1 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 traders[1]. 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

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.

1.1 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

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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

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).

1.2 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 cautions, 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

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

infrastructures are also opportunities for the production of politics, moralities, alliances, and struggles that shape the market. Indeed, if there is a specter within finance, it is found not only in the polished steel, clear glass, and cold granite of the corporate front office; the specter is also conjured in the fractured and multiple politics that belie the infrastructures of the marketplace.

1.3 RETHINKING MARKETS, ORGANIZATIONS, AND TECHNOLOGIES

There are two broad consequences of shifting our analytical focus toward infrastructures. The first involves rethinking markets beyond a dominant transactional metaphor that privileges exchange as the cornerstone of the economy and its constitutive interactions. In addition to informing discussions about automation, the histories that I explore in this book have an ideational objective: to expand how we collectively imagine markets to include the infrastructural objects and forms of work that constitute communities of transactions and exchange. Emphasis on these is warranted for both theoretical and empirical reasons. For instance, despite a wealth of social-scientific studies of economies throughout the last century, relatively little has changed in our conception of what constitutes markets. And albeit apparent divergences in worldviews and political attitudes, sociologists, neoclassical economists, and scholars further afield share much of their conceptual terrain. For many social scientists (and publics at large), markets are first and foremost mechanisms of exchange and matter precisely because of how they provide a means for reallocating goods and services through monetized and impersonal bilateral transactions[2]. Firmly grounded on the economic literature of his time, for

[2] This is a view held primarily by neoclassical economists from the early twentieth century onward. Not all economists (or social scientists, for that matter) are neoclassical, of course. Classical political economists, for instance, had a much more inclusive conception of markets. The abstraction of markets as generalized mechanisms for exchange is a particular innovation that can be traced to the emergence of neoclassical theories in the late nineteenth and early twentieth centuries (Mirowski, 1988).

example, Max Weber saw markets as archetypes "of all rational social action ... a coexistence and sequence of rational consociations, each of which is specifically ephemeral insofar as it ceases to exist with the act of exchanging the goods" (Weber, 1978: 635). Weber's contemporary, Émile Durkheim (1976), similarly replicated an economistic definition, writing of markets as institutions geared primarily toward exchange. During the formative years of new economic sociology, Harrison White reproduced this paradigm by defining markets as "self-reproducing social structures among specific cliques of firms" (White, 1981). For White, markets are formed by agents that produce and exchange goods and services – that is, by actors whose identity is defined through exchange and transactions. Mark Granovetter (1985) echoed this transactional metaphor: his is not a challenge to the exchange-oriented conceptualization of markets but, rather, a proposal for explaining allocation outcomes in terms of "personal relations and networks of relations between and within firms." Note that his is a theory of the embeddedness of transactions in social relations, rather than a challenge to the classical conceptualization of markets as essentially transactional institutions. The concept is similar in Neil Fligstein's (2001) work, where markets are conceived as "situations in which some good or service is sold to customers for a price that is paid in money." Viviana Zelizer (2010) also presents markets as "institutionalized type[s] of social relations involving consumption, production and exchange." This account is consistent across sociological traditions. For Pierre Bourdieu (2005), markets are "the product of a twofold social construction ... the construction of supply ... and the construction of demand." Don Slater and Fran Tonkiss's (2005) review identifies markets as "the buyers and sellers of a particular good or service [comprised by] supply ... demand ... and price." And Patrik Aspers's (2011) recent work defines markets as social structures "for the exchange of rights in which offers are evaluated and priced, and compete with one another."

Richard Swedberg (2005) rightly indicates that sociology has "suggested new ways of conceptualizing how markets operate."

It has shown, through great empirical dexterity and theoretical rigor, that market transactions are embedded in, and shaped by, cultures, institutions, and interpersonal networks. But sociology, as other social sciences, has not entirely escaped what Bernard Barber (1977) memorably identified as the "absolutization" of the market – that is, an intellectual settlement that privileges the abstract, eminently exchange-oriented transactional market processes over the more mundane dynamics of the physical and material marketplace. By investigating the production of market infrastructures and their role in transforming finance, this book recovers some of this lost theoretical emphasis on the material, situated market*place*: even within finance's digital transactions, the materiality and obduracy of where exchanges occur matters fundamentally.

