abs Inventory	0.812		0.813	
	<0.001		*<0.001*	
Inventory		-0.226		-0.163
		<0.001		*<0.001*
*Inventory*Abs Inventory High*				-0.136
				<0.001
Trading Revenue Low	0.112	-0.012	0.111	-0.017
	<0.001	*0.191*	*<0.001*	*0.060*
Volatility	-0.034		-0.047	
	<0.001		*<0.001*	
Volatility VolatilityHigh*			0.034	
			<0.001	
Return		-0.002		-0.003
		0.258		*0.038*
*Return*ReturnHigh*				0.006
				0.088
Abs CD Imbalance	-0.097		-0.055	
	<0.001		*<0.001*	
Abs CD Imbalance ACDI_High*			-0.063	
			<0.001	
CD Imbalance		-0.003		-0.005
		0.026		*0.011*
CD Imbalance ACDI_High*				0.007
				0.023
BidAsk Spread	0.012		0.016	
	<0.001		*<0.001*	
BidAsk Spread SpreadHigh*			-0.024	
			<0.001	
Volume	0.056		0.056	
	<0.001		*<0.001*	
Mills Ratio		0.140		0.191
		<0.001		*<0.001*
Chi Sq	*<0.001*		*<0.001*	
R Sq		0.113		0.123
N	1257308	445990	1257308	445990

Table 5 – Locals' Trading Activity by Market Conditions: Multivariate Analysis

This table presents a (Heckman) 2-stage regression analysis of *Locals* trading during periods of market stress. The first stage models the probability of a *Local* trading during the minute. The second stage models the direction and magnitude of the *Local*'s trading, conditional on trading. The analysis is conducted over using data from the time-period January to March, 2006.Periods of market stress are identified as periods when market conditions (Eg: *Volatility* or *CD Imbalance*) are abnormally high (greater than 2 std. deviations) for prolonged period of time. For example, *Volatility-High* is a binary variable equal to 1when 1-min *Volatility* (and/or *CD Imbalance*) over the past 1 hour has been greater than twice its standard deviation over the sample period. *Locals* are traders who trade more than 25 trades a day and are categorized under CTI (Customer Type Indicator) 1 category. Two tailed *p-values* are also reported.

Parameter	Model 1		Model 2	
	Selection Equation	Delta Inv	Selection Equation	Delta Inv
Intercept	-2.626	-0.259	-2.652	-0.280
	<0.001	*<0.001*	*<0.001*	*<0.001*
Abs Inventory	0.546		0.545	
	<0.001		*<0.001*	
Inventory		-0.269		-0.220
		<0.001		*<0.001*
*Inventory*Abs Inventory High*				-0.069
				<0.001
Trading Revenue Low	0.130	0.020	0.126	0.016
	<0.001	*0.451*	*<0.001*	*0.536*
Volatility	-0.046		0.047	
	<0.001		*0.002*	
Volatility VolatilityHigh*			-0.081	
			<0.001	
Return		-0.013		-0.019
		<0.001		*0.002*
*Return*ReturnHigh*				0.021
				0.003
Abs CD Imbalance	0.049		0.115	
	<0.001		*<0.001*	
Abs CD Imbalance ACDI_High*			-0.078	
			<0.001	
CD Imbalance		-0.011		-0.009
		<0.001		*0.050*
CD Imbalance ACDI_High*				-0.004
				0.488
BidAsk Spread	0.130		0.072	
	<0.001		*<0.001*	
BidAsk Spread SpreadHigh*			0.008	
			0.280	
Volume	0.448		0.436	
	<0.001		*<0.001*	
Mills Ratio		0.271		0.296
		<0.001		*<0.001*
Chi Sq	*<0.001*		*<0.001*	
R Sq		0.132		0.134
N	1088000	116071	1088000	116071

Table 6 – EMMs' Trading Activity by Market Conditions (1 minute): Multivariate Analysis

This table presents a (Heckman) 2-stage regression analysis of Electronic Market-Makers' (EMMs) trading during periods of market stress. The first stage models the probability of an *EMM* trading during the minute. The second stage models the direction and magnitude of the *EMM*'s trading, conditional on trading. The analysis is conducted over using data from the time-period January to March, 2011. Periods of market stress are identified as periods when market conditions (Eg: *Volatility* or *CD Imbalance*) are abnormally high (greater than 2 std. deviations) over the previous minute. For example, *Volatility-High-1min* is a binary variable equal to 1when 1-min *Volatility* (and/or *CD Imbalance*) over the past 1 minute has been greater than twice its standard deviation over the sample period. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. Two tailed *p-values* are also reported.

