HIGH FREQUENCY REGULATION: A NEW MODEL FOR MARKET MONITORING

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INTRODUCTION

In 1968, traders on the New York Stock Exchange (NYSE) faced a rather sizable problem. For the first time ever, the market experienced a daily trading volume of over twenty million shares.[1] Unfortunately, each of the twenty million shares came in paper form, which meant that in order to complete a trade a broker needed to transport and deliver a physical stock certificate, along with an average of thirty-three paper forms, from one party to another.[2] Traders described the resulting chaos as a "paper work blizzard."[3] According to one account, "stock certificates" were "found everywhere from the women's bathroom to trash bins."[4] Indeed, it was common for the back office of a brokerage firm to resemble "a trackless forest."[5] In the resultant chaos, stock certificates were often misplaced, exacerbating the problem by creating failed orders and lost shares.[6] Eventually, the paperwork grew so large that traders were forced to stop trading to catch up. For the second half of 1968, the NYSE was closed on Wednesdays.[7] Trading ended early every other day of the week.[8] The paperwork crunch came with significant costs. Over $4 billion worth of securities were lost in the mess of paperwork.[9] Many firms, defeated by the

1. *Market Turmoil; Averting Blizzard of Paper*, N.Y. TIMES (Oct. 25, 1987), http://www.nytimes.com/1987/10/25/us/market-turmoil-averting-blizzard-of-paper.html [hereinafter *Blizzard of Paper*].

2. David C. Donald, *Heart of Darkness: The Problem at the Core of the U.S. Proxy System and Its Solution*, 6 VA. L. & BUS. REV. 41, 50 (2011).

3. Leon T. Kendall, *The Certificateless Society: A Realistic Appraisal*, 24 BUS. LAW. 141, 141 (1968). Headlines on the financial pages also described the problem as a "'Paper Tiger.'" *Id.*

4. *Blizzard of Paper*, *supra* note 1. According to another account, "'[s]tock certificates and related documents were piled "halfway to the ceiling."'" Joel Seligman, *Cautious Evolution or Perennial Irresolution: Stock Market Self-Regulation During the First Seventy Years of the Securities and Exchange Commission*, 59 BUS. LAW. 1347, 1366 (2004) (quoting JOEL SELIGMAN, THE TRANSFORMATION OF WALL STREET: A HISTORY OF THE SECURITIES AND EXCHANGE COMMISSION AND MODERN CORPORATE FINANCE 451 (Aspen Pub. 3d ed. 2003) [hereinafter SELIGMAN, TRANSFORMATION OF WALL STREET]).

5. SEC. & EXCH. COMM'N, STUDY OF UNSAFE AND UNSOUND PRACTICES OF BROKERS AND DEALERS, H.R. DOC. NO. 92-231, at 13 (1971) [hereinafter STUDY OF UNSAFE AND UNSOUND PRACTICES].

6. *Id.* at 19 ("For many firms, it became utterly impossible to keep books and records apace with the mounting speed and volume of transactions."). The report went on to describe how, to keep up with their paperwork, many brokerage firms rushed to hire backroom workers to process trades. *Id.* Unfortunately, these workers were often "untrained" and "unsavory" and thus tended to exacerbate the problem. *Id.*

7. *Blizzard of Paper*, *supra* note 1; Donald, *supra* note 2, at 52.

8. Donald, *supra* note 2, at 52; Seligman, *supra* note 4, at 1366.

9. STUDY OF UNSAFE AND UNSOUND PRACTICES, *supra* note 5, at 19; Donald, *supra* note 2, at 52; Abram Brown, *What Can Close the NYSE? World War, Presidential Funerals and Hurricane*

magnitude of their own success, lost track of so many shares they were forced out of business.[10] It was clear that if brokers were to continue trading at such large volumes, they would need a new system.[11] And so, electronic trading was born.

In December of 1969, Institutional Networks Corporation launched the world's first electronic securities market, Instinet.[12] Two years later, the National Association of Securities Dealers created the NASDAQ, "the world's first electronic stock market that used computers to gather and match buy-and-sell orders."[13] As more time passed, electronic trading systems grew more complex: traders used computers to collect and analyze market data, to implement automated trading strategies, and to coordinate trading activity across dozens of electronic markets[14] around the world.[15] Perhaps most importantly, advances in computer and network technologies increased the speed at which trades could be conducted. In 1968, it took over a week to complete a trade.[16] By the end of the 1990s, with electronic trading systems, that time had decreased to twenty seconds.[17] As of 2011, the average time to complete a trade was only one second.[18] Today, with the help of computers and advanced networking capabilities, a trade can be conducted in as little as ten microseconds.[19]

Unfortunately, speed comes with a price. The increase in speed was accompanied by a corresponding increase in trade *volume*. While the markets of 1968 handled a daily volume of twenty million shares, today's

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Sandy, FORBES (Oct. 29, 2012, 8:04 AM), http://www.forbes.com/sites/abrambrown/2012/10/29/what-can-close-the-nyse-world-war-presidential-funerals-and-hurricane-sandy.

10. Seligman, *supra* note 4, at 1366 ("SEC Chairman Budge testified, 'brokerage firms [found] themselves in the paradox of being forced out of business by having too much business.'" (quoting SELIGMAN, TRANSFORMATION OF WALL STREET, *supra* note 4, at 451)). Approximately 160 firms went out of business from 1969 to 1970. Seligman, *supra* note 4, at 1376.

11. Kendall, *supra* note 3, at 141 (calling for a change to a "certificateless society").

12. Diego Leis, High Frequency Trading: Market Manipulation and Systemic Risks From an EU Perspective 6 (Feb. 29, 2012) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2108344.

13. *Id.*

14. *See* Concept Release on Equity Market Structure, 75 Fed. Reg. 3594, 3594 (Jan. 21, 2010) (to be codified at 17 C.F.R. pt. 242) (diagraming various types of exchanges and electronic markets, and the share volumes they execute).

15. Alyse Gould, *Regulating High-Frequency Trading: Man v. Machine*, 12 J. HIGH TECH. L. 273, 279–81 (2011).

16. STUDY OF UNSAFE AND UNSOUND PRACTICES, *supra* note 5, at 43.

17. Andrew G. Haldane, Exec. Dir., Fin. Stability, The Race to Zero, Speech Given at International Economic Association Sixteenth World Congress 4 (July 8, 2011) (transcript available at http://www.bankofengland.co.uk/publications/Documents/speeches/2011/speech509.pdf).

18. *Id.*

19. *Id*. at 5.

markets have a daily volume exceeding one billion *orders*.[20] This is made even more staggering by the fact that each order can involve hundreds or thousands of shares.[21] Despite the increase in transaction speed, markets have not been able to adjust. On numerous occasions, markets have been forced to halt trading in the face of excessive volume and market chaos.[22] With millions of orders taking place every minute, the status of any given share at any given time is something of a complete mystery.[23] To that effect, it can take months to reconstruct just a few *minutes* of trading activity.[24]

Just as in 1968, these problems have caused traders to lose billions of dollars,[25] driven brokerage firms out of business,[26] and led many to question the integrity of the market.[27] Ironically, the systems put in place to address the paperwork crunch seem to have exacerbated many of the problems they sought to solve.

In this Article, I explore many of the problems associated with high frequency trading (HFT), and introduce a framework that can be used to solve these problems. Specifically, I argue that the problems caused by complex, dynamic, and flexible *trading* algorithms can best be solved through the development of complex, dynamic, and flexible *regulation*

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20. Charles M. Jones, What Do We Know About High Frequency Trading? 45 (Mar. 20, 2013) (unpublished manuscript) (on file with Columbia Business School), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2236201.

21. *See* Concept Release on Equity Market Structure, *supra* note 14, at 3599 (stating that in 2009 each order involved an average of approximately 300 shares). This means that trade volume in 2009 was on order of 15,000 times larger than trade volume in 1968.

22. *See* Jones, *supra* note 20, at 34, 39–42 (explaining how trading ground to a halt during the 2010 Flash Crash when the price of E-Mini S&P 500 Futures dropped by over 7% over the course of fifteen minutes; in August 2012, when Knight Capital Group introduced an algorithm into the market that caused the group to lose hundreds of millions of dollars in just a few hours; and in May 2012, when an exchange's matching algorithms were overwhelmed by orders during the Facebook IPO); s*ee also* Charles R. Korsmo, *High-Frequency Trading: A Regulatory Strategy*, 48 U. RICH. L. REV. 523, 523–26 (2014) (explaining the 2010 Flash Crash in more detail).

23. Henry T.C. Hu, *Too Complex to Depict? Innovation, "Pure Information," and the SEC Disclosure Paradigm*, 90 TEX. L. REV. 1601, 1706 (2012) (indicating that on at least one occasion "[m]arket makers did not know what they and their clients owned" and that they "were not sure if their orders had been filled").

24. Edward E. Kaufman Jr. & Carl M. Levin, *Preventing the Next Flash Crash*, N.Y. TIMES (May 5, 2011), http://www.nytimes.com/2011/05/06/opinion/06kaufman.html; *see infra* Part II.A.

25. Jones, *supra* note 20, at 39–41.

26. *E.g.*, Beverly Goodman, *Tapping the Brakes on High-Speed Trading*, BARRON'S, http://online.barrons.com/news/articles/SB50001424052748703754104577239231746043566 (last visited Nov. 25, 2014).

27. *See generally* MICHAEL LEWIS, FLASH BOYS: A WALL STREET REVOLT (2014) (reporting on a small group of Wall Street investors who claim that the U.S. stock market is fixed to benefit insiders).

algorithms—algorithms that can respond to market problems in real time by modulating structural aspects of trade such as transaction fees, information sharing, and rate of data flow.

At the outset it is worth noting that HFT has already received a fair amount of attention in the literature. Financial institutions and business scholars have written a number of papers explaining how HFT works, accounting for the most common trading strategies, and discussing common criticisms that have been levied against the practice.[28] A handful of legal scholars have also weighed in on the issue by considering possible solutions to HFT problems. The most common proposals seek to expand the current regulatory framework by enhancing market monitoring capabilities,[29] imposing trade obligations on the most active market participants,[30] and improving the market's ability to quickly halt trading in response to large market fluctuations.[31] While these solutions show promise, they are also limited in scope—once they are put in place, the rules are static and unchanging. That is, the most common solutions are indifferent to changing market conditions and cannot account for unexpected trading strategies.

This Article expands on the previous literature by proposing a new kind of solution. Specifically, I argue that market rules should change in real time to reflect the state of the market and the trading practices of specific actors.

This Article has two parts. In Part I, I define high frequency trading and explain the types of strategies used by high frequency traders, along with the problems most commonly associated with these strategies. In Part II, I explore some of the problems with the current regulatory scheme and introduce "high frequency regulation" as a solution to these problems. I endeavor to show how high frequency regulation would enable regulators to

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28. *See generally* R.T. LEUCHTKAFER, HIGH FREQUENCY TRADING AND PREDATORY MARKET MAKING: BIBLIOGRAPHY OF EVIDENCE-BASED RESEARCH (Dec. 2013), *available at* http://blog.themistrading.com/wp-content/uploads/2013/12/RTL-HFT_Bibliography_2013.pdf (providing an in-depth annotated bibliography of articles and reports related to HFT).

29. *See, e.g.*, Gould, *supra* note 15, at 324–25 (advocating for the development of a consolidated audit trail); Korsmo, *supra* note 22, at 597 (recommending a consolidated audit trail and system of circuit breakers to regulate HFT).

30. *See, e.g.*, Andrew J. Keller, *Robocops: Regulating High Frequency Trading After the Flash Crash of 2010*, 73 OHIO ST. L.J. 1477, 1478 (2012) ("Imposing requirements on the stock exchanges to monitor HFT might be a better alternative than government regulators sifting through enormous amounts of data."); Korsmo, *supra* note 22, at 543–44 (suggesting that markets should impose obligations on specialists and market makers).

31. *See, e.g.*, Gould, *supra* note 15, at 310–25 (advocating for the expansion of circuit breaker protocols); Korsmo, *supra* note 22, at 608 ("[C]ircuit breakers are the most straightforward way to prevent a repeat of the major dislocations of the Flash Crash or the smaller dislocations seen in the numerous mini-Flash Crashes before and since.").

monitor ongoing transactions, *evaluate* the transactions, and *respond* to irresponsible or abusive trading practices. I also address some potential objections to high frequency regulation.