It would be too partial to focus solely on devices and the brute materialities of financial markets, of course. As noted above, automation was not only a product of technologies, but, as importantly, of the organizations where they came to matter. To use the language of Wanda Orlikowski and Susan Scott (2015), automation is a *sociomaterial* achievement. I aim to convey this sensibility about the intersections of infrastructures and organizations throughout this book. *Automating Finance* can be read as a "traditional" historical account of the automation of twentieth-century stock markets. But it can also be read as a broader argument about the relevance of the organizational middleware where much infrastructural work happens. This is largely because, unlike existing histories of finance, this book looks at a seldom studied category of actors that was arguably central to market automation: professionals of different backgrounds involved in designing, maintaining, and organizing the infrastructures of the marketplace. Unlike the recent sociological literature on technology and financial markets that has tended to emphasize a distinct professional group (economists) as key actors in performing the economy (Callon, 1998; MacKenzie, 2008, 2011; Fourcade, 2009), here I look at the role of a varied set of agents in the mundane construction and tinkering of market technologies. This group includes expert

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computer scientists and trained telecommunication engineers, but also self-trained electronics enthusiasts, industrialists with knowledge of computing, heterogeneous systems operators, and a wide gamut of individuals who, simply put, *make* things for the marketplace. Overall, the presence of these agents within capitalist organizations questions the way markets operate and are reproduced. In particular, they mirror the type of technical experts of whom Thorstein Veblen wrote in *The Engineers and the Price System*, his telling essay on the role of knowledge and management of the modern capitalist enterprise. For Veblen, the captains of industry cannot sustain the capitalist firm on their own. In addition to workers, the gears of industrial capitalism rely on "corps of technological production specialists, into whose keeping the due functioning of the industrial system has now drifted by force of circumstance" (Veblen, 1965). In tense collaboration with the owners of capital, these specialists – the "engineers" in Veblen's essay – make mass manufacture possible, determining "on technological grounds, what could be done in the way of productive industry, and to contrive ways and means of doing it." Note that these engineers are powerful in distinctively epistemic ways: while they may not own the means of production, they possess the cognitive instruments necessary for production to occur in an orderly manner; similarly, they directly facilitate entrepreneurialism both within and outside their organizations, combining techniques, knowledge, and devices in novel ways. (Admittedly, Veblen romanticized the image of the engineer, presenting her as driven by a more neutral quest for efficiency in contrast to the capitalists' interest in extracting profits through control and monopoly.) Following from Veblen, this book looks at the "engineers" of finance, the technical specialists that have contrived means for changing the way investors trade. So, while this is a book on infrastructures, it is also a study that compels us to think about the engineers or infrastructural workers that reconfigured and automated market organizations from within.

The studying of market "engineers" also offers an alternative way of thinking about the politics of markets. It would be tempting to

consider market technologists as driven by a common cause, sharing particular affinities that made them a homogeneous group pursuing common ends through technological means. But as I explore in the following chapters, such an image reduces the richness and contingency of market making. Market engineers came for all walks of life – from elite universities to humble polytechnics, from the machinery of the war to the fields of Midwestern America. Their interests were varied, as were their politics. Perhaps the only thing they clearly shared was a belief in technology as a solution to problems, in the capacity to organize things through machines, and of the possibility of transforming markets into digital domains to some extent or another. This will be clear in the interviews and documentary materials that I present throughout this book, but it is also notable in the way technologists represented their future when automation was still a largely imagined horizon. One image is particularly striking: a poster produced by Peter Bennett, one of the main developers of the London Stock Exchange's electronic systems (Figure 1.1). Used in a

