

I Markets in Milliseconds

Changes in valuation are greatly increased and even often brought about by the flexible quality of money to express them directly. And this is the cause as well as the effect of the fact that the stock exchange is the centre of monetary transactions. It is, as it were, the geometrical focal point of all these changes in valuation, and at the same time the place of greatest excitement in economic life. Its sanguine-choleric oscillations between optimism and pessimism, its nervous reaction to ponderable and imponderable matters, the swiftness with which every factor affecting the situation is grasped and forgotten again – all this represents an extreme acceleration in the pace of life, a feverish commotion and compression of its fluctuations, in which the specific influence of money upon the course of psychological life becomes most clearly discernible.

Georg Simmel, *The Philosophy of Money*, 1900

In today's high-tech exchanges, firms can execute more than 100,000 trades in a second for a single customer. This summer, London and New York's financial centres will become able to communicate 2.6 milliseconds (about 10%) faster after the opening of a transatlantic fibre-optic line dubbed the Hibernia Express, costing US\$300 million. As technology advances, trading speed is increasingly limited only by fundamental physics, and the ultimate barrier – the speed of light.

Nature, 2015

It would take more than a century, but sociologist Georg Simmel eventually met physicist Albert Einstein, if not in the halls of an illustrious university, then metaphorically within the frenzied commotion of the electronic stock exchange. When Simmel wrote of stock exchanges as the capitalist nexus where values are “rushed through the greatest number of hands in the shortest possible time” (Simmel, 2004 [1900]: 506), he could not have foreseen just how short time could get. In the electronic systems that operate in most modern stock exchanges, the time of transactions is often measured in microseconds – roughly the same magnitude of time that it takes individual

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molecules of neurotransmitters to travel across the 20 nanometers of a synaptic cleft between neurons, itself less than 100,000th of the threshold of human perception. Financial transactions are so fast that relativity – not only of meaning, but also of space–time – must be accounted for when designing trading platforms for the market (see Wissner-Gross and Freer, 2010). For some, even light is too bulky, having to travel through optical fiber cables and microwave relays on the awkwardly spherical surface of the planet (Laumonier, 2014; MacKenzie, 2018). If used to transmit information, weakly interacting neutrinos (or perhaps even the hypothetical reverse time-traveling particles known as tachyons) could cut directly through the earth's mantle and save a dozen or so milliseconds of latency for a new generation of ultra-high-speed traders¹. This is where finance is today: caught between Simmel's nexus and Einstein's faster-than-light dreams.

In this book, I explore the histories of some of the technologies that accelerated stock markets over the past half century. My interests are both in the infrastructures that made speedy transactions possible and in the humble and largely invisible engineers that tinkered with and built the networks and machines of automated finance. This is a recent history. Just a few decades ago, well within the lifespan of most readers, stock exchanges were not the feverish spaces of electronic, algorithmic, automated activity that they are today. As Madonna topped the charts in the early 1980s, stock markets were relatively subdued spaces where, bar sporadic moments of great activity, most of the trading took the form of personal interactions and brisk

¹ Talking in 2015 at the Equity Market Advisory Committee meeting of the Securities and Exchange Commission (SEC) of the United States, renowned economists Andrew Lo of Massachusetts Institute of Technology (MIT) noted that as technology develops market participants transform their expectations of market temporalities. As an example, he noted: "a few years ago you may recall that an experiment out of Switzerland, the Large Hadron Collider, demonstrated erroneously that the existence of tachyons, faster-than-light particles, existed. The next day after the announcement, I received a phone call from an algorithmic trader, asking me to introduce him to a physicist engaging in tachyon research" (Securities and Exchange Commission, 2015).