I. HIGH FREQUENCY TRADING

While there is no formal definition of HFT,[32] in this Article I use the term to mean "trading activity that employs extremely fast automated programs[33] for generating, routing, canceling, and executing orders in electronic markets."[34] While it is difficult to specify a threshold for "extremely fast," the types of HFT strategies discussed in this Article function at the speed of milliseconds. At the outset, it is worth distinguishing HFT from algorithmic trading and from low frequency trading (LFT). Algorithmic trading is "generally defined as the use of a computer algorithm to make decisions about order submissions and cancellations."[35] In light of this definition, we can say that high frequency trading is a subset of algorithmic trading—that is, all HFT strategies are implemented and executed by computer algorithms. Low frequency trading, on the other hand, should be understood as a complement to HFT, covering any trading activity that does not qualify as high frequency trading.

With an understanding of what it means to engage in HFT, it is possible to consider some of the prominent HFT strategies. Generally speaking, HFT strategies fall into one of three categories: strategies that manipulate the market, strategies that attempt to take advantage of market movements, and strategies that facilitate a variety of high- and low-frequency trading activities. In this Part, I describe the strategies that fall into each of the three trading categories, explain the benefits and risks associated with each strategy, and discuss some of the factors that motivate traders to choose one strategy over others.

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32. Leis, *supra* note 12, at 18 ("High frequency trading is not easy to define as it is very recent and a combination of pre-existing trading strategies with new technology.").

33. One could argue that the definition of HFT need not include a reference to an automated program—that high frequency trading should be defined solely by reference to the frequency at which trades are conducted. In practice, however, such an argument falls short. With trades taking place every millisecond, it would be impossible for a trader, working without computer assistance, to keep up. Accordingly, it makes sense to include automated programs in the definition of high frequency trading.

34. Jakša Cvitanić & Andrei Kirilenko, High Frequency Traders and Asset Prices 2 (Mar. 11, 2010) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1569067.

35. Jones, *supra* note 20, at 5.

A. Unfair Strategies and Market Manipulation

Some HFT strategies rely on market manipulation and unfair exploitation. In order to understand these strategies, it is helpful to have a feel for the speed at which transactions are conducted. In what some have described as a "'race to zero,'"[36] traders have invested billions of dollars[37] to decrease the time needed to send an electronic signal from one location to another. The natural byproduct of this race is that some traders are faster than others. Many manipulative trading strategies rely on this difference in speed.

1. Front-Running

Consider the act of front-running. For the purposes of this Article, front-running describes the practice of trading a security while in possession of non-public information concerning an upcoming transaction in the same or related security.[38] In the context of HFT, front-running is all about speed. The best example of front-running in HFT involves "flash-orders." When a trader submits an order to a market, national securities regulations require that the order be executed at the best available market price, as indicated by the National Best Bid and Offer Price (NBBO).[39] That is, SEC regulations "bar exchanges from filling orders that would receive

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36. Haldane, *supra* note 17, at 5.

37. LEWIS, *supra* note 27, at 15 (describing how traders paid a total of $2.8 billion for access to a high speed connection between New York and Chicago).

38. It is worth noting that there are two conceptions of the term "front-running." Traditionally, the term has referred to the practice of trading ahead of one's own clients. Under this definition, only broker dealers and market makers could front-run. *Front Running: CNBC Explains*, CNBC (Apr. 2, 2014, 2:13 PM), http://www.cnbc.com/id/101549039 ("In conventional terms, front running is something that happens within a firm: A trader gets word that a customer is interested in purchasing a big block of a company's shares, and that trader will purchase shares for his individual account before executing the customer's order."). More recently, the term has taken on a broader meaning (the meaning advanced in the text above). *Id.* (noting that Michael Lewis's book, *Flash Boys*, has changed the meaning of front-running). While the broader understanding has only recently gained traction among the general public, scholars and regulators have used it for decades. *See* Securities Exchange Act of 1934, Exchange Act Release No. 14156, 13 SEC Docket 635, 661 (Nov. 9, 1977); Jerry W. Markham, *"Front-Running"—Insider Trading Under the Commodity Exchange Act*, 38 CATH. U. L. REV. 69, 70–71 (1988); Steve Thel, *$850,000 in Six Minutes—the Mechanics of Securities Manipulation*, 79 CORNELL L. REV. 219, 225–26 n.31 (1994).

39. Lawrence Harris & Ethan Namvar, The Economics of Flash Orders and Trading 4 (Jan. 15, 2011) (unpublished manuscript) (on file with the Mendoza College of Business, University of Notre Dame), *available at* http://business.nd.edu/uploadedFiles/Academic_Centers/Study_of_Financial_Regulation/pdf_and_documents/SSRN-id1953524.pdf.

better prices at other exchanges in the national market system."[40] If a given exchange cannot fill the order at the best price, it is required to route the order to another exchange.[41] Flash orders function as an exception to this rule. Instead of immediately rerouting an unmatched order, an exchange can "flash" the order at the NBBO price to participating traders.[42] For a brief period of time, ranging anywhere from 30 to 500 milliseconds,[43] participating traders have the ability to fill the order. If the order is filled, no further action is necessary. If the order is not filled, it is rerouted, as before, to another exchange.[44]

The motivation behind flash orders is that they can reduce the costs of trading.[45] There are two reasons. First, flash orders make it possible for traders to avoid additional fees.[46] Absent flash orders, traders would have to pay two fees—a transfer fee, which covers the cost of rerouting an order from one market to another, and an access fee, which is imposed by the market that receives and executes the order.[47] Flash orders avoid these fees by eliminating the need to reroute an order. Second, flash orders allow trades to be executed faster.[48] Because the NBBO price often lags behind actual market activity, it is possible for quotes to disappear during the time it takes to reroute an order.[49] Flash orders avoid inefficient or stale rerouting attempts by displaying the sale price of an order before it is transferred. As a result, flash orders provide traders with a comparative speed advantage.[50]

Despite their potential benefits, flash orders create two opportunities for front-running. The most problematic front-running scenario is when market participants use the 30 to 500 millisecond flash period to "beat rerouted orders to the second exchange."[51] Consider the following example:

1. *A* wants to buy 100 shares of *XYZ* at no more than $5 a share.
2. *A* submits his order to the *ABC Exchange*.
3. The NBBO price for a share of *XYZ* is $4.90 per share.

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40. *Id.*
41. *Id.*
42. *Id.*
43. Michael J. McGowan, *The Rise of Computerized High Frequency Trading: Use and Controversy*, 16 DUKE L. & TECH. REV. ¶ 1, ¶ 27 (2010); Harris & Namvar, *supra* note 39, at 4.
44. Harris & Namvar, *supra* note 39, at 4.
45. *Id.* at 5.
46. *Id.*
47. *Id.* at 11.
48. *Id.* at 6.
49. *Id.* at 5.
50. *Id.* at 6.
51. *Id.* at 8.

4. After attempting to match *A*'s order, the *ABC Exchange* is unable to find a match.
5. Before rerouting *A*'s order, the *ABC Exchange* "flashes" the order for 0.5 seconds.
6. *B*, another participant in the *ABC Exchange*, sees the flash order and uses the 0.5 second rerouting delay to buy all available shares of *XYZ* from other exchanges at a rate of $4.90 per share.
7. *A*'s order is rerouted to a different exchange, but by the time the order arrives, no more shares are available at the desired price.
8. *A* buys 100 shares of *XYZ* from *B* at the new NBBO price of $4.95 per share.

In the above example, *A* was front-run by *B*. *B* took advantage of the time gap between order placement and order execution to profit from *B*'s advance knowledge of *A*'s order.

The second opportunity for front-running is more controversial.[52] Many traders believe that flash orders themselves constitute front-running—that the flash of sale information, combined with the execution of a flash order, is unfair.[53] Under this view, the flash sale would constitute front-running by providing a small number of traders with non-public information and giving them the opportunity to act on that information.[54]

While flash orders show how HFT makes front-running possible, front-running is not limited to flash orders. In fact, the largest way in which HFT enables front-running depends on the fragmented nature of the market place. As indicated above, there are currently dozens of electronic securities exchanges.[55] Because there are so many market places, it is common for large orders to be split across several different markets.[56] The result is that orders placed in one market (whether public or private) often correlate with

52. *See* Rishi K. Narang, *High-Frequency Traders Can't Front-Run Anyone*, CNBC (Apr. 3, 2014, 9:38 AM), http://www.cnbc.com/id/101551570 (arguing that HFT is not front-running).

53. *See* Elimination of Flash Order Exception from Rule 602 of Regulation NMS, 74 Fed. Reg. 48,632, 48,638 (proposed Sept. 23, 2009) (to be codified at 17 C.F.R. pt. 242) ("[T]he benefits of flash orders for some market participants do not justify their costs to other market participants, the national market system, and the public interest.").

54. *See id*. at 48,636 ("The Commission also is concerned that flash orders may create a two-tiered market in which the public does not have access, through the consolidated quotation data streams, to information about the best available prices for listed securities."). *But see* Narang, *supra* note 52 (arguing that information relating to a pending or executed order cannot constitute front-running).

55. *See supra* note 14 and accompanying text.

56. Korsmo, *supra* note 22, at 547.

orders placed in other markets.[57] HFT front-runners can use this information, and a speed advantage, to reverse-engineer an order and beat it to the punch.[58] Consider the following example:

1. *A* wants to buy 1,000 shares of *XYZ* at no more than $100 per share.
2. There are currently a total of 2,000 shares of *XYZ* for sale on the market, at a rate of $95 per share. The 2,000 shares are distributed evenly across ten markets (200 shares are for sale in each market).
3. *A* attempts to buy 100 shares from each of the ten markets.
4. Because *A* is geographically closer to some markets than others, his orders do not arrive at the same time in each market.
5. *B*, who has an ultra-fast connection, sees that an order for 100 shares of *XYZ* has been filled.
6. *B*'s algorithms correctly ascertain that the 100 share order is a small part of a larger order.
7. *B* submits an order for 200 shares of *XYZ* to each of the other nine markets. Because *B*'s connection is faster than *A*'s, *B*'s order arrives and is executed first.
8. There are no shares left for *A* to purchase at $95. *A* is forced to buy all of his shares from *B* for $97 a share.[59]

In the above example, as before, *A* was front-run by *B*.[60] *B* took advantage of market fragmentation and the gap between the time *A* placed his order and the time *A*'s order was received by several exchanges. This

57. *See id.* at 533–34 (describing the shift in trade patterns, particularly on the NYSE in 2005).

58. Nicholas H. Hirschey, Do High-Frequency Traders Anticipate Buying and Selling Pressure? 2, 6, (Apr. 1, 2013) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2238516 (indicating that HFTs are able to "anticipate and trade ahead of non-HFT order flow" in a way that "increase[s] non-HFT trading costs").

59. This example is motivated by many of the trading stories told in Michael Lewis's *Flash Boys*. LEWIS, *supra* note 27, at 31. This practice is also explained in Leis. Leis, *supra* note 12, at 24.

60. One could argue that the above example is not actually an instance of front-running. If we suppose that *A*'s order was placed on a public market or recorded as an NBBO price, then *B*'s strategy does not use any non-public information. As a technical matter, this argument is correct. But it misses the point. From a functional perspective, information is only "public" if members of the public are able to view, analyze, and respond to the information in a timely fashion. Because only a small subset of the public can use the information on the timescales involved with HFT, we have good reason to conclude that the information should be deemed non-public. If we accept this argument, then we can say that front-running includes the practice of placing a securities order (Order B), while possessing information concerning another securities order that has been or will soon be placed (Order A), with the intent to complete Order B before Order A can be executed. This argument is explored in greater detail in Part II.

practice is sometimes referred to as order anticipation.[61] This example shows why speed is important in HFT. The faster you are able to send and receive trades, the harder it is for opponents to reverse-engineer your order (whether through flash sales or otherwise) and force you to trade at a loss. The unfortunate result is that, for many, the market no longer works. If you attempt to use only one exchange, it will be difficult to place large orders; if you attempt to branch out to multiple exchanges, the orders you place in one will hinder your ability to trade successfully in another.

2. Fictitious Trades and Order Spoofing

Another type of market manipulation involves the creation of fictitious or disingenuous market orders. The purpose of such orders is to trick HFT algorithms into taking aggressive trade action.[62] This strategy, sometimes referred to as a "momentum ignition" strategy,[63] often involves reverse-engineering competitors' trading algorithms.[64] Such a strategy might work as follows:

1. I create a market-monitoring program to scan the stock market so I can determine the trading patterns of my competitors.
2. Through my analysis, I determine that many of my competitors will lower the price at which they are willing to sell shares of stock *XYZ* by $1 for every 100 sell-orders placed at or higher than the current market price.
3. The current market price for stock *XYZ* is $5 per share.
4. I place a limit order to buy 100 shares of *XYZ* as soon as the price reaches $4 per share.[65] Because the current buy-price is higher than $4, this order will not affect the market.

