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the re-making of finance**

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Insurgent capitalism: Island, bricolage and the re-making of finance

Donald MacKenzie and Juan Pablo Pardo-Guerra

Abstract

Drawing on recent discussions of the material cultures of markets and of financial innovation as bricolage, this paper explores the development of Island, a new share-trading venue set up in 1995. We examine Island's roots in a very specific conflict in the US financial markets and in the information libertarianism of 'hacker culture', and examine the material bricolage involved in Island's construction. The paper also outlines the processes that led to a dramatic 'Latourian' change of scale: Island was originally a 'micro' development on the fringes of US markets, but within little more than a decade key features of Island became close to compulsory, as the nature of North American and Western European share trading changed utterly.

Keywords: social studies of finance; materiality; bricolage; Island; matching engine; high-frequency trading.

If you walk down Broad St in lower Manhattan, you cannot help noticing the neo-classical façade of the New York Stock Exchange, the police barriers and the tourists taking photographs. A hundred metres further south, you would probably pass 50 Broad St without a second glance. It has a handsome enough frontage, but otherwise seems an ordinary Manhattan office building (Figure 1): one of its occupants in the 1990s told us that 'it was such poor office space no real company would ever be in there ... the space was weird and long and dark

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Figure 1 50 Broad St, October 2012. Authors' photograph

... catacombed with small little firms' (Andresen interview). By 2012, there was only one remaining vestige of the role the building, now renovated, had played in the history of finance: inscribed in panels attached to the stonework above an empty shop-front is the word 'island'.¹

At one level, the story of Island – a new electronic platform for the trading of shares – is a microhistory, an account of the efforts of a small number of people over a few years (1995–2002) in a handful of rooms in a nondescript New York building. When we have just witnessed, and continue to witness, what Bryan and colleagues, writing in the pages of this journal, rightly call the giant-scale 'tsunami destructiveness of financial instability' (Bryan, Martin,

et al., 2012, p. 309), a focus on the small-scale may seem suspect, exactly the kind of thing that has led to suspicion of research on finance influenced by science and technology studies (see, for instance, Bryan *et al.*, 2012; Riles, 2010). While the suspicion has multiple layers – one of which is discussed briefly in note 4 below – a basic concern is nicely expressed by *The Guardian*'s Aditya Chakraborty. Attention to the small-scale – to what seems like ‘detail’ – may appear to ignore ‘context or politics’, to paint a picture that is ‘all cogs and no car’ (Chakraborty, 2012). However, actor-network theory has taught us, ever since the earliest statement of it in English (Callon & Latour, 1981), to beware the assumption of fixed scale implicit in Chakraborty’s metaphor: as actor-network theorists argue, the small (the ‘micro’, the cogs) can become big (the ‘macro’, the car), and vice versa. Such changes of scale are rare events, but we are dealing here with one of them: Island has become a continent.

What we mean by that is that Island was the paradigm (in the more profound of the two main Kuhnian senses)² of the modern North American, Western European and East Asian trading of shares: it became the single most influential exemplar of how shares *should* be traded. Island charged unprecedently low fees. It was the first trading venue fully and deliberately to facilitate entirely automatic trading. The practice of co-location (of placing trading firms’ servers right next to a trading venue’s ‘matching engine’) was first introduced by Island. ‘Rebates’ – an incentive crucial to the contemporary economics of share trading, explained below – began with Island. In the late 1990s, these were features Island voluntarily chose. Within a decade, they became close to necessary: they are features that by around 2008 it was hard for a share-trading venue in North America, Western Europe and East Asia *not* to have. They are increasingly to be seen too in ‘emerging markets’: Brazil, in particular, has a very active automated-trading sector.

The history of Island speaks to an apparent dichotomy in scholarship on markets. On the one hand, the propagation of Island’s model – its emphasis on automatic trading and on the importance of speed, its low fees and novel form of market incentive – invokes well-known discussions of how innovators transform fields (Fligstein, 1996) and of the processes that generate institutional isomorphism (DiMaggio & Powell, 1986). On the other hand, Island references the importance of materiality and its associated cultures (cf. Miller, 2005). Influenced by work in science and technology studies (Pinch & Swedberg, 2008) and perhaps also by a strong tradition of ethnographies of exchange (e.g. Geertz, 1978), a recent sociological tradition focuses on how artefacts are implicated in constructing, maintaining and transforming markets. This tradition takes account of the cogs, to borrow Chakraborty’s metaphor. Think, for instance, of canonical studies of market devices that co-ordinate valuation and are generative of economic action (Beunza & Stark, 2004; Callon & Muniesa, 2005; Preda, 2006). Island was one such device: through code, cables and computers, it orchestrated an electronic market-place.

