



# High frequency trading, information, and profits

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# **High frequency trading, information, and profits**

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# Abstract

In this paper I outline the different types of short term information used by high frequency traders (HFTs) and discuss the various sources of their profits. First, the different sources of information that drive HFTs' activity are described. Next, this paper analyzes the possible ways in which HFTs earn returns. Finally, the paper discusses implications of these results and potential changes in market structure that may occur over the next ten years.

## Introduction

The aim of this paper is to clearly identify and describe prominent types of information utilized by high frequency traders (HFTs) and the ways they earn their profits. High frequency trading (HFT) has risen over the past decade from non-existence to having a dominant presence in many electronic asset markets. The literature on HFT has yet to focus on the type of information that drives HFTs' trading and how they use it to earn profits. While HFTs may not readily share their historical profitability records or the details of their trading strategies, much of the information they use and the source of their trading profits follow from existing academic literature.

There are three parts to this paper's analysis. First, it outlines the different sources of information that drive HFTs' activities. Where HFTs get their information is important in understanding how other market participants may benefit or be harmed by the introduction of fast algorithmic trading systems. Second, it discusses the possible sources of HFTs' profits. The profits of HFT need to be put in context to determine whether they are extracting rents or whether they are being compensated for socially valuable services. Finally, the paper discusses how HFTs' role, profitability, and activities may evolve in the future.

There are a variety of types of information that can be useful to HFTs and that likely influence their trading activity. Among these are order book dynamics, trade dynamics, past stock returns, cross stock correlations, cross asset correlations, and cross exchange information delays. Other types of information that may be illegitimately obtained or created could come from front running, quote stuffing, or layering.

While there are a variety of information avenues available to HFTs, the underlying profitability can be categorized into a limited number of groups. These include market making, collecting liquidity rebates, detecting statistical patterns, upholding the law of one price, and manipulating markets.

The final part of the paper examines the future of HFT. The ten year horizon is very uncertain for HFT. There is already a sense that the profitability of HFT is reaching its limit (The Maturation of High-Frequency Trading, 2011). By design there is some upper bound on how much market activity can be by HFTs before they are simply trading amongst themselves. In addition, as markets continue to mature there will be pressure on the information HFTs can utilize. Finally, changing regulation may limit HFT outright or reduce its profitability.

HFT can play an important role in financial markets by collecting legitimate information and incorporating it into asset prices. However, the value gained from the speed of this process is not well understood. In addition, the potential for market manipulation is present and needs to be monitored. The future of HFTs' role in processing information will depend to a large extent on

how markets and regulations evolve. As the tools to utilize high frequency information become more readily available, competition will likely increase and profits decrease. New regulation could also deter HFTs from utilizing short term information or could increase competition and reduce profits.

The rest of this paper is as follows. Section 2 discusses the different types of information HFTs use. Section 3 discusses the different ways HFTs can earn profits. Section 4 speculates about what may come to fruition over the next ten years regarding HFT, information, and profitability. Section 5 concludes.

# Information

## Overview of the role and type of information in HFT activity

Information drives HFT activity. If HFTs simply bought and sold randomly, then they would almost certainly lose money due to transaction costs. While the precise information that each HFT strategy trades on is proprietary and beyond the scope of this analysis, there are only a limited number of information sources that change quickly enough to impact HFTs' trading activities. This information comes from the supply and demand for assets as displayed through the order book, past trading activity, and cross asset relationships.

The information subcategories include order book dynamics, trade dynamics, past stock returns, cross stock correlations, cross asset correlations, and cross exchange information delays. Other types of information that may be illegitimately obtained or created could result from front running, quote stuffing, or layering.

## Order book dynamics

The order book contains information about the supply and demand of an asset by listing those who want to buy and sell it. It has been shown to contain important predictive information (Cao, Hansch, & Wang, 2009; Parlour, 1998). For instance, a larger number of bids than offers can suggest that stock prices will rise in the near future. Beyond the number of orders on each side of the book, the proximity of those orders to the best bid and offer can be informative. In addition, the size of the orders as well as the sequence of orders, the cancellation of orders, time the order is active, time before the order is crossed and whether orders are displayed or hidden may be used to detect the buy and sell interests of traders.