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61. Korsmo, *supra* note 22, at 547 & n.126 (citations omitted); AUTH. FOR THE FIN. MKTS., HIGH FREQUENCY TRADING: THE APPLICATION OF ADVANCED TRADING IN THE EUROPEAN MARKETPLACE 34 (2010), *available at* http://www.afm.nl/~/media/files/rapport/2010/hft-report-engels.ashx.

62. *See* Leis, *supra* note 12, at 24 (explaining the use of a "momentum ignition" strategy to trick competitors' algorithms).

63. Concept Release on Equity Market Structure, *supra* note 14, at 3609; Korsmo, *supra* note 22, at 548.

64. *See* Leis, *supra* note 12, at 46–47 (describing how two Norwegian traders reverse-engineered a trade algorithm to manipulate the market).

65. A limit order is a standing order where one agrees to buy or sell a stock as soon as it reaches a predetermined price. This is in contrast to a market order, which is executed immediately at the best available price. Leis, *supra* note 12, at 3.

5. To drive the price of *XYZ* down, I place 100 sell-orders for one share of *XYZ* at just above the current market price ($5.01). Because my sell-order is above the current market price, no buyers will fill the order.
6. Acting in conformity with his trading patterns, my competitor lowers the price at which he is willing to sell shares of *XYZ* from $5 to $4.
7. My standing order to purchase 100 shares of *XYZ* at $4 per share executes.
8. I cancel my sell-orders, and then sell 100 shares of *XYZ* at $5 per share to either my competitor or other market actors, earning $100 on the transaction.[66]

By reverse-engineering algorithms, traders can use false orders to manipulate the market at will.[67] Similar strategies involve traders who simulate market activity by trading large quantities of shares to themselves, or by working with other parties to fool the market into believing that supply or demand for one or more stocks is changing.[68] As some have recognized, "[t]he only purpose of an artificial transaction is to inflate or depress the apparent supply, demand or price of a product without any commercial rationale and/or without transfer of market risk to the manipulator."[69] As was the case with front-running, these market manipulating strategies are illegal.[70]

3. Quote-Stuffing

The last form of market manipulation I discuss is quote-stuffing. "Quote stuffing is a manipulative practice in which a large number of orders to buy or sell securities are placed and then almost immediately

66. This example was motivated by an LFT instance of market manipulation perpetrated by Trillium Brokerage Services. *Id.* at 48–49. *See also FINRA Sanctions Trillium Brokerage Services, LLC, Director of Trading, Chief Compliance Officer, and Nine Traders $2.26 Million for Illicit Equities Trading Strategy*, FIN. INDUS. REGULATORY AUTH. (Sept. 13, 2010), http://www.finra.org/Newsroom/NewsReleases/2010/P121951 (discussing Trillium Brokerage Services' use of this trading strategy).

67. *See, e.g.*, Leis, *supra* note 12, at 46–47 (using the Norwegian "'Robot Case'" to show how reverse-engineering algorithms can be used to manipulate the market).

68. *See id.* at 33 (comparing two techniques of artificial trades that create the appearance of market activity).

69. *Id.*

70. Concept Release on Equity Market Structure, *supra* note 14, at 3609 ("Of course, any market participant that manipulates the market has engaged in misconduct that already is prohibited.").

cancelled."[71] The purpose of quote-stuffing is to slow down the market and provide the manipulator with a speed advantage.[72] This speed advantage comes in two forms. First, the sheer number of orders slows down the consolidated quotation system, allowing the quote-stuffer to create an artificial arbitrage opportunity between the (stale) quotes displayed by the quotation system and the actual value found in the market.[73] Second, the quote-stuffer gains a functional speed boost in processing power relative to his competitors.[74] This is because his competitors' algorithms are using processing power (and time) to analyze each of the junk transactions.[75] In this sense, quote-stuffing is the market equivalent of a Distributed Denial of Service (DDoS) attack. A DDoS attack "is an attempt to make an online service unavailable by overwhelming it with traffic from multiple sources."[76] Just as a DDoS attack overwhelms servers with false web traffic, a quote-stuffing attack (and for all intents and purposes, it *is* an attack) attempts to make trading algorithms ineffective or unavailable by overwhelming them with false orders.

Although quote-stuffing is similar to spoofing, the two types of manipulation can be distinguished in that spoofing attempts to manipulate competitors' algorithms to illicit a certain response,[77] while quote-stuffing does not care how competitors interpret its false orders.[78]

4. The Harms of Manipulative Trading Strategies

The problems associated with manipulative and unfair trading strategies are three-fold. First, such strategies functionally increase transaction costs.[79] If traders do not know whether one of their orders will be front-run, and if they cannot tell whether a newly placed order is legitimate or part of a market manipulation scheme, then all of their trading decisions come with a certain amount of non-market based risk. The result

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71. Leis, *supra* note 12, at 64.

72. Korsmo, *supra* note 22, at 575.

73. *Id.*

74. *Id.*

75. *Id.*

76. *What Is a DDoS Attack?*, DIGITAL ATTACK MAP, http://www.digitalattackmap.com/understanding-ddos (last visited Nov. 25, 2014).

77. Leis, *supra* note 12, at 24.

78. *See id.* at 64–65 (describing how quote-stuffing can flood the market with false orders in the blink of an eye causing congestion and slow-down of rival firms).

79. Wallace C. Tuberville, *Cracks in the Pipeline 2: High Frequency Trading*, DEMOS 1, 7 (Financial Pipeline Series No. 2, Feb. 2013), http://www.demos.org/sites/default/files/publications/HFT_CracksInThePipeline_Demos.pdf.

is that traders end up hedging, not based on the value of the stock or the state of the market, but rather on the likelihood that their trade relies on deceptive or improper information.[80] The product of this hedging is that investments and trade sizes are smaller in volume than they would be otherwise. In other words, the flow of capital into the system is much smaller with market manipulation than without. This is especially true in the context of front-running, which functionally amounts to a tax on the transaction.[81]

The second problem with manipulative trading strategies is an overall decrease in market integrity in the eyes of the public.[82] Indeed, one need only look to local op-eds to see that the practice has significantly damaged perceptions of the free market system.[83] While this impact is bad enough on its own, a loss of market integrity or public trust in financial investments also has real-world impacts: A lack of trust makes individuals less likely to view the market as a responsible or respectable investment. Indeed, the number of Americans holding stocks has significantly decreased over the past few years.[84] While this decrease cannot be attributed solely to HFT, it is relatively easy to see how the perception of unethical or manipulative trading practices would undermine investor confidence and reduce the size and quantity of investments.

The final problem with manipulative trading strategies is that they are fundamentally unfair. This harm is based on the uncontroversial normative assumption that individuals should be able to conduct business (including

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80. Korsmo, *supra* note 22, at 604–05.

81. *See* Jones, *supra* note 20, at 14 ("Explicit transaction costs affect share prices, because they subtract from returns every time a share of stock is bought or sold. A buyer knows that she will have to sell one day and incur transaction costs. She also knows that the investor who buys from her will have to pay transaction costs when he buys and again when he sells, and so on down the line.").

82. *See* David Paul, *High-Frequency Trading Marks High Water of Financial Corruption,* HUFFINGTON POST (Apr. 3, 2014), http://www.huffingtonpost.com/david-paul/high-frequency-trading_b_5140147.html (discussing how computerized front-running has undermined any "market benefits that HFT might theoretically have provided").

83. *See, e.g.*, *id.* ("[I]ndustry participants [have] realized the enormous damage that HFT has done to the integrity of the industry."); Charles Schwab, *Schwab Statement on High-Frequency Trading*, CHARLES SCHWAB CORP. (Apr. 3, 2014), http://www.aboutschwab.com/press/statements/schwab-statement-on-high-frequency-trading (referring to HFT as "a growing cancer that needs to be addressed"); *cf.* David Sirota, *How Corrupt Chicago Politics Fueled the High-Frequency Trading Mess*, PANDODAILY (Apr. 10, 2014), http://pando.com/2014/04/10/how-corrupt-chicago-politics-fueled-the-high-frequency-trading-mess (drawing a connection between high frequency trading, the stock market, and political corruption).

84. Luka Orešković, *Institutional Corruption in High Frequency Trading*, HUFFINGTON POST (Apr. 8, 2014, 5:46 PM), http://www.huffingtonpost.com/luka-oreskovic/institutional-corruption-_b_5102246.html.

investment business) on equal terms and without interference. Further, the information markets provide should be consistent and reliable. Traders and investors should be able to trade freely without having to worry about their orders being stolen, manipulated, or otherwise disrupted. In sum, the practices described in this section are objectionable because they are unethical and anti-competitive.

B. Market-Motivated Strategies

The second category of HFT strategies I discuss is market-motivated strategies. Traders who employ market-motivated strategies predict the direction in which the market will move and attempt to trade ahead of that movement.[85] These traders use a variety of methods and techniques to predict this movement. Some of these methods (such as those described in Part I.A) are illegal and unethical. In this section, I explore some of the more legitimate strategies.

1. Wave-Riding

One of the best ways to predict market movement is to look at the direction in which the market is already moving.[86] This strategy makes the most sense in the context of market derivatives.[87] That is, traders can look at: whether the price of a share is moving up or down (whether the share price's first derivative is positive or negative); the rate at which the price of a share is moving (the value of the share price's first derivative); and the rate at which the share price's rate of change is increasing or decreasing (the value and sign of the share price's second derivative).[88] The basic idea is that the current rate and direction at which a stock is moving has some predictive value into the future price of the stock.[89] By building an accurate model, traders can trade ahead of expected price movements.

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85. Boyce Watkins, *Riding the Wave of Sentiment: An Analysis of Return Consistency as a Predictor of Future Returns*, 4 J. BEHAV. FIN. 191, 191 (2003).

86. *Id.* at 200.

87. When I use the word "derivative" I refer to the mathematical concept, not the financial instrument.

88. Watkins, *supra* note 85, at 191.

89. *See* Stephen J. Brown et al., *The Dow Theory: William Peter Hamilton's Track Record Reconsidered*, 53 J. FIN. 1311 (1998) (supporting Dow Theory, the key theorem stating that past and current trends can be used to predict future market conditions). *But see*, Eugene F. Fama, *The Behavior of Stock–Market Prices*, 38 J. BUS. 34 (1965) (refuting Dow Theory and supporting Random Walk theory).

Note that in some cases, wave-riding strategies can have the same effect as front-running strategies. For example, if *A* attempts to buy 100 shares of *XYZ*, other traders, upon registering the completed trade, will determine that the demand (and thus the market equilibrium price) for *XYZ* shares has increased. As a result, traders executing a wave-rider strategy might buy shares of *XYZ* to profit from the increasing share price. If *A* has a slower connection speed than his competitors, it is possible, and indeed likely, that the price of *XYZ* will increase before *A* has obtained the desired number of shares.

What distinguishes front-running from wave-riding is the methodology underlying the trading strategy.[90] Strategies that attempt to reverse-engineer orders to beat them to the punch constitute front-running strategies. These strategies attempt to beat the market by trading in advance and at the expense of individual traders.[91] On the other hand, strategies that simply respond to preexisting market movements—strategies that "ride the wave" of price movements—focus not on individual traders, but rather on the direction of the market as a whole.[92] Such strategies are *responsive* rather than *manipulative*. Of course, in many cases it can be difficult to determine whether a given trading strategy qualifies as front-running or wave-riding.[93] These difficulties are addressed in Part II.

Thus far, my explanation of wave-riding strategies is missing an essential component—speed. Speed is an important component in any market-motivated strategy because it allows traders to respond quickly to changing market conditions. Suppose a trader develops a model and determines a share price will increase by one cent over a small period of time. Absent the ability to trade quickly, the trader would only be able to purchase a small number of shares before the price increased. If we suppose

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90. One could argue that wave-riding constitutes front-running for the same reason that order anticipation constitutes front-running: both rely on information that, while accessible by the public, is not *meaningfully* accessible by the public. Technically speaking, the public has access to market prices, but functionally the access is only meaningful if one has an advanced computer system that can respond to price changes at ultra-fast speed. The reason this objection fails is that it ignores a major component of the definition of front-running. In order to constitute front-running, one must engage in trading activity while in possession of non-public information *concerning an upcoming transaction in the same or a related security*. Because large orders are often split into smaller chunks, information relating to a small order arguably constitutes information concerning an upcoming order. The same cannot be said about stock prices or changes in stock prices. This information does not necessarily concern an upcoming transaction (even though it *does* correlate with upcoming transactions). For this reason, we can be confident that wave-riding strategies are neither unethical nor illegal.

