Journal of Financial Economics 113 (2014) 156–169

Contents lists available at ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/jfec

A dynamic limit order market with fast and slow traders ☆

Peter Hoffmann

European Central Bank, Financial Research Division, Kaiserstrasse 29, D-60311 Frankfurt am Main, Germany

ARTICLE INFO

Article history:
Received 5 July 2012
Received in revised form
14 October 2013
Accepted 3 November 2013
Available online 16 April 2014

JEL classification:
G12
G19
C72

Keywords:
High-frequency trading
Limit order market

ABSTRACT

This paper considers the role of high-frequency trading in a dynamic limit order market. Fast traders' ability to revise their quotes quickly after news arrivals helps to reduce the inefficiency that is rooted in the risk of being picked off, which increases trade. However, their presence induces slow traders to strategically submit limit orders with a lower execution probability, thereby reducing trade. Because speed is a source of market power, it enables fast traders to extract rents from other market participants and triggers a costly arms race that reduces social welfare. The model generates a number of testable implications concerning the effects of high-frequency trading in limit order markets.

1. Introduction

High-frequency trading (HFT), a variant of algorithmic trading, relies on sophisticated computer programs for the implementation of trading strategies that involve a vast amount of orders in very small time intervals. The fact that market participants are spending considerable resources in an effort to gain speed advantages of a few milliseconds suggests that there are large payoffs to being faster than others (Financial Times, 2013). Accordingly, HFT has grown tremendously over the past decade and recent estimates suggest that it accounts for 70% of trading in US equities as well as 40% of spot foreign exchange volume (Reuters Newswire, 2013). This development has ignited a heated debate among financial economists, practitioners, and regulators about the benefits and concerns related to HFT. While its advocates argue that technology increases market efficiency through improved liquidity and price discovery, others claim that faster market participants use their speed advantage to extract rents and are a threat to market stability and integrity.[1]

This paper contributes to the debate by presenting a stylized model of trading in a limit order market where

☆ This paper is a substantially revised version of the second chapter of my doctoral dissertation at Universitat Pompeu Fabra. Financial support from the Generalitat de Catalunya is gratefully acknowledged. I would like to thank the editor, an anonymous referee, Álvaro Cartea, Jean-Edouard Colliard, Hans Degryse, Thierry Foucault, Başak Güneş, Roberto Pascual, Francisco Peñaranda, Augusto Rupérez Micola, and seminar and conference participants at the European Central Bank, the European Financial Management Association 2012 meetings in Barcelona, Spain, the 2012 Frontiers of Finance conference in Warwick, England, the Institut d'Economie Industrielle and NYSE Euronext conference on high-frequency trading, and the Recent Advances in Algorithmic and High-frequency Trading conference at University College London. All remaining errors are mine. The views expressed in this paper are mine and do not necessarily reflect those of the European Central Bank or the Eurosystem.
E-mail address: peter.hoffmann@ecb.int

http://dx.doi.org/10.1016/j.jfineco.2014.04.002

[1] See, e.g., the 2011 Optiver position paper, “High frequency trading”, http://fragmentation.fidessa.com/wp-content/uploads/High-Frequency-Trading-Optiver-Position-Paper.pdf; and Securities and Exchange Commission chairman Mary Schapiro's speech “Remarks before the Security Traders Association”, www.sec.gov/news/speech/2010/spch092210mls.htm.

agents differ in their trading speed, which is thought to capture the difference between (fast) high-frequency traders and (slow) human market participants. I build on the model of Foucault (1999), in which outstanding limit orders face the risk of becoming stale because they cannot be revised after the arrival of new value-relevant information. The resulting risk of being picked off gives rise to an inefficiency, because a high level of asset price volatility leads agents to choose limit orders with a low execution probability and, thus, reduces the likelihood that gains from trade are ultimately realized. I extend Foucault's model by endowing a proportion α of the trading crowd with a relative speed advantage that improves its ability to manage outstanding limit orders compared with the remaining market participants. More specifically, I assume that fast traders (FTs) are able to revise their limit orders after news arrivals, but only in case the next agent is a slow trader (ST).