Why is the order book informative for future stock prices? Theoretically this is hard to explain as a trader who is placing the orders would like the efficient price. If she enters orders in a predictable fashion, then others, such as HFTs, can utilize this information to reduce risk and increase returns. Three explanations are consistent with why a trader may enter orders in a systematic fashion that leads to predictable stock price movements. First, she may not be aware that she is providing a market signal and that such information can be used to systematically earn profits. Alternatively, the cost of randomizing order submissions for the trader may be larger than the benefits of doing so. For instance, many investment banks offer order submission software to optimize execution. Such services come at a sizeable cost and may not be worthwhile for small and medium sized institutions, much less individuals. Finally, there are theoretical models that, in equilibrium, can produce systematic patterns in trading prices endogenously (Parlour, 1998).

### Trade dynamics

Trades, like quotes, can contain information about the short term direction of stock prices. The number of orders per trade execution in US equities markets has rapidly grown so that there frequently are as many as 90 orders per trade (Schapiro, 2010). In addition, there is a great deal of price discovery that occurs in the order book compared to trade prints (Chng, 2005). Nonetheless, there is still information in trades (Easley, Kiefer, & O'Hara, 1997). Whether past trades were initiated more so by buyers than sellers can provide information about where future prices will head (Chordia & Subrahmanyam, 2004). In addition, the size of past trades, the time between trades, which exchange those trades occurred on, the trades' time of day, and the number of trades in a given period can provide predictive information regarding asset prices. As with the order book, trade dynamics leave a trail of information that allows for predictable future price movements, and the same possible explanations given in previous section apply here.

How a trade is entered also has implications for future stock price movements. There are, among others, limit orders, market orders, and stop limit orders. While not directly observable in most exchange data feeds, the order type can be determined to an extent. In addition, it can be informative to know whether a trade was filled by one limit order or whether it took several orders to fill; likewise, the relative depth of the order book required to fill a trade is informative.

### Past stock returns

Past trades and stock returns, while closely related, may have different properties with respect to the predictability of stock prices. Past stock returns and their volatility can be used to predict future returns (Abhyankar, 1995; Yu, Rentzler, & Wolf, 2005). This information can be used in combination with the past trade and order book dynamics. In particular, in certain circumstances a momentum strategy may be profitable while in other conditional circumstances price reversal better reflects the expected return path (Yu, Rentzler, & Wolf, 2005). How the past stock return developed, such as whether it was a result of different types of public news announcements, whether it was because of an excessive number of small orders, or one large order, among other situations, can be useful.

### Cross stock correlation

Some stocks tend to move together. This is often seen as a within industry effect. For example, stocks in a given industry, such as energy, will all be affected by a jump in oil prices. This is not surprising. But it is also true that less direct relationships also exist between different stocks. For instance, a pairs trading strategy is a well documented Wall Street trading strategy (Gatev, Goetzmann, & Rouwenhorst, 2006; Engelberg, Gao, & Jagannathan, 2008). An arbitrageur looks for two stocks, either in the same industry or not, that have tended to move together in the past. When they deviate in the future the arbitrageur buys the underpriced stock and short sells the overpriced security. In the academic literature such a strategy has been shown to be profitable at the day level interval.

HFTs can take advantage of a similar strategy between pairs of stocks or bins consisting of several stocks. While the cross stock correlation information has been shown to contain information over a variety of time intervals, HFTs are primarily interested in the shortest of these intervals. Thus, HFTs likely only use such a strategy with stocks that have a high short-term correlation in their trading history. It may be the case that a pair link is not obvious at the day or hour intervals, but by examining the short term intraday activity a pattern exists that is informative of future price movements.

### Cross asset correlation

Compared to cross stock correlation, cross asset correlation can have an even stronger relationship. For instance, an ETF on gold and gold futures move closely together. Similarly, an S & P 500 futures asset will move depending on how the 500 underlying stocks move. In the same way, the price of an options contract will closely relate to the movements of its underlying asset. (Jin, Livnat, & Zhang, 2011). Just like the pairs trading discussed previously, an arbitrageur can set up systems on multiple asset classes and attempt to be the first to take price discovery (or price movements more generally) that occur in one asset and impound it into the others. Two or more assets that tend to move together in short term intraday intervals can provide HFTs with a potential profitable trading opportunity because of their ability to be the first to react to price movements in one market that are relevant to assets in other markets. This likely happens for those assets that are subject to the same risk factors, or, stated differently, that have similar or identical payouts in different states of the world.

### Cross exchange information delays

Regulation – National Market System (NMS) allowed for the fragmentation of market activity in US equity markets. The academic literature has only begun to analyze market fragmentation (O'Hara & Ye, 2011), and has not yet focused on the potential implications of small time delays between exchanges that trade the same asset. The result of market fragmentation is that only a fraction of many stocks' trades now occur on NYSE or NASDAQ. The rest occur on new exchanges, like BATS, electronic communication networks, such as Island ECN, and other alternative trading systems. The different trading venues can lead to differences in data reporting between the exchange data and the consolidated tape data. This difference can give those with the exchange data feeds notice of trades prior to market participants who only monitor the consolidated tape. Such a speed of information differential may provide HFTs information that is useful in determining forthcoming buying or selling.

