PART I

# Revenue Models of High-Frequency Trading



In Part I, we cover the introduction to high-frequency trading and the existing revenue models of high-frequency trading. In addition, we discuss the roots, history, and future of the industry.

CHAPTER 1

# High-Frequency Trading and Existing Revenue Models



In this chapter, we discuss the basic concepts of high-frequency trading: what it is; why it is important; who the major players are in the United States; how it earns a profit; and how to categorize high-frequency trading operations.

## WHAT IS HIGH-FREQUENCY TRADING?

High-frequency trading has swept Wall Street and made quite a few news headlines since 2008, with the stunning profit generated by top tier investment banks. Only a small percentage (about 2 percent) of all the trading firms operate the high-frequency trading business. So many financial institutions and professionals would like to know what high-frequency trading is. Let's answer the question here.

High-frequency trading extends program trading that normally uses computer algorithms to execute a collection of trading orders at fast speeds, boosting market liquidity (see Hendershott, Jones, and Menkveld, in press). The word *high-frequency* implies the boosting effect on market liquidity compared to manual trading practices. For example, as a liquidity booster, high-frequency trading operations may use sophisticated computer algorithms to analyze multiple markets and execute arbitrage strategies with many orders at the same time.

Based on the definition, there are four elements of a high-frequency trading system: computer algorithms (algos); market liquidity booster;

collection of orders; and faster speed than manual executions. Among the four elements, computer algos and liquidity booster are the necessary conditions to forming a high-frequency trading operation.

As there is not yet a widely acceptable definition of high-frequency trading among academia, practitioners, and regulators, we hope that the definition in this book will be adopted by many, as it addresses the benefit of high-frequency trading to market liquidity at a higher level of abstraction. This benefit is of critical importance to the existence of high-frequency trading practices, as regulators, who are the major force in monitoring and regulating high-frequency trading, have acknowledged the benefit of liquidity boosting of high-frequency trading to the securities markets. More on the concept of high-frequency trading may be found in Irene Aldridge's book *High-Frequency Trading* (2009).

Computer algos are programs written by financial engineers or software engineers that automate the trading activities or quantitative models that are traditionally conducted by human traders or researchers. Some of the algos are based on mathematical models and some are not. For example, a computer algo to compute the value at risk with Monte Carlo simulation uses statistical models. Another computer algo to get the real-time quote of a security over the Internet may not require statistical or mathematical backing.

Collection of orders refers to the grouping of buying or selling orders that are normally used for arbitrage operations that, for example, attempt to profit from price differences between securities or exchanges within a short period of time. Another example may be hedging: A trader may use computer algos to combine a long position of an underlying asset (stock or bond) and in the meantime hedge the risk of losing money by buying a put option on this asset. As a result, a collection of orders (buy the asset and the option) are formed as part of the automated trading strategy.

The advantage of speed has been the major factor of success for early high-frequency trading operations. This is enabled by super computing technology and sophisticated computer algos. For example, it has been reported that Goldman Sachs and IBM collaborated on this type of high-frequency trading to catch the price difference between buying and selling orders within milliseconds, which has delivered significant profits. In general, it is well received by the practitioners that the speed of order execution would position the trades with a better chance of profit-making. The principle of co-location, requiring that the trading servers be located as close as possible to an exchange, emphasizes this point for high-frequency trading. However, the speed of execution is not a required condition for a high-frequency trading system that may use advanced computer algos to outperform peers.

## WHY HIGH-FREQUENCY TRADING IS IMPORTANT

Why is high-frequency trading so important today? First, from a functional perspective, high-frequency trading is a type of electronic trading that uses information technology to increase transparency and liquidity of securities markets. The primary benefit of engaging high-frequency trading is boosting liquidity for the securities markets. As such, according to Bloomberg news on May 13, 2009, Tim Geithner,[1] the U.S. Secretary of the Treasury, has urged electronic trading for over-the-counter (OTC) derivatives that lack liquidity and transparency (Leising and Seeley 2009). Note that the 2008 U.S. GDP is $14.4 trillion (data from the World Bank). The OTC derivatives market is a major part of the $600 trillion global derivatives markets that have been frozen due to the lack of liquidity, which was triggered by the financial crisis from late 2008 to the end of 2009.

The second reason for high-frequency trading's importance is its trading volume. According to the data circulating in the trading community, by the end of 2009, the high-frequency trading firms, approximately 2 percent of the 20,000 trading firms of the U.S. markets account for over 70 percent of all U.S. equity trading volume. These 2 percent of companies include proprietary trading desks for a few major investment banks, less than a hundred of the hedge funds, and hundreds of small trading shops. They all operate with one mission: maximizing profit by being smarter or faster than their peers.