91. Korsmo, *supra* note 22, at 547–48.

92. *See id.* at 546 (describing "'directional'" HFT strategies and stating that "HFTs may also seek to trend-follow, riding waves of market momentum just like classic day-traders").

93. *Id.* at 548–49.

the trader earns only one cent per share, the trader might not earn enough to justify the amount of time it took to develop the model! If we increase the rate at which transactions can take place, then we increase the number of shares a trader can purchase before the price moves. This explains why speed is essential for wave-riding strategies. Note that the increase in profit potential is not limited to stocks whose prices only see small changes. Suppose that instead of increasing by one cent, the price of a share increased by $30 before quickly decreasing by $40. As with the one-cent increase, it is the ability to act quickly that allows a trader to use this knowledge to make a profit. Absent the ability to trade quickly, it is likely that a trader could not complete his order until after the price change had already taken place, causing him to miss a lucrative trading opportunity, or worse, forcing him to take a significant loss.

2. Arbitrage

One of the more prominent market-motivated strategies is market arbitrage. Arbitrage strategies take advantage of discrepancies between the prices of identical shares in different markets.[94] If the price of a share of Google is $514.90 on the NASDAQ and $514.91 on the London Stock Exchange (LSE), an arbitrage strategy would entail buying Google on the NASDAQ and selling it on the LSE. As with the other strategies discussed so far, speed is an essential element of arbitrage efforts.[95] Because many HFT traders attempt to profit from price discrepancies, and because markets around the world are connected,[96] price differentials across markets do not last very long. A similar type of arbitrage strategy involves price differentials between two correlated stocks in either the same or a different market.[97]

3. Defensive Strategies

A problem associated with all, or almost all, market-motivated strategies is that attempts to interact with the market inevitably change the market.[98] An attempt to buy a stock signals an increase in demand (and a

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94. Concept Release on Equity Market Structure, *supra* note 14, at 3608; Korsmo, *supra* note 22, at 545; Jones, *supra* note 20, at 7.

95. *See* Korsmo, *supra* note 22, at 545; Jones, *supra* note 20, at 7.

96. Leis, *supra* note 12, at 76.

97. *Id.*

98. *See* George Soros, *Fallibility, Reflexivity, and the Human Uncertainty Principle*, 20 J. ECON. METHODOLOGY 309, 310 (2013) (explaining the principle of reflexivity, stating that "if investors

decrease in supply), which tends to drive the stock's price up. Likewise, an attempt to sell a stock signals a decrease in demand (and an increase in supply), which tends to drive the stock's price down.[99] This causes something of a paradox, wherein an attempt to profit from an upcoming price change ends up *creating* the price change. As indicated above, many market-motivated strategies rely on making a large volume of low-profit trades. If a trader accelerates the rate at which a stock's price increases, then it will be all the more difficult for the trader to make a profit. This problem is exacerbated by the fact that other traders constantly scan the market for newly placed orders and small price movements, such that markets are increasingly sensitive to changes in supply and demand.[100]

Generally, traders attempt to prevent such preemptive price changes by employing defensive trade strategies.[101] These strategies work by hiding an order or series of orders from competitors.[102] The idea is that if rival traders do not perceive a significant change in supply or demand, then stock prices will not change.[103] Two of the most common methods of disguising orders involve "order chunking" and "dark pools." Order chunking attempts to minimize an order's impact by decreasing the apparent size of the order.[104] For example, rather than submitting one order in a single market for 500 shares of a stock, a trader might submit an order of fifty shares to ten different markets. The trader might further obscure the orders by submitting them at different times. The optimal size and distribution of orders is usually determined by advanced trading algorithms.[105]

Another prominent defensive strategy involves the use of dark pools. The term "dark pools" refers to private markets that do not disclose order information to the public until after the order is matched and completed.[106]

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believe that markets are efficient then that belief will change the way they invest, which in turn will change the nature of the markets in which they are participating").

99. *See, e.g.*, Charles R. Korsmo, *Mismatch: The Misuse of Market Efficiency in Market Manipulation Class Actions*, 52 WM. & MARY L. REV. 1111, 1143 (2011) (explaining that manipulation relies on the assumption that there is a relationship between trade, supply and demand, and stock prices).

100. *See* X. Frank Zhang, High-Frequency Trading, Stock Volatility, and Price Discovery (Dec. 2010) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?ab-stract_id=1691679 (concluding there is a positive correlation between HFT and stock volatility).

101. *See* Korsmo, *supra* note 22, at 534–35, 547 (discussing defensive trade strategies, such as dark pools, broker-dealer internalization, and order chunking).

102. *See id.* (stating that defensive trade strategies result in "less transparent trading").

103. *Id.* at 534, 546–47.

104. Korsmo, *supra* note 22, at 547; Jones, *supra* note 20, at 9; *see also* Leis, *supra* note 12, at 23–24 (stating that HFTs find ways to detect large orders that have been "hidden" or "sliced").

105. Jones, *supra* note 20, at 9.

106. Concept Release on Equity Market Structure, *supra* note 14, at 3599 ("Dark pools . . . do not provide their best-priced orders for inclusion in the consolidated quotation data. In general, dark

The motivating idea is that if traders use dark pools, then competitors (most notably front-runners, but also competing wave-riders) will not be able to intercept order information or profit from models that are not their own.[107]

Unfortunately, while dark pools show promise, they are not a complete solution. There is an inherent tension in dark pools between their size and their efficacy. If a pool is small—if there are only a limited number of participants in the pool—then it is unlikely that any participants will be able to have their order filled to their satisfaction. Conversely, if a pool is large, then it is likely that some (or many) of the pool's participants are active in other markets and will use order detection strategies to discover and exploit the dark pool orders before those orders are fully realized.

4. Problems with Market-Motivated Strategies

While market-motivated strategies are neither fraudulent nor manipulative in the same way as front-running and order-spoofing, they still pose serious problems for the market. As indicated in the previous section, it is difficult, if not impossible, for traders to implement their trading strategies without influencing stock prices. This is because for those implementing a market-motivated strategy, trading decisions are not motivated by the underlying value or merit of the company, but rather by market movements.[108] The result is that trading strategies cascade into each other.[109] For example, Algorithm A perceives a price movement or directional change and buys shares of *XYZ*. Because demand for the stock has increased, the price of *XYZ* stock also increases. Algorithm B perceives the price increase caused by Algorithm A and attempts to join the bandwagon by purchasing even more shares of *XYZ* (perhaps competing with Algorithm A in the process). This continues for some time, until eventually Algorithms C, D, and E are also attempting to buy *XYZ*. This process yields something of a curious result—the price of shares of *XYZ* has

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pools offer trading services to institutional investors and others that seek to execute large trading interest in a manner that will minimize the movement of prices against the trading interest and thereby reduce trading costs."); Korsmo, *supra* note 22, at 534–35; Jones, *supra* note 20, at 9.

107. *See* Korsmo, *supra* note 22, at 535 (citation omitted) ("[D]ark pools . . . render[] a large block trade invisible to other market participants until after it has already been executed.").

108. Lawrence H. Summers & Victoria P. Summers, *When Financial Markets Work Too Well*, 3 J. FIN. SERV. 261, 265 (1989).

109. *See* Korsmo, *supra* note 22, at 567–71 (discussing "rogue" algorithms and giving examples of cascade trading strategies that caused "extreme dislocations in security prices").

seen a significant increase even though there has been no change in the profitability of the underlying company.[110]

The problem is that when trading strategies are not strongly linked to the value of the underlying asset (as is the case with market-motivated strategies), these strategies can yield bizarre and unexpected consequences that are wholly divorced from real world conceptions of value. This is more than a theoretical possibility. In 2010, the market experienced a Flash Crash when a series of algorithms created a feedback loop that caused several stocks to plummet.[111] Similarly, in 2012, an algorithm created by Knight Capital caused the price of 148 stocks to skyrocket.[112]

These sorts of events explain why regulators have imposed "circuit breakers" or "cool off" periods in trading. A "circuit breaker" is a trading protocol built into exchanges that automatically cancels or restricts trading for a few minutes if stock prices change too quickly.[113] On average, rapid price fluctuations trigger circuit breakers and disrupt trading more than once on every day of trading.[114]

In a sense, circuit breakers seem like a reasonable solution. When the value of stocks as ascertained by algorithms deviates noticeably from the value of stocks as ascertained by humans, it is *obvious* that trading should not continue. But at the same time, circuit breakers seem like an

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110. *See* Summers & Summers, *supra* note 108, at 265 (explaining how market-driven strategies drive a wedge between stock prices and fundamental values, and observing "that even speculators who recognize a deviation of prices from fundamental values will be reluctant to trade on the basis of their observation as long as there is the possibility that the deviation will get larger before it gets smaller"); Joseph E. Stiglitz, *Using Tax Policy to Curb Speculative Short-Term Trading*, 3 J. FIN. SERV. RES. 101, 106–07 (explaining some of the factors that cause stock prices to deviate from the value of their underlying companies); Adair Turner, Address at the Inaugural Conference for the Institute of New Economic Thinking: Economics, Conventional Wisdom, and Public Policy 13 (Apr. 2010), *available at* http://ineteconomics.org/sites/inet.civicactions.net/files/INET%20Turner%20%20Cambridge%2020100409_0.pdf (arguing that flash orders and high frequency trading do not contribute to price discovery). *But see* Jonathan Brogaard et al., *High-Frequency Trading and Price Discovery*, 27 REV. FIN. STUD. 2267, 2303 (2014) ("Overall HFTs increase the efficiency of prices by trading in the direction of permanent price changes and in the opposite direction of transitory pricing errors.").

111. Korsmo, *supra* note 22, at 526.

112. Jones, *supra* note 20, at 39–40; Caroline Valetkevitch & Chuck Mikolajczak, *Error by Knight Capital Rips Through Stock Market*, REUTERS (Aug. 1, 2012), http://www.reuters.com/article/2012/08/01/us-usa-nyse-tradinghalts-idUSBRE8701BN20120801.

113. Korsmo, *supra* note 22, at 581; *Investor Bulletin: New Measures to Address Market Volatility*, SEC. & EXCH. COMM'N, http://www.sec.gov/investor/alerts/circuitbreakersbulletin.htm (last visited Nov. 26, 2014) [hereinafter *Investor Bulletin*].

114. *See* Nathaniel Popper, *Stock Market Flaws Not So Rare, Data Shows*, N.Y. TIMES (Mar. 28, 2012), http://www.nytimes.com/2012/03/29/business/mishap-at-bats-stock-exchange-is-indicative-of-market.html ("[E]xchanges have halted trading in company shares after sudden spikes or falls . . . at least 265 times over the last year—more than one for every day of trading . . . .").

unsatisfactory solution. Rather than relying on crude, rough heuristics that come into play only after significant damage has been done, traders should adjust their strategies to prevent price discrepancies from forming in the first place. This does not mean market-motivated strategies should be deemed per se illegitimate or harmful. Instead, it means traders should recognize and incorporate into their strategies (and algorithms) the observation that there is more to valuation than the direction stocks are moving.

C. Facilitative Strategies

The final category of HFT strategies can best be understood as facilitatory strategies—strategies that enable HFT to work. These strategies are most commonly understood and referred to as "market making" strategies.[115] In order to trade, there must be someone to trade with. The reason why trades can happen at such fast speeds is that there are entities, "market makers," that are willing to buy and sell the same security at any given time.[116] The more a market maker is willing to buy or sell, the faster a transaction can take place. This benefits the HFT environment in several important ways. Perhaps most importantly, it makes it more difficult for unfair HFT strategies to gain traction. Suppose there was a market maker that could support any order, no matter how large. If this were the case, intercepting an order before it reaches the market would do little good. It would be impossible to front-run the order, because it would not be possible to buy all the available shares of a stock at the desired price. Moreover, because the market maker would be able to fill the entire order, traders would not need to split orders into smaller chunks, nor would they need to submit orders to multiple exchanges. Analysts refer to the ability to make trades quickly, easily, and without impact on the market as "market liquidity."[117] Generally, liquid markets are good because they facilitate trades and increase market confidence.[118]

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115. *See* Leis, *supra* note 12, at 21 (describing "market making" as a common strategy employed by HFTs).

116. *See id.* at 4 (defining market makers and explaining how market makers constantly provide both bid and ask prices).

