



Contents lists available at ScienceDirect

## Technological Forecasting &amp; Social Change



# Innovations in financial IS and technology ecosystems: High-frequency trading in the equity market

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## ARTICLE INFO

## Article history:

Received 2 February 2014

Received in revised form 4 December 2014

Accepted 7 December 2014

Available online xxxx

## Keywords:

Algorithmic trading

Financial markets

Financial innovation

High-frequency trading

Technology-based innovation

Paths of influence

Technology ecosystems

## ABSTRACT

Technology-based financial innovations over the past four decades have led to transformations in the financial markets. Understanding technological innovations in financial information systems (IS) and technologies has been challenging for technology consultants and financial industry practitioners due to the underlying complexities though. In this article, we propose an ecosystem analysis approach by extending the *technology ecosystem paths of influence model* (Adomavicius et al., 2008a) to incorporate stakeholder actions, considering both supply-side and demand-side forces for technological change. Our ecosystem model brings together three original core elements: technology components, technology-based services, and technology-supported business infrastructures. We also contribute a fourth new element to this approach involving *stakeholder analysis*. We investigate innovations in the area of *high-frequency trading* (HFT) technologies as a basis for empirically validating the existence of several different patterns in the historical path of technology evolution. Our analysis results suggest that supply-side and demand-side forces influenced HFT technology innovations and contributed to changes in the financial markets. This research represents some of the first work that investigates financial market technology innovations at the technology and stakeholder levels. It also offers a useful and practical tool to help managers and analysts to understand the nature of technology-based financial innovations and the relationships between technology and financial markets that support their emergence.

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## 1. Introduction

Information technology (IT) is important as a driver of product, service and business innovation in financial services and financial markets (Steiner and Teixeira, 1989; Wriston, 1988, 2007). When we consider their impacts on how securities and other financial instruments have been traded over the past four decades, the extent of IT-enabled innovations and transformations that have occurred has been dramatic and far-reaching (Mishkin and Strahan, 1999; Stoll, 2006). The rate of change in the core technologies of *algorithmic* and *high-*

*frequency trading* (HFT) also has been rapid for market participants. Starting from the 1980s, program trading emerged and trades were sent to market with computers, diminishing floor trading at the exchange (Hasbrouck et al., 1993). The emergence of other fully-electronic trading venues, especially electronic communication networks (ECNs), further changed trading on the NASDAQ and New York Stock Exchange (NYSE) in the late 1990s (Weston, 2002). This, in turn, led to the wider use of algorithmic trading and eventually the rise of HFT (Aldridge, 2013). With HFT, proprietary trading firms known as *high-frequency traders* use computer systems to monitor market data, identify opportunities to make profitable trades, and submit large numbers of orders to the markets (SEC, 2010).

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<http://dx.doi.org/10.1016/j.techfore.2014.12.001>

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Please cite this article as: Kauffman, R.J., et al., Innovations in financial IS and technology ecosystems: High-frequency trading in the equity market, Technol. Forecast. Soc. Change (2014), <http://dx.doi.org/10.1016/j.techfore.2014.12.001>

Competition has been intense among rival trading firms in the equity markets. In 2005, the U.S. Securities and Exchange Commission (SEC) (2005) promulgated the Regulation National Market System (NMS) to improve price display and trading execution fairness, promote pricing in pennies instead of eighths and sixteenths, and democratized market-wide access to market data. These regulatory changes set the stage for the current electronic trading mechanisms, leading to rapid development of HFT technologies and enabling new trading strategies. HFT is characterized by: a dependence on high-speed and sophisticated computer programs; ultra-low latency in the delivery of orders to an exchange's computer systems; the submission of numerous orders that can be canceled shortly after submission; the limited shelf-life of the trading algorithms that are used; and trading in multiple asset classes involving numerous exchanges (McGowan, 2010). In response to the automated process and winner-take-all nature of HFT, high-frequency traders have found it important to invest in hardware, software and network capabilities to minimize latency, which enable them to continue to refine their trading programs and algorithms, update their technology infrastructures, and be successful in the related "arms race."

