

FOLDING: INTEGRATING ALGORITHMS INTO THE FLOOR OF THE NEW YORK STOCK EXCHANGE

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Abstract

How does automation reshape markets? Existing sociological studies have argued that market automation need not entail a dilution of social relations, but the empirical evidence is inconclusive. Our multi-period ethnography of the New York Stock Exchange addresses this gap by exploring how the NYSE automated trading while preserving its floor intermediaries. Our study reports on observations in 2003 before automation was introduced, outlining the functions traditionally played by specialists and floor brokers. It then analyzes how the Exchange preserved these intermediary roles in 2006-08 as it introduced algorithmic order matching, and proposes the notion of folding to denote the process of automating a market while preserving its social structure. Finally, our analysis of the Flash Crash in 2010 suggests that folding allowed the NYSE to outperform its floorless rivals.

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The automation of financial markets poses new challenges to scholars of markets as well as to policy makers. Trading in American stocks is currently dominated by financial algorithms. Automation has not only reduced labor costs but also displaced traditional intermediaries such as floor brokers and specialists, altering the social structure of the market. Partly for this reason, automation has brought with it new risks. These risks became apparent during the Flash Crash of May 6, 2010, the fastest and second-largest percentage-point price decrease in the history of the Dow Jones. The severity of the Flash Crash, widely attributed to the misuse of trading algorithms (CFTC/ SEC 2011), suggests that financial automation has not been fully understood and calls for a more thorough analysis of its potential side effects. Specifically, we argue, it calls for an examination of how the partial replacement of floor intermediaries by algorithms alters the functions traditionally performed by exchanges. Furthermore, because such replacement of people by machines entails a significant change in the social structure of the market, we argue that a sociological approach to market automation can offer a distinct contribution to existing studies in the economics of market microstructure. We thus ask, how have the changes in social structure introduced by automation impacted on the US equities market?

In grappling with the complex consequences of financial automation, sociologists can draw on an established literature on market intermediaries. This line of research points to the embedded and institutionalized nature of securities exchange (Baker 1984, Abolafia 1996) but needs to be updated as it assumes the presence of a human at both ends of the transaction – a presence that automation has consigned to the past. An alternative literature in the social studies of finance offers a more concerted focus on technology in markets (MacKenzie 2006, MacKenzie and Millo 2003, Beunza and Stark 2004). Yet this literature has mostly emphasized the mediating effects of financial models, rather than the effects of automation. Finally, a related literature in science and technology studies has considered the effects of new technologies on social relations. For instance Callon (1998) has pointed to the link

between the introduction of technology and the dilution of social relations (see also Knorr Cetina 2003, Preda 2006). Automation, Callon concludes, need not imply a more impersonal market if it is informed by a non-atomistic conception of market actors. Yet, with the possible exception of Muniesa (2004), the literature has not yet offered any empirical case of market automation that preserves social structure.

Our study addresses this gap by examining the automation of the New York Stock Exchange (henceforth, NYSE or “the Exchange”). Founded in 1792, the Exchange is known for its iconic trading floor and a “specialist system” whereby transactions are organized by floor intermediaries such as specialists and floor brokers. The floor of the Exchange remained vibrant through the early 2000s even after rival exchanges in London and Paris closed theirs. But, in 2006, the Exchange faced a regulatory mandate to automate by the Securities and Exchange Commission. In response, the Exchange decided to introduce automation while preserving its trading floor. Its first attempt to do so was largely unsuccessful, leading to a steep drop in its market share. But, a second attempt in 2008 resulted in a stable market share and contributed to a robust performance during the Flash Crash of 2010, suggesting the viability of automating a market while preserving its social structure.

Our study addresses three questions about the automation of the NYSE. First: what were the key functions of the floor intermediaries prior to automation? To answer this, we draw on ethnographic observations on the floor of the Exchange in 2003 before automation. We categorize the functions of floor intermediaries into three broad domains: matching, sensemaking and norm enforcement. We find that these functions are consistent with existing sociological studies of intermediation (Simmel 1902/1950, Burt 1992, Baker 1984, Obstfeld 2005) as well as ethnographies of trading floors (Abolafia 1996, Zaloom 2001, Pitluck 2011).

We ask a second question. On returning to the Exchange in 2008, we noted that the NYSE had preserved its floor intermediaries even as it adopted automation. How did the Exchange accomplish this? Using a combination of ethnography and oral history interviews, we identify the underlying mechanism that made it possible to combine automation and human intermediation, a process that we designate as *folding*. In conventional parlance

folding is defined as “to make compact by doubling or bending over parts,” as in the folding of a sheet of paper (American Heritage Dictionary, 4th edition). Instead, we draw on the use of “folding” in the context of cooking, where it means “to blend (a light ingredient) into a heavy mixture with a series of gentle turns,” as in folding beaten egg into batter (American Heritage Dictionary, 4th edition). Drawing on this usage of the word, we propose the sociological notion of folding to denote an automation design that preserves the social structure of a market.

Third, the Exchange’s automation strategy also has implications for an ongoing sociological debate on the relationship between technology and society. Over the past two decades, sociologists in the field of science and technology studies have challenged mainstream sociology by putting forth the view that the sphere of the social is inseparable from that of the material (Pickering 1993, Orlikowski and Scott 2008, Leonardi 2008). But, despite the controversy raised by such claims, there are few empirical examinations that test whether the material and the social are indeed analytically separable. Our study provides one such test by using the automation of the NYSE as a natural experiment. In preserving the role of the floor intermediary, we found, the Exchange ended up retaining the intermediary’s original material basis, namely, the trading floor. We interpret this as a form of inseparability between the material and the social. Our analysis also highlights how the top management of the Exchange paid focal attention to preserving the role of the specialist, suggesting that this role entailed what Feldman and Pentland (2003) call an ostensive, abstract dimension.

Finally, our study turns to the consequences of automation for the US equities market at large. What are the effects of automation on market-wide properties such as liquidity and volatility? To answer this question, we use the Flash Crash of 2010 as a natural experiment. The Crash posed an equal threat to all American stock exchanges (SEC/CFTC 2011). By comparing the relative impact of the Crash across floor-based and floorless exchanges, we explore the relative effectiveness of the floor intermediary. We find that the NYSE, the only trading venue with floor intermediaries among US equities exchanges, was also the only exchange that did not experience erroneous trades during the Crash. All the other exchanges,

including Nasdaq, Direct Edge and Bats, had to cancel many of their trades --as many as 15,000 in total. Our analysis of the Flash Crash thus confirms that the floor intermediary fulfills important market functions that were not performed by the automated systems in floorless exchanges.

AUTOMATING THE FLOOR INTERMEDIARY

How does automation reshape markets? Addressing this question calls for an understanding of *what* is being automated, as well as of *how* it is automated. In the case of financial exchanges, automation replaced the intermediaries on the floor. Such was the importance of intermediaries --specialists and floor brokers-- at the NYSE that the Exchange was typically described as a “specialist system”. According to Saar (2010: 1425), a specialist market is “a hybrid market structure that includes an auction component (e.g., a floor auction or a limit order book) together with one or more designated market makers (‘specialists’) who trade as dealers for their own account. The designated market makers have some responsibility for the market.” Saar thus points to three aspects of a specialist market: a set of roles (specialist and broker); a practice or routine (the call auction); and a material setup, primarily the trading floor.

To understand what a specialist system accomplishes, we draw on a rich sociological literature on market intermediaries. This harks back to the notion of third-party mediation formulated by Simmel (1902/1950). Simmel’s third party profits from exploiting the disunion of the other two, as elaborated in Burt’s (1992) concept of brokerage. Alternatively, this third party can profit from moderating the forces that divide the group, as formalized by Baker (1984), Khurana (2002), and Obstfeld (2005). This structuralist approach is complemented by ethnographies that explored the institutional, material and embodied aspects of trading floors (Abolafia 1996, Zaloom 2001, Pitluck 2011). Taken together, the aforementioned studies offer a comprehensive answer to the question of what floor intermediaries do. The presence of floor intermediaries in financial exchanges is consistent with a conception of markets as social structures, where trading is threatened by opportunism and uncertainty (Baker 1984). In such settings, intermediaries provide matching (Khurana 2002, Abolafia 1996), sensemaking

(Zaloom 2001, Pitluck 2011) and norm enforcement (Baker 1984, Abolafia 1996). Finally, the sociological literature also suggests that intermediaries give rise to their own form of opportunism (consistent with Burt 1992). We consider each of these aspects below.

Matching. One key contribution of intermediaries is to facilitate exchange by matching the transacting parties. The theoretical mechanisms are particularly clear in Khurana's (2003) study of a different form of intermediary, executive recruitment firms. The function of headhunters entails facilitating the match between buyer and seller by mobilizing the intermediary's contacts, expanding the array of potential trading partners. Matching extends to the task of mitigating the uncertainties entailed in the transaction, often by pacing the rhythm at which the parties interact by dictating a schedule and offering resources to help the transaction take place. Ethnographies of trading floors have identified how brokers and market makers accomplish these functions. Abolafia (1996), for instance, underscored the role of NYSE specialists in matching buyers and sellers, and in buffering imbalances in demand and supply.

Sensemaking. Ethnographies of exchanges have also outlined how trading floors produce social cues that facilitate sensemaking. As with other sensemaking processes, these assign meaning to orders and prices amidst market uncertainty (Weick 1993). Zaloom (2001, 2006) documented how these social cues arise non-purposefully in the very act of trading: an order conveyed with a fearful voice, for instance, elicits a different response than one with confidence. As Zaloom (2001: 263) states, "because of the physical and emotional information conveyed with numbers not all bids and offers are equal." Sensemaking also helps intermediaries overcome the problem of adverse selection identified in the economics literature. As microstructure economists have established, a customer agreeing to trade at a given price may be doing so because he or she knows something that the other side does not, posing a risk for the latter (Glosten and Milgrom 1985). Such adverse-selection (or "lemons") problem discourages transactions, drying up liquidity. But, as the ethnographic work of Pitluck (2011) shows, floor intermediaries can address this problem by crafting their discourse appropriately. For instance, they can disclose the identity of the seller in a limited

fashion by using an abstract description rather than the full name. This partial identification can give meaning to the seller's actions, eliminating the buyer's suspicions of adverse selection while simultaneously protecting the seller's identity.