117. Haldane, *supra* note 17, at 7; Leis *supra* note 12, at 26; *see* Korsmo, *supra* note 22, at 535.

118. *E.g.*, *What's Liquidity and Why Do We Need It?*, BLOOMBERGVIEW (Sept. 5, 2013, 6:00 PM), http://www.bloombergview.com/articles/2013-09-05/what-s-liquidity-and-why-do-we-need-it-; Jones, *supra* note 20, at 1; Jim Mueller, *Understanding Financial Liquidity*, INVESTOPEDIA, http://www.investopedia.com/articles/basics/07/liquidity.asp (last visited Nov. 23, 2014).

Several studies have found that HFT increases market liquidity.[119] But this statement is a bit misleading. The more apt statement is that HFT increases market liquidity *for high frequency trading*. That is to say, because of high frequency market makers, there is enough liquidity in the market for traders to execute their HFT strategies.[120]

Of course, one could argue that this greater liquidity also benefits LFT. If there is a lot of liquidity available in arbitrarily small units of time, then there should be more than enough liquidity available at lower frequencies and in lower quantities. Unfortunately, the reality of HFT, at least as it works now, is that LFT traders cannot take advantage of this additional liquidity because they are too slow to respond to the market.[121] While market makers add liquidity, they do not add infinite liquidity: Market makers are willing to buy or sell only so many shares of any given stock.[122] The result is that there is enough liquidity for HFT traders, but not enough for LFT traders. As described above, if an LFT order is of any sizable quantity, the order will be intercepted, front-run, and wave-ridden.[123] As one study concluded, "in capturing some of the non-HFT's information rent, the HFT reduces the non-HFT's profits."[124] The result is that in order to take advantage of the added liquidity, one has to employ HFT strategies. In a sense, this creates a two-tiered market system.

Thus far, my account of liquidity is missing an important piece of the puzzle. On its face, there is a fair amount of risk associated with being a market maker: In order to satisfy market buy-and-sell orders, market makers must have a large enough supply of each share to satisfy market demand. This requirement can be problematic. If a market maker has too many shares, it is possible that its supply will exceed demand, leaving the market maker with shares it is unable to sell. Likewise, if the maker has too few shares and demand exceeds supply, then it will lose out on future profits.[125]

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119. Jones, *supra* note 20, at 1–2 ("Over the past ten years, HFT has increased sharply, and liquidity has steadily improved. . . . [T]he results in these papers are consistent. Every time there has been a market structure change that results in more HFT, liquidity and overall market quality have improved.").

120. *Id.* at 1.

121. Cvitanić & Kirilenko, *supra* note 34, at 1, 3 (noting that high frequency trading makes "positive expected profits by 'sniping' out human orders").

122. *See* Hirschey, *supra* note 58, at 16–17 (stating that market makers profit most from non-marketable orders and try to minimize the inventory risk associated with marketable orders).

123. *Id.* at 1.

124. *Id.*

125. *See* Haldane, *supra* note 17, at 7 (explaining that market makers bear the risk of changes to supply and demand).

In light of the risks associated with market making, it is worth considering what motivates institutions and financial entities to step in and play the role of market maker. There are three answers to this question. First, market makers earn a small profit from each trade.[126] Because market makers are the entities accepting buy-and-sell orders, they get to set the terms of the trade—they are able to dictate the amount at which they are willing to buy or sell a share. In order to compensate for the risks associated with market making, market makers typically introduce a gap between the amount at which they would buy and the amount at which they would sell a stock.[127] This is commonly referred to as the bid-ask spread.[128] For example, if a market maker agreed to buy a stock for $5 and to sell the stock for $5.05, the stock would have a bid-ask spread of $0.05—the market maker would earn $0.05 from each transaction. Generally speaking, the more risk involved in serving as a market maker, the larger the bid-ask spread, and the more a market maker earns by providing liquidity.[129] It is worth acknowledging that there are several market makers in the market at a time, creating an environment where bid-ask spreads are themselves subject to competition.[130] Therefore, if one market maker offers a lower spread, that maker will be able to satisfy more orders and thus earn more money.[131] One of the benefits cited by proponents of HFT is a more competitive environment for market makers.[132] And this makes sense. With more frequent trades, the possibility that a market maker will be "stuck" with extra shares is considerably reduced. This means the cost of trading in the high frequency context is lower than the cost of trading in the low frequency context.[133]

Stock exchanges themselves provide the second incentive for market makers. To encourage market-making activity and increase liquidity in their markets, many exchanges provide a small trade rebate to traders that supply liquidity.[134] While each rebate is quite small on its own, the rebates add up

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126. *Id.*

127. *Id.*

128. *Id.* (citation omitted) ("The market-maker earns a bid-ask spread to protect against . . . risk.").

129. *Id.*

130. Korsmo, *supra* note 22, at 549.

131. *Id.* at 549–50 ("HFTs have brought intense competition and superior technology to market making, reducing . . . costs dramatically.").

132. *Id.*

133. *Id.* at 550.

134. *Id.* at 544; Leis, *supra* note 12, at 22.

in the context of HFT, where rebates from many thousands of trades can cumulate.[135]

The final benefit for market makers is faster and better access to markets. Because market makers facilitate buy-and-sell transactions for many securities, they are uniquely positioned to quickly and effectively stake out a position for themselves with respect to any stock or group of stocks. For example, if a market maker has reason to believe that a given stock's price is increasing, or will soon increase, it can make considerable profit by upping the price at which it will sell the stock, or by electing not to sell as many shares as it would in the absence of an anticipated price increase. Likewise, a market maker could avoid considerable loss by withdrawing liquidity from the market if it determines that the value of a stock is likely to decrease or is actually decreasing. When trading becomes risky, market makers can protect their assets by taking off their market-maker hat and putting on their market-participant hat. Indeed, this is what happened during the Flash Crash.[136] High frequency traders who normally functioned as market makers accurately observed that prices were decreasing and changed their strategy so as to offload (sell) as many of their assets as possible. They "aggressively [took] liquidity from the market when prices were about to change."[137] By taking liquidity from the market, these former market makers made it more difficult for other traders (many of whom were market makers themselves) to offload *their* shares, causing share prices to drop even faster.[138]

A similar, but related problem demonstrated by the Flash Crash is the tendency of market makers to overestimate the total amount of liquidity in the market.[139] To see how this happens, consider three market makers, *A*, *B*, and *C*. Suppose each market maker owns twenty shares of *XYZ* and is

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135. *See, e.g.*, Korsmo, *supra* note 22, at 544 (stating that in 2009 NASDAQ paid nearly $1.4 billion in market maker rebates).

136. *See, e.g.*, Andrei Kirilenko et al., The Flash Crash: The Impact of High Frequency Trading on an Electronic Market 26 (May 5, 2014) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1686004 [hereinafter Kirilenko et al., May 2014] (explaining that HFTs exacerbated the Flash Crash and contributed to the downward price move by "aggressively" selling off their last few contracts at best bid levels so that they could establish new best bid levels).

137. Andrei Kirilenko et al., The Flash Crash: The Impact of High Frequency Trading on an Electronic Market 4 (Jan. 12, 2011) [hereinafter Kirilenko et al., Jan. 2011] (unpublished manuscript), *available at* http://www.ftm.nl/wp-content/uploads/content/files/Onderzoek%20Flash%20Crash.pdf).

138. Jones, *supra* note 20, at 36–37 (describing numerous empirical studies verifying this conclusion).

139. *See, e.g.*, Kirilenko et al., Jan. 2011, *supra* note 137, at 16 (noting that in the days leading up to the Flash Crash executable order sizes of "Fundamental Sellers" were more than twice that of "Fundamental Buyers").

willing to sell these shares to any interested buyer. When determining how many shares it has to sell, each market maker considers not just the shares it owns, but also the shares it could purchase if demand were sufficient. *A*, viewing the standing orders placed by *B* and *C*, sees that each is willing to sell twenty shares. In light of this information, *A* decides it can fill orders of up to sixty shares—*A* owns twenty shares directly, and if necessary, it can purchase forty shares from *B* and *C*. If the scenario stopped here, everything would be fine. However, *B* and *C* are also monitoring the orders placed by *A* (we are not operating in a dark pool, so all orders are public). Recognizing that *A* can obtain sixty shares, *B* updates its order to indicate that it can supply *100* shares—*B* owns twenty shares directly, and if necessary, it can purchase sixty shares from *A* and twenty shares from *C*. The problem is that by incorporating the inventory of other market makers, *A*, *B*, and *C* collectively created liquidity out of thin air. So what happens if a buyer attempts to purchase eighty shares from *B*? *B* would fill the order by attempting to purchase sixty shares from *A*. *A*, in turn, would attempt to purchase twenty shares from *B* and twenty shares from *C*. Of course, this would not work because by this point, *B*, having filled its order, would have withdrawn its offer from the exchange. Suddenly, a scenario that *seemed* to contain an excess of liquidity would collapse into a stalled market.

The above hypothetical is a simplified version of what happened during the Flash Crash. Several market makers improperly evaluated the amount of liquidity in the market.[140] The result was that when a number of traders attempted to sell a share that was quickly dropping in value, the apparent liquidity evaporated and each of the market makers was left playing a game of futures hot-potato—rapidly buying and selling contracts to and from one another many times.[141]

In response to these problems, some observers have proposed imposing special obligations on market makers that would require them to provide liquidity during times of financial difficulty.[142] As was the case with circuit breakers, this solution seems to go about solving the problem in the wrong way. Rather than imposing obligations on market makers *after* liquidity has dried up, market makers should amend their strategy to properly account for actual liquidity in the market. This means market makers should avoid

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140. Leis, *supra* note 12, at 64.

141. Kirilenko et al., May 2014, *supra* note 136, at 16; Leis, *supra* note 12, at 61.

142. Concept Release on Equity Market Structure, *supra* note 14, at 3607 & n.70; *see* Amber Anand et al., *Paying for Market Quality* (Fin. Res. Grp., Working Paper F-2006-06, 2005), *available at* http://www.hha.dk/bs/wp/fin/F_2006_06.pdf (suggesting contractual obligations for market makers to provide improvement in liquidity).

folding other traders' capacities into their own. If market makers only offer orders they can actually fill, liquidity shortfalls would not be nearly as harmful or unexpected. This idea is explored in further detail in Part II.

II. High Frequency Regulation as a Solution to High Frequency Trading

At its core, high frequency trading makes some important contributions to the market. By adding liquidity and lowering transaction costs, HFT encourages trade and creates a more efficient market place. But these benefits come with a price. HFT creates information asymmetries that encourage unfair trading practices and undermine market stability. HFT also drives a wedge between the price of stocks and the value of their corresponding assets. Moreover, many of the benefits of HFT seem self-serving—most or all of the increased liquidity and decreased transaction costs come at the expense of LFT traders. In this sense, many of the arguments in favor of HFT seem circular: HFT is good because it increases liquidity for HFT.

This creates something of a difficult problem for regulators: How can we keep the benefits of HFT while avoiding the harms? A useful starting point might be to recognize that many of the problems discussed in this Article are not unique to HFT.[143] Indeed, some believe that all of the problems with HFT can be found, in some form or another, in algorithmic trading generally and, to a lesser extent, in traditional paper trading.[144] What makes HFT exceptional is the speed at which it interacts with the market. The speed of HFT makes it difficult to address problems head-on because categories and distinctions that are clear in a slow context become fuzzy and indeterminate at high speeds.

In this Part, I expand on the analysis from Part I and explain some of the difficulties regulators have experienced in their attempts to regulate HFT. I then introduce the concept of high frequency regulation (HFR) as a means of solving these difficulties. The motivating idea behind HFR is that regulation in the HFT context should be preventative rather than ameliorative. Instead of waiting for a market disaster, regulators should respond to irresponsible trading practices in real time. HFR would match speed against speed. Regulators would use computer systems to monitor the

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143. Korsmo, *supra* note 22, at 551.

144. *See generally id.* at 553–57 (giving an historical account of market manipulation and stating that HFT forms of manipulation are "simply a technologically augmented version of one of the classic forms of market manipulation").

market in the same way that traders do, but rather than scanning the market for price patterns and profit opportunities, HFR systems would look for manipulative trading practices, market feedback loops, and liquidity crunches. Once an HFR system identifies these problems, it would immediately and automatically respond by altering market rules to prevent any serious harm and to discourage market manipulators from pursuing irresponsible trading strategies.

High frequency regulation is not intended to be a one-size-fits-all solution. I leave open the possibility that traditional, static, rule-based regulations might be the best response (or part of the best response) for some improper trading practices. At the same time, I hope to show that there are distinct benefits that come with the ability to respond flexibly and dynamically to abusive or irresponsible strategies as they appear. After all, HFT traders update their algorithms weekly, if not daily.[145] It makes sense, then, that regulatory strategies should be able to keep up. A faster mouse deserves a faster mouse trap.