I analyze the stationary equilibrium of this dynamic limit order market and compare it with the baseline case of identical traders studied by Foucault (1999). Overall, the presence of FTs has two opposing effects on the probability that gains from trade are shared. On the one hand, their ability to revise some of their quotes after news arrivals reduces the existing inefficiency due to the risk of being picked off and, therefore, increases trade. On the other hand, FTs' speed advantage creates a new inefficiency by inducing STs to strategically submit limit orders with a lower execution probability, which diminishes trade.

To understand this second effect, it is useful to interpret the limit order market as a sequential bargaining process, in which traders can either accept outstanding offers (via a market order) or make an offer to the next agent (via a limit order). As usual in these situations, agents' bargaining power is determined by their outside option, which here is given endogenously by the expected payoff earned from submitting a limit order. Now because they face a lower risk of being picked off, the alternative of posting quotes is relatively more attractive for FTs. This implies that they need to be offered a higher share of the surplus to be convinced to accept an existing offer by using a market order. This situation creates a dilemma for STs: They can either keep their chances of execution constant by increasing the aggressiveness of their limit orders to attract both STs and FTs or accept a decrease in execution probability by targeting only STs. While the value of their outside option decreases in either case, the latter choice (which is optimal if α is small) is socially inefficient as gains from trade are realized less often.

Aside from affecting trading volume and STs' limit order execution probabilities, the shift in market power between STs and FTs yields a number of additional testable implications concerning the effects of HFT in limit order markets. For example, one can show that FTs are more likely to act as makers than as takers in equilibrium and that their market orders execute at more favorable prices than those of STs. While FTs' limit orders face a reduced risk of being picked off, the risk of adverse selection simultaneously increases for STs. In addition, the presence of FTs pushes quotes closer to the asset's fundamental value if volatility is sufficiently high (the opposite holds for low volatility). These predictions are consistent with the growing body of empirical research on HFT.

Even though the presence of FTs can ultimately allow more gains from trade to be reaped, this increase in efficiency does not benefit STs because their reduced bargaining power ensures that they obtain a smaller share of the total surplus and are always worse off in equilibrium. This has important consequences for social welfare once one discards the assumption that speed is given exogenously and instead considers the possibility that agents become fast upon investing in trading technology at a fixed cost. Because STs and FTs must earn the same net profits in equilibrium, the equilibrium level of investment always leads to a social welfare loss compared with the benchmark situation with only STs. Consequently, policy interventions that aim at reducing the rents associated with being fast can improve upon the market outcome by preventing a costly arms race. Based on this intuition, I suggest that regulators consider mandating pro-rata matching for the most liquid stocks as well as randomized speed bumps similar to those recently adopted in several foreign exchange markets.

The literature on algorithmic trading and HFT has grown substantially in recent years (see, e.g., the surveys by Biais and Woolley, 2011 and Foucault, 2012). Most closely related to my work is the paper by Biais, Foucault, and Moinas (2013), which studies the impact of HFT in a Glosten and Milgrom (1985) framework. In their model, FTs have a higher chance of finding trading opportunities than slow market participants and, therefore, help to increase the likelihood that gains from trade are realized. But at the same time, they are a source of adverse selection due to private information, which raises the bid–ask spread payable by everyone and thus reduces trade. Just like here, FTs exert a negative externality and investment in HFT can be excessive in equilibrium. However, the underlying mechanism is different. In my model, FTs are able to avoid being adversely selected. However, because agents trade directly with each other in a dynamic setting, this effectively increases their market power and allows them to extract rents from slower market participants.

Also closely related, Jovanovic and Menkveld (2012) study competitive middlemen who intermediate between early limit order traders and late market order traders. Similar to my model, high-frequency traders can reduce adverse selection by updating quotes quickly and, therefore, help to increase trade. Yet, their ability to process (hard) information quickly can also introduce a new adverse selection problem that lowers trade. Based on the entry of a new trading venue for Dutch stocks, the authors conduct a calibration exercise that reveals a slight increase in welfare.

A number of other papers also study HFT from a theoretical perspective. In the model proposed by Cartea and Penalva (2013), high-frequency traders' speed advantage allows them to impose a haircut on liquidity traders, which raises trading volume and price volatility but reduces the welfare of liquidity traders. Foucault, Hombert, and Rosu (2013) study the trading strategy of an informed trader who is able to react faster than others to news. They conclude that this speed advantage makes the informed trader's order flow more volatile and increases his relative share in trading volume. Martinez