In addition, Regulation NMS created a trade-through rule (Securities and Exchange Commission, 2005). The rule states that if an exchange receives an order while it is not offering the national best bid or offer, that exchange must route the order to the competing exchange that is offering the national best bid or offer. It need not be the case that prices on all the exchanges are the same. If a participant on one exchange has a quote that becomes outdated and the other exchanges' quotes move away from it, then this may suggest the stale quote is mispriced and would provide HFTs an opportunity to buy an asset at a discount or sell it at a premium.

### Illegitimate activity concerns

#### Front running

Front running is when a trader, having proprietary information concerning a client with whom the trader has a fiduciary duty to serve the client's best interests, utilizes the proprietary information for his own personal gain by entering a trade position just prior to the client's (FINRA, 2008). This is not seemingly possible for HFTs to do. First, they tend to be proprietary trading firms without clients. Second, they receive information at the same time as the rest of the market through exchange data feeds and so they are unable to trade in front of an order that they are unaware of until after it has occurred. Any foresight they have with respect to future orders comes from their statistical modelling, not from prior knowledge of a specific order.

#### Quote stuffing

Quote stuffing is the alleged practice of putting in a large number of quotes and then immediately cancelling them (Lauricella & Strasburg, 2010). It may be that such a large

placement of orders and near immediate cancellation is for some economically meaningful purpose, such as updating orders based on information coming from other sources. Alternatively, it may be a way to obtain an informational advantage over competitors.

Two such malevolent motives may drive the activity. First, it may be that the trader wants to slow down his competitor by placing orders that he knows have no economic content, while his competitor does not. As a result, the malevolent actor will be able to submit fewer orders for processing to his analysis algorithms compared to his competitor (assuming the competitor is not also quote stuffing). The speed difference will likely be micro- or milliseconds, but that is enough to obtain an advantage. Second, it may be that, instead of trying to slow down an individual competitor's ability to process information, the malevolent actor may be trying to slow down an entire exchange's processing of order and trade information. If the trader can extend the time delay between how fast an exchange can update its quotes, post trades, and report data to its clients, then the trader will have more time to take advantage of cross exchange price differences.

### Layering

Layering is an illegitimate strategy by which a malevolent trader places hidden orders on one side of the market, and then puts in displayed orders on the other side so as to deceive other traders into thinking that the price is moving in a given direction. Once the hidden orders have been crossed and a trade occurs, the malevolent trader withdraws his displayed orders. This is illegal and at least one firm, Trillium Trading, has been caught engaging in it (FINRA, 2010).

For example, if a trader wants to buy a stock at 10.01, but its current bid is 10.02 and its ask is 10.03, it may put in a limit order to buy (a bid) at 10.01 that is hidden (or displayed). It will then place several limit orders to sell (offers) at a slightly higher price, say 10.05. Others will see that there is strong selling pressure and will subsequently adjust their bids and offers lower. Once the offer price hits 10.01 there will be a trade. The trader will have bought the stock for 10.01 and will withdraw his offer quotes.

## HFT and profitability

### Overview of HFT profitability

HFTs profits are derived from a limited set of activities. These include market making activities, collecting liquidity rebates, successfully performing statistical pattern detection, upholding the law of one price, and potentially manipulating markets. These items need not be mutually exclusive. For instance, since market makers provide liquidity in a large number of trades, they usually receive liquidity rebates from exchanges. Nonetheless, the gains can be conceptually decomposed into their respective components. The different sources of profitability can be tied to the different kinds of information processing described in the previous section. The mapping between profit and information is highly intermingled. All but the market manipulation activities can be thought of as services that HFTs are bringing to the market. That is, the profits obtained by HFTs may be compensation for monitoring markets and subsequently increasing their efficiency or by improving liquidity (in the short term at least). While such services should be compensated, the price of compensation is debatable as are the externalities resulting from HFTs providing these services as opposed to more traditional market participants.

### Market making

Market makers are market participants who provide liquidity for other traders. That is, they stand ready to trade with other market participants. The theoretical and empirical literature show this

service is compensated through the bid-ask spread for those who are adept at it (Stoll, 1989). Some markets have informal market makers, such as U.S. futures, while others have formal, registered ones, like U.S. equities. Many HFT firms engage in market making activities, standing ready to trade with others by having outstanding quotes on the order book. However, only a fraction of these firms register as market makers. Nonetheless, a core part of their activities can be classified as market making. Those that are profitable at market making are the ones who can most capably analyze and use the informational sources discussed previously to be the first in the order queue with uninformed traders and to minimize losses from trading with informed traders.