Studies of fields and of calculative devices are, however, relatively disconnected. They appear to deal with phenomena of different sizes and

scopes: the macrostructures of fields and institutions versus the microstructures of calculation and exchange. In this paper, we bridge this apparent divide through history. Studying the trajectories taken by market devices, and the institutions they enable, allows us to see a crucial aspect of how the markets around us, to paraphrase David (1985), got to be the way they are. For example, histories of market devices make visible forms of cultural work that shape broader economic structures. Like bicycles, machine tools and genomic techniques, market devices – from trading pits to trading screens, from cheques to point-of-sale systems – are as much cultural projects as they are feats of engineering. They are, however, often not ‘big culture’ projects, but – at least initially – ‘little culture’ projects, rooted in local struggles and in material ‘bricolage’ (see below) guided by local priorities.

Island is a case of that kind in two ways. First, its roots were in an exceptionally sharp but very specific conflict within the trading of shares on NASDAQ at the end of the 1980s and in the 1990s. The side in the conflict out of which Island evolved often saw itself as challenging finance’s established order and contesting the privileges of insiders. Second, Island exemplified a specific thread within computer programming in the United States: ‘hacker’ culture (Levy, 1984; Turner, 2006). This was and is libertarian (although by no means always in the left-wing sense of libertarianism), committed to opening up technologically or socially closed systems, and hostile to over-restrictive forms of intellectual property. Our title highlights these two aspects of Island: its conflict with the established order of trading and its culture of ‘information libertarianism’. Island was a capitalist enterprise – a very successful one – but it was shaped also by these two forms of dissent.

Culture, bricolage and market technologies

What are markets made of? Sociology has challenged the ‘ontological indeterminacy’ (Lie, 1997, p. 342) of markets that characterizes neo-classical economic thought: its lack of attention to the specific material and cultural forms that markets take. Markets are ‘social arenas where firms, their suppliers, customers, workers, and government interact’ (Fligstein & Dauter, 2007, p. 107). They are not an ahistorical abstraction, but rather are formed by tangible social elements, be they institutional fields structured through resource and power differentials between agents (Fligstein, 1990, 2001; DiMaggio & Powell, 1986), relational networks that define the possibilities of action and shape the dynamics of exchange (Granovetter, 1985) or collections of actants that articulate valuation (Callon, 1998; Callon & Muniesa, 2005).

It is that last answer to the question ‘what are markets made of?’ that is particularly relevant here. ‘Performativity’ scholars have answered: markets are made of calculation, but calculation embedded not just in social networks; rather, the focus in the approach inspired by Callon has been on calculation created through the interactions between humans and their ‘prostheses, tools,

equipment, technical devices, algorithms, etc.’ (Callon, 2005, p. 4). It is a distributed form of calculation (Hutchins, 1995), a cognitive system in which pattern recognition and categorization is co-ordinated across and between both multiple human beings and instruments of different sorts (e.g. Hardie & MacKenzie, 2007).

Adding technology and techniques to the ontology of markets introduces new questions to economic sociology. How is it, for instance, that market technologies are created, selected and grow to become dominant? How did Island become a continent? The ever-present temptation of simplistic, even technologically determinist views of innovation means that (as Engelen *et al.*, 2011, point out) we need to be very careful how we conceptualize ‘financial innovation’. An important hypothesis of the sociology of science and technology – invoked in the case of finance theory in MacKenzie (2003) and generalized to financial innovation at large by Engelen *et al.* (2011) – is that successful innovation is nearly always bricolage: the creative, ad hoc re-use of existing resources (ideas and other cultural resources as well as artefacts),³ not the mechanical implementation of a grand plan nor simply logical deduction from existing scientific theory (or, in the case of finance, from economics – a reading of the idea of performativity that surely cannot be correct).⁴