conversations on the floors of century-old, club-like exchanges. Then and before, finance was a matter of bodies and voice, punctuated by the banter of the clerks and brokers, the clicking of keyboards, the striking of pencils, the crushing of paper, and the creaking of wooden floorboards. Perhaps best exemplified by the ground-breaking sociological work of Wayne Baker (1984) and Mitchel Abolafia (1996), stock and commodities markets at the time were densely social, communicative spaces. The cacophony of the marketplace and apparent randomness of trade was coordinated through shared norms and expectations, networks of competition and collaboration, and elaborate means for signaling, rewarding, and reprimanding the members of the trading floor's community. Fast-forward a mere 30 years. Madonna is still an active performer. Yet most trading floors have disappeared, replaced by what anthropologist Ellen Hertz (1998) calls a "community of effects" built through computers, screens, and cables scattered across inconspicuous locations throughout the world and where actions are not the result of a distinct collective intention but of the exercise of countless individual wills. In present-day financial markets, the logic is not one of coordinating interpersonal interactions but of managing the punctuated electronic signals that encode the orders from masses of anonymous investors. The art of finance is no longer about gazes and hand signals, but about toying with the nimble algorithms, sophisticated computer processors, hacked routers, and specialized telecommunication systems that are the material foundations of the contemporary stock exchange. Through technology, trading floors became an amalgam of cables and software; and through automation, rowdy human crowds were refashioned into silent and speedy electronic queues.

This book is not a conventional history of technology or automation: it does not care for the vision of leadership, the importance of careful planning, or the power of innovation as much as it does for the obduracy of bureaucracy, the potential of bricolage, and the significance of tinkering and maintenance on the sidelines of organizations. This book is also not about managers and their historically coherent

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institutions, jostling traders, interested politicians, and powerful financiers. In the following pages, there are neither Thomas Edisons nor John Pierpont Morgans. Rather, this book is about the workers and experts that make up financial institutions but that are seldom seen; it is a story of the vast sections of organizational hierarchies where change happens not necessarily through the power of authoritative control or the promise of revolution, but through the trials and tribulations of routine and surprise, the charm of performance, and the force of surreptitious standardization. This focus is decidedly important for understanding not only transformations in finance, but also markets, organizations, and automation more generally. Although scholars of technology have placed many efforts in reexamining the mythical figure of the lonely entrepreneur, images of automation as driven by heroic and radical inventors are still oddly persistent (a recent case in finance being the ruckus about the potentially revolutionary consequences of blockchain technologies; see Tapscott and Tapscott, 2016; Maurer, 2017). By examining the automation of finance, I want to stress the importance – and unpredictability – of the organizational middleware, the bulky center of market organizations that connects the public front office and the grueling and oftentimes obscured back office, the human software from the material hardware, the legacy systems from the technological vanguard. Change and stability are not created at the pinnacle of the organizational hierarchy but in the sometimes-tedious bureaucratic work of the vast middle. The historical implications are telling: financial automation was not entirely planned or designed, it just sort of happened.

I. I WHY FINANCE?

At a time of great social and political upheaval, it might seem that investigating the automation of financial markets is an extravagant scholarly fancy. Why not, some have asked, expose automated finance as a more exacting form of capitalist activity? Why focus on the history of technologies rather than behaviors, on invisible workers

rather than the thinkers and leaders that made financialized neoliberal societies possible?

I admit that this was the original motivation for this book. When I started research on financial markets more than a decade ago, my main interest was identifying the overt politics underlying these behemoths. Students of science and technology have demonstrated in countless occasions that artifacts and technological projects are never neutral, but are always the continuation of politics by other means. From speed bumps and bicycles to bridges and algorithms, devices and their associated practices always encode assumptions about how the social world *should* work.

These somewhat classical examples of how politics get built into artifacts are not the only possible narratives for technological projects. To say that financial automation was part of a coherent political project that leveraged technology to shape the world in particular ways would be an unfaithful, first degree approximation to the interviews and documentary materials that I collected in the field. For years, I looked for collective forms of manifest politics in the works of market managers and technologists, but these were simply not to be found. Intentional agency was elusive. What I encountered was not one but many fragmented projects, some involving the leadership of organizations though many others incubated in the invisible underbelly of the market. I sought ideologues but found (entrepreneurial) bureaucrats whose politics were fragile, disjointed, and eminently mangled with the effort of keeping the market in shape. This was not the story of a cunning and powerful urban planner who designed the world to crystallize dubious politics (Winner, 1980). Nor was it the story of how a single paradigm emerged to govern and discipline the field. No, this was a story of buildup, contingency, and unpredictability, and while politics certainly mattered, they did so in a rather more modest, mundane, lowly, and practical way.