An illustrative work by advancedtrading.com (citing the research by TABB Group's Iati) visualizes the three types of trading firms that create the over 70 percent trading volume of U.S. equity with high-frequency trading. First are the traditional broker-dealers who undertake high-frequency strategies, separate from their client business. Second are high-frequency hedge funds. Third are proprietary trading firms that are mainly using private money.

The third reason for high-frequency trading's importance is that it has produced a high-paying labor market that is hiring large numbers of traders, developers, strategists, and analysts, even in an economy in financial crisis with an unemployment rate of more than 10 percent in December 2009, when the recovery of the economy and employment situation was remote.

Here is a job posted in December 2009 by a Wall Street recruiter seeking a quantitative algo trader: "Looking for someone with a quantitative background who comes with/can create their own algorithms. Must have experience with putting algo's into a live production

environment on equities, FX/futures or fixed Income. PhD in Financial Engineering, Physics, Chemistry, Economics, Finance, or similar preferred. Roles in NYC and Fairfield County, CT. Total compensation $350k–$750k+."

Apparently, this job posting is very attractive to students or experienced professionals, especially as it claims to pay three times the average salary of an equivalent employee in other fields such as technology consulting with similar technical skills, or scientific research with similar quant skills.

I teach graduate courses on Financial Engineering (with a focus on high-frequency trading algos, financial institutions, and derivatives) at Johns Hopkins University Carey Business School. One of the courses had an original limit of 30 enrollments. It was quickly wait-listed for the first time. The school then raised the enrollment limit to 40. Within weeks, it was wait-listed again with 40 graduate students enrolled. This happened three to four months before the start of the class.

These examples demonstrate the popularity and importance of high-frequency trading and financial engineering in the investment management industry. It has been perceived to be the future of major investing activities for private investors such as hedge funds, and for public investors such as investment banks and mutual funds.



## MAJOR HIGH-FREQUENCY TRADING FIRMS IN THE UNITED STATES

In the United States, the major locations of the headquarters for some of the major high-frequency trading firms are New York City in the Northeast and Chicago in the Midwest. Part of the reason is the need for co-location; an important requirement for high-frequency trading is to place the algo trading servers as close as possible to the exchange. The New York Stock Exchange (NYSE) is located in New York City. CME Group is in Chicago, which operates two self-regulatory futures exchanges, the Chicago Mercantile Exchange (CME) and the Chicago Board of Trade (CBOT). CME Group is the result of a merger of CBOT and CME in 2007 that formed one of the largest derivatives exchanges in the world.

Table 1.1 shows a small portion of around 200 high-frequency trading firms in the United States as of 2009. The table displays the names of major high-frequency trading players in the United States, the location of their headquarters, and their main characteristics of trading.

**TABLE 1.1** Locations and Characteristics of U.S. High-Frequency Trading Shops

| Name | Headquarters Location | Characteristics |
|---|---|---|
| Goldman Sachs | New York, NY | Milliseconds advantage to see buy and sell orders |
| Citadel Investment Group | Chicago, IL | Hedging |
| Renaissance Technologies | East Setauket, NY | Superfast trading; started in 1982 by legend James Simons |
| Getco LLC | Chicago | Market maker |
| Jane Street Capital | New York, NY | Quantitative proprietary trading |
| Hudson River Trading | New York, NY | Advanced mathematical and statistical modeling; high-performance computing |
| Wolverine Trading | Chicago, IL | Derivatives; superior technology |
| Jump Trading | Chicago, IL | Sophisticated high-frequency trading strategies |
| Millennium | New York, NY | Strong quantitative models |
| D.E. Shaw | New York, NY | Large hedge fund |
| Worldquant | Greenwich, CT | Private institutional investment; trade automation |
| Susquehanna International Group | Philadelphia, PA | Algo trading and market making; comprehensive asset classes |

*Source:* Most data were collected in August 2009 by Scott Patterson and Geoffrey Rogow for the *Wall Street Journal*.

## EXISTING REVENUE MODELS OF HIGH-FREQUENCY TRADING OPERATIONS

In a recent *Wall Street Journal* article entitled "What's Behind High-Frequency Trading," Scott Patterson and Geoffrey Rogow (2009) investigated the goals and revenue models of high-frequency trading firms. For a multi-line firm that operates on financial products from stocks to currencies to commodities, the revenue model is to profit from fleeting moves in these products. The high-frequency trading operation looks for "signals," such as the movement of option prices, that indicates which way the market may move in short periods. Some other high-frequency trading operations attempt to profit from finding ways to exploit the defects in the network or computer infrastructure of trading.

Market making is another revenue model for some of the high-frequency trading operations. As a result of the frequent buying and selling, securities on both buy and sell side become easy to liquidate.