Norm enforcement. The sociological literature has discussed yet another role that intermediaries in exchanges perform, namely, enforcing norms and limiting opportunism. Baker (1984) established that market makers in an options exchange enforce norms such as not selling while prices are falling. They do so by “freezing out” opportunistic colleagues from trading (Baker 1984: 782). Norm enforcement has also been identified as one of the specialist's functions at the NYSE, as shown in Abolafia's (1996) ethnographic study of the Exchange. Over the years, he found, the Exchange instituted formal controls over its specialists, including “affirmative” and “negative” obligations, an embryonic computerized auction (discussed below), and a bureaucracy that awarded new listings to compliant specialists. These formal means of control were reinforced by an informal culture of “rule veneration” (Abolafia 1996) whereby the Exchange's rulebook was repeatedly cited and known by everyone on the floor.

Opportunism. Sociologists have also explored the problems that intermediaries in trading floors can themselves create. These relate to the intermediary's tendency, discussed by Burt (1992), to exploit his or her structural advantage. In the context of trading floors, these ideas are echoed in Abolafia's (1996: 105) analysis of the NYSE prior to the reforms of the 1960s: “in the 1920s,” he explains, “specialists aided and abetted ‘bear raids’ and manipulated their stocks” (see also Brooks 1969, Sobel 1975). In other words, while floor intermediaries aim at limiting opportunism among transacting parties, they can also generate their own form of abuse.

In sum, sociological studies highlight three key functions of intermediaries in exchanges, as well as a danger of opportunism. But as exchanges become automated these key characteristics are transformed. Developing a sociological theory of market automation thus calls for understanding how these functions change. We turn to this below.

How does automation reshape the floor intermediary?

In theorizing the effect of automation on financial exchanges we draw on the literature from science and technology studies. Callon's (1998) analysis of the strawberry auction house in the French town of Sologne emphasized that technology need not lead to a more impersonal market. The introduction of technology into the auction house by an economics-trained manager, Callon argued, reduced the effect of social relations on valuation. This took place through two changes: first, the erection of a wall between buyers and sellers that made it impossible for actors to know the identity of the counterparty. Second, the creation of better labeling of the fruit, which allowed buyers to take into consideration properties such as weight, size, ripeness, etc. (Callon 1998, Garcia-Parpet 2007). These two changes had the effect of separating or "disentangling" the strawberries from the social relations between buyer and seller; and of framing or "formatting" the value of the fruit, bringing the market closer to the economic ideal of the atomized decision-maker originally espoused by the director of the auction house (see also MacKenzie and Millo 2003, Knorr Cetina 2003). Technology thus made social relations less central in valuation. But, importantly, this effect was shaped by the economics-based conception of the market held by the director of the auction house. A different conception of the market, Callon adds, could lead to a different outcome: it would be equally possible to design automation so as to reinforce rather, than dilute, social relations.

To date, however, the sociological literature has only lent partial empirical support to Callon's conjecture. Muniesa's (2004) study of the Bourse de Paris documents how the French exchange initially entertained an automation design that would preserve the trading floor. By keeping the trading terminals on the exchange floor rather than at the banks' offices, the planners hoped to have "something like *criee* groups [crowds] with computers" (Muniesa 2004: 16). Yet the Bourse eventually changed course, eliminating the trading floor altogether. As result, the literature still lacks an empirical case that illustrates how market automation can be introduced while preserving social structure. We nevertheless drew inspiration from

Muniesa's use of the term folding, as in "Folding a Market Into a Machine," for our own theoretical formulation.

Automation designs that complement social structure are also important from a public policy perspective. Such designs, we argue, could address a key problem that legal scholars have identified in automation: the loss of norm-enforcement mechanisms that make markets viable (David 2010). According to Lessig (2000), automation entails a fundamental change in the governance of economic activity. As legal rules and social norms are replaced by computer code, power is shifted to new groups with different interests (see Barley 1986 for a related argument). Left unattended, Lessig adds, this replacement of rules by code is at risk of being hijacked by technologists. Technologists may find ways to profit from opportunistic activities that were previously barred by social norms, yielding technologies that run ahead of the system's ability to manage them. Lessig thus insists that automation must be designed in a way that forestalls opportunism. The automation designs that Callon hints at, if empirically established, may offer a framework to address Lessig's concerns.

The separability between the social and the material

The distinct automation path of the NYSE speaks to the aforementioned debate over the effect of technology on society. Starting with the work of Simmel and Weber, sociology has been premised on a notion of the social that is independent of the material setting – a conception of social structure as “enduring and relatively stable patterns of relationship between different entities or groups” (Levi Martin 2009: 4). Science scholars have recently challenged this view by contending that there is a co-constitution between the social and the material (Pickering 1993; see Orlikowski and Scott 2008 for a review). Specifically, Pickering (1993) shows that the emergence of the scientific instrument known as the bubble chamber involved both material and human agencies, and that it is impossible to separate both effects. Pickering sees material agency in Glaser's accommodation of the chamber design as response to the failure of vapor to register cosmic rays in the chamber. Yet Pickering also sees human agency in David Glaser's decision to redesign the chamber again so as to remain in a small lab rather than joining a large bureaucratized one. Both material and social factors,

Pickering (1993: 559) concludes, shaped the eventual design of the chamber in a way that cannot be analytically separated.

Actor network scholars have added to this debate with a further deviation from mainstream sociology. Social relations, Latour (1986) has argued, are not an explanatory cause of phenomena, but a *consequence* of material associations. The importance of material artifacts in shaping social relations can be learnt from societies that lack technology, such as those of animals. “If sociologists had the privilege to watch more carefully baboons repairing their constantly decaying ‘social structure,’” Latour (2005: 70) writes, “they would have witnessed what incredible cost has been paid when the job is to maintain, for instance, social dominance with no *thing* at all, just social skills.” By contrast, in human societies inanimate objects enforce norms. Speed bumps, for example, keeps school streets safe for pedestrians without need for school principals admonishing drivers to slow down. The heavy keychain used by traditional hotels ensures the safety of guests by forcing other guests to leave their keys in reception before they leave the hotel, reducing the danger that they might lose their key. In short, Latour goes beyond Pickering’s (1993) contention that the social and the material co-constitute each other, positing instead that the social is constituted by the material.

More recently, Feldman and Pentland (2003) contributed to this debate by detailing a different form of separability between the social and the material. The authors follow Latour in distinguishing between the ostensive (abstract, ideal) and the performative (enacted, concrete) aspects of social phenomena, focusing this distinction on organizational routines. Feldman and Pentland go on to challenge Latour’s (1986: 272) contention that “we have to shift from an ostensive to a performative definition of society,” arguing instead that routines entail *both* definitions. A hiring routine, the authors note, is not just a set of performed acts to be understood ex-post as an HR routine: it is also an abstract set of components (attracting, screening, choosing applicants) that need to be present for organizational actors to be satisfied that a hiring routine was enacted. The distinction is crucial, according to Feldman and Pentland, because it explains how routines can lead paradoxically to organizational change.

More central to our purposes, the ostensive dimension of routines provides a way in which the social can have a separate existence from the material setting as an abstract idea.

RESEARCH METHODS

Research Site

While our study is primarily ethnographic, its design departs in various ways from the canonical single-site, single-period study. It relies on a core set of ethnographic observations on the floor of the NYSE during 2008-10. It complements these with observations of the floor in 2003, with oral history interviews of actors at the NYSE during 2008-10, on interviews outside the NYSE in the field of securities trading during the same time period, on the outcome of the Flash Crash of 2010, and on follow-up interviews at the Exchange in 2011-12. We discuss each of these below.

Data sources

Fieldwork and interviews at the NYSE, 2008-10. Our primary data entails ethnographic observations and interviews at the NYSE during 2008-2010. By then, the regulatory mandate to automate had already been promulgated and the Exchange was well down the path of automation. Over the period between 2008 and 2010 we made 44 visits to the NYSE, interviewed 19 officials, including its chairman, its top management team and several floor governors. We conducted detailed observations of the floor booths of two brokers, VDL and Rosenblatt Securities; and the specialist post of Bank of America later sold to Getco Llc. We interviewed the designated market makers and floor brokers responsible for these booths, as well as the clerks that worked with them. In addition, we also observed two regular market openings, one market closing, and one special situation during the record-volume stock-rebalancing auction of Citibank Group.

Observations in 2003. In making sense of the observations noted above, we benefited from previous fieldwork at the NYSE. We first visited the Exchange in June 2003 and we observed the work of a specialist, a floor broker, a research official and a compliance officer, witnessed a market opening ceremony, and conducted observations on the trading floor and at the Luncheon Club. This provided us with a window of observation into a world that would

subsequently disappear, and gave us grounds to compare the Exchange before and after automation.

Follow-up after 2010. Our data extends beyond 2010. During 2011 we conducted five follow-up interviews in person at the NYSE, as well as two telephone interviews. We also conducted seven follow-up interviews in person during 2012. These allowed us to gauge the response of the Exchange to the Flash Crash. More importantly, by returning to the same group of actors at the NYSE over a period of 8 years, we gained a longitudinal perspective that allowed us to capture the different dimensions of the change undergone by the Exchange (Benner and Tushman 2002, Katila and Ahuja 2002).