The regulatory problems created by HFT fall into three categories: discovery, evaluation, and response. Roughly speaking, discovery refers to the ability of regulators to reconstruct trading behavior—to figure out who traded what, to whom, and when. Evaluation refers to the act or process of matching trading behavior with trading strategies. Finally, response refers to the actions a regulator can take in response to observed and matched trading activities. In this Part, I explore each of these categories and show how HFR can solve these regulatory problems.

A. Regulatory Discovery: Reconstructing the Audit Trail

1. Difficulties

Perhaps the largest problem facing HFT regulators is the task of reconstructing trades. HFT traders place thousands of orders every second. These orders are placed in markets across the country and world. Some of these markets are public and some are private. Moreover, some keep order information confidential (dark pools), while others publish all orders they receive.

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145. Richard Finger, *High Frequency Trading: Is It a Dark Force Against Ordinary Human Traders and Investors?*, FORBES (Sept. 30, 2013, 8:41 AM), http://www.forbes.com/sites/richardfinger/2013/09/30/high-frequency-trading-is-it-a-dark-force-against-ordinary-human-traders-and-investors.

Regulators must sometimes revisit trades in order to determine what caused negative market events (such as the Flash Crash) or whether traders acted inappropriately. While exchanges keep a log of the orders and trades they receive and are sometimes required to report executed orders, there are several reasons regulators might have a hard time piecing together trading activity.

The first reason reconstructing trade activity can be difficult is the sheer volume of activity. As indicated above, thousands of orders are placed every second. If regulators are interested in revisiting trades that took place over the span of just a few minutes, they would have to comb through data relating to millions of trades. On the NASDAQ alone in June 2010, there were about one billion orders placed every day—amounting to thirteen gigabytes of order-level data.[146] Volume problems are made even more difficult by the fact that most HFT strategies involve a large order-trade ratio,[147] meaning most of the data given to regulators is useless—the hay in the proverbial hay stack. Moreover, quote-stuffing strategies, which are predicated on making junk orders seem like real ones, might also make it difficult for regulators to find the trades they are looking for. This problem has played out in the real world. Following the Flash Crash in 2010, it took regulators *months* to *partially* reconstruct just a few minutes of trade activity from the day of the crash.[148] The difficulties regulators experience reconstructing just a few minutes of trading activity suggest that the notion of a more comprehensive, longitudinal survey of trading activities, of the type seen in other fields,[149] is laughably unrealistic.

The second reason reconstructing trade activity can be difficult is that trading is not limited to a single location. Because many HFT strategies involve arbitrage and cross-applications of trading data, it is not possible to gain a complete understanding or record of trading activity without consolidating information from multiple sources. This task is made particularly difficult by the fact that many exchanges are international and are not obliged to cooperate with United States regulators. Further,

146. Jones, *supra* note 20, at 45.

147. Korsmo, *supra* note 22, at 574–75.

148. *Id.* at 600; Kaufman & Levin, *supra* note 24.

149. *See generally* U.S. DEP'T TRANSP., LONGITUDINAL STUDY OF ITS IMPLEMENTATION: DECISION FACTORS AND EFFECTS (2013), *available at* http://www.its.dot.gov/research/pdf/longitudinal_study.pdf (describing a longitudinal study of transportation technologies); Alexander Gaffney, *FDA Wants to Leverage Electronic Medical Records to Probe for Adverse Events*, REGULATORY AFFAIRS PROF'L SOC'Y (Jan. 6, 2014), http://www.raps.org/focus-online/news/news-article-view/article/4449/fda-wants-to-leverage-electronic-medical-records-to-probe-for-adverse-events.aspx (describing a comprehensive, longitudinal study by the FDA of drug research).

exchanges collect and organize their data differently, such that if they *do* agree to cooperate, there are still significant costs associated with data collection and management.

The final reason reconstructing trade activity can be difficult is that at least some markets collect only censored data. Recall that dark pools only publish orders once those orders have been matched.[150] In keeping with this limited information mindset, dark pools are subject to less stringent disclosure requirements.[151] This means it is incredibly difficult, if not impossible, for regulators to obtain a complete picture of trading activity even if they know when, where, and how to look. What was once a small needle in a large haystack is now an *invisible* needle in an even larger haystack.

To solve the problem of trade reconstruction, the SEC has proposed a consolidated audit trail—an automated system that would collect market data in real time from a variety of exchanges.[152] While such an initiative shows promise, it misses an essential piece of the puzzle. Even if regulators had access to market data, they would still have to wade through inordinately large volumes of censored, mostly irrelevant information. This does not mean a consolidated audit trail is bad, but rather that regulators should supplement the audit trail with a real time monitoring system so that they can analyze and respond to market data as it is collected.

2. The High Frequency Solution

High frequency regulation solves the audit trail problem by changing the objective. Rather than reconstructing trades, HFR would attempt to monitor the market in real time. By using some of the same tools as HFT traders, regulators can monitor trading activities across different securities and different markets. The creation of sophisticated regulatory algorithms would make the HFR monitoring system possible. These algorithms would scan the market for improper or anomalous trading behavior in the same way that HFT algorithms scan the market for trading opportunities. In essence, HFR would build on the consolidated audit trail by backing up data *collection* with data *monitoring*. Interestingly, NASDAQ has already

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150. *See supra* notes 106–07 and accompanying text.

151. *See* Korsmo, *supra* note 22, at 534 (stating that dark pools do not have to make their limit order books public); Matthew Phillips, *Where Has All the Stock Trading Gone?*, BLOOMBERG BUS. WK. (May 10, 2012), http://www.businessweek.com/articles/2012-05-10/where-has-all-the-stock-trading-gone ("Public exchanges are subject to more regulatory requirements than dark pools are.").

152. Korsmo, *supra* note 22, at 599–600.

attempted to implement an HFR-type solution to the market monitoring problem. For several years, NASDAQ has operated MarketWatch, which "monitors compliance with Exchange rules and policies through real-time surveillance of price and volume information."[153] While MarketWatch is far from perfect,[154] the existence of an automated surveillance system (even one as seemingly rudimentary as MarketWatch) seems to suggest that HFR is a step in the right direction.

3. A Few Wrinkles

There are a few wrinkles with HFR monitoring worth discussing. First, in order for a monitoring system to function, it would need access to a considerable amount of information that is currently non-disclosed. Specifically, it would need access to orders placed in dark pools and in international markets. This information is essential. If an HFR algorithm only monitored public or domestic markets, market manipulators would be able to use information obtained in public or domestic markets to exploit private or foreign markets. For example, a trader could use flash order data from markets in the United States to reverse-engineer a trading strategy and front-run orders on the London Stock Exchange. Similarly, a trader could use flash order data from a foreign exchange to front-run orders placed in a United States market. So long as information is incomplete, HFR strategies will also be incomplete. Unfortunately, this problem has no easy solution. While Congress and the SEC can change disclosure requirements in the United States, regulators likely would not be able to obtain the desired information from foreign sources without a trade agreement or treaty.

The second problem with HFR monitoring protocols (and with HFR in general) is one of resources. Creating the infrastructure for an HFR system would be expensive. According to one estimate, the creation of a consolidated audit trail, which might form the backbone of an HFR system,

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153. *Market Watch*, NASDAQTRADER.COM, http://www.nasdaqtrader.com/Trader.aspx?id=MarketWatch (last visited Nov. 26, 2014).

154. Unfortunately, NASDAQ has not divulged much information about its MarketWatch system. However, MarketWatch was online during the 2010 Flash Crash, and while MarketWatch technicians identified irregularities in the market as they took place, Matt Phillips, *Nasdaq: Here's Our Timeline of the Flash Crash*, WALL ST. J. BLOGS (May 11, 2010, 12:34 PM), http://blogs.wsj.com/marketbeat/2010/05/11/nasdaq-heres-our-timeline-of-the-flash-crash, it still took auditors several months to reconstruct trading activity and to identify the cause of the crash. *See supra* note 148 and accompanying text. This suggests that MarketWatch, in its current form, is not terribly robust.

would cost over $4 billion.[155] Perhaps more problematic is that such a system would require significant investments in human capital. If HFR algorithms and systems are to be competitive—if they are to keep traders in check—they must be crafted with the same level of intensity and rigor as HFT algorithms. This means that it is essential for HFR engineers to be as talented as their HFT counterparts, if not more so.[156] As it stands, software engineers working for large banks and investment firms earn significantly more money than any other type of software engineer.[157] It is unlikely that government salaries would be able to keep up.

There are a few potential solutions to this problem. The first solution would be to outsource some of the engineering and infrastructure building to financial institutions. There are a number of banks and trading companies that are skeptical of or opposed to HFT.[158] These companies have the resources and motivation to create an HFR system that could keep their competitors in check. While regulators would need to work closely with any private actors to avoid complete regulatory capture or conflicts of interest, enlisting help from external, interested parties would be an effective way to solve the human capital problem. Indeed, some scholars have found that cooperation with industry representatives can be beneficial when it comes to monitoring computer activity.[159] Alternatively, the government could recognize that talented engineers are in high demand and agree to pay competitive market rates to attract such engineers.

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155. Bonnie Kavoussi, *SEC May Monitor High-Frequency Trading With Consolidated Audit Trail*, HUFFINGTON POST (Oct. 10, 2011, 1:34 PM), http://www.huffingtonpost.com/2011/10/10/sec-high-frequency-trading_n_987378.html.

156. It might turn out that it is much easier to create market regulating algorithms than it is to create trading algorithms. If so, then this problem will likely disappear. Because we do not yet know exactly how HFT and HFR algorithms will interact, it would be wise to proceed with caution and find the best talent possible.

157. Dave Mandl, *So You Wanna Be a Wall Street Techie? Or Anyway, Get Paid a Lot*, THE REGISTER (June 19, 2012), http://www.theregister.co.uk/2012/06/19/working_on_wall_street.

158. *See, e.g.*, Paul, *supra* note 82 (explaining that the financial industry defended HFT until it realized the "enormous damage" it had done to market integrity); Schwab, *supra* note 83 ("[H]igh-frequency trading has run amok and is corrupting our capital market system . . . ."); *cf.* Concept Release on Equity Market Structure, *supra* note 14, at 3604 (suggesting that long-term investors have different interests than high frequency traders).

159. *See generally* David Thaw, *Enlightened Regulatory Capture*, 89 WASH. L. REV. 329 (2014) (discussing how regulatory capture enabled regulators to "harness private expertise" to advance exclusively public goals).

B. Evaluation

The ability to monitor the market and determine what types of trades are taking place is important, but monitoring and observation are not enough. In order to have an effective system, regulators must also be able to *evaluate* trading behavior. That is, they must have the ability to identify patterns in observed trading behavior and determine whether a trade or series of trades reflects an illegal, impermissible, or harmful trading strategy.

1. Difficulties

Evaluation is difficult for two reasons. First, while regulators understand what manipulative trading strategies look like in the context of LFT, it is not clear how traditional descriptions and understandings of manipulative practices extend to HFT. We can call this a definitional difficulty. Second, the speed and automation of HFT make it difficult to establish essential facts—most notably, facts related to culpability and motivation. We can call this a factual difficulty.

To further understand these difficulties, consider front-running. Recall that front-running can be described as the illegal practice of trading a security while in possession of non-public information concerning an upcoming transaction in the same or a related security.[160] Under this definition, to demonstrate that a trader employed an illegal front-running strategy, one must establish two facts: access to non-public information, and improper action based on that information. Both elements are considerably more difficult to establish in the high frequency context: the first because of a definitional difficulty, and the second because of a factual difficulty. Let us consider each element in turn.

The first element of front-running is access to non-public information. In the LFT context, this element is straightforward—information is non-public if it "has not been disseminated in a manner which makes it generally available to the trading public through recognized channels of distribution."[161] In the context of HFT, however, this definition seems to break down. Is information public if one has to pay a fee for access (as is sometimes the case with flash orders)? What if information is accessible to everyone, but is only meaningful or useful if one has access to complex trading algorithms or a fast trading connection? What about information

160. *See supra* note 38 and accompanying text.

161. Markham, *supra* note 38, at 124.

that can only be gleaned by quickly stitching together data from a dozen different markets or exchanges?

The traditional understanding of "public" does not sufficiently capture the policy considerations that motivated front-running prohibitions. It is not enough for information to be "available" to the trading public—the information must also be *useful*. Information that is only actionable if one has access to ultra-fast, ultra-expensive connection speeds might be "public" under a formal definition. Functionally, however, it is not. The end result is that the phrase "non-public information" means very different things in LFT and HFT contexts. Nevertheless, the results—and the harms—are the same: A select few traders are able to see a trade coming and beat it to the market.