### Liquidity rebates

Many markets have different trading venues that compete for business. In competitive markets trades go to exchanges where the cost to trading is the lowest. This cost includes the actual charge coming from the exchange as well as implicit costs such as offering the best services and prices, and having the most liquidity available (Parlour & Seppi, 2003). Many exchanges thus want liquidity providers to post quotes on their venue and consequently provide a small financial incentive to do so. For the largest liquidity providers, exchanges pay a couple of cents per 100 shares traded. This small sum, when aggregated over millions of trades, can become substantial. Some HFT firms focus less on predicting the direction of future prices and care more about determining when prices won't move too much so that they can pick up liquidity rebates by providing outstanding quotes while avoiding losses on price movements. Again, the information avenues studied above are used so as to improve the likelihood of avoiding unprofitable trades.

### Statistical pattern detection

The previous two methods of profit generation by HFTs have dealt with the liquidity provision side of trading. Statistical pattern detection or "stat arb" can be done using either limit orders or market orders and relies on profiting from anticipating directional stock price movements rather than bid-ask spreads or liquidity rebates. Using the available high frequency data, HFTs have developed models that, if successful, predict more often than not the direction stock prices will move. The service that statistical pattern detection brings to the market is price discovery – taking short term information embedded in public data sources and impounding it into the current stock price. If a trader's algorithm signals that prices will fall in the next second and she sells now, she profits and assists in moving the price to its new short-term efficient level.

### Law of one price

A basic tenant of finance and the foundation for financial engineering is that two assets with the same payout structure will have the same price. The mechanics of this theorem are not always explained but such a result depends on the activity of market participants. Someone has to know that two assets with the same payout structure have different prices, and this person must have access to investable capital in order for the deviation to be corrected. HFTs' competitive advantage is their ability to quickly analyze information, making them very good candidates to play this role for small intraday discrepancies.

HFTs can perform this function in a variety of different ways. For instance, an option derives its price from information based on its underlying asset. If an option price moves there should be a corresponding move in the underlying asset (assuming the other state variables in the option equity relationship are unchanged). But such a price movement does not necessarily happen instantaneously. There often is a short interval during which the law of one price fails to hold. Some market participant must come in and trade in such a way so the two different prices return to equilibrium and the law of one price is upheld. HFTs likely play this role.

Not only are there cross asset law of one price profits being generated, but there are also gains from engaging in cross exchange law of one price activities. The benefit of having multiple trading venues is that the competition rewards better service and lower costs. One downside, though, is that multiple trading venues invariably lead to delays of information across them. HFTs might be taking advantage of this delay and profiting when they bring the different trading venues into alignment.

### Market manipulation

The previous four methods of profit generation are legitimate and may be compensation for services rendered. Market manipulation, in whatever form, breaks laws and is forbidden. Nonetheless, it may not always be detected and eliminated by regulators. If market manipulation occurs, then the profits it generates come from a lack of competition or the illegitimate private information, likely generated by the culpable HFT firm itself and held by the deceptive party.

## Ten year speculation

### Overview of what the future may hold

HFT quickly rose to become a dominant part of the structure of financial markets. Its future depends on changes in regulation and how the competitive environment of HFT develops. A well-defined regulatory structure is necessary for HFTs to operate. While there are regulatory uncertainties in the future for HFT, many potential regulatory changes will simply change which algorithms HFTs use. What will happen to the profitability of HFT? That is an important question and one that is quite speculative. HFTs to date have been highly innovative in reducing the latency of the trading process. The decreased latency gave HFTs a competitive edge in being the first to react to new information. As the tools and technology necessary to conduct such research disseminates to a larger set of market participants, there will be increased competition that may reduce the profitability of HFT. In addition, the potential for regular sub-penny trading in more markets may also put pressure on the profitability of HFTs.

### HFTs conveying information

The avenues by which HFTs obtain information that drives their trading strategies are limited. Some types of information over the next ten years may be more difficult to detect. For example, order book dynamics as well as trade and price dynamics may become less informative of future trading opportunities. This follows from the likelihood that smaller institutional investors will either learn that they are indirectly providing valuable future price information through their patterned trades and quotes or that the cost of algorithmic randomization services will decrease so they become worthwhile for smaller firms to use.