Interviews outside the NYSE. We complemented our ethnographic data with interviews of industry participants and scholars of financial exchanges during the period 2008-12. This contextualization was important in light of the external impetus that forced the Exchange to automate: it gave us both sides of the debate over market microstructure, rather than just the Exchange's (see Fligstein 2008 for a general elaboration of this argument). These interviews of NYSE outsiders included the president and chief executive officer of the International Stock Exchange, the chairman and one specialist at the American Stock Exchange, as well as two officials at the Nasdaq, one at Bats, one at Goldman Sachs, one of the founder of Instinet, one at the automated trading firm Aegissoft, and one at brokerage firm Themis Trading. Beyond practitioners, our interviewees included the Chief Economist at the Securities and Exchange Commission during the period when automation was mandated, as well as his successor. Finally, we interviewed three industry consultants and two academic specialists in market microstructure.

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Analysis

We build theory from the case with various analytical strategies. Following Agar (1986), we identified breakdowns in our initial conception of the phenomenon and reconceptualized our thinking around them. We also rely on grounded theory (Glaser and

Strauss 1967) with two explicit within-case comparisons. We first compare the first and second automation designs at the NYSE. The first design was unsuccessful in making floor intermediaries compatible with the algorithmic matching-engine; the second, by contrast, was successful. The comparison between these two allows us to identify the mechanism that underlies a successful integration of algorithms into the Exchange. Second, we compare the practices at the NYSE before automation was introduced in 2003 with those after the second phase of automation in 2008-10. This allows us to gauge the extent to which the original functions of the floor intermediaries were preserved by the automation design favored by the Exchange.

While our main method for data collection is ethnographic, the methodological scope of our investigation extends into historical sociology. We regard the data we collected on the day-to-day practices of the actors at the NYSE as being contingent upon wider transformative events (Paige 1999) such as the secular trend towards automation among exchanges in equities markets across the globe. For that reason, we abandoned the ethnographic convention to anonymize our informants and decided instead to use their names after obtaining permission from them.

Finally, our analysis conducts two natural experiments (Rosenzweig and Wolpin 2000). That is, we treat two historical developments as exogenously determined treatment conditions, and draw lessons from them. First, we examine whether the Exchange was able to reproduce the social roles that characterized its specialist system with independence of its particular material incarnation. In other words: was the Exchange able to reproduce the specialist role algorithmically, or did so as a combination of humans and a physical floor? Second, we exploit the Flash Crash in 2010 to ascertain the effectiveness of floor intermediaries. We ask, did a floor-based exchange such as the NYSE withstand the Flash Crash better than floorless exchanges such as the Nasdaq? We think of both events as somewhat analogous to natural experiments, as both were reactions to external changes and, specifically, to Regulation NMS and the Flash Crash of 2010. Naturally, the usual caveats of natural experiments apply to ours.

AUTOMATING THE NYSE

2003: The NYSE before automation

It did not take long for us to witness the social nature of the NYSE. We first entered the floor of the Exchange at 9:25 am on the morning of May 23, 2003, invited by Exchange official Murray Teitlebaum. Looking up from the floor, we saw the chairman of the NYSE, Richard Grasso, standing on a podium and surrounded by a mixed troupe constituted by high-ranking military officers and Miss America (O. Jennifer Rose), dressed in full Beauty Queen costume -- including bathing suit, crown and band. As the countdown to the ringing of the bell began, the crowd of brokers on the floor began clapping. At exactly 9:30 am the bell clanged, and a raft of camera flashes immortalized the moment. After the bell, a loudspeaker invited everyone to join in as Miss America sang the national anthem to commemorate Memorial Day.

With the exception of the anthem, such elaborate market openings are performed daily at the NYSE. The ceremony was revamped by Grasso in 1995 in response to a technology-themed advertisement campaign by the Nasdaq. By inviting celebrities to ring the bell and giving television stations access to the floor of the Exchange, Grasso created an event that could be broadcast live, in stark contrast to Nasdaq's electronics. The strategy proved successful, and by 2003 the Exchange had 55 international television networks broadcasting live from its floor (Gasparino 2006). Social interaction, we understood on our very first visit to the Exchange, was not just a means to conduct transactions, but part of its brand and identity.

The floor of the NYSE, we quickly learnt, rested on a social division of labor between specialists and floor brokers --the specialist system. Specialists acted as both principals and agents on designated stocks: as principals they were expected to "make a market," that is, act as counterpart to buyers and sellers; as agents, they were expected to hold call auctions. Brokers, on the other hand, handled clients' orders. This division of labor extended to the physical location of these two groups. Specialists stood at their trading post in the center of the floor, while brokers took clients' orders from vertical telephone booths in the

periphery of the floor and placed those orders by walking to the specialists' post. Specialists wore sober suits, while clerks and brokers dressed in colorful jackets. Seen from above, then, the Exchange looked like many other markets: a chaotic-looking combination of few individuals standing, surrounded by others walking between them. Like a public square (and unlike the trading rooms of investment banks) the floor of the Exchange brought together both sides of the transaction in the same space, facilitating face-to-face interaction across the buyer-seller divide.

What functions did this setup allow? We pursued this question with ethnographic observation and interviews. We started at the post of Fleet Financial, where Robert Hardy worked as specialist on a panel of several French companies. Hardy gave us the first clues into the nature of the specialist's job, confirming the presence of the three mechanisms discussed above -- matching, sensemaking and norm enforcement.

Matching. Hardy matched buyers and sellers by conducting call auctions at his posts at designated times, with a clerk behind him typing the prices he dictated on a computer terminal known as the Display Book. In doing so, Hardy established the price at which demand and supply equilibrated, an activity that the Exchange denoted "price discovery." These were call auctions in that they batched all the orders before setting a price, "pouring orders like water on a swimming pool," as a specialist explained to us. The call auction, Hardy argued, reassured brokers that their orders would be processed at the same time, preventing the proverbial rush to the fire exit. It also ensured that small orders got the same price as large ones, thus protecting the small investor.

As we soon found out, there was an important personal component to conducting call auctions. A former specialist explained to us how a call auction had elements of crowd control:

Let's say you are a seller for 200,000; you are a seller for 200,000; you are a seller for 200,000; I'm a specialist, I come in and say 'Calm down, all right, just everybody calm down, what do you have to do? [moving his head left] What do you have to do? [moving right] What do you have to do?' Ok the market right now is \$20 bid for 100 shares and a million shares offered at \$21' you show it on the screen. 'Ok what do you want to do? You want to sell 100 shares now at the dollar? Ok now you sold 100 shares, now the market is \$19 for 100 shares, do you want to sell another 100 shares?'

‘ok let’s calm down, let’s see if we can find some buyers, let’s see what happens at various prices, let’s talk this thing out, let’s do business’.

The quotation suggests that price discovery is a form of economic intervention, smoothing prices by managing people. Such pacing of the rhythm resulted in “slowing the transacting, preserving the flow,” as another specialist explained. The role of time, we realized, was particularly important in trading because liquidity is a temporal variable: liquidity denotes the availability of counterparts during a given time interval. Batching orders as the specialists did with their call auctions extended the length of time used for matching, increasing the likelihood of finding a counterparty. In this sense, the task of the specialists was similar to the work of the headhunters analyzed by Khurana (2002): by managing the speed of the interaction between buyer and seller, both headhunters and specialists ensured that the rhythm of activity was not destructive to the successful completion of the transaction. Indeed, in their efforts at pacing, the specialists went as far as to routinely freeze the computerized Display Book to prevent it from sending orders during the call auction (Rutigliano interview).

The specialists’ role included market making, dealing in stock for their own proprietary account in order to limit volatility. Specialists, Hardy explained, were “like shock absorbers,” compensating the pressures of supply and demand to make prices more stable. This contributed to fulfill one of their affirmative obligations, namely, keep a “fair and orderly market.” To do this, Hardy relied on the information he had about the upcoming orders in the book. The resulting temptation to sell ahead of a client’s order, or “front-run” the customer, was partly limited by the existence of a negative obligation: the specialist was not allowed to trade for his own account at a price at which an unexecuted agency order he or she was holding could be executed. In practice, then, the specialist took a position in the reverse direction of the latest price movement: if the specialist received many sell orders, he would want to buy (Rutigliano interview). The specialists also relied on price and order book signals: as we saw, Hardy used price charts with trend lines as a retail investor would. Indeed, such was the Exchange’s preference for public information that the use of personal mobile

phones was not allowed on the floor. In sum, the specialists' market-making activity performed a matching function, relying primarily on flow information to do so.

Sensemaking. Our observations also underscore the importance of sensemaking. We observed this first hand when a broker named Salvatore Gentile walked up to Hardy's post. "Salvatore and I," he said, touching Salvatore's shoulder in appreciation, "worked together fifteen years ago." Salvatore's visit post was not a courtesy call: "still here snooping?" asked another broker when Salvatore arrived. Salvatore, it turned out, had a large buy order. Instead of simply handing it over to Robert he told him about it. "I think it's a little heavy," Robert replied, suggesting that there were many other buy orders at that time, and that Salvatore might want to come back later. This partial disclosure of book orders enabled Salvatore to better time his order. The practice, known as "giving a look," allowed specialists to provide information in order to elicit additional orders without compromising the positions of the existing ones. We observed this yet again as we followed Dan, another floor broker, from one specialist post to another. When Dan approached a specialist with a question, the answer was revealing but somewhat diffuse: "stock's hanging in there, lots of machine buying, Morgan's a seller, Merrill has an interest."

In subsequent interviews with industry consultants, we learnt just how elaborate and important these looks were. These were crucial for matching large blocks of shares, where the problem of adverse selection is most acute. Specialists and floor brokers avoided disclosing the size of their position for fear of showing their hand and influencing the price. But, as we learnt from microstructure consultant Wayne Wagner, some disclosure is inevitable. Given the adversarial nature of transacting, one side cannot interest the other without disclosing something about the size and nature of the block (Wagner interview). As Wagner wrote in a trade journal, this complicates matters as even a minimal disclosure exposes the actor to opportunism: "it is impossible to draw a black and white distinction between seeking liquidity and violating confidentiality (...) The market maker cannot accelerate liquidity arrival without revealing trading interest" (Wagner 2004: 5). Matching large orders is thus fraught with risk, and calls for a high level of trust among trading partners. It was this trust that

allowed NYSE specialists to tap into the latent demand and supply for blocks of shares held by institutional investors (Wunsch interview; see also Wunsch 2011). In sum, sensemaking at the NYSE took place through partial disclosure and was particularly important for large blocks of shares.