Given the assumption of an efficient market for financial markets and exchanges, some high-frequency trading operations exploit temporary "market inefficiencies" and trade in ways that can make money before the brief inefficiency disappears. This extends the traditional arbitrage practice that profits from opportunities such as temporary price difference of a financial product (e.g., gold) in two exchanges (e.g., New York versus Japan). If risk is not involved, such as buying and selling the product at the same time, it is called pure arbitrage; if risk is involved, such as holding the product with one's own capital, the operation is called risk arbitrage.

Detecting and taking advantage of the bid-ask spread is another revenue model for high-frequency trading operations. A bid-ask spread indicates the difference between investors buying and selling a security. A high-frequency operation, for example, a computer algo, may detect the difference in milliseconds while the trade between the buyer and seller is to be matched, and make the trade happen for the buyer and seller. As a result, the algo takes the tiny profit for the matching. With the algo working automatically, the tiny profit may accumulate to a large sum.

Many exchanges, such as the New York Stock Exchange, offer liquidity rebates of about one-third of a penny a share to high-frequency trading operations that are willing to make trades between buyers and sellers easier to complete. The exchange becomes more liquid than before due to the high trade volumes. The frequent trading volumes would produce profit for the trading firms as the exchange awards the trades with the liquidity rebates.

**TABLE 1.2** Existing Revenue Models

| Existing Revenue Model | Focus | Participants |
|---|---|---|
| Fleeting moves | Stocks; currencies; commodities | Institutions |
| Signal detection | Interest rates | Institutions; individuals |
| Infrastructure | Defects of computing environment | Institutions |
| Inefficient market | Tiny gains; financial models | Institutions; individuals |
| Bid-ask spread | Stock | Institutions |
| Liquidity rebates | Exchange offers 0.33 penny per share for improving market liquidity | Institutions |

To summarize, we organize some of the existing revenue models of high-frequency trading in Table 1.2.



## CATEGORIZING HIGH-FREQUENCY TRADING OPERATIONS

To further categorize high-frequency trading operations at a higher level of abstraction, let's discuss the two criteria that organize high-frequency trading operations, followed by the four types of high-frequency trading operations. The two criteria are (1) the types of financial markets (efficient versus inefficient) where a high-frequency trading operation produces revenue, and (2) the participants or actors of the high-frequency trading operations (institutions or private investors).

The revenue models of high-frequency trading firms may be categorized in two parts: Does the model produce profit in an efficient market, or an inefficient market? The notion of efficient versus inefficient markets comes from academic literature. An efficient market refers to the financial market that all players, institutions or individuals, can maximize the utility of their resources with super computing power and advanced intelligence. In reality, the efficient market assumption may not hold, especially for trades that are conducted by human traders. Therefore, some financial markets are inefficient in that the trading represents characteristics such as bias, overconfidence, sentiment-driven, rumor-led, and so forth.

The participants of a high-frequency trading operation may be loosely defined as two groups: financial institutions or private ("individual")

**TABLE 1.3** Categorizations of High-Frequency Trading

| | Efficient Market | Inefficient Market |
|---|---|---|
| Institutions | Examples: Liquidity rebates; infrastructure defects | Example: Tiny gains on pure arbitrage |
| Private investors | Example: Trades with signals | Example: Algo-trade with financial anomalies such as behavioral economics models |

investors. Financial institutions refer to the entities that handle a large volume of financial resources that are pooled from the public. For example, investment banks, mutual funds, pension funds, and insurance companies are institutional investors. Private or individual investors, sometimes called retail investors, use brokerage services to invest their own financial resources in various financial instruments. For example, individual traders, family offices of high net worth investors, private equities, and hedge funds are private investors. A good example to clarify the criterion of institutions versus private investors is to compare mutual funds and hedge funds. Both funds pool financial resources from many people or institutions (e.g., commercial banks) and invest in various financial markets. However, the difference between the two kinds of funds is that mutual funds register with the U.S. Securities and Exchange Commission (SEC), while hedge funds normally do not register with the SEC. This distinction makes a mutual fund "institutional" or "public" and a hedge fund "individual" or "private."

Based on the revenue models and participants that a high-frequency trading operation has engaged, we may categorize high-frequency trading operations as one of four types: the high-frequency trading operation (1) in an efficient market with institutional investor; (2) in an efficient market with individual investors; (3) in an inefficient market with institutional investors; and (4) in an inefficient market with private or individual investors. Table 1.3 shows the categorizations.



## CONCLUSION

In this chapter, we discussed the following topics:

- The definition and concept of high-frequency trading.
- Reasons why high-frequency trading is important.

- Major high-frequency trading firms in the United States.
- Basic revenue models of high-frequency trading firms.
- Four types of high-frequency trading operations.

In the next chapter, we trace the roots of high-frequency trading to one of the eight major functions of investment management, namely program trading.