Parameter	Model 1		Model 2	
	Selection Equation	Delta Inv	Selection Equation	Delta Inv
Intercept	-1.166	-0.083	-1.238	-0.117
	<0.001	*<0.001*	*<0.001*	*<0.001*
Abs Inventory	0.809		0.809	
	<0.001		*<0.001*	
Inventory		-0.226		-0.163
		<0.001		*<0.001*
*Inventory*Abs Inventory High*				-0.135
				<0.001
Trading Revenue Low	0.100	-0.013	0.099	-0.018
	<0.001	*0.159*	*<0.001*	*0.044*
Volatility_1min	-0.037		-0.043	
	<0.001		*<0.001*	
*Volatility_1min * VolatilityHigh_1min*			0.022	
		]	*<0.001*	
Return_1min		-0.003		-0.006
		0.049		*0.038*
*Return_1min *ReturnHigh_1min*				0.009
				0.088
Abs CD Imbalance_1min	0.075		0.286	
	<0.001		*<0.001*	
*Abs CD Imbalance_1min * ACDI_High_1min*			-0.242	
			<0.001	
CD Imbalance_1min		-0.021		-0.070
		<.0001		*0.011*
*CD Imbalance_1min * ACDI_High _1min*				0.066
				0.023
BidAsk Spread_1min	0.004		0.024	
	0.028		*<0.001*	
*BidAsk Spread_1min * SpreadHigh_1min*			-0.059	
			<0.001	
Volume_1min	0.139		0.125	
	<0.001		*<0.001*	
Mills Ratio		0.123		0.176
		<0.001		*<0.001*
Chi Sq	*<0.001*		*<0.001*	
R Sq		0.114		0.126
N	1257360	446007	1257360	446007

Table 7 – Longer-Term HFTs' Trading Activity by Market Conditions (1 minute): Multivariate Analysis

This table presents a (Heckman) 2-stage regression analysis of the trading of Electronic Market-Makers (EMMs) with slower rates (lowest quartile) of mean-reversion in inventories during periods of market stress. The first stage models the probability of an *EMM* trading during the minute. The second stage models the direction and magnitude of the *EMM*'s trading, conditional on trading. The analysis is conducted over using data from the time-period January to March, 2011. Periods of market stress are identified as periods when market conditions (Eg: *Volatility* or *CD Imbalance*) are abnormally high (greater than 2 std. deviations) for prolonged period of time. For example *Volatility-High* is a binary variable equal to 1when 1-min *Volatility* (and/or *CD Imbalance*) over the past 1 hour has been greater than twice its standard deviation over the sample period. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. Two tailed *p-values* are also reported.

Parameter	Model 1		Model 2	
	Selection Equation	Delta Inv	Selection Equation	Delta Inv
Intercept	-1.763	0.009	-1.812	0.008
	<0.001	*0.002*	*<0.001*	*<0.001*
Abs Inventory	1.298		1.299	
	<0.001		*<0.001*	
Inventory		-0.003		0.000
		<0.001		*0.5775*
*Inventory*Abs Inventory High*				-0.018
				<0.001
Trading Revenue Low	0.150	0.001	0.150	0.001
	<0.001	*0.226*	*<0.001*	*0.152*
Volatility_1min	0.021		0.022	
	<0.001		*<0.001*	
*Volatility_1min * VolatilityHigh_1min*			0.009	
			0.342	
Return_1min		0.000		0.000
		0.294		*0.289*
*Return_1min *ReturnHigh_1min*				0.000
				0.556
Abs CD Imbalance_1min	0.054		0.202	
	<0.001		*<0.001*	
*Abs CD Imbalance_1min * ACDI_High_1min*			-0.167	
			<0.001	
CD Imbalance_1min		-0.002		-0.004
		<.0001		*0.011*
*CD Imbalance_1min * ACDI_High _1min*				0.003
				0.023
BidAsk Spread_1min	0.001		0.019	
	0.028		*<0.001*	
*BidAsk Spread_1min * SpreadHigh_1min*			-0.055	
			<0.001	
Volume_1min	0.100		0.089	
	<0.001		*<0.001*	
Mills Ratio		-0.014		-0.013
		0.001		*<0.001*
Chi Sq	*<0.001*		*<0.001*	
R Sq		0.031		0.012
N	314340	86099	314340	86099

Table 8A – EMMs' Liquidity Provision by Market Conditions: Multivariate Analysis

This table presents multivariate analysis of Electronic Market-Makers' (EMMs) liquidity provision. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. *Customers* are traders who are classified under the CTI (Customer Type Indicator) 4 categories in the dataset. *EMM -Customer Volume* is the sum of all trades during the minute where *EMMs* traded against *Customers*. *EMM Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity. *EMM -Customer Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity to *Customers.* The analysis is conducted over using data from the time-period January to March, 2011.Two tailed *p-values* are also reported.