Norm enforcement. We gained insight on the Exchange's norm enforcement mechanisms from Robert Hardy over breakfast at the NYSE's Luncheon Club. Conflicts, he explained, were managed on the floor through a combined mechanism of formal rules and informal norms. These included the figure of the floor governor, appointed by the Exchange. The Exchange also controlled a formal system to allocate listings that rewarded the specialists who followed the norms. Hardy provided us with various examples of how self-interest was kept in check even in the absence of competition among specialists for the same stock.

Referring to one particular instance, he said:

The governor said to me, 'Bobby, that was a good trade.' I lost money on twelve consecutive orders, and then made money on the last one. But all got the same price.

In other words, specialists were characterized by restraint as much as by eagerness to profit – an argument also made by Abolafia (1996). The Exchange had developed internal mechanisms that rewarded specialists for foregoing private gains for the sake of the good functioning of the system.

Formal rules were not the only means of norm enforcement. As we followed Dan, the floor broker mentioned above, from one post to the next, we also noticed how he addressed, backslapped and saluted with nicknames the people he met on his way. Everyone on the floor was Johnny, Jimmy or Bobby; there were no Johns, James or Roberts. Indeed, over the course of our many interactions --whether on the elevator, on the floor or elsewhere-- we observed that actors had a remarkable ability to make a quick joke that acknowledged the presence of the other without being formulaic. Interactions were humorous, fast, witty and casual. Such penchant for banter is consistent with Baker's findings (1984), which highlight the importance of network cohesiveness in forestalling opportunism and bringing about an orderly market.

In sum, our observations at the NYSE in 2003 suggest that the floor intermediaries at the Exchange were indeed fulfilling the three functions discussed above. By holding call auctions, giving looks, matching blocks, respecting obligations, and living up to informal norms, the specialists and brokers effectively performed matching, sensemaking and norm enforcement.

Although our limited observations in 2003 did not hint at any form of the broker opportunism that the literature has discussed, soon after our initial fieldwork in 2003 the Exchange confronted various lawsuits against its Chairman and specialists. In July 2003, news that the board of the NYSE had granted Richard Grasso a combined retirement and compensation package of \$190 million prompted widespread media outcry. The ensuing resignation by Grasso did not draw a line under the crisis, however, and in May 2004 the SEC and New York State's attorney general Eliot Spitzer submitted a civil lawsuit accusing Grasso and other board members of manipulating the NYSE board. In October 2006 the New York Supreme Court ordered Grasso to repay the NYSE part of the compensation package. However, this ruling was reversed in 2008 following an appeal.

Shortly after the Grasso controversy, in 2003 the SEC sued a number of specialists for neglecting their obligations. They were accused of engaging in inter-positioning (unnecessarily placing of an order at a price between current bids and offers) and front running (trading ahead of a client's order), as well as of freezing the Display Book. Following an internal investigation, on October 2003 the NYSE imposed a fine of \$150 million on five of the seven specialist firms for "habitual abuse" of their market roles. The specialists firms also agreed to pay \$240 million to settle with the Exchange, but the SEC persisted with the case separately. In 2006, however, a judge reversed the conviction of leading specialist David Finnerty in the SEC court case (Colesanti 2008).

2004-08: Algorithms vs. floor intermediaries

The lawsuits prompted a change in the NYSE's top management, helping pave the way for automation. While the departed Chairman, Richard Grasso, was a vocal detractor of automation, the new interim Chairman appointed by the Board, John Reed, was a noted

proponent of technology in finance, known for pioneering the use of automated teller machines in banks as CEO of Citibank during the 1970s. At the Exchange, Reed introduced a new governance structure, and led a CEO search culminating in the appointment of another technology enthusiast, John Thain (Gasparino 2006). Thus, in barely more than a year the NYSE replaced its chief executive and reformed its governance.

Starting in 2005, a sequence of changes in regulation and technology combined to create an algorithm-based approach to securities exchange that challenged the dominance of the NYSE. The SEC used automation to put in place a form of managed competition among exchanges known as the National Market System (NMS). This connected the various exchanges via order routers, directing incoming orders to the exchange with the best price. The NYSE was initially excluded from the requirement to connect owing to the slower speed of its manual matching system. But in the early 2000s the SEC, with the leadership of its Chief Economist Lawrence Harris, opposed NYSE's exception on the grounds that it gave the specialists an unfair advantage -- a "look-back option" (Harris interview; see glossary). In December 2005 the SEC promulgated Regulation NMS. This required, among other provisions, the disclosure and immediate tradability of prices in all the exchanges of the National System, including the NYSE. This particular provision, known as Rule 611 and informally referred to as the "trade-through rule," forced the Exchange to respond to an incoming order within a second. Because the humans on the floor could take up to 30 seconds to do so, the NYSE found itself in urgent need to accommodate automated trading.

While promulgated in 2005, the roots of Regulation NMS go back to a series of debates on the organization of securities exchange that started in the 1960s. In 1963 the SEC published its "Special Study of Securities Markets," highlighting shortcomings in the self-regulation of stock exchanges, and putting forth automation as the solution. The conception of trading that lies at the root of the Regulation NMS was, according to Muniesa (2007), also influenced by the utopian vision of Black (1971). The renowned economist had previously pioneered the computerization of libraries and hospitals as a consultant for Arthur D. Little (Mehrling 2005), and advocated automating the NYSE (Harts interview). At the heart of

Black's 1971 proposal laid a vision of trading as information processing, and of exchanges as self-organized books of orders -- namely, as databases. The critical role of price discovery performed by NYSE specialists, Black argued, could be left to investors if they could post orders that specified a price and not just a quantity -- the so-called "limit orders." As for the specialists' obligation to keep fair and orderly markets, Black interpreted this as a mandate to dampen price volatility. Such intervention, he added, was undesirable and inconsistent with an efficient market and random walk prices that fluctuate freely. Black (1971: 87) concluded that in an automated exchange "there will be little need" for floor intermediaries. Black's ideas can be found in the thinking of Lawrence Harris, the architect of Regulation NMS. In Harris' view, "trading is essentially an information problem when sellers are looking for buyers. Bilateral search. Were it not for some difficulties concerning order exposure, this would just be a database problem" (Harris interview).

In parallel to these regulatory developments, the related efforts of banks, technologists and entrepreneurs during the 1990s led to a range of computerized solutions that replaced the matching activity normally performed by specialists and traders. Foremost among these was the creation of order-matching algorithms. This was led by outsiders to the world of stock exchanges: in 1996, the entrepreneurs that pioneered online trading company Datek also developed a share-trading venue known as Island Inc. The company, which matched and executed internally the orders sent by clients, eventually came to be known as an "electronic communication network" (ECN). At the heart of Island and its many followers was a so-called "matching engine" that paired orders using explicit rules like "price-time priority," making it impossible for any participant to arbitrarily favor some participant over another (MacKenzie 2012, Krell interview). Unlike dealer-dominated exchanges like the Nasdaq, ECNs delegated the pricing of stocks to an algorithm, doing away with the market maker's prerogative to set prices. ECNs, in other words, hand over control of trading to the customers: as one of our interviewees put it, in an ECN "every customer is a dealer." The number of ECNs soon grew to include Brut, Archipelago and others. Their standing gained a key endorsement in 1998 when the SEC put ECN customers on an equal footing with Nasdaq

market makers by giving them access to the inter-exchange order-routing system. Unable to compete, a nearly bankrupt Nasdaq acquired three ECNs in 2003 and replaced its market makers with algorithms. As a Nasdaq executive explained, “the ECNs won” (Concannon interview).

A parallel threat to the dominance of the NYSE was the rise of new exchanges like Bats Exchange and Direct Edge in the 2000s. Designed from the outset as floorless exchanges and run as consortia for the benefit of their customers (including Wall Street banks), these exchanges offered low prices, high speeds and quickly took market share away from the NYSE (Wolkoff interview, Williams interview).

Automation was further developed by the rise of algorithmic order-matching providers, known as “dark pools.” Broker-dealer firms such as Goldman Sachs or Credit Suisse started to offer services in which prices were only displayed after a trade had been executed. By not publicizing bids and asks, these venues allowed fund managers to trade large blocks of shares without creating price movements against them. Dark pools added to the challenge posed by ECNs to the NYSE by pursuing the flow that ECNs could not easily match – the large blocks of shares. Similarly, dark pools challenged the NYSE by cherry picking orders --matching those that were perceived to come from uninformed traders, and routing the rest (so-called “toxic” order flow) to other dark pools or exchanges. Indeed, the first internal matching algorithms built in a bank took advantage of the absence of obligations on the part of the broker-dealers by routing off toxic flow to other dark pools or the Exchanges (Harts interview). Institutional funds such as Fidelity added to the trend by developing technology for algorithmic order execution. These systems “sliced,” or broke up, large orders into small parts to minimize price impact. Best known among them was the so-called VWAP, or “Volume-Weighted Average Price” algorithms. According to an expert from the Bank of America, these VWAP algos sought to replicate average outcomes:

They [algorithmic designers] have convinced the buy side and the sell side: “hey give me your million share order, I’m going to put it into my little wood chipper here at 9:15 in the morning,” and this little wood chipper is going to read what your stock—

General Motors—is doing in the day (...) And guess what, no one is ever going to know who you are, because you'll just be buying 200-300 shares a lot, and you'll never kick your hand.

In other words, the promise of algorithmic execution was to replicate the human ability to “work” an order. This facilitated the use of ECNs by providing investors with a mechanism to handle large orders, eroding the dominance of the NYSE’s matching capacity.