This problem is not limited to front-running. Analogous definitional difficulties arise in the context of market manipulation (How many orders are needed before we can say there has been an attempt to manipulate the market? Does the time interval between order placement matter? Can a cancelled order constitute an attempt to manipulate?); market-motivated strategies (How large of an initial price change or market movement is needed before we can be confident that a strategy is responding to these movements?); and market maker practices (What ratio of buy-sell orders must one have to qualify as a market maker? How do we evaluate provisions of liquidity during market bubbles or spirals?).

To understand what *factual* difficulties look like, consider the second element of front-running: improper action made on the basis of non-public information. Because high frequency trades take place on the order of milliseconds, computers and algorithms—all of which are confidential and proprietary—control all trading decisions. Moreover, sophisticated traders rarely restrict their trades to a single market. Instead, they spread their trading activity across multiple exchanges. The result is that, even with perfect information, it can be difficult, if not impossible, to determine why or how an algorithm made any given trading decision. The algorithm's decision to place an order might have been made on the basis of non-public information, or it might have been made on the basis of quarterly reports, natural language processing of a press release, or on any other number of public pieces of information. A related problem involves the issue of culpability. Because trades are conducted by autonomous computer algorithms, many of which make trading decisions without direct human input, it can be difficult to determine whether an irresponsible or illegal trade was made at the behest of a trader, or whether the trade was the result of a computer "bug" or software error. That is, traditional concepts of agency and liability do not apply cleanly at high speeds.

The point of this example is to show that the problems associated with HFT are exceptional. Even though many of the problems of HFT fall into the same *category* as LFT problems (e.g., front-running), the fact remains that our conception and identification of these problems differs significantly between high- and low- frequency settings.

2. The Solution

When it comes to applying LFT definitions in an HFT context, it appears that some level of flexibility is needed. Rather than analyzing market activities according to strict or formal definitions, HFR algorithms would search for patterns and trends that reflect the *effects* of certain market-related behavior. This will bear out differently for different trading practices.

As described in Part I, the concern over front-running is that trades will be intercepted and pre-empted (through flash orders or otherwise), or that trades will be reverse-engineered. An algorithm could detect these activities by monitoring the market for trading patterns: for instance, by searching for pairs of orders where one of the orders is placed first but executed second; or by searching for a series of orders where a small order from one trader is followed by a large order from another trader on the same, or a closely related, security. If some traders frequently pre-empt the orders of others, then it would likely be safe to classify them as front-runners.

We could adopt a similar approach to identify quote-stuffers. An algorithm could, for example, compare the order-trade ratio among various traders, as well as the content of the orders. If a trader has an anomalously high order-trade ratio, or if a trader places then cancels a large chunk of orders at the same time, an algorithm could identify the trader as a potential quote-stuffer. Scanning various exchanges for patterns that match a functional, effects-driven understanding of various trading practices would solve the problem by enabling an HFR system to properly evaluate all, or almost all, trading strategies.

A natural implication of this flexible, results-oriented strategy is that evaluations will be based more on objective trade practices than on intentionality or motivations. That is, a flexible HFR approach would constitute a good solution to definitional problems, but a rather poor solution to factual problems. On its face, this seems unsatisfactory: How can regulators take corrective or punitive action against traders if they cannot know whether a trader intended to front-run or manipulate the market? There are a few solutions to this problem.

First, even though HFR might not be able to ascertain culpability or intentionality with 100% certainty, a pronounced and repeated pattern provides strong circumstantial evidence that a trader agreed to the patterned strategy, or at the very least, that a trader was aware of the strategy. In this sense, even though HFR is not a perfect answer to factual problems, it can still function as a reasonable proxy. The second solution to this problem is to change the scope of corrective actions. Insofar as HFR regulators cannot be certain that a trade or series of trades constitutes an illegitimate or actionable trading strategy, the types of real time corrective actions should be restricted. For example, rather than suspending a trader's ability to trade, HFR should only be able to restrict the speed at which a trader is able to place orders. As I demonstrate in the next section, HFR systems could execute a variety of corrective actions. If reasonable doubts or uncertainties impact the evaluation step of the HFR process, the appropriate response might be to pass that uncertainty along to the corrective action step. Perhaps the strength of the corrective action could depend on the strength of the observed pattern. A weak pattern might justify sending a warning to the trader, while a strong pattern might trigger a more extensive, non-algorithmic human investigation. This possibility might make the most sense, as intentions and motivations are formed at human speeds and are best ascertained using traditional regulatory and investigatory techniques.

C. Response

What sets HFR apart from traditional market regulation is the speed at which HFR systems could respond to potential market problems. In recent years, several countries have implemented trading reforms to curb abusive HFT practices. For example, Germany recently passed a rule that imposes a fine on any trader who exceeds a maximum order-to-trade ratio.[162] Similarly, Italy and France have introduced a small tax on all HFT activities.[163] The EU has considered rules that would require all exchanges to hold incoming orders for around 0.5 seconds before execution.[164] The problem with these responses is that they are too slow and too broad. Taxes

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162. Tim Cave, *Germany Lays Out High-Frequency Trading Hurdles*, FIN. NEWS (June 12, 2013), http://www.efinancialnews.com/story/2013-06-12/germany-lays-out-high-frequency-trading-hurdles?ea9c8a2de0ee111045601ab04d673622.

163. Matt Clinch, *Italy Launches Tax on High-Frequency Trading Transactions*, CNBC (Sept. 2, 2013), http://www.cnbc.com/id/101002422.

164. Laurence Norman & Riva Froymovich, *EU Lawmakers Call for Enforced Delay on High-Frequency Trades*, WALL ST. J. (Sept. 26, 2012, 2:51 PM), http://online.wsj.com/news/articles/SB10000872396390443916104578020470662664506.

and holding periods might be appropriate in some instances, but applying them indiscriminately punishes all HFT traders for the irresponsible actions of a select few. And while maximum order-to-trade ratios can stop quote-stuffing strategies, the ratios imposed by the German plan are measured on a monthly basis,[165] which would allow traders to avoid punishment by counterbalancing abusive strategies with fair strategies.[166] Not all HFT strategies are the same, so not all HFT strategies should be subject to the same boundaries and limitations—what makes sense for a quote-stuffer might not make sense for a market maker or wave-rider. Likewise, evaluating HFT strategies on a monthly (or even daily or hourly) basis does little to discourage abusive practices on the millisecond level.

As it stands, the only *immediate* corrective actions in effect are "circuit breakers" that halt or limit trading on certain securities to within a narrow price range.[167] As argued above, the use of circuit breakers is an unsatisfactory solution. Circuit breakers respond to problems only *after* traders have lost control of the market. In order to ensure financial stability, regulators and exchanges should have the ability to intervene and take corrective action before trading gets out of hand.

Up until now, this Part has focused on the question of *when* HFR systems would intervene in the market. In this section, I introduce a variety of mechanisms and techniques HFR systems could use to determine *how* an HFR system should intervene. Specifically, I describe response mechanisms that would enable an HFR system to respond in real time to the observed trends, patterns, and practices of the market place.

At the outset, it is worth noting that in order for an HFR system to work, it would need to have considerable access to the market. Specifically, HFR systems would need to have control over nearly every aspect of trading, including: who can place orders, when orders can be placed, transaction fees, how orders are matched, when orders are published, to

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165. Cave, *supra* note 164.

166. For example, if the maximum order-trade ratio allowed were four, a trader could function with a ratio of six for the first week of the month, so long as he maintained a ratio of two for the remaining three weeks (holding equal the number of trades made).

167. *See supra* notes 113–14 and accompanying text. While many circuit breakers are fairly simplistic, there are at least some that operate under a complex set of instructions. For example, the Financial Services Agency in Japan recently used circuit breakers to implement a new "uptick rule" in Japanese markets. Chris Jenkins, *Revised Short-Selling Rules Commence in Japan*, THE TRADE (Nov. 5, 2013), http://www.thetradenews.com/news/Asset_Classes/Equities/Revised_short-selling_rules_commence_in_Japan.aspx. Specifically, Japan only applies the uptick rule to stocks that have lost 10% (or more) of their value in one day. *Id.* As with NASDAQ's MarketWatch, the implementation of more robust circuit breakers shows that there is room for greater complexity and nuance in the sphere of technology-based regulation.

whom orders are published, what information about orders is published, and so on. Control over these and similar trading elements is essential, as the HFR system will use these variables to respond to market shortcomings and encourage traders to act responsibly.

Next, I discuss four response mechanisms an HFR system might use to encourage fair and responsible trading practices: order bundling, speed control, information hiding, and order taxing.

1. Order Bundling

Order bundling is a trading option that, when available, would allow traders to submit multiple orders to one or more exchanges at the same time. If the orders are bundled, they would be matched and executed, but not published to the trading public until all orders in the bundle are filled or until a time threshold (the delay time) is satisfied, whichever comes sooner. Order bundling would prevent many instances of front-running. Let us consider how this would work. As discussed in Part I, traders wishing to execute a large order often split the order into smaller chunks to avoid moving the market until the order is completed. Predatory traders observe these smaller orders and use their speed advantage to trade ahead of the upcoming trade requests. Order bundling would prevent this behavior by allowing a trader to keep his order hidden until it is completed. This means a predatory trader would be unable to intercept and reverse-engineer an order until it is too late. In other words, order bundling would ensure that an order will not move the market until it *should* move the market. In doing so, order bundling can provide traders with a greater level of confidence and security that would allow them to trade without fear of front-runners.

As presented, this HFR mechanism is fairly simple, but given the complexity of high frequency and algorithmic trading, it is worth considering how the proposal could change depending on the state of the market. For example, it might not always be optimal to give traders the option to bundle their orders. In the abstract, a more transparent market with a free flow of information is preferable to a censored market. Accordingly, we would only want to hide information (to bundle orders) if there is a large enough risk that the absence of order bundling would lead to harm.

To determine whether traders should have the option to bundle their orders, we could create a sliding scale whereby the availability of the bundling option would depend on the number of shares in the bundle—the more shares in the bundle, the more likely it is the trade will move the market, and the greater the harm of a front-running incident. Of course, the stock at issue is also significant, as some stocks are more sensitive to price fluctuations than others. If we combine all of this information into a single metric, then the availability of a bundling option depends on the ratio between the size of the bundle (in shares, across multiple markets) and the rate at which the stock is normally traded. If the ratio (market deviance) is small—if a given trade or series of trades is not anomalously large relative to normal market operations—then there is no need to obscure the trade across several markets. Conversely, if the trade is significantly larger than most trades conducted in the market for the given stock, then it is reasonable to conclude that such a trade would raise eyebrows and spur front-runners to tag along. This, in turn, would justify a restriction on information until the trade is complete.

Other variables of this proposal could be dynamically tweaked in a similar fashion. Consider the delay time—the amount of time an exchange must wait before publishing an order that succeeded in only some of its desired marketplaces. This time interval can be set at a fixed number, or it can be set dynamically such that it could depend on the size of the filled order, the size of the unfilled order, the order's market deviance ratio, overall trade volume, or any other number of relevant variables. The complexity of this proposal provides a way for market regulators and exchanges to regulate HFT—in a manner that matches and takes into account the nuances of the market and the unique problems posed by HFT and information asymmetry. By creating and adopting a robust HFR algorithm, regulators could determine the conditions in which a bundling option is most helpful, and could allow traders to bundle their orders only when they satisfy those conditions.

2. Speed Control

One of the largest problems with HFT is the information asymmetry caused by disparities in connection speeds. HFR algorithms could eliminate these disparities by changing the way orders are processed. Rather than submitting an order to the matching engine as soon as the order is received, an HFR algorithm could impose a brief delay in order processing. During this delay, an HFR system would continue to receive orders, but would sort them based on the time the order was sent. Once the delay time had elapsed, all orders would be entered into the matching engine.[168] Another form of

168. It might help to consider this proposal in light of concepts from patent law. The current market is similar to a "first-to-file" system; orders are matched as soon as they are received. A time delayed system would function more like a "first-to-invent" system, in which orders are matched in the

speed control would attempt to level the playing field for *outgoing* information. As it stands, traders located closer to exchanges receive information faster than those located farther away.[169] Functionally, this provides these traders with a speed advantage since they receive (and can process) information sooner than their competitors. An HFR algorithm could neutralize this speed advantage by measuring the amount of time it takes for a message from an exchange to reach each of the servers to which it is connected. It can then stagger the rate of its outgoing communications such that many (if not all) of its participants would receive trade data at the same time.