Parameter	EMM Liquidity Provision Volume / Total Volume		EMM-Customer Volume / Total Customer Volume		EMM - Customer Liquidity Provision Volume /Total Customer Volume	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-0.092	-0.095	-0.102	-0.107	-0.080	-0.083
	<0.001	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Abs Inventory	0.152	0.152	0.168	0.168	0.133	0.133
	<0.001	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
*Abs Inventory*Diff Sign*	-0.006	-0.006	0.000	0.000	-0.004	-0.004
	0.014	*0.014*	*0.876*	*0.876*	*0.088*	*0.087*
Volatility	-0.007	-0.005	-0.012	-0.012	-0.006	-0.006
	<0.001	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Volatility VolatilityHigh*		-0.004		-0.001		-0.002
		0.024		*0.4402*		*0.3932*
Abs CD Imbalance	-0.006	0.002	-0.008	0.000	-0.006	0.000
	<0.001	*0.308*	*<0.001*	*0.9511*	*<0.001*	*0.8708*
*Abs CD Imbalance * ACDI_High*		-0.011		-0.013		-0.010
		<0.001		*<.0001*		*<0.001*
BidAsk Spread	0.003	0.003	0.000	0.000	0.003	0.002
	<0.001	*0.008*	*0.890*	*0.677*	*<0.001*	*0.168*
BidAsk Spread SpreadHigh*		0.000		0.001		0.003
		0.867		*0.7025*		*0.1177*
R Sq	0.011	0.011	0.014	0.014	0.009	0.009
N	1254084	1254084	1254084	1254084	1254084	1254084

Table 8B – Locals' Liquidity Provision by Market Conditions: Multivariate Analysis

This table presents multivariate analysis of *Locals*' liquidity provision. *Locals* are traders who trade more than 25 trades a day and are categorized under CTI (Customer Type Indicator) 1 category. *Customers* are traders who are classified under the CTI (Customer Type Indicator) 4 categories in the dataset. *Local -Customer Volume* is the sum of all trades during the minute where *Locals* traded against *Customers*. *Local Liquidity Provision Volume* is the sum of all trades during the minute where *Locals* provided liquidity. *Local - Customer Liquidity Provision Volume* is the sum of all trades during the minute where *Locals* provided liquidity to *Customers.* The analysis is conducted over using data from the time-period January to March, 2006.Two tailed *p-values* are also reported.

Parameter	Local Liquidity Provision Volume / Total Volume		Local - Customer Volume / Total Customer Volume		Local - Customer Liquidity Provision Volume /Total Customer Volume	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-0.073	-0.070	-0.047	-0.045	-0.058	-0.055
	<0.001	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Abs Inventory	0.105	0.105	0.072	0.072	0.084	0.084
	<0.001	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
*Abs Inventory*Diff Sign*	0.002	0.001	-0.004	-0.004	0.001	0.001
	0.517	*0.598*	*0.219*	*0.197*	*0.632*	*0.692*
Volatility	-0.001	0.033	-0.001	0.019	-0.001	0.026
	0.754	*<0.001*	*0.715*	*<0.001*	*0.691*	*<0.001*
Volatility VolatilityHigh*		-0.026		-0.016		-0.022
		<0.001		*<0.001*		*<0.001*
Abs CD Imbalance	0.014	0.023	0.007	0.009	0.010	0.014
	<0.001	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
*Abs CD Imbalance * ACDI_High*		-0.017		-0.006		-0.009
		<0.001		*0.010*		*<0.001*
BidAsk Spread	0.030	0.020	0.018	0.011	0.020	0.010
	<0.001	*<0.001*	*<0.001*	*0.002*	*<0.001*	*0.003*
BidAsk Spread SpreadHigh*		-0.027		-0.012		-0.015
		<0.001		*<0.001*		*<0.001*
R Sq	0.091	0.095	0.038	0.039	0.056	0.057
N	1061800	1061800	1049000	1049000	1049000	1049000

Table 9 – EMMs' Trading Activity During the 2008 Crisis: Univariate Analysis

This table presents univariate analysis of Electronic Market-Makers' (EMMs) trading during the financial crisis of 2008. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. *Customers* are traders who are classified under the CTI (Customer Type Indicator) 4 categories in the dataset. *EMM -Customer Volume* is the sum of all trades during the minute where *EMMs* traded against *Customers*. *EMM Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity. *EMM - Customer Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity to *Customers.* The analysis is conducted over using data from the time-period April to December, 2008.Two tailed *p-values* are also reported.