In a related development, the decade of the 2000s saw the rise of so-called “high frequency trading” firms. These firms made algorithms a central part of their trading strategy (as opposed to just part of their execution), and typically involved electronic market-making. That is, they provided liquidity by posting limit orders that others execute against (MacKenzie, Beunza, Millo and Pardo-Guerra 2011). High frequency trading is conducted by large hedge funds such as Chicago-based Citadel, as well as by specialist firms like Chicago-based GETCO (Global Electronic Trading Co.), Kansas City-based Tradebot, and Amsterdam-based Optiver.

In sum, by 2006 the developments described so far brought new regulation (NMS), new exchanges (ECNs), new forms of exchanging shares (dark pools), new practices among existing actors (algorithmic execution), and new actors with automated strategies (high frequency traders). The related efforts of economists, entrepreneurs and regulators thus assembled an alternative to the NYSE. Traditionally, an investor wanting to buy shares in IBM would call his brokerage firm and this broker would relay the order to its floor broker, who would walk to the specialist post and place the order. Following the aforementioned developments, an investor (even one holding a large block of shares) had a range of options, including sending the order to a dark pool, having it sliced by the execution algorithm of its own broker, or sending it directly to an new floorless exchange. In the new model, an exchange was a form of database -- an electronic repository of orders. And in an important sense, this new model appeared successful: as microstructure economists Hasbrouck and Saar (2010) argued, spreads in the most-often traded indexes had narrowed following the introduction of Regulation NMS (see also Hendershott, Jones and Menkveld 2011).

An information-processing conception of trading. The introduction of automation by the SEC can be seen as an attempt to disentangle equities trading from the social relations between brokers and specialists. And such pressure can be understood as a natural consequence of a conception of trading as information processing. The SEC, according to an NYSE informant, believed that the Exchange was “nothing more than an old boy’s network, a bunch of guys who take care of each other.” In this sense, the reforms led by the SEC, with Lawrence Harris at its helm, were not unlike those of the strawberry auction house described by Callon (1998). Indeed, by 2008 the SEC’s conception of the market as a database was well accepted among pro-automation industry participants. Automation would not only improve market structure, but also eliminate opportunism. Indeed, as one executive at the International Securities Exchange (Gregory Maynard) explained to us, automation would eliminate floor practices that had traditionally been dubious by constraining behavior among traders to those practices that were explicitly permitted. “The rules tell you what you *can* do in the computer,” he argued, but “they tell you what you *can’t* do on the floor” (Maynard interview). In his view, then, automation would lead to better norm enforcement. Maynard’s case for automation was representative of a view that we found elsewhere: the need for algorithms was not only technical, but also moral.

2008-10 The automation of the NYSE

The passage of Regulation NMS, alongside with the other developments discussed so far, had profound consequences for the NYSE. The reforms at the NYSE started in 2005, led by John Thain. The chief executive started with demutualization, buying the seats of the Exchange’s members and gaining control of the board in the process. With a greater handle on the Exchange, Thain proceeded with several other reforms. He diversified the Exchange’s business away from floor trading, and towards electronic trading, by acquiring an ECN, Archipelago Exchange (Concannon interview). He also moved away from low-margin US equities by merging with Euronext, a European exchange conglomerate active in both equities and higher-margin derivatives. The combined effect of these moves reduced the power of the specialists and shrank the relative importance of the floor to ten percent of the Exchange’s

overall revenue. Finally, Thain initiated an automation program that would culminate in the so-called “Hybrid” system.

We first observed the effects of Hybrid as we returned to the NYSE in February 2008. We started with a guided visit to the floor with Murray Teitlebaum, the same official we interviewed in 2003. This time, however, the floor looked markedly emptier. “Things have been very, very difficult,” Murray explained. Hybrid, NYSE’s response to Regulation NMS, had failed to live up to its promise. The NYSE had lost the bulk of its market share, dropping from a peak of 83 percent in 2003 to 27 percent in 2009, and specialist firms had laid off clerks and specialists to the point that three of the five trading rooms of the NYSE had closed (See Table 2).

---- Table 2 here ----

With Hybrid, the NYSE attempted a difficult compromise between automated and manual trading. First, the Exchange had disabled the artificial limit that constrained its previous automated system to trades smaller than 1,000 stocks; this “opened the floodgates” to algorithmic trading (Barry interview). In addition, Hybrid preserved the presence of the specialist at the post, giving customers a choice between automatic and manual auctions. Yet it soon became clear that this was not working as intended. A basic problem was speed: NYSE’s servers and routers took 360 milliseconds to process an order, while the competitors were in the ten-millisecond range (Pastina interview) and in some cases even less (MacKenzie and Pardo-Guerra 2013). Another problem was the incompatibility between algorithms and specialists: while algos matched orders in a continuous auction, specialists engaged in a discrete call auction that made it impossible for them to interact with a continuous electronic order flow (Wunsch interview). As a former specialist explained, “the bid that you think you are matching has already been hit and it’s offered there [somewhere else]” (O’Donnell interview). As another specialist put it, “the order walks away from you.”

As a result, the participation rates of the specialists, which measure the degree to which they engaged, fell from twenty percent to between one and two percent. One specialist firm even handed back its license rather than attempting to sell it, arguing that it was worth

nothing. Similarly, floor broker participation rates (their percentage of volume traded relative to total volume) fell from ten percent to three-four percent. At some point, an Exchange official recounts, “it became clear that while the operation [automation] was a success, the patient [the intermediary] was really dying” (Pastina interview).

The extent of the dissatisfaction became clear to us when we met with another specialist, standing at the post of LaBranche. As he spoke, we noticed a peculiar artifact resting on the top of one of his monitors: a small statue of a bull with a folded cylinder of paper protruding from behind it. The bull was labeled “Hybrid” and the cylinder read “ECNs.” When we asked about it, the clerk gave us an embarrassed look. “No, it’s ok,” The specialist said to him. And, to us: “that’s what we think is happening with the market right now. We’re getting screwed by the ECNs.” One of the specialists went on to describe problems that other NYSE officials had already highlighted: a proliferation of ECNs and dark pools had led to a system that he perceived as unfair. “Stocks are now very volatile, very thin margins. Before, it used to be everyone on an equal footing. Now, the people who have the bigger computer and the more money are winning. It’s a poor system.”

Amidst its limitations, Hybrid had one important strength. The system could slow the pace of trading and change into manual trading. The feature, known as Liquidity Replenishment Point (LRP), shifted the auction from automatic to manual when prices moved beyond a fixed threshold. This feature aimed at dampening volatility under crises by conducting a call auction at the specialist post. Hybrid thus preserved the specialists’ ability to match orders, but only during crisis. Yet the benefits of the LRPs were being lost amidst the widespread difficulties posed by Hybrid.

A second attempt at automation: the New Generation Model. In December 2007, a change in the management of the Exchange created an opening for reforming Hybrid. Following the departure of John Thain for Merrill Lynch, the Exchange appointed Thain’s second in command, Duncan Niederauer, as chief executive officer. Niederauer started by investing around \$500 million in automation, building a state-of-the-art data center in Mahwah, New Jersey. This would allow high frequency traders to co-locate their servers,

helping the Exchange benefit from their business. But Niederauer also showed an appreciation for the NYSE's heritage, making clear his interest in maintaining the floor while continuing to invest in technology – a strategy described by some interviewees as “all things to all people.”

To reform Hybrid, Niederauer assembled a team of executives that were both familiar with the NYSE and successfully employed outside it. This team went on to debate how to redesign Hybrid. There were two key issues under discussion. First, how to preserve the interaction between brokers and specialists? Some wanted to maintain the obligation for brokers to walk to the specialists' post, while others did not (Willis interview). A second issue under debate was how to regain block trading.

Aside from these debates, our key observation from interviewing the management team was the heightened attention that participants devoted to the specialist role. “What does it mean to be a specialist?” asked Leibowitz philosophically, in conversation with us. “Being a floor broker or a specialist,” Rutigliano told us, “was a ballet ... I get goose bumps thinking about it.” It was, as a former specialist summed up, “what I did best” (Barry interview). Indeed, the director of floor operations of a leading floor brokerage firm, Gordon Charlop, went as far as to enroll in a doctoral program in management and write a dissertation about the specialist. “The move away from the distinctive floor trading system to an electronically mediated one,” Charlop posited in his thesis, “shows signs of isomorphic forces at work” (Charlop 2009:ii). In short, the management team at the Exchange was comprised of reflexive observers of the specialist system, and (as we argue below) it redesigned the Exchange so as to preserve it. The new automation design that emerged from these debates was called New Generation Model, and launched in November 2008. It introduced a clear separation in time between automatic and manual trading, and a number of measures aimed at increasing specialist activity during automated trading.

The new specialists. In designing the New Generation Model, the Exchange acceded to specialists' demands, providing them with algorithms that would allow them to interact with the algorithmic matching engine. In turn, the specialists gave up their ability to have an

advance look at the order book. The combination of these two changes pushed the specialist away from their price-setting role to a more peripheral role of automated market participant. The Exchange also altered the payout structure of the specialists, introducing parity and subsidies. Parity was aimed at incentivizing specialist participation, and subsidies were a version of the rebates that other exchanges gave traders. These two measures aimed at increasing the chances that the specialist system would survive economically. Given the fundamental nature of these various changes, the name “specialist” was changed to “designated market maker” (DMM).

We observed the consequences of this reform during a visit to the specialist post of Bank of America in 2009. There, we had the chance to observe the work of the designated market maker for Goldman Sachs, Peter Giacchi, as well as to interview him. We found Giacchi standing outside his post, as specialists had always done. But instead of talking to the floor brokers who walked up to him as we saw Robert Hardy do --not a single broker came to Giacchi during the hour we observed him at the post-- Giacchi focused on six screens in front of him. His trading strategy, he explained, reproduced the mean-reversion approach he had used in the manual environment but now the algorithm did the information processing. “Before,” he said, he would see “sell, sell, and suddenly sell, buy, sell, sell, buy, and go ‘this is it, this is it.’” Now, his algorithm replicated the approach, and it initiated a buy order whenever the price of a stock moved more than three dollars away from the VWAP. But despite having the technology, Giacchi did not seem willing to delegate his trading to the algorithm completely: “I’ve got seventeen algos,” he explained; “they’re carrying the noise back and forth. They have no mind of their own. But what they allow me to do is wait till I can commit capital.” By giving algorithms to the specialists, we concluded, the New Generation Model had allowed them to engage in new practices, a combination of manual and algorithmic market making.