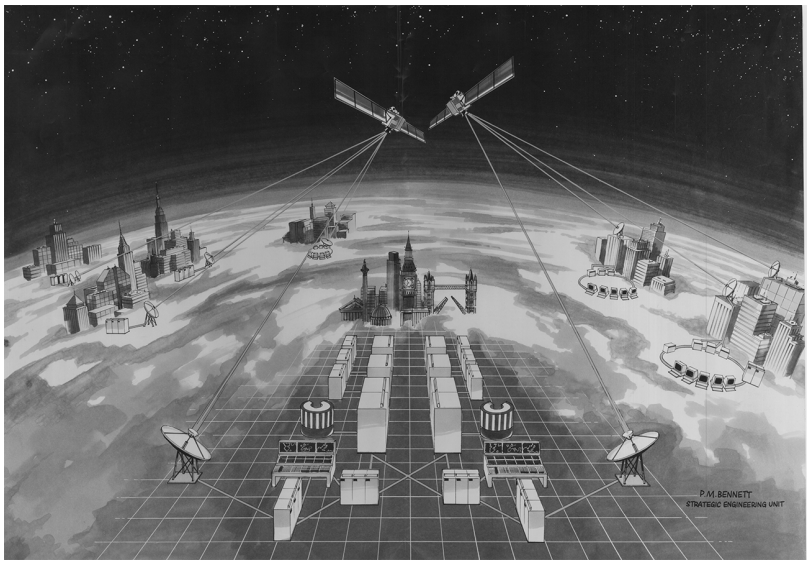

FIGURE 1.1 Poster by Peter Bennett, c. 1986/1987, representing the future of trading and stock exchanges. Reproduced with permission from the author.

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presentation for the exchange's management in 1987, the image displays a world connected by technologies and devoid of human hands. The financial centers of Tokyo, London, and New York are connected by real-time satellite communications; in each, data is churned by locally networked supercomputers that serve as substitutes for the trading floor. The image is doubly powerful. On the one hand, it reinforces the invisibility of market engineers but foregrounds their objects of work: the satellites, computers, and data packages represented in the poster are designed, built, maintained, repaired, and upgraded. They are kept going and relevant by the unseen armies of technical experts that inhabit global finance. On the other hand, the image hints at what automation could ostensibly do to the social life of the markets. When applied to markets, the discrete architecture of computers and digital data transmission moved transactions from messy conversations on trading floors into ordered electronic queues. The sociology of markets changed not because of some political ideal, but because of the affordances of the devices that technologists introduced to the market.

1.4 MARKETS, KINSHIP, AND RELATIONS

The infrastructural turn advocated in this book is relevant for a second reason: it entices a different way of thinking about the permanence of the social in the face of great degrees of mechanization and automation. Let me explain this point in more detail.

A recurrent theme in the literature on financial markets involves condemning automation's role in dissolving social relations. Consider the fascinating and pernickety history of the City of London offered by David Kynaston (2001) – undoubtedly one of the most accomplished works on the social life of British banking and finance. In telling the numerous and tumultuous transformations of the city's institutions over the twentieth century, Kynaston conjures an almost melancholic image of a financial sector that was once a place of great sociality and that more recently succumbed to the humdrum rationalizing logic of mechanized globalization. In this, Kynaston is in

illustrious company. In her path-breaking study, anthropologist Ellen Hertz also stresses a discontinuity in the stock markets of Shanghai, from being quite tangible, culturally dense, and relationally present communities of exchange to large techno-social assemblages "linked to [themselves] by a seemingly infinite network of computers … profoundly wrapped up in the process of imagining [what they mean]" (Hertz, 2000). Fiction writers also harnessed this trope to demonstrate the cultures lost to the machines (De Boever, 2018). I, too, have fallen to the allure of thinking about the end of culture and social control when caught within the virtual gears of information technologies. In a paper written with Daniel Beunza, Yuval Millo, and Donald MacKenzie (Beunza et al., 2011), we argued that automated markets are tied to the rise of a generalized culture of impersonal efficiency, that is, the idea that streamlining financial transactions and operations is best achieved by impersonal technical mechanism rather than social ties, eliminating the forms of interpersonal surveillance and control that were once a hallmark of the trading floor. This is not entirely far-fetched, for, after all, market participants themselves recall a mythical past when finance was about jovial conversations, long and lavish lunches, the smoke of cigarettes on the floor, and tight-knit relations that endured over time. Finance, we are told from multiple speakers, was simply more exciting, more emotional, more *social,* before computers took control.

This oppositional trope of humans/machines is not unique to finance. Quite the contrary, it is a contested yet foundational element of the intellectual project of modernity/anti-modernity (the reader can think of other relevant dichotomies: civilization/wilderness, society/nature, reason/emotion, machine/organism). But when studying automation, this trope is analytically counterproductive precisely because it obfuscates the modern categories of "the social" and "the machinic" as being obvious, stable and inherently opposed (Latour, 2012). By focusing on infrastructures and their location in organizations, I want to move away from this way of conceptualizing the world. Specifically, I highlight the continuities in what social

relations mean to markets, automated or otherwise. If markets are more than simply sequences of transactions, if markets are indeed organizational achievements, then relations endure because of, rather than despite of, infrastructural change. Infrastructures and the knowledge complexes that they necessitate are *generative* of relations; they imply the production of connections, work, and communities rather than of disruption, isolation, and anomie.