In addition, these technological innovations have been supported by transformations in operational practices and infrastructures over time. The relevant changes have included the immobilization and dematerialization of securities through the establishment of multi-tiered financial intermediation and centralized securities depositories, such as the Depository Trust and Clearing Corporation (DTCC, 2012a). They make it possible for different kinds of organizations – retail investors and investment funds; institutional investors, hedge funds and exchange-traded funds; domestic and foreign brokers; commercial, savings and investment banks; and local and global custodian services providers – to share the same infrastructure (Chan et al., 2007; Russo et al., 2002). This allows the securities to be held in digital rather than physical form at one location, where they can be available for clearing and settlement. It also obviates the need for the costly exchange of physical certificates after trades are completed, improving efficiency and security, and increasing the likelihood that intraday settlement can be achieved (DTCC, 2012b). Other recent developments further supported HFT diffusion. They include the deposit of securities at the DTCC (2014): via fully-automated straight-through agents; for provisional credit pending agent approval; and for immediate credit.

A related development is the specter of software errors in HFT operations that lead to dramatic, fast and irrecoverable losses. Examples include the May 2010 "flash crash" (Kirilenko et al., 2014) and Knight Capital's 2012 software glitch that caused US\$460 million losses in its millisecond and microsecond trading. This occurred at a time when it held 15% to 20% market share of all HFT activities in the U.S., and ultimately this event led to Knight Capital's acquisition by another firm (SEC, 2013a). A recent DTCC (2013) report includes a quotation from Mahatma Gandhi of India, who said: "There is more to life than just increasing its speed." The regulatory agencies and financial intermediaries such as the SEC and DTCC in the U.S. have responded by discussing the possible requirement of having HFT firms submit data on their fast trades on a near real-time basis, and not permitting a practice known as *pre-netting*,

which makes it much more difficult to monitor market quality (SEC, 2013b).<sup>1</sup> There are no longer any technical difficulties for firms to selectively hold back the sharing of data on netted trades. This practice dramatically compromises the capacity of governmental financial intermediaries that are charged with market oversight. They need to effectively monitor market quality and performance, and ensure operational fairness and transparency while mitigating the major risks. These things led to promulgation of detailed rules since the 1990s, for example, for fixed income securities trading (Fixed Income Clearing Corporation, 2014).

The most impactful trading technology innovations in financial markets have been difficult for managers and industry observers to assess. Though there have been bellwether signs of technology-related developments in the high-tech industries, it has not been easy to characterize how they arose, or what was the extent of their impact.<sup>2</sup> The primary questions are: What have been the historical paths of technological innovation in financial markets? What shape have they taken, and what patterns seem to be present? Can they be identified based on relevant empirical observations? Is there a methodology that can be applied to cut through the complex relationships among technology, financial markets, and stakeholders so the ecosystem's evolution can be understood? Will this be helpful for looking ahead and trying to understand what ecosystem changes are likely to occur in the future?

In this article, we adopt a view that is focused on *technology components*, *technology-based services*, and *technology-based business infrastructure*. Adomavicius et al. (2008a) proposed an early image of this view in research they conducted on *paths of influence* models in *technology ecosystems*. We employ this view to address issues that financial decision-makers and analysts face, as they think through what will drive key innovations in a financial market's technology ecosystem. Components, services, and infrastructure in financial IT are the key building blocks for the insights we offer. In addition to these, we also offer a new contribution by extending this approach to consider some other forces associated with the potential influences and actions of a range of stakeholders present in the financial

<sup>1</sup> According to the U.S. National Securities Clearing Corporation (NSCC), *pre-netting practices* involve: "(i) *summarization* (i.e., a technique in which the clearing broker nets all trades in a single CUSIP by the same correspondent broker into fewer submitted trades); (ii) *compression* (i.e., a technique to combine submissions of data for multiple trades to the point where the identity of the party actually responsible for the trades is masked); (iii) *netting*; and (iv) any other practice that combines two or more trades prior to their submission to NSCC ...".

<sup>2</sup> The *Journal of Technological Forecasting and Social Change* has published exemplary research that gets at different aspects of this problem. They include: (1) forecasting pathways in science and technology innovation based on identification of relevant technical elements, consideration of knowledgeable people and groups related to distinctive functions of new technologies, how various high-value functions are supported by applications, and what are the links between applications and commercial opportunities (Robinson et al., 2013); (2) understanding technological innovation through analysis of diffusion of relevant technical knowledge via patents, articles and institutional collaboration (Cunningham and Kwakkel, 2013); and (3) through industry network structure that supports transmission of knowledge to where it can be creatively applied for technology, component, product, service, and infrastructure innovation (Van der Valk et al., 2011), and mergers and acquisitions (Chellappa and Saraf, 2010).

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