In addition to the algos, the New Generation Model introduced changes to the specialist’s job that integrated norm enforcement within algorithmic trading. This was accomplished in two ways. First, the specialists’ quoting obligations were retained, although

reduced. Second, the Exchange created a new version of the specialist, called the Supplemental Liquidity Provider, that did not have to be on the floor but had similar (though lighter) obligations. The decision to have specialists outside the floor was a logical implication of automation: by allowing actors to participate from outside the floor, and especially by subjecting them to obligations, the Exchange leveraged algorithms for the purpose of norm enforcement.

The NYSE also made an unsuccessful attempt to recreate block trading. It developed a new type of order that would not be visible in the book, the Non-Displayed Reserve Order (O'Donnell interview), and developed block trading platforms known as MatchPoint as well as a feature known as BlocTalk. But these efforts were to no avail, as trading in large blocks had shifted to dark pools. Indeed, by 2012 the combined market share of dark pools and other order “internalizers” added up to an unprecedented third of the total volume of the US equities market (MacKenzie and Pardo-Guerra 2013: 45).

The new floor brokers. As with the specialists, the introduction of the New Generation Model offered the Exchange the opportunity to re-equip floor brokers to trade algorithmically. Instead of buying and selling from the specialist, as they had done before, brokers were to buy and sell directly from the algorithmic order book. To that end, the NYSE allowed brokers to transform their rudimentary handheld terminal (a tablet-like portable computer) to support execution algorithms. In this way, brokers went from using the handheld terminal for trade annotation to using it for trade execution.

We observed these changes in action at the broker's booth of VDM Institutional Brokerage in August 2009. There, we observed Benedict Willis use his NYSE-designed handheld (known as eBroker). “By standing here, he said, “I am technically in every one of the crowds.” Instead of walking frantically from one specialist post to another, Willis just tapped on the screen to place orders. Furthermore, the handheld reproduced some of the sensemaking possibilities of a trading crowd at the post with a messaging application. In one of the windows, Benedict could see a list of tags with the badges of the other floor brokers

who were buyers or sellers in a given stock – those who had a potential interest. He explained,

You can just tap a button, you can look at a stock and find out who the players were in it and then you can actually tap the line where the broker's badge is and you'll get like a messaging window.

Benedict demonstrated this by opening up a window, writing a question mark and sending it to a colleague. After a few seconds, the colleague replied with another handwritten note, saying “just stray. sorry,” meaning that he did not have any specific information, and apologized for not being able to provide insight.

Nevertheless, the handheld was not a substitute for a crowd of live brokers at the post. While a crowd creates unintended communication trajectories (Hutchins 1995), offering social cues without the need for anyone to elicit them, the handheld requires brokers to purposefully communicate with each other. Indeed, the lack of crowds at the specialist post was a cause of concern for Benedict Willis. The management team at the NYSE concurred: as one official explained, while brokers were effectively communicating among themselves within the broker booths, brokers were not talking to specialists during routine trading and thus not helping each other make sense of price movements. As he explained, “at the booths it's a busy beehive, but cross pollination is not happening” (Pastina interview). Automation, in other words, had glued floor brokers and the new specialists to their respective computer screens, limiting communication.

Market open and close. The New Generation Model preserved the market's open and close auctions largely as they had been in 2003. These auctions, with prices shouted at the post, offered partial disclosure of the interests of the actors in the crowd. This allowed the specialists to begin trading a stock at the price they thought it was going to reach during the first minutes of trading, rather than the price where the last buy and sell orders crossed (O'Donnell interview). Specialists benefited from these auctions because they could see who was bidding at various prices, and could use that information to match orders, and because it gave them a critical source of revenue -- as high as 70 percent of their total income (Rutigliano interview). While conversation between specialists and brokers disappeared once

the electronic matching started at 9.30 am, brokers and specialists still interacted from 9.20 am to 9.30 am, preserving a routine of daily interaction that helped market participants confront interruptions of automated trading during crises -- much as the military retain preparedness for war by constantly training during peacetime.

Taken together, the changes introduced by the New Generation Model managed to revive the health of specialists and floor brokers. According to NYSE officials, the new specialists increased their participation rate from three percent in 2007 to thirteen percent in 2009, and the new brokers tripled theirs from two to six percent (Rutigliano interview). In this way, the New Generation Model managed to preserve the role of floor intermediaries, even as it automated order matching.

Folding

In theorizing the developments described so far, we propose the expression “folding” to denote the automation design that we observed. As noted, the Exchange introduced algorithms while preserving the original role structure of floor brokers and specialists, namely, the specialist system. This outcome, we contend, is similar to what chefs and cooks call folding, that is, mixing an airy mixture like beaten egg whites into a heavier one such as flour or batter, in a manner that does not split the bubbles of the beaten egg whites – thus preserving its culinary properties. We propose the use of the expression folding in economic sociology to denote an automation design that preserves the original social structure of a market (for a different but sociological use of “folding” see Deleuze and Strauss 1991; Vedres and Stark 2010). The notion of folding allows us to better understand market automation by challenging the contraposition between automation and social relations implicit in early studies of market automation (MacKenzie and Millo 2003, Knorr Cetina 2003). In this sense, it provides a language to describe and substantiate Callon’s (1998) argument that the introduction of technology in markets need not to bring about the dilution of social relations.

How is folding accomplished? We infer the underlying mechanisms by considering the differences and similarities between the first and second automation designs at the NYSE. The first design, Hybrid, was largely unsuccessful in reconciling automation with the

specialist system. By contrast, the second design --the New Generation Model-- was largely successful. An examination of their differences and similarities can provide a grounded theory of the mechanisms that work and do not work. We observe, first, that two designs were similar in three key respects: both entailed duplicative technologies (an algorithmic matching engine and a trading floor), both could shift from algorithmic to manual trading during crises, and both preserved manual trading during the market open and close. Such similarities suggest that duplication is key to folding: dual practices (manual and algorithmic trading) as well as dual technologies such as a trading floor and a data center.

At the same time, the differences between Hybrid and the New Generation Model hint at other key features of effective folding. We note, first, that the New Generation Model eliminated manual trading from so-called trading hours (9.30 am to 4.00 pm), suggesting that a strict separation in time is necessary for algorithmic trading to coexist with manual trading. Second, the New Generation Model included not just a data center but a state-of-the-art data center in Mahwah, NJ. Similarly, the New Generation Model equipped brokers and specialists to let them engage algorithmically with the Mahwah data center. These two observations suggest that retooling—building a dedicated material basis such as a new data center and algorithmic tools and interfaces—played a crucial role in providing a new function for NYSE floor intermediaries during the segment of the day in which trading is automated. Indeed, retooling allowed the floor intermediaries to switch their role: as Leibowitz put it, during trading hours (9.30 am to 4.00 pm) they “become high frequency traders.” The final difference we observe between Hybrid and the New Generation Model is that the Exchange changed its rules to develop the floor into a more inclusive platform, loosening restrictions and introducing a new form of algorithmic off-floor specialist.

Sociomaterial duplication. Taken together, the differences and similarities between the Hybrid and New Generation Model suggests a mechanism behind folding. This includes, first, a duplication of practices, in which there is room for both manual and automatic trading. Second, a separation in time, according to which manual and automated trading never take place at the same time. Third, retooling, that is, developing of new tools and material basis

that let actors to engage the algorithmic system. And fourth, inclusiveness, that is an extension of the formal rules to encompass algorithmic activity. The combined result is not just material duplication, but also a duplication of social roles and practices. Following the terminology developed by Orlikowski and Scott (2008), we refer to this as sociomaterial duplication. By sociomaterial duplication we mean the use of two different material technologies for the purpose of sustaining two different role structures: the traditional one that was in place during manual trading, plus a new one that allows the same actors to engage in algorithmic trading.

Folding and the separability of the material and the social

As noted above, the case of the NYSE can be thought of as a natural experiment on the analytical separability of the social and the material. The first lesson it offers points to the analytical inseparability of the social and material: the NYSE did not replicate the role of the specialist in a new material setting; instead, it kept the old material setting in order to preserve the figure of the specialist. The original social role of the specialist thus seems to be inseparable from its original material basis, that is, the post on the floor. In this sense, the automation of the NYSE provides corroborating evidence that the social and the material are indeed analytically inseparable, as science scholars such as Pickering (1993) have contended.

The natural experiment offers a second lesson. This points to an ostensive element in the social structure of Exchange, in line with the arguments of Feldman and Pentland (2003). Indeed, another of our observations entails the remarkable extent to which the management team at the Exchange was focused on the survival of “the specialist”. That senior executives would give a social role such attention suggests that social structure existed in what Feldman and Pentland (2003) call an “ostensive” form, that is, in an abstract and ideal dimension. But whereas Feldman and Pentland (2003) focus on only one aspect of social structure, namely, organizational routines, our findings suggest that this ostensive dimension applies to other aspects of structure such as social roles. This ostensive element is critically important to understand the automation process, as it suggests that the social guided the efforts of the Exchange in designing the material setup. Such primacy of the social over the material

challenges the work of Pickering (1993) and specifically his position that social and material agency are equally important.

