# High Frequency Trading Literature Review
## October 2011

This brief literature review presents a summary of recent empirical studies related to automated or "high frequency trading" (HFT) and its impact on various markets. Each study takes a unique approach, yet all paint a consistent picture of markets being improved by competition and automation.

| Author(s) / Title | Dataset | Findings |
| --- | --- | --- |
| Angel, Harris, Spatt<br><br>"Equity trading in the 21st century", February 2010 | U.S. equities, 1993 – 2009 | Trading costs have declined, bid-ask spreads have narrowed and available liquidity has increased |
| RGM Advisors<br><br>"Market Efficiency and Microstructure Evolution in US Equity Markets:  A High Frequency Perspective", October 2010 | U.S. equities, 2006-2010 | Bid-ask spreads have narrowed, available liquidity has increased and price efficiency has improved |
| Credit Suisse<br><br>"Sizing Up US Equity Microstructure", April 2010 | U.S. equities, 2003-2010 | Bid-ask spreads have narrowed, available liquidity has increased and short-term volatility (normalized by longer term volatility) has declined |
| Hasbrouck, Saar<br><br>"Low-Latency Trading", May 2011 | U.S. equities, full NASDAQ order book<br><br>June 2007 and October 2008 | Low latency automated trading was associated with lower quoted and effective spreads, lower volatility and greater liquidity |
| Hendershott, Riordan<br><br>"Algorithmic Trading and Information", August 2009 | Automated vs. other trades.<br><br>Deutsche Börse equities, January 2008 | Automated trades made prices more efficient and did not contribute to higher volatility |
| Chaboud, Hjalmarsson, Vega and Chiquoine<br><br>"Rise of the Machines: Algorithmic Trading in the Foreign Exchange Market", October 2009 | Automated vs. other trades.<br><br>EBS forex market, 2006-2007 | Automated trades increased liquidity and may have lowered volatility |

| Author(s) / Title | Dataset | Findings |
|---|---|---|
| Markets Committee, Bank for International Settlements (BIS)<br><br>"High-frequency trading in the foreign exchange market", September 2011 | Various FX venues, notably Reuters and EBS, and various dates, notably May 6, 2010 and March 17, 2011 | HFT is found to be beneficial during normal market periods, with similar behavior to traditional market participants during high volatility periods |
| Brogaard<br><br>"High frequency trading and its impact on market quality", August 2010 | HFT vs. other trades. U.S. equities on NASDAQ, various periods in 2008 – 2010 | HFT helped to narrow bid-ask spreads, improved price discovery and may have reduced volatility |
| Brogaard<br><br>"High Frequency Trading and Volatility", October 2011 | HFT vs. other trades. U.S. equities on NASDAQ, various periods in 2008 – 2010 | HFT activity tends to decrease idiosyncratic and intraday volatility. |
| Hendershott, Riordan<br><br>"High Frequency Trading and Price Discovery" (working paper) | HFT vs. other trades. U.S. equities on NASDAQ, various periods in 2008 – 2010 | HFT trades were positively correlated with permanent price changes and negatively correlated with transitory price changes, suggesting that HFT improves price discovery |
| Jarnecic, Snape<br><br>"An analysis of trades by high frequency participants on the London Stock Exchange", June 2010 | HFT vs. other trades.<br><br>LSE equities, April – June, 2009 | HFT improved liquidity and was unlikely to have increased volatility |
| CME Group<br><br>"Algorithmic trading and market dynamics", July 2010 | Automated vs. other trades.<br><br>CME futures, May 2008 – May 2010 | Automated trading was associated with improved liquidity and reduced volatility |
| Menkveld<br><br>"High Frequency Trading and the New-Market Makers", April 2011 | Dutch equities traded on Chi-X and Euronext, 2007 | A single high frequency trader played an important role in the development of a competitive market center, resulting in better liquidity and lower trading costs |
| Lepone<br><br>"The Impact of High Frequency Trading (HFT): International Evidence", September 2011 | HFT vs. other trades. Singapore Exchange (SGX), Australia Securities Exchange (ASX), NASDAQ and London Stock Exchange | HFT has become a major provider of liquidity, particularly during periods of market uncertainty |