The argument that automation does not dissolve "the social" but simply reconfigures modes of interaction and knowledge-making could be made through some of the existing theoretical repertoires of science and technology studies (think, in particular, of Bruno Latour and Michel Callon's tradition of actor-network theory, or literatures that incorporate users into the formation of meaningful sociotechnical worlds). For this book, I adopt a slightly oblique perspective: rather than thinking mainly about the super-symmetric ontologies of actor-network theory that distribute agency across humans and nonhumans, I resort to an anthropological metaphor that focuses explicitly on the status of relations and connectedness in order to understand what changes and what persists with the automation of finance. I think of markets and their organizations as kindred systems of relations, mediated as much by personal interactions and the density of meaning as by instruments and technologies that designate who is legitimately related to whom.

This shift turns to the work of anthropologist Marilyn Strathern, for whom the "relation" is not an obvious empirical fact, but rather a constantly produced designation. I find the idea of querying the status of (market) relations both intriguing and productive. In particular, it affords a vocabulary and conceptual framework that moves beyond both metaphors of markets as sequences of transactions and the reductive yet dominant metaphor of embeddedness often used by social scientists to understand market action. The second is particularly problematic, since conceptions of embeddedness assume a clear divisibility between otherwise distinguishable "spheres" (whether "the economic" or "the social"). This is

troublesome, however, given the fact that market and social relations are difficult, if not impossible, to disentangle: for instance, the gift, as Mauss classically argued, transits a relation that is neither entirely social/emotional nor entirely economic/rational (Mauss, 2000). There is always some expectation of reciprocity in gifting and, while not monetary, it is market-like.

Rather than assuming the "social" embeddedness of "economic" transactions, I conceptualize markets as fundamentally relational systems. As Strathern rightly observes in her discussion of kinship, relations are not stable but constantly shift their boundaries and registers of application to reflect broader struggles in law, family practice, and scientific knowledge around parentage, siblinghood, relatedness, responsibility, and ownership more generally. This is why infrastructures matter: reconceptualizing markets as systems of kindred relations places attention on the invisible forms of knowledge and work that make market transactions legible, that allow buyers and sellers to be legitimately related to and then be rightfully quits (a matter cannot be "quits," or settled, if there was not a relationship in the first place!).

In the days of face-to-face trading on the floor, interpersonal knowledge and social skills played an important part in stock trading. Deals were tied to the social and organizational relations crafted between members of the exchange themselves inscribed in larger bureaucracies of administration and record keeping (or infrastructures, in a more general sense). Deals struck on the floor were processed and settled through a laborious and largely invisible machinery of clearing that required the use of special instruments and organizational expertise. Utterances only became trades when administered by these infrastructures: they *made* relations out of them. The relational work performed through infrastructures is not restricted to the markets produced on the old physical trading floors. Despite automation and the apparent disappearance of humans from the marketplace, the making and refashioning of relations persist in modern trading systems. Computer servers also converse and

communicate, but their electronic exchanges only become legitimate transactions under the light of specific forms of knowledge (for instance, growing expertise in market microstructure that contrast with previous economic theories), operational standards (such as price-time priority), and legal agreements (such as sub-penny pricing, or order-routing rules set by the state); the relation can only be said to exist under certain circumstances, much in the same way as utterances on the trading floor only acquired meaning if properly registered by the relevant infrastructural bureaucracy. When these fail, relations cease to exist: after US markets crashed dramatically on May 10, 2010, in an event known as the "flash crash," trades conducted at abnormal prices were canceled. Although by all means technically reasonable market transactions, they were not considered legitimate and so were erased. Answering the question of how things are related shows the breaks and continuities in the historical development of financial markets. Rather than assuming that "the social" disappeared through automation, it focuses on identifying the boundaries of how legitimate relations were reinvented over time.