Third, the natural experiment also challenges Latour's (1986, 2005) claim that the ostensive is different and incompatible with the performative. In a move away from social science traditions in which scientists are seen as better placed to understand the social world than the social actors themselves, Latour (1986) advocated a shift from an ostensive to a performative understanding of the social. Social scientists, Latour (1986) argued, should stick to what they see actors do – what he refers to as “the performative.” While seemingly contrary to Latour's approach, the ostensive dimension that we find in the automation of the NYSE, is in fact compatible with it. The ostensive dimension that we argue for is not imposed by us as social scientists, but stems instead from the actors at the NYSE and their tendency to be reflexive about their own social world, as well as to be active in preserving it. Our argument is thus based on the recognition that the actors we observed were lay sociologists of their own world, and were actively molding it to advance their agendas. But while compatible with Latour's advocacy for symmetry between the social scientist and the social actors, our analysis challenges Latour's conception of the social, and specifically the primacy he accords to the material: whereas Latour sees the social as the outcome of material associations, our analysis views the material as the outcome of an ostensive conception of the social.

Finally, the NYSE's automation prompts one additional question. How did routines, a central feature of Feldman and Pentland (2003), shape the outcome (see also D'Adderio 2008)? The question is relevant, for the move to the New Generation Model was not only prompted by the specialists' losses but also by their inability to continue performing a concrete routine --the call auction-- once the matching engine was operating. Interestingly, the New Generation Model did not restore the specialists' ability to conduct call auctions but simply redefined that routine as unviable--that is, as not part of the model. Instead of preserving the old routines, the Exchange provided tools that allowed the specialists develop new routines. The organization, in other words, did not narrow the gap between the ostensive and the performative, as Feldman and Pentland (2003) found in their study, but discarded

some routines and developed others that address the key goal of the Exchange -- preserving the intermediary role. Thus, whereas Feldman and Pentland (2003) make use of the ostensive aspect of structure to explain change, our extension of their approach to organizational roles accounts for permanence of the structure amidst technological change.

Taken together, our emphasis on both inseparability and the ostensive offers a new way to think about technology in the context of organizational change. First, it can explain the role of top management in a way that the performative does not, as it accounts for the presence of actors specialized in design. Second, it explains the workings of top-down organizational change: if roles and routines could only be identified ex-post in a performative fashion, as Latour (2005) argues, management would only be able to exert a limited influence. Yet this is not what we observed at the NYSE: as we saw, the management of the Exchange had developed a view of what structural components it sought to preserve, and designed the technology around it. Change was led by management, rather than emerging from the floor.

Folding and the Flash Crash

Our analysis of the NYSE has so far considered the process of automation, but paid less attention to its outcome. In what ways did folding impact the Exchange? The question shifts our focus away from the roles of the intermediaries, towards their functions. In other words, were the specialists able to continue providing matching, sensemaking and norm enforcement in 2010 as they did in 2003? The answer is a qualified yes. The NYSE retained some (but not all) of the social properties of the original trading floor, and especially so in manual trading. Specifically, in manual trading (during market open and close, and during crises) the New Generation Model preserved the sensemaking advantages of partial disclosure. It also retained norm enforcement, in the form of obligations for the new specialists and the secondary liquidity providers.

In automated trading, by contrast, the New Generation Model preserved matching and norm enforcement but offered no form of sensemaking. In short, the new NYSE preserved its original functions in manual mode, but lost part of them in its automated mode.

Yet because the Exchange switches from manual to algorithmic trading during crises, the specialists can tackle crises in manual mode with their sensemaking properties relatively intact. Finally, folding appears to have had a somewhat positive effect on the performance of the NYSE: while its market share did not return to the NYSE peak of 82 percent in 2003, it remained constant at around 25 percent. Automation may thus have played an important role in stemming the NYSE's market share decline, but was not able to reverse it.

The Flash Crash. Notwithstanding the above, the commercial impact of the redesigned NYSE is not the only way to measure its success, and perhaps not the most relevant one. The NYSE's redesign was put to critical test during the Flash Crash of May 6, 2010. The most comprehensive report of the Crash blamed a Kansas-based fund that set the parameters of its Sell Algorithm very aggressively (SEC-CFTC 2011). The rapid selloff of 75,000 E-Mini S&P 500 futures contracts prompted what organizational theorists would describe as a breakdown in sensemaking (Weick 1993). Indeed, as high frequency trading funds absorbed part of the selling volume stemming from the Kansas fund (with a net long position of 3,300 E-mini contracts), their volume of transactions went up to as much as 140,000 contracts. This is usual for high frequency funds, as they routinely issue numerous order cancellations in the process of trading. But such a high volume of transactions had an unexpected effect on the Sell Algorithm: as the report explains, it increased the sales volume. "The Sell Algorithm," the report states, "responded to the increased volume by increasing the rate at which it was feeding the orders into the market, even though orders that it already sent to the market were arguably not yet fully absorbed" (SEC/CFTC 2011: 3). The response of the Sell Algorithm thus flooded the market, prompting a sharp decrease in price. At the root of such flooding was a decision rule on the part of the Sell Algorithm that proved fatal: it used trading volume as a proxy for liquidity, whereas in fact (as the report argues), "in times of significant volatility, high trading volume is not necessarily a reliable indicator of market liquidity" (SEC/CFTC 2011:3). The interaction between the decision rules of the various algorithmic participants can thus be seen as an algorithmically induced breakdown in sensemaking.

Leaving aside the question of what caused the Flash Crash, the event offers an opportunity to understand the comparative effectiveness of various automation designs in the American equities market. As noted above, automation led to disintermediation: more than three quarters of traded volume is now handled by algorithmic order matching at Nasdaq, Bats and dark pools, as well as order internalizers at banks. Given that the NYSE retained its floor intermediaries, the relative impact of the Flash Crash on the various exchanges (floor-based like the NYSE, versus floor-less exchanges) can shed light on the merits of floor intermediaries. We thus ask: which exchanges performed better during the Flash Crash?

The performance of the NYSE during the crisis appears to be vastly superior to that of floorless exchanges. Consider order cancellations: such was the dislocation of prices during the Flash Crash that the SEC decided to cancel all trades beyond a 20 percent band of the prevailing price twenty minutes before the crash. This led to extensive cancellations in all exchanges except in the NYSE. As stated by Jane Kissane, legal counsel of the NYSE, in a letter to the SEC (Kissane 2010: 4):

In the aftermath of May 6, other exchanges ... engaged in a much criticized process of cancelling approximately 15,000 trades as 'clearly erroneous.' In contrast, not a single NYSE trade (excluding NYSE Arca, its electronic version) was required to be cancelled.

In other words, the NYSE's performance was exceptional. As we argue below, this performance is consistent with the functions that the sociological literature has outlined when discussing floor intermediaries.

Sensemaking. In explaining the performance of the NYSE, officials point to the Exchange's ability to switch from automated to manual auctions thanks to the Liquidity Replenishment Points, which were highly active during the crash. While on a normal trading day there are around 50 LRPs activated, on the day of the Flash Crash there were more than 70,000 (Pellecchia interview). In a much-discussed article in *Tabb Forum*, microstructure specialist Wunsch (2010) concurs:

The partially manual LRPs allowed the Big Board to apply some measure of old-fashioned reasonability tests to price formation. As a consequence, no NYSE trades printed at zero or anywhere close to it. Unlike all the other stock exchanges, the NYSE did not have to break any trades.

As Wunsch notes, one reason for the NYSE's superior performance was its ability to sustain sensemaking. Intermediaries on the floor could draw on social cues and their prior experience to establish that the sudden drop in the Dow Jones was purely due to factors internal to the market, with no economic news that could justify it. As soon as the price of stocks like Accenture and Procter and Gamble began falling sharply, floor brokers were running to the post of the designated market maker and conferring among themselves. "I was on the Procter post at that time," explained to us a trader, "the away orders were off, they came six dollars below the previous price (Scherer interview; our emphasis). Ours [the NYSE's] was one dollar below." In accounting for the better price, he adds: "what the market makers had to remember was, what's happening everywhere else *is not real*." That is, the prices given by the automated exchanges did not represent the value of the companies but rather internal processes.

Norm enforcement. A related reason for the performance of the NYSE was the norm enforcement function performed by the floor intermediaries. As Wunsch (2010) emphasizes, once the problems started, high-frequency traders withdrew their participation:

Their high frequency market makers, sensing trouble, disappeared. With little else in their books, the market orders pushed prices to where the stub quotes were, producing ridiculous trade prices. With no floor governors or other manual processes to spot the difference between real trades and market structure failure, the electronic NMS printed them all.

This argument was echoed by NYSE officials. For instance, the low price in one of the more erroneously traded stocks, Procter and Gamble, was \$39 in other exchanges but \$56 at the NYSE. The reason for the difference, according to an Exchange executive, was that unlike market makers at database exchanges, NYSE specialists had a positive obligation to commit capital (Mecane interview). Back in 2008, he explained,

One of the flaws of electronic markets is that in general people don't have obligations with respect to the market so they come and go as they please. So if they get nervous about a situation, a macroeconomic event, a political event, they go away.

In other words, the absence of obligations contributed to an episode of illiquidity.

Finally, a more detailed consideration of the impact of the Flash Crash also allows us to rule out alternative explanations. First, the lack of cancellations at the NYSE Market (excluding Arca) was not due to disengagement: the NYSE's market share between 2:30 pm and 3 pm was 26 percent, as compared to 21 percent on prior days (Kissane 2010: 5). As a result of the NYSE's shift to manual model, the counsel adds, prices on the NYSE were far less volatile than prices on electronic exchanges. Second, NYSE Arca (the electronic division of the NYSE purchased in 2006) experienced similar trade cancellations as the floor-less exchanges, which is further confirmation of the advantages conferred by the ability to shift to manual trading: the NYSE did not do better because of its location or brand (Arca had the same advantages), but because of its reliance on the intermediaries on the floor.