This is precisely why studying finance matters: it offers a cautionary tale of the sources and messy politics of technology and automation that is lacking in contemporary public discourse. Consider

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the recent contributions by Erik Brynjolfsson and Andrew McAfee (2014), who argue that societies are now facing forms of automation that will displace workers in traditionally cognitively intensive industries such as law, medicine, and other services. At the heart of this argument sits the old language of David Ricardo's (1891) political economy, which presented "the substitution of machinery for human labor [as] very injurious to the interests of the class of laborers." The problem is not with Ricardo's theory of labor substitution, but with his metaphor of "the machine" as a punctual object, as an entity that emanates from the interests of the capitalist. Discrete technologies, we are often told, are what automate the workplace, whether in the form of the steam-powered looms of the nineteenth century, Harry Braverman's cybernetic data-processing-and-storing machines, or the ubiquitous robots that are prognosticated to displace employment into extinction. These are the mechanisms that, as Marx wrote, "after being set in motion, perform with its tools the same operation as the worker formerly did with the same tools" (MacKenzie, 1984). They are the very substance of automation.

But automation is a peculiar chimera: it conflates knowledge, devices, and organizations in intricate ways; it requires buildup, buy-in diffusion; it sits atop invisible platforms, standards, and gateways; it reconfigures cyborgs as much as novel and apparently independent machines. Automation is necessarily heterogeneous. The prevalent imagery of automating machinery deals poorly with such messiness: in finance, for example, there was not a single device or moment of transformation that heralded the arrival of automation; some devices mattered centrally, but only made sense when meshed within a network of practices, standards, platforms, and logics of action. If automation happened, it was as a long and contested historical process. Its boundaries were fuzzy; its meanings malleable; its participants heterogeneous; its politics numerous and contradictory. Automation emerged from the accumulation of legacy and the creation of the new as these were linked, wrangled, modified, and disconnected within organizations over time. To use the language of science and

technology studies, automation was the product of extended *infrastructures* rather than of discrete machines – assemblages of practices, routines, standards, and devices that seamlessly fade into the background as if natural elements of our human environments (Bowker and Star, 1999; Edwards, 2003; Star and Bowker, 2006; Larkin, 2013).

I.2 INFRASTRUCTURES OF FINANCE

At a broad empirical level, this book makes a contribution to discussions about the history of the automation of finance within stock markets in Britain and America. Historians of financial markets have produced exceptionally clear and detailed accounts of the institutional evolution of the City of London and Wall Street – two epicenters of financial activity in the United Kingdom and the United States, respectively. A common feature of these histories is that they often conceptualize technology as something of a black box, closer to the machinery of Ricardo’s metaphorical repertoire than to the messy narratives that characterize contemporary stories of infrastructures. Take the work of Ranald Michie (1999), who documents with tremendous assiduousness the history of the London Stock Exchange (LSE), the prime stock market in Britain. While Michie acknowledges the importance of technologies for the exchange, he does so by rendering their development a rational reaction to competitive threats and market opportunities instead of contested projects that transformed the organization and its logics from within. Market technologies, we read, were developed with apparently little effort and as required to meet to some external demand. This conceptualization of innovation as an exogenous process is also notable in the work of other historians of finance. For example, Youssef Cassis (2010) weaves an intriguing history of how global financial centers emerged over the last one and a half centuries, but he does not query the organizational dynamics that underpinned technological innovation. Charles Geisst’s (2012) history of Wall Street recognizes the importance of technology in shaping modern American finance but asks few

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questions about the technologies that encroached the practices of the marketplace. Joel Seligman's (1982) several works also present a uniquely detailed story of the legal and institutional trajectories that forged American financial markets, recognizing the challenges of technological innovation to market participants; yet like other historians of finance, he does not delve into how technologies were assembled within organizations. Admittedly, we cannot ask financial historians to account for everything. But what is interesting about these and similar studies is the way technology and innovation are framed: not as something that happened and was fostered within the financial sphere but, rather, as an opportunistic appropriation from elsewhere (Cortada, 2003). Technology certainly matters, but only as an input rather than as an internal process.