| Author(s) / Title | Dataset | Findings |
|---|---|---|
| Hendershott, Jones, Menkveld<br><br>"Does Algorithmic Trading Improve Liquidity?", February 2011 | Automated quoting facility, NYSE equities, 2003 | Automated trading narrowed bid-ask spreads, lowered trading costs, and improved price efficiency |
| Riordan, Storkenmairm<br><br>"Latency, Liquidity and Price Discovery", 2009 | Xetra high-speed trading system, Deutsche Börse, 2007 | Higher system speeds led to increased liquidity and improved price discovery |
| Hendershott, Moulton<br><br>"Automation, Speed and Stock Market Quality: The NYSE's Hybrid", February 2010 | NYSE TAQ database plus others, June 1, 2006 - May 31, 2007 | Introduction of automation via the NYSE hybrid system improved price discovery and made prices more efficient |
| Gomber, Arndt, Lutat, Uhle<br><br>"High-Frequency Trading", March 2011 | Various | Survey paper that highlights beneficial aspects of HFT, while noting that perceived problems are largely a result of U.S. market structure |

*This following studies measured improvements in overall market quality:*

**Angel, Harris and Spatt (February 2010)** examined many measures of market quality and how they have changed over time and in response to regulatory and structural changes in the U.S. equity markets.[1]  Drawing from a diverse set of data sources, they show that there has been significant improvement in virtually all aspects of market quality. They state "execution speeds have fallen, which greatly facilitates monitoring execution quality by retail investors. Retail commissions have fallen substantially and continue to fall. Bid-ask spreads have fallen substantially and remain low, although they spiked upward during the financial crisis as volatility increased. Market depth has marched steadily upward. Studies of institutional transactions costs continue to find U.S. costs among the lowest in the world."

**RGM Advisors, LLC (October 2010)** studied recent data from the U.S. equity markets.[2]  The authors examined trends in a number of U.S. equity market quality metrics over the period from January 2006 through June 2010 and how these metrics differed by market capitalization and by listing venue.  They presented data that confirmed that over this period quoted bid-ask spreads declined, quoted market depth increased and short-term measures of market efficiency significantly improved.

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[1]  Angel, J., Harris, L. and Spatt, C., "Equity trading in the 21st century", http://papers.ssrn.com/so13/papers.cfm?abstract_id=1584026

[2] Castura, J., Litzenberger, R., Gorelick, R., and Dwivedi, Y., 2010:  "Market Efficiency and Microstructure Evolution in US Equity Markets:  A High Frequency Perspective", http://www.rgmadvisors.com/docs/MarketEfficiencyStudyOct2010.pdf

**Credit Suisse (April 2010)** released a report on related topics and showed that in recent years, bid-ask spreads declined, depth at the inside quote increased and intra-day volatility normalized by longer-term volatility declined substantially.[3]  The authors concluded on this last point that "[t]his seems to be confirmation that the new market participants are successfully finding and removing mispricings, as well as dampening volatility that might otherwise be created by large institutional orders filled during the day."

**Hasbrouck and Saar (October 2010)** explored the nature and impact of low-latency (algorithmic) trading on the NASDAQ exchange during June 2007, a 'nominal' market period, and October 2008, a volatile, uncertain period.[4]  They identified periods of high market activity due to algorithms and relate these to longer-term market quality metrics such as spread, effective spread and depth of liquidity.  They observe in both periods "that higher low-latency activity implies lower posted and effective spreads, greater depth, and lower short-term volatility."


***The following studies examined market data sets that distinguished between automated trades and other trades:***

**Hendershott and Riordan (August 2009)** reported on the impact of automated trading on the Deutsche Börse's Xetra market, an equity market where automated trading activity could be distinguished.[5]  The paper found that automated trading accounted for about half of the total volume in the top 30 volume stocks, and that automated trading was better than non-automated trading at driving prices toward efficiency. The authors also showed that automated trading "contributes more to the discovery of the efficient price than human trading." Furthermore, they find there is "no evidence of [automated trading] behavior that would contribute to volatility beyond making prices more efficient."