1.5 OVERVIEW OF THE BOOK

Because automation involves a gamut of technologies, this book covers the histories of devices and systems across different layers of stock markets, from the grueling clerical labor of the settlement back office to the more visible work of trading, order matching, and execution. I nevertheless admit that most of the narrative focuses on two types of systems that are particularly relevant to the forms of automated financial activity that we see today: data communication systems, which allow the orders from investors to travel across the world, and systems for matching and executing customer orders in an automated fashion. An important element of the narrative is the transition from trading floors to electronic order books – lists made up by the volumes and prices at which market participants are willing to trade specific financial instruments and that serve as the infrastructural gateways connecting the constituencies of the marketplace in a

single electronic site of negotiation and exchange (without electronic order books, automated trading would not be possible in its current form). While immensely important operationally, economically, and sociologically, the history of order books has not yet been told and this is one of the tasks at hand in the remainder of the book.

The book is organized in two parts, tackling the conjoined trajectories of exchange, infrastructures, and relations. Thematically, the first corresponds to the market organization as a place of infrastructural change and deals with the transformations of a key institution of British financial markets, the London Stock Exchange. In particular, it examines how the makers of market infrastructures, largely invisible and subsumed within the stock exchange's old and traditional hierarchy, created systems and devices that captured finance and converted the marketplace to a digital, electronic form.

This first part starts in the next chapter, which asks the question of what changed with automation by exploring the early twentieth-century London Stock Exchange. A central concern is indicating how the predigital exchange operated as a distinct "market community," to use Max Weber's vocabulary. This vantage point is used to understand modifications induced by mechanization and automation. As a story of infrastructures, my emphasis is not so much on purely "social" forms (in a classical sociological sense), but on the distinct technologies that gave coherence to the market community on the trading floor. I call these "infrastructures of kinship" in order to allude to the way distinct social, technical, and organizational devices created relations in the market that defined the boundaries of the exchange as an organization and cultural entity and of the act of exchange itself as a relational form. As the chapter shows, automation did not start at the core of the community, but rather in its less visible underbelly, through the mechanization of some of the central devices (particularly those of clearing and settlement) that give markets their relational legitimacy. The kernel of automation was not the floor, I argue, but in the pipes, tubes, and number-crunching gears that gave credence to transactions in the marketplace.

Chapter 3 explores the roots and sources of financial automation between the mid-1960s and late 1970s within the London Stock Exchange by looking at how the mechanization of clearing and settlement spilled over into trading and data dissemination. A central theme of this chapter is the importance of the largely invisible cadre of workers that were responsible for the first wave of automation within the exchange. Relegated to the basements and alcoves of the organization and possessing expertise gained in developing and maintaining the exchange's early clearing and settlement systems, the initial generation of stock exchange technologists produced the first electronic price and quote visualization systems that would later transform trading practices across British finance. A condition for this process of capture was the invisibility of both the infrastructures and their makers that served as a powerful resource for surreptitiously reimagining the marketplace.

The theme of organizational change is continued in Chapter 4, exploring a period of rapid expansion of the stock exchange's technical teams and of their systems and devices. Propelled by regulatory constraints and a change in the structure of the British economy, LSE technologists seized the period between the mid-1970s and late 1980s to capture the normative and administrative core of their organization. During this time, they redefined what it meant to be an exchange. This chapter focuses on how the earlier generation of technologies coalesced into larger sociotechnical networks for the marketplace as the number of technologists ballooned into the thousands. As part of this process, I highlight a twist in the conceptions of stock exchange technologists from an interest in creating discrete stand-alone systems to developing all-encompassing platforms – that is, entities capable of supporting numerous tasks and monetizing services for their users. While bold and almost utopian, the platforms conceived by LSE technologists also demonstrated the dangers of capture and the hubris of rapid development. The chapter closes precisely with this theme, showing how growing too fast and large became a liabilty for LSE technologists as markets entered the

uncertain and turbulent period after 1987. By 1992, most technologists had left the exchange.

When the LSE's technologists left the stock exchange in the early 1990s, they did not fade into darkness. Chapter 5 shows the consequences of the technological diaspora that followed the organizational changes and uncertainties produced by the 1987 market crash. By looking at the trajectory of a small group of leading technologists that broke away from the stock exchange in 1990, the chapter shows how infrastructural workers revolutionized the wider British securities markets rather than simply one of its (undoubtedly important) organizations. Critically, this involved developing and commercializing the first electronic limit order book in London. The challenges for technologists were not so much technical as social: they had to convince and convert a larger field that order books were the way of the future. As the chapter shows, the strategies of enrolling used by the technologists were ingenious: in addition to relying on the social and technological capital accrued in their tenure at the LSE, they resorted to the power of prophecy and charisma. Their strategy proved successful since their efforts were partly responsible for shifting British securities markets toward order books and electronic trading.