Under the current regulatory framework, which allows for overlapping assets and exchange competition, there will likely be a role for HFT to keep the law of one price upheld in the shortest time frames possible. On the other hand, regulatory changes may be put in place systems to self-correct some of the law of one price anomalies. For instance, in cross-exchange mispricing it may be that new types of limit orders will be created that self-update based on how prices have moved on other exchanges. Effectively this will mean that orders of this type will be updated to take into account the new price information that occurred on a different exchange. It would remove the need for HFTs to maintain efficient prices across exchanges, as well as remove the associated profits HFTs capture from this activity.

### HFT profitability

As HFT matures it may be that its profitability declines. It seems that currently HFTs are making above-market returns (Brogaard, 2010). However, it appears they are making lower returns than traditional market makers (Brogaard, 2010) and also perhaps less than traditional law of one price arbitrageurs. Like other industries, the firms that adopt new and successful technology are rewarded by earning abnormal returns for their inventiveness and ingenuity. But shortly thereafter other firms adopt the new standard and the abnormal profits initially realized are diminished and become standard again.

This competitive profit – innovation cycle breaks down when there is competition distortion, either through collusion, an oligopoly, or a monopoly. HFT seems to be a highly competitive business. Along most dimensions there are low barriers to entry: one can set up shop with well-trained computer programmers and statisticians, a couple million dollars in capital, and with co-located servers and real-time exchange data feeds. As the details of how HFTs make profits disseminates, competition may reduce their profitability. The main barrier is likely human capital – the requisite background to develop and implement successful signal processing systems.

### Regulation

To operate HFT relies on regulation and the stable rule-based framework of markets. Future regulation will change how HFTs function and will either allow them to continue to flourish and be an integral part of the market, or to become unprofitable and to exit the industry. Regulation varies by asset class and by industry and there are too many types and derivations to address here. Instead, only a few general ideas and their potential implications for the future of HFT will be discussed.

A Tobin tax has been suggested in the U.S. equity markets (Clark, 2009). A Tobin tax is a transaction based tax. The idea is to reduce “excessive” trading and to encourage longer holding intervals. A Tobin tax may reduce trades and increase trading times. Even a small transaction tax would be likely to greatly reduce the profitability, and hence activity, of HFTs as HFT profits are very small on a per-trade basis but accumulate over millions of transactions to become sizeable. If a Tobin tax is put in place and it exceeds HFTs’ profitability, they will likely limit their trading activity to the most profitable activities, or exit the markets all together, and the negative and positive services and externalities associated with them will be reduced or eliminated. There have also been discussions of mandating a small charge to post and/or withdraw orders from the order book. This would be an additional cost that, like a Tobin tax on transactions, would decrease activity in the order book. In the US equity markets there is currently no charge for placing or removing limit orders from the book. However, there is a small cost to an exchange for receiving and storing this data. As a result, there is a misalignment of services and costs: HFTs have the ability to enter orders but do not fully internalize the associated costs of doing so. Perhaps a small charge would help remove this misalignment of incentives. The worry, though, is that the charge could be too large and have a detrimental impact on liquidity. Similarly there has been talk of limiting the number of quote cancellations per trade or implementing a minimum time in which a quote must stay active. While the aim of limiting any game-playing in the order book is reasonable, the side effects may be costly. If quotes cannot be cancelled within a certain time then HFT firms and others will, at the margin, be less willing to put a quote on the order book. That is, there will be less liquidity. In addition, the delay will allow others to pick off the HFT liquidity provider when new information becomes available during the interval after the quote has been placed and before the quote can be removed. The end result could be an increase in bid-ask spreads.

Finally, a decade ago U.S. markets went from being quoted in eighths to pennies. There may be a change in regulation reducing the minimum tick size from a penny to a sub-penny interval. If the order queue remains based on price-time priority, then a minute improvement in price at the sub-penny level will allow a market participant to jump to the front of the order queue. This will change the dynamics of how HFTs place orders. In addition, the decrease in minimum spread will likely lower the profitability of being a market maker in those assets for which the one penny spread is binding.

## Conclusion

HFT is a new, exciting, and not yet well-understood development in financial markets. This paper has focused on information, profitability, and HFT. In particular, it discusses the role of information in HFT, how HFTs earn their profits, and analyzes the potential future developments of the information and profitability of HFT as the field matures and potential regulations are enacted. There are a handful of types of information that adjust quickly enough for HFTs to utilize in their strategies, and similarly there are only a few ways in which HFTs can earn profits. While the future of HFT is uncertain, it will undoubtedly be shaped by the actions of regulators and will become less exceptional as competition drives down profits.

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