Similarly, in the foreign exchange market, **Chaboud, Hjalmarsson, Vega and Chiquoine (October 2009)** used a dataset that separately identified computer generated trades from human generated trades and showed that an increase in automated trading may be associated with less market volatility, and that automated traders tend to increase liquidity provision after exogenous market events such as macroeconomic data announcements.[6]

**The Bank for International Settlements (September 2011)** released a related study on the impact that growing HFT participation has had on the foreign exchange market.[7]  The authors based their findings on observations made from several banks and other foreign exchange

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[3]    Credit    Suisse,    2010:    "Sizing    Up    US    Equity    Microstructure", https://tradeview.csfb.com/edge/Public/Bulletin/Servefile.aspx?FileID=14377&m=1337434953

[4]    Hasbrouck,    J.    and    Saar,    G,    "Low-Latency    Trading", http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1695460

[5]    Hendershott,    T.    and    Riordan,    R.,    2009:    "Algorithmic    Trading    and    Information", http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1472050## ("Hendershott and Riordan (2009)")

[6] Chaboud, Alain, Hjalmarsson, Erik, Vega, Clara and Chiquoine, Ben, "Rise of the Machines: Algorithmic Trading in the Foreign Exchange Market" (October 2009). Federal Reserve Board International Finance Discussion Paper No. 980, http://ssrn.com/abstract=1501135 ("Chaboud, Hjalmarsson, Vega and Chiquoine (2009)")

[7] Bank for International Settlements, "High-frequency trading in the foreign exchange market" (September, 2011), http://www.bis.org/publ/mktc05.pdf .

markets, in addition to using historical data from Reuters and EBS, two of the largest FX trading platforms. They cited a general consensus that HFT benefits the markets under normal conditions, and therefore focused on two significant FX shocks: May 6, 2010 and March 17, 2011. In both cases, they found evidence suggesting that HFT did not withdraw from trading during the shocks, and that they may have been quicker to resume normal trading as the shocks stabilized than traditional market participants.

**Brogaard (August 2010)** investigated the impact of "high frequency trading" or "HFT" on US equity trading on the NASDAQ exchange.[8] Using a data set provided by the exchange that labeled all activity as either 'HFT' or 'everything else', Brogaard examined the exact impact that HFT participants have on the market. His analysis used a well-known regression framework to isolate various factors in the market and how HFT impacts each of these. In particular, he shows that HFT activity contributes more to price discovery than other activity, that HFT quotes are at the best bid or best ask price about 50% of the time, that HFT reduces price impact (an important component of trading costs) for other participants, and that HFT activity reduces volatility.

**Brogaard (October 2011)** used the same data set to investigate the impact of HFT on volatility.[9] He performed a series of measurements in an attempt to determine the causal nature of the relationship between HFT activity and volatility. He found evidence that HFT liquidity provision increases during times of short-term volatility, but decreases during periods of long-term volatility. Using the 2008 short-sale ban as an exogenous control variable of HFT activity levels, Brogaard found that restrictions that reduced HFT participation lead to higher volatility.

**Hendershott and Riordan (2011)** examined the impact of HFT on the price discovery process using the same dataset used in Brogaard (2010).[10] Overall they found that HFT trades are positively correlated with permanent price changes, thereby aiding price discovery, and are negatively correlated with temporary pricing errors, thereby improving the price discovery process. By distinguishing trades initiated by an HFT, the authors found that marketable high frequency trades actively drive prices towards fair value.

A similar study done by **Jarnecic and Snape (June 2010)** used data provided by the London Stock Exchange (LSE).[11] Like the NASDAQ data set, this set labeled all activity by participant type; HFT, investment bank, retail, etc., providing a finer granularity of participation rates and behaviors. The authors used a similar regression framework as Brogaard in order to isolate the impact of HFT on various market metrics. They found that HFT participants tend to provide liquidity when spreads are wide, demand liquidity when spreads are narrow, that they are more likely to "smooth out liquidity over time and are unlikely to exacerbate stock price volatility".

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[8] Brogaard, J., "High frequency trading and its impact on market quality", www.futuresindustry.org/ptg/downloads/HFT_Trading.pdf

[9] Brogaard, J., "High frequency trading and volatility", http://papers.ssrn.com/so13/papers.cfm?abstract_id=1641387

[10] Hendershott, T. and Riordan, R., 2011: "High Frequency Trading and Price Discovery", working paper

[11] Jarnecic, E. and Snape, M., "An analysis of trades by high frequency participants on the London Stock Exchange", http://mfs.rutgers.edu/MFC/MFC17/MS/MC10~447_Snape_Jarnecic.pdf

**The CME Group (July 2010)** released a report on automated trading activity on the CME futures exchange.[12]  They labeled all participants as either "ATS" (automated trading system) or "non-ATS." They compared trade volume and messaging rates for each participant against market measures such as liquidity and volatility.  ATS's impact on these measures varies by futures contract, but as a whole, they concluded that ATS-based "volume and message traffic tend to be associated with enhanced liquidity and reduced volatility".