	N	Non-EMM Volume / Total Volume	EMM - Customer Volume / Customer Volume	EMM Liquidity Provision Volume / Total Volume	EMM - Customer Liquidity Provision Volume / Customer Volume
Crisis Period 1: Sept,15 to Oct, 14	22	43.30%	43.78%	35.14%	22.71%
Pre-Lehman	91	42.84%	44.27%	35.23%	22.43%
Difference		0.47%	-0.49%	-0.09%	0.27%
Percentage Difference		1.09%	-1.11%	-0.27%	1.22%
p-value		*0.32*	*0.592*	*0.884*	*0.519*
Crisis Period 2: Oct,14 to Nov, 30	32	55.16%	34.08%	26.54%	17.52%
Pre-Lehman	91	42.84%	44.27%	35.23%	22.43%
Difference		12.32%	-10.19%	-8.69%	-4.91%
Percentage Difference		28.77%	-23.01%	-24.68%	-21.88%
p-value		*<0.001*	*<0.001*	*<0.001*	*<0.001*
Crisis Period 3: Dec 1 to Dec, 31	22	64.32%	26.46%	20.66%	13.82%
Pre-Lehman	91	42.84%	44.27%	35.23%	22.43%
Difference		21.48%	-17.81%	-14.58%	-8.61%
Percentage Difference		50.14%	-40.23%	-41.37%	-38.40%
p-value		*<0.001*	*<0.001*	*<0.001*	*<0.001*

Table 10 – EMMs' Trading Activity during the 2008 Crisis: Multivariate Analysis

This table presents a 2-stage regression analysis of Electronic Market-Makers' (EMMs) trading the financial crisis of 2008. We use the three exogenous shocks – proxied by variables *Crisis Period 1*, *Crisis Period 2* and *Crisis Period 3* - to the Crude Oil market to further examine the relation b/w EMMs' liquidity provision and market variables of interest. *Crisis Period 1* is a binary variable equal to 1between September 15 (Lehman Bankruptcy) and October 14,2008. *Crisis Period 2* is a binary variable equal to 1between October 15 (Retail Sales hit 3-year low and Bernanke says recovery will be slow) and November 30, 2008. *Crisis Period 3* is a binary variable equal to 1 between December 1 (NBER Report Confirms Recession and US Manufacturing hits 26-year low) and December 31,2008. In the first stage we extract the components of market variables that are exogenous to EMM trading – the predicted components from the regression. In the second stage we regress different measures of EMM liquidity provision on the hence extracted exogenous components of market variables. The analysis is conducted over using data from the time-period April to December, 2008. *EMMs* are traders who trade more than 2000 trades a day and carry less than 5% of their daily trading volume overnight. *Customers* are traders who are classified under the CTI (Customer Type Indicator) 4 categories in the dataset. *EMM -Customer Volume* is the sum of all trades during the minute where *EMMs* traded against *Customers*. *EMM Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity. *EMM -Customer Liquidity Provision Volume* is the sum of all trades during the minute where *EMMs* provided liquidity to *Customers.* Two tailed *p-values* are also reported.

	First Stage Regression		
Independent\Dependent Variables	*Volatility*	*CD Imbalance*	*BidAsk Spreads*
Intercept	-0.116	0.000	-0.133
	<0.001	*0.978*	*<0.001*
Crisis Period 1	0.178	-0.008	0.170
	<0.001	*0.478*	*<0.001*
Crisis Period 2	0.236	-0.001	0.287
	<0.001	*0.900*	*<0.001*
Crisis Period 3	0.383	0.009	0.442
	<0.001	*0.445*	*<0.001*
Lag Volatility	0.149		
	<0.001		
Lag CD Imbalance		0.0646	
		<.0.001	
Lag BidAsk Spreads			0.1165
			<0.001
N	66852	66852	66852
R-Square	0.049	0.0042	0.0474

Second Stage Regressions				
Independent\Dependent Variables	Non-EMM Volume / Total Volume	EMM -Customer Volume / Customer Volume	EMM-Liquidity Provision Volume / Total Volume	EMM -Customer Liquidity Provision Volume / Customer Volume
Intercept	0.480	0.400	0.317	0.205
	<0.001	*<0.001*	*<0.001*	*<0.001*
Volatility(Predicted)	0.070	-0.062	-0.047	-0.029
	0.098	*0.076*	*0.104*	*0.091*
CD Imbalance(Predicted)	0.104	-0.238	-0.070	-0.116
	<0.001	*<0.001*	*<0.001*	*<0.001*
BidAsk Spreads (Predicted)	0.292	-0.110	-0.199	-0.062
	<0.001	*<0.001*	*<0.001*	*<0.001*
N	66852	66852	66852	66852
R-Square	0.202	0.149	0.176	0.093