Just as with order bundling, speed controls can be implemented in whole or in part for some stocks but not others, and for some traders but not others. Speed delays for incoming orders can be large or small depending on market volatility, recent trading patterns, or the quantity of trades seen in the market or on a given share. Similarly, speed delays for outgoing information can be adjusted to allow *all* market participants to receive information simultaneously, or to ensure that no trader receives trade information sooner than *X*% of other participants.

Unlike order bundling, speed controls are relevant for virtually every trading worry or concern. Synchronizing orders would prevent front-running, but it would also slow orders down, making it possible for traders to sift through junk orders in response to a quote-stuffing strategy. Similarly, if the market finds itself in a feedback loop, slowing trade rates can solve the problem by providing HFT algorithms with more time to analyze or assess the market. Normatively, speed controls for both incoming orders and outgoing data make the markets fairer by eliminating or limiting the speed advantage many participants currently enjoy.

Finally, as was the case with order bundling, an HFR algorithm would determine the *exact* policies implemented by an HFR system and would likely change dynamically over time as market conditions required. This is what sets apart HFR speed control from the one-size-fits-all speed controls proposed by the EU.[170] The point of introducing the mechanism is not to advocate for a type of regulation, but rather to show the types of changes an HFR system could make to the market and explain how some of those changes might impact the market.

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order they are placed. As with patents, a first-to-file system place more emphasis on communication speeds, while a first-to-invent system places more emphasis on information processing and innovation.

169. *E.g.*, Korsmo, *supra* note 22, at 563.

170. *See* Norman & Froymovich*, supra* note 166.

3. Information Hiding

Information hiding would allow an HFR system to hide order information from traders until after those orders are executed. We saw a specific instance of information hiding in the discussion of order bundling.[171] Information hiding would functionally create partial dark pools of liquidity in the marketplace. The purpose of information hiding would be to reduce manipulative trading activities and decrease the possibility of market feedback loops. It is not difficult to see how information hiding would reduce manipulative practices. Because orders would only be published upon execution, it would no longer be possible to influence traders by placing then deleting orders. Similarly, quote-stuffing would not bog down traders' processing power because traders would never see the junk orders.

The effect of information hiding on market feedback loops is a bit more complicated. Recall that an arithmetic error can sometimes cause liquidity problems when market makers incorporate each other's liquidity estimates into their standing orders, and thus double count the shares available to buy or sell.[172] Blocking market makers from observing the inventory of other market participants prevents such double counting. This means the market would have an accurate sense of available liquidity and would act accordingly, avoiding the conditions that led to the 2010 Flash Crash.

Once again, information hiding can be dynamic. An HFR system could elect to hide certain information from certain market actors. For example, a system might prevent market makers from seeing each other's standing orders. Similarly, a system might restrict information relating to volatile stocks or traders who have recently been placed on notice for manipulating the market.

4. Order Taxing

The final HFR mechanism I will discuss is order taxing. Many scholars have suggested that the best response to HFT would be to impose a small tax on each order.[173] The motivating idea is that a tax would discourage

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171. Information hiding, on the other hand, is more general. The general practice of information hiding can be used to hide information about specific stocks, singular orders, or specific market actors.

172. *See supra* Part I.C.

173. *See, e.g.*, Steve Matthews, *Stiglitz Calls High-Speed Trading "Front Running," Suggests Tax*, BLOOMBERG (Apr. 15, 2014), http://www.bloomberg.com/news/2014-04-15/stiglitz-calls-high-

frivolous orders and encourage traders to base their trades on stock value rather than HFT gimmicks.[174] While a tax on *every* HFT order would functionally amount to an HFT prohibition[175] that does not mean there is no room for tax. Instead, it means taxes should be applied selectively as a means of penalizing improper or irresponsible trading behavior.

For example, an HFR system could impose an order cancellation tax on any order placed by a trader with an anomalously high order-trade ratio. The system could also tax orders that constitute a reversal of a recently adopted trading position. For instance, if a trader placed a long order on a stock, cancelled the order, then placed a short order on the same stock. Taxes of this nature would reflect the idea that such trading behavior is per se illegitimate and that it should be more difficult for traders to profit from this type of behavior.

D. Objections to High Frequency Regulation

1. Creation and Implementation

There are three additional problems related to HFR that are worth discussing. The first major problem involves the creation and implementation of an HFR system. As indicated above, to be effective, an HFR system must have access to information at almost every exchange in the world. Further, to regulate effectively, it needs to have system level control of all major exchanges in the United States. Simply put, this amount of regulatory control over the market is unprecedented. Some might argue that such a system would cede too much power to the SEC. There are three responses to this objection.

First, an HFR system need not be implemented by the SEC. Stock markets and exchanges have an interest in ensuring market integrity. The more reliable and robust the market, the more people will be willing to trade. And the more trades there are, the more an exchange can collect through transaction costs and market fees. In light of these benefits, there is no reason why the various exchanges cannot coordinate to develop an HFR

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speed-trading-front-running-suggests-tax.html; Nelson D. Schwartz, *'Flash Boys' Fuels More Calls for a Tax on Trading*, N.Y. TIMES (Apr. 7, 2014), http://www.nytimes.com/2014/04/08/business/argument-for-financial-transaction-tax-regains-footing.html.

174. Schwartz, *supra* note 173; Matthews, *supra* note 173.

175. Lee Sheppard, *A Tax to Kill High Frequency Trading*, FORBES (Oct. 16, 2012, 12:08 PM), http://www.forbes.com/sites/leesheppard/2012/10/16/a-tax-to-kill-high-frequency-trading/4 ("A low-rate [tax] could kill off HFT quickly and easily by wiping out HFT's thin profit margins.").

system on their own. As an added benefit, self-regulation would likely be an effective way to *minimize* SEC involvement or oversight.

Second, an HFR system need not take any direct control out of the hands of exchanges. Because exchanges already work closely with the SEC, there is no reason an HFR system cannot be administered by the exchanges themselves subject to oversight from the SEC. The SEC already has a similar relationship with exchanges with respect to circuit breakers: Regulations mandate that when certain conditions are met, such as when prices change too quickly, exchanges must stop or restrict trading.[176] Even though the market "kill switch" is controlled by the exchanges themselves, the SEC is nevertheless responsible for the creation of the switch.[177] HFR systems could follow a similar model. Exchanges would be required to integrate HFR capabilities into their systems and use those capabilities in accordance with certain rules and regulations. Viewed in this light, my proposal is much less radical than it may seem at first.

Finally, an HFR system would not fundamentally change or expand the scope of the SEC's powers. As it stands, the SEC can and does have the power to control the manner in which trades are conducted. Specifically, the SEC has the power to issue fines and impose penalties,[178] limit trading activities,[179] create disclosure requirements,[180] and take other corrective steps to create a healthy and productive market.[181] These pre-existing powers show that HFR would not constitute an expansion of the SEC's powers, but would instead qualify as a much-needed change in the way the SEC executes its powers.

2. Regulation Transparency

The second problem related to HFR is regulation transparency. Because an HFR system would change market rules quickly and

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176. *Investor Bulletin*, *supra* note 113.

177. *Id.*

178. *See, e.g.*, Press Release, Sec. & Exch. Comm'n, SEC's Enforcement Program Continues to Show Strong Results in Safeguarding Investors and Markets (Nov. 14, 2012), http://www.sec.gov/News/PressRelease/Detail/PressRelease/1365171485830#.U54JfvldUmN (describing recent SEC action in obtaining "disgorgement, penalties, and other monetary relief" related to the financial crisis).

179. *E.g.*, *Investor Bulletin*, *supra* note 113.

180. *The Investor's Advocate: How the SEC Protects Investors, Maintains Market Integrity, and Facilitates Capital Formation*, SEC. & EXCH. COMM'N, http://www.sec.gov/about/whatwedo.shtml (last visited Nov. 26, 2014) (describing how the SEC creates disclosure requirements to promote sound investment decisions).

181. *See id.* (explaining how the SEC has the power to create, implement, and enforce market rules).

dynamically, and because its rule changes will often be asymmetric, traders might not know what market rules and restrictions will be in effect at any point in the future. As one might expect, this has the potential to throw a wrench in trading activity. As a simple example, consider order bundling. Because order bundling would be available at some times and not others, it would be unclear to traders whether they should execute a desired trade or wait for regulatory conditions to improve. One could argue that this hesitance and uncertainty would harm the market, increase the cost of trading, and even leave open the possibility that traders might place certain orders to manipulate market regulations. This objection has considerable merit. However, there are good reasons why the harms it espouses likely would not come to pass.

Most notably, this objection ignores the fact that HFR mechanisms are activated to address specific risks. If the risks are no longer present, the mechanism would no longer be active. This means that for market participants who are not actively penalized by an HFR tactic (by way of a tax or a speed penalty), there is little to gain from waiting out an HFR protocol. As an example, consider order bundling. The purpose of order bundling is to prevent high frequency traders from intercepting or reverse-engineering orders. If the order bundling option were not available, that would mean the HFR system determined that orders likely would not be intercepted. The result is that the trader would have little to gain from bundling his order, and little to gain by waiting for the bundling option to become available.

A motivating idea behind HFR is that traders should be free to interact with the market without worrying about unfair or irresponsible trading behavior. To that end, traders who engage in unfair trading behavior would certainly want to take an HFR system into account, and structure their trades to avoid HFR penalties (whether that penalty comes in the form of a bundling option for one's competitors or a speed handicap). Likewise, traders who engage in responsible trading behaviors need not consider the HFR restrictions, as they function only to these traders' benefit. Viewed in this light, an HFR system would lead to an increase in market integrity and trader confidence.

An alternate response to this objection is that it is possible an HFR system could use a publicly disclosed deterministic algorithm to scan the market and take corrective action. A deterministic algorithm is an algorithm that responds the same way to any given set of inputs. This open-book approach would let traders know exactly what type of activities would trigger a change in trading rules, placing them in a good position to make decisions on the basis of current or future HFR settings. This would solve the transparency problem. All traders would know how the system worked and could decide for themselves, based on complete information, whether it was worth waiting for a rule change before placing an order. Of course, as indicated above, if the algorithm were properly constructed, there would be little to gain from any attempt to "wait out" an HFR rule.

3. Software Bugs

The final, and perhaps largest, problem related to HFR is that HFR algorithms might contain bugs that would threaten to destroy the market, or that could be used to exploit HFR rules. Given the broad control HFR systems would have over exchanges, the presence of a bug could have an immeasurably negative effect on the market. As with the previous objection, this argument has considerable merit. Once again however, the harms are likely overstated. There are two reasons. The first relates to the ways an HFR system interacts with the market. The mechanisms employed by an HFR system are, for the most part, defensive and conservative. They decrease risk by slowing the market down and reducing asymmetries. For this reason it is unlikely any bugs would lead to market devastation. Instead, the most likely errors would result in slower trading or false bundling. In this sense, the risk of a bug in an HFR system is analogous to the risk of a bug in the market's current circuit breaker systems—relatively small.

The second reason the possibility of an HFR software error should not prevent the adoption of an HFR system is that, all told, the risk of a bug in the current market place exceeds the risk of a bug in the HFR context. As it stands, there are thousands of HFT traders. Each trader has his own trading algorithm. Any one of these algorithms might have a software error, and any one of these errors could trigger a devastating market crash.[182] In light of this possibility, it makes sense to accept some risk if doing so would allow us to decrease the overall likelihood of a market collapse. That is, relative to the current state of the market, an HFR system would likely decrease the net risk of a market disaster.

In sum, while there are a number of objections to HFR, it is clear the benefits of a robust and dynamic regulatory framework outweigh the risks and harms it might create.

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182. *Cf.* Leis, *supra* note 12, at 61 (explaining how a single trade triggered the Flash Crash).

CONCLUSION

Today's stock market is something of a wild world. With billions of trades taking place every day, the market has grown out of control. Unfortunately, regulators have not been able to keep up. As we have seen, the regulatory techniques and methods that worked in the low frequency context have proven ineffective at high speeds. The time has come for a fundamental change in the way we approach market regulation. HFR matches speed with speed. It enables regulators to monitor and respond to every trade in real time, eliminates the need for clumsy circuit breakers, and has the ability to restore fairness and integrity to the markets. Following the Paper Crunch of the 1960s, it was clear that Wall Street had a paper problem.[183] Today, it is just as clear that Wall Street has a computer problem. HFR is the solution to that problem.

183. *See supra* notes 1–11 and accompanying text.