In sum, the NYSE performed far better than the floorless exchanges during the Flash Crash. It increased its overall participation, its designated market makers honored their obligations, its prices were less volatile, and it did not cancel any trades. The reason for this performance is that the specialists and floor brokers at the NYSE were able to engage in their matching, sensemaking and norm enforcement functions, helping other market participants confront radical uncertainty and limit the individual incentive to pull out under crisis. Our analysis of the Flash Crash thus points to the strengths of the floor intermediary, in line with the sociological notion that in the absence of intermediaries, markets may be beset by opportunism and uncertainty.

CONCLUSION

Our study of the automation of the NYSE offers three distinct contributions to the sociological analysis of markets and organizations. First, it contributes to the literature on market automation with the notion of folding, which we define as automating a market while preserving its social structure. Folding challenges the view that automation implies depersonalization, and points to the existence of an alternative design that, in the specific case of exchanges, does not entail closing off the trading floor. At the NYSE, folding entailed preserving the intermediary roles of specialists and floor brokers, allowing investors to benefit from their ability to engage in sensemaking and norm enforcement. Our study also

explains how folding can be accomplished. The NYSE achieved it through a mechanism of sociomaterial duplication. This includes retaining the old technology while adopting the new one, introducing new tools to allow floor intermediaries operate algorithmically, and updating the rules to encompass automated activity.

Second, our analysis contributes to science studies and organization theory by engaging with the debate on the analytical separability of the social and the material. In line with the arguments of science scholars like Pickering (1993), our analysis underscores the difficulties of separating a given structure of social relations from the original material basis that spawned it. Our analysis also departs from other literatures within science studies such as actor network theory (Latour 1986, 2005) by according an ostensive dimension to social structure. In this sense, our analysis falls in line with recent work on routines within organizational theory (Feldman and Pentland 2003) and offers a novel way to conceptualize the mediating effect of technology in organizational change.

Third, our findings connect with an ongoing discussion within economic sociology about the effect of institutions and technology on markets. Our study shows that the various conceptions of the market held by different actors played a central role in the design of market automation. Indeed, while the regulation issued by the SEC was consistent with an information-processing view of markets, the automation design finally chosen by the NYSE has a much better fit with a conception of markets as socially structured and mediated by intermediaries. Our study thus extends to financial exchanges the institutionalist contention that ideas about the market shape its subsequent evolution (Fligstein 1993). In addition, our study supports Callon's (1998) contention that different tools, inspired in diverse conceptions of the market, lead to widely divergent market outcomes. By combining the Fligsteinian emphasis on abstract ideas with the Callonian interest in material tools, our analysis hopes to start reconciling the institutionalist and performativity literatures.

Finally, our study has implications for public policy. The solidity of the Exchange's performance during the Flash Crash highlights the value of the floor intermediary, and suggests that the SEC's vision of markets as information-processing devices that inspired

Regulation NMS may lack the necessary mechanisms to deal with crises. By contrast, our study shows how the Exchange's design preserved the advantages of floor intermediaries. It thus suggests that as regulators reform the microstructure of the American equities market to prevent the occurrence of another Flash Crash, they would do well to take into account the importance of the floor intermediaries.

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TABLES AND FIGURES

Table 1. Interviews conducted for the study

Interviewee	Date	Affiliation on first interview
Todd Abrahall	May 7, 2009 May 11, 2010	Vice President, NYSE Euronext
Rich Barry	August 25 th , 2009	Vice President, NYSE Euronext
Herbert Beherens	May 25, 2009	Advisor, Brill Securities
Paul Bennet	May 08, 2008	Chief Economist, NYSE Euronext
Gordon Charlop	August 10, 2008 July 30 th , 2009 * December 9, 2012	Managing Director, Rosenblatt Securities Inc.
Christopher Concannon	June 22, 2008	Executive Vice President, Nasdaq
Joseph Gawronski	August 13, 2012	President, Rosenblatt Securities Inc.
Peter Giacchi	August 26, 2009	Director, Bank of America
Lawrence Glosten	February 9, 2009	Professor of Finance, Columbia University
Mark Gurilacci	June 23, 2003	Managing Director, NYSE
Robert Hardy	June 23 rd , 2003 February 25, 2008	Specialist, Fleet Financial
Lawrence Harris	December 12, 2009	Professor of Finance, University of Southern California
William Harts	June 15, 2009 August 10, 2012	President, Harts & Co.
Frank Hathaway	June 30, 2008	Chief Economist, Nasdaq
David Humphreville	May 5, 2009	President, The Specialist Association
James Hyde	December 1, 2008	Vice President, NYSE Euronext
Bryan Hyndman	August 14, 2008	Senior Vice-President, Nasdaq
Charles Jones	March 18, 2009	Professor of Finance, Columbia University
Gary Katz	January 12, 2009	President and CEO, International Stock Exchange
David Krell	January 26, 2009	Chairman, International Stock Exchange
Gregory Maynard	August 4, 2008	Officer, International Stock Exchange
James McGuire Sr	September 1, 2009	Specialist, Barclays Capital
Joseph Mecane	August 4, 2009	Executive Vice President, NYSE Euronext
Nina Mehta	May 15, 2009	Editor, Traders Magazine
Duncan Niederauer	May 8, 2009	Chief Executive Officer, NYSE Euronext
Lawrence Leibowitz	June 25, 2008	Chief Operating Officer, NYSE Euronext
Thomas Luby	May 5, 2011	Chief Executive Officer, Clearingbid Inc.
Daniel O'Donnell	July 24, 2009 December 9, 2009 August 15, 2012	Managing Director, Bank of America
Stephen Oppenheimer	August 19, 2008	Director of Marketing, Aegisoft
Bradford Paley	August 25, 2009	Principal, Digital Image Design Incorporated
Ray Pallecchia	August 14, 2009 December 9, 2009 February 26, 2013	Vice President, NYSE Euronext
Lou Pastina	August 14, 2009 February 22, 2012	Executive Vice President, NYSE Euronext

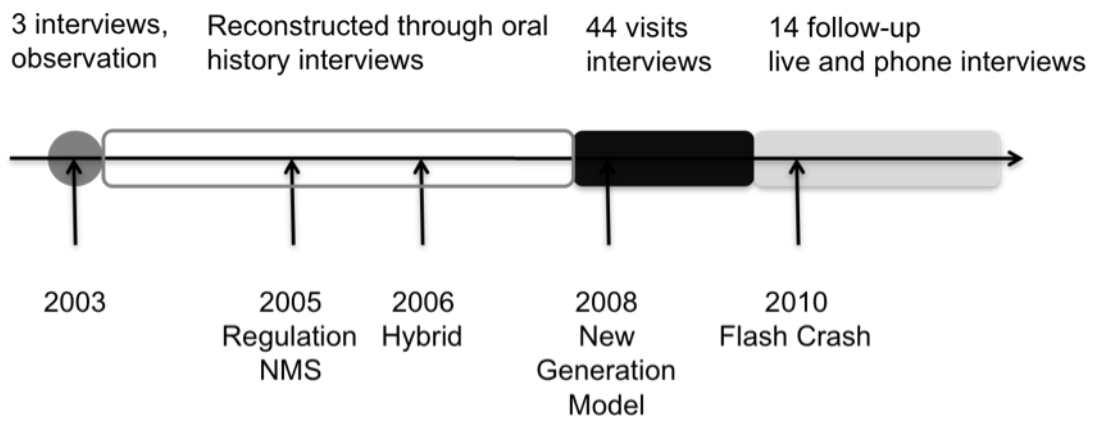
Gerard Petti	August 14, 2009	Designated Market Maker on NYSE floor, Getco LLC
Alice Rivlin	August 18 th , 2010	Senior Fellow, Brookings Institution
Michael Rutigliano	July 7, 2009 December 10, 2009	Vice President-Broker Liaison, NYSE Euronext
Joseph Saluzzi,	December 20, 2011	Partner, Themis Trading LLC
Alyssa Schoenfeld	August 24, 2008	Managing Director, NYSE Euronext
Edward Schreier	August 13, 2008	Managing Director, Deutsche Bank AG
Andrew Schwartz	September 10, 2008	Senior Partner, AGS Specialists
George Sofianos	June 24, 2009	Vice President, Goldman Sachs
Chester Spatt	February 9, 2009	Professor of Finance, Carnegie Mellon University
Murray Teitlebaum	June 23 rd , 2003,	Education Director, NYSE
Wayne Wagner	August 13, 2008 *	Former Chairman, Plexus Group
Randall Williams	July 24, 2009	Vice President, Bats Exchange
Benedict Willis	August 17, 2009 April 10, 2012 April 4, 2012	VDM Institutional Brokerage
Neal Wolkoff	January 21 st , 2008 September 21 st 2009	Chairman, American Stock Exchange
Stephen Wunsch	August 26, 2008 December 4, 2008 August 13, 2012	Corporate Initiatives, International Stock Exchange

Note: An asterisk indicates that the interviewers were both authors. All other interviews were conducted by the first author.

Table 1. Market Share of the NYSE. Note: Data is for market share for all us equities turnover, Tape A. Source: Thompson Reuters

Year	Market share
2000	80.00%
2001	80.61%
2002	78.14%
2003	77.92%
2004	76.07%
2005	76.03%
2006	71.00%
2007	44.27%
2008	29.41%
2009	27.16%
2010	27.78%
2011	26.86%
2012	23.80%

Figure 1. Interviews and site visits to the NYSE



In addition: interviews of regulators (2), academics (3), rival exchanges (9), others (3).

APPENDIX A. Glossary of financial terms.

Parity: the ability of a market maker such as the NYSE specialist to participate in an order at the same price (on par) as the customer.

Look-back option: a financial option that allows investors to "look back" at the underlying prices occurring over the life of the option and then exercise based on the underlying asset's optimal value.

Stub quote: An offer to buy or sell a stock at a price so far away from the prevailing market that it is not intended to be executed, such as an order to buy at a penny or an offer to sell at \$100,000.

E-Mini: A market index-based contract. One of the popular E-mini contracts is based on the S&P 500 stock index. The face amount (or notional value) of one E-mini S&P 500 contract is 50 times the value of the S&P 500 stock index.