Some economists and legal scholars have placed more attention on the technical and organizational minutiae of financial automation. For example, Ruben Lee's *What Is an Exchange?* (Lee, 1998; see also Lee, 2002) provides one of the best accounts of the strategic and managerial challenges faced by stock exchanges as digital technologies expanded throughout the financial services industry. For Lee, automation posed a series of important problems for the leadership of stock exchanges that required redefining the operational logic of their organizations: should they run as members-owned marketplaces as they did throughout most of their history, or should they become for-profit publicly traded corporations with a leadership voted in by anonymous shareholders? Should they cater to small retail traders, or should they work for larger institutional investors? Should they protect the interests of so-called market makers (agents that traditionally bought and sold securities on their accounts to provide liquidity to the market), or should they allow unfettered competition to take hold of the exchange? Lee explores these tensions in order to identify how competition drove stock exchanges down different paths of automation: some automated earlier while others were more cautious, depending on how they made sense of the institutional pressures of their local environments. Ian Domowitz and Benn Steil (1999; also

Domowitz, 2002) provide a similar analysis of the patterns of automation observed in financial markets during the 1980s and 1990s. By identifying how automation was expressed in the various layers of the market – from information dissemination to trading and settlement – their work provides an important point of reference for thinking about the global factors that shaped decisions on how to automate markets. Although slightly more processual and cognizant of organizational dynamics, a Ricardian explanation remains at the core of these accounts: technology was introduced from the managerial outside to make the economics of stock exchanges leaner and more efficient. As Domowitz and Steil wrote in 1999, cost was “undoubtedly the most significant factor driving the rapid expansion of automated trading in the past several years.”

The economics of machinery certainly contributed to automation but they were far from being the only factor that shaped outcomes. As Lee’s work demonstrates, automating an exchange is a tremendous achievement that requires reengineering organizational hierarchies, regulatory environments, creating interests, governance structures, client relations, and operational practices *in addition* to the technologies and devices of the marketplace. Automation is difficult because it implies a transformation of the market itself, and while reducing costs certainly makes it more attractive, it necessitates inspiration beyond the logics of profit and thrift. To paraphrase Bruno Latour (1992), something is missing that is central to the dynamics of technological change: the organizational sections that construct and maintain the infrastructures of the marketplace.

Some of these missing masses are found in the type of places traditionally surveyed by students of science and technology. Think here, for instance, of the seminal work of Karin Knorr Cetina (with Bruegger, 2002) who studied the distributed, screen-based forms of interaction that make coordination possible in global foreign exchange markets. Think, too, of Caitlin Zaloom’s (2006) accounts of how traders in futures markets dealt with the transition from the pits on trading floors to the anonymous screens of electronic trading

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environments. Think, also, of Fabian Muniesa's (2003) study of how the creation of prices at the Paris Bourse was automated as part of a broader organizational reinvention. Or think of Alex Preda's (2006) work on how stock tickers profoundly transformed the cultures and temporalities of American finance. As members of a growing community of scholars interested in the imbrications between markets, technologies, and cultures, these authors recognize the stark materiality of finance, but they do so by stressing the contextual and interpretative nature of market technologies rather than their alleged intrinsic features.

Undoubtedly, the work of these and other authors contributed to uncovering, what Donald MacKenzie (2008) calls, the technicalities of finance, that is, the "systematic forms of knowledge deployed in markets [that are] social matters, and consequential ones." In studying finance, though, authors in this tradition have too often focused on devices defined in terms of their visibility: whether instant messaging systems that communicate traders, screens where information is appresented, controversial algorithms that determine closing prices, or analog devices that discern the ebbs and flows of market information, scholars have attended to perceptible technologies of finance that are intimately bound to the act of exchange.

What I do in this book is slightly different: to explore automation, I certainly look into the histories of some of the visible technologies that populate the front stage of markets – the trading screens, telephones, and controversial algorithms used to generate profits in fractions of a second (Muniesa and Callon, 2005). But importantly, I also focus on the less tended, slightly more invisible devices that operate beneath routine market action and that are deeply embedded in the bureaucracies of market organizations. These, I argue, are important "technicalities" when assessing the longer histories and trajectories of automation. As networks of devices, standards, and practices operating mostly in the background, they provide a stable frame of reference for action, cognition, and coordination, creating a sense of legitimacy, perhaps even inevitability, to automation. As perennial sites of organizational work, these less visible