**Menkveld (April 2011)** studied the development of the Chi-X European stock MTF in 2007 and the simultaneous entry of a large high frequency trading participant on Chi-X.[13]  He found that this new participant was largely responsible for the increase in market share of Chi-X and ultimately led to reduced spreads for the stocks that it traded.

**Lepone (2011)** summarized the results of a series of research conducted by the Australian organization Capital Markets Cooperative Research Centre (CMCRC).[14]   These papers examined the impact of HFT on market quality for exchanges based in Singapore, Australia, the U.S., and the United Kingdom.   Their data allowed them to identify trading participants and classify them into HFT and non-HFT groups.   Following a methodology similar to Brogaard (2010), each of these papers measured the impact of HFT on market quality metrics. The findings showed a consistent pattern of improved market quality coinciding with growing HFT participation.  They also demonstrated that HFT is active during all volatility conditions and "become the primary providers of liquidity" in periods of high uncertainty.

*These event studies investigated the impact of improvements to a market center's trading technology:*

**Hendershott, Jones and Menkveld (2007)** examined the impact on the NYSE of their auto-quoting facility introduced in 2003.[15]  This study showed that for all stocks, and particularly large-cap stocks, automated trading increased liquidity.  It also demonstrated that the increase in automated trading caused a reduction in effective spreads, thereby reducing costs to investors.

**Similarly, Riordan and Storkenmairm (2009)** reported on how a 2007 upgrade to the Deutsche Börse's Xetra trading system focused solely on latency reduction, positively affected market quality.[16]   After latency reductions in the exchange's trading systems, liquidity increased across market capitalization and trade sizes, and adverse selection and permanent price impact were dramatically reduced.

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[12]    The    CME    Group,    "Algorithmic    trading    and    market    dynamics", http://www.cmegroup.com/education/files/Algo_and_HFT_Trading_0610.pdf

[13] Menkveld, A., 2011: "High Frequency Trading and the New-Market Makers", available from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1722924

[14] Lepone, A., 2011: "The Impact of High Frequency Trading (HFT): International Evidence",  available from the CMCRC: http://www.cmcrc.com

[15] Hendershott, T., Jones, C.M. and Menkveld, A.J.,: "Does Algorithmic Trading Improve Liquidity?", Journal of Finance, Volume LXVI, No. 1, February 2011

[16] Riordan,  R.  and  Storkenmairm,  A.,  2009:  "Latency,  Liquidity  and  Price  Discovery", http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1247482

**Hendershott and Moulton (February 2010)** studied the introduction of the NYSE hybrid system in 2006, which moved the NYSE to a faster and more automated matching system. [17] They found that prices became more efficient due to faster price discovery and reduced noise in prices.

*This paper provides an overview of "high frequency trading" and related market structure issues:*

**Gomber et al (March 2011)** presented background information on HFT. Their paper analyzed HFT and "certain proposed regulatory measures.[18] They claimed that HFT is a technology rather than a strategy, and is a natural evolution in the market place. They highlighted the beneficial aspects that HFT can provide, and noted that perceived problems with HFT are largely a result of U.S. market structure rather than anything inherent in HFT itself. They provided several recommendations for policy makers that would maintain the beneficial aspects of HFT while providing markets with additional safety.

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[17] Hendershott, T. and Moulton, P., February 2010: "Automation, Speed, and Stock Market Quality: The NYSE's Hybrid", http://www.hotelschool.cornell.edu/research/facultybios/research-papers/documents/AutomationSpeedHybrid_accepted.pdf

[18] Gomber, P., Arndt, B., Lutat, M., and Uhle, T., March 2011: "High-Frequency Trading", http://www.frankfurt-main-finance.com/en/data-facts/study/High-Frequency-Trading.pdf