Whereas the first part of the book is concerned with engineers, infrastructures, and organizations, the second is preoccupied with the imbrications of national politics and infrastructural change. How do large infrastructural projects develop? And how do they crystalize political and moral struggles? Thematically, this second part moves from Britain to the United States with chapters that explore the creation of the National Market System.

Chapter 6 starts by looking at the problem of automation in American securities markets as a manifestation of a long-standing moral and political anxiety connected to the role of humans in the marketplace (particularly the New York Stock Exchange's specialists). Through the histories of some of the first efforts to automate stock markets in the United States, the chapter shows that projects of market automation were couched in moral and political terms,

anchoring discussions of virtuosity upon a very specific device: the electronic limit order book. The chapter explores embryonic designs of the order book. One of these, a never-realized patent by Frederick Nymeyer, an American industrialist, amateur economist, and fervent Calvinist, demonstrated an overtly ethical concern in creating justice through automation. Contemporaneous with Nymeyer's work, the chapter also explores two other early experiments in market automation: on the one hand, those at Instinet, which sought a private solution to the problem of trading; and those of the Cincinnati Stock Exchange, one of the true pioneers of automation that tried to change the field for small investors amidst growing demand for retail investment.

Chapter 6 closes by looking at the consequences of electronic limit order books to the meaning and making of market relations. On trading floors, relations are almost sociologically and anthropologically obvious: buyer and seller are related through conversations, interaction, and exchange. But how does this apply to the electronic order book and the domain of automated trading that it makes possible? In the second part of the chapter, I argue that "relatedness" in modern finance depends on how distinct epistemic instruments are applied to resolve the existence or not of relations. By exploring some contemporary discussions on so-called spoofing (a practice that involves deceit in the market and connects to Nymeyer's moral concerns of the New York Stock Exchange's specialists), I show that the relations that seem to have been made meaningless through automation were recomposed by using novel forms of expert knowledge that shadow the logic of digital infrastructures. Specifically, I argue that the type of economic knowledge that matters changed in the transition from the floor to the computer server: whereas neoclassical financial economics was once the interpretative keystone, today the role is shifting to market microstructure theory, an area particularly attuned to the electronic fabric of modern exchanges.

From a discussion on how the first generations of electronic limit order books were designed and what they changed in our shared

conceptions of finance, Chapter 7 moves on to identify how specific market designs propagated and colonized American stock markets. This involves dealing with the mechanism of infrastructures that compelled the simultaneous creation of institutional settings and technical environments that, once established, alter the distributions of what is possible, permissible, and imaginable. For infrastructures to emerge, actors must prepare terrains, create habits, and establish the boundaries required for infrastructures to work; once there, these terrains, habits, and boundaries both enable and constrain – to paraphrase Anthony Giddens (1984; see also Orlikowski, 1992), they "infrastructurate" the social world, creating restrictions and possibilities of action by means of the relations they entail between humans, categories, and things (Pipek and Wulf, 2009; Le Dantec and DiSalvo, 2013).

Empirically, the chapter explores the regulatory efforts by the US Congress and the Securities and Exchange Commission to incentivize markets toward a particular market design that spoke to their concerns about efficiency and access. Rather than fomenting a centralized solution that provided equality to all investors, regulators and government officials promoted a fragmented system of interconnected trading sites that, with time, became a fertile ground for the contentious practices of latency-sensitive trading. A key element of this process was an often-underappreciated episode in the history of the American financial system: the debate about how best to lay the common infrastructures for a national, internal stock market. As I argue in this chapter, the debate implied multiple political interests and worldviews but was part and parcel of a common dream, the creation of a national community – a financial democracy – that tied all citizens to financial markets and their fates.

Chapter 8 brings the book to a close by reflecting on three theoretical lessons from the automation of financial markets. It explores how changes to the infrastructures of exchange signaled a broader transformation within modern societies: that is, the emergence of systems based on queues that displaced crowds and

their forms of collective deliberation. Rather than thinking of the automation of financial markets as a consequence of a deeper, murkier politics, I argue that stock markets condensed and amplified the ways societies reconstituted their lifeworlds through information technologies and rationalized organizations. As indicators, though, automated stock markets are telling: they offer insights into the quirky politics and uncanny moralities that inform the type of queues that, for better or for worse, increasingly shape the course of multiple domains of social life.

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