Island is a good test of the bricolage hypothesis because it is tempting to see it – harbinger as Island was of what has become a hegemonic form of market – as simply a product of contemporaneous ‘big culture’ ideologies such as neo-liberalism. Indeed – on the face of it – Island was the product of a man with a plan. Its co-founder Josh Levine, had a ‘dream’, as the main existing source on Island puts it, and in the new trading venue that dream was to ‘come alive’ (Patterson, 2012, p. 107). While not disputing Levine’s centrality, we will argue, as suggested above, that his ‘dream’ was initially forged quite locally, in a very specific material-cultural struggle. Indeed, the bricolage hypothesis strikes us as likely to hold more generally. Neither economics nor ideology defines singlehandedly the constitution of markets. Even in a case in which there is an explicit ideological commitment to a particular idea of the marketplace – in the United States, the main market regulator, the Securities and Exchange Commission (SEC), long advocated mechanization as imperative for financial markets – the making of devices involves putting together, retuning and refashioning systems. To be successful this bricolage has to be oriented towards local situations and immediate problems as well as wider goals, and it sometimes inverts the relationship between ends and means. The makers of finance’s technologies help to shape the *mise-en-scène*, but they do so by drawing on existing materials to solve concrete problems.

The bricolage hypothesis has a corollary: history matters. If innovation is shaped by local experiences and local priorities and consists mainly of the creative re-use of existing resources, then those experiences, priorities and resources can have lasting effects. Again, this corollary – the essential historicity of innovation – is widely accepted in technology studies, where the canonical illustration is David’s (1985) example, the QWERTY keyboard: a

configuration shaped by the specific exigencies of mechanical typewriters that has remained entrenched even after such typewriters have nearly vanished. If historicity is also present in finance, it means that the outcomes of local struggles and local culture can be consequential. As Riles (2010, p. 795) argues, ‘finance is an explicit politics ... a purposeful and stated compulsion of self and others, a realm of must, shall, and will’. Devices permit and compel, just as laws, regulations and ideologies do, and if their histories matter, then the ‘explicit politics’ of finance is shaped locally as well as globally.

Sources

Island has attracted little attention in the academic literature. We know of only three papers that discuss it, all by economists (Biais *et al.*, & Spatt, 2003; Hasbrouck & Saar, 2001; Hendershott & Jones, 2005), and none of these investigates what we are interested in: how Island was shaped and what its consequences were for the evolution of financial markets. Our examination of these issues draws on three sets of primary sources. First is the primary-source documents that remain available on the website (josh.com) of Island’s co-founder, Josh Levine: particularly useful are the source code of the most crucial part of Island’s computer system, its ‘matching engine’ (Levine, n.d.); a guide (Anonymous, n.d.) to Watcher, the system out of which Island developed; and a compilation (Anonymous, 1995–1997) of the messages sent to Watcher users between March 1995 and December 1997.⁵

The second set of sources is interviews. We interviewed Matt Andresen, who was appointed Island’s CEO in 1998, and six of its employees.⁶ These interviews form part of a larger corpus of interviews (numbering 140 in total), which we have conducted with those involved in the mechanization of trading venues and of trading itself (we draw on this wider corpus mainly when discussing the processes that led Island’s features to become all-pervasive in share trading in the United States). Levine met with MacKenzie, but preferred to answer our questions by email rather than be interviewed face-to-face: we sent him these questions in two large batches, to which he responded in January and May 2012. Levine also made available to us a corpus of email messages he wrote to provide information for a *Wired* article about Island (Brekke, 1999).

Contemporaneous articles, such as Brekke’s, in the financial and other press form our third set of sources. In addition, after the empirical sections of this paper were drafted and circulated to Levine and our interviewees, a popular book in which Island features heavily appeared (Patterson, 2012). Its overall tone is somewhat sensationalist, and some passages involve authorial imagination rather than documented history. However, these passages aside, its factual narrative is generally well-sourced, and we draw on it in a number of places below.

NASDAQ broker-dealers versus 'SOES bandits'

The immediate context of the emergence of Island was not its Broad St neighbour, the New York Stock Exchange (NYSE), but geographically dispersed 'over-the-counter' share trading (i.e. trading outwith exchanges such as NYSE). To trade shares, over-the-counter broker-dealers, wherever they were located in the United States, were forced by 1930s regulations to join a regulated securities association. Of the several organizations that emerged, one came to dominate: the National Association of Securities Dealers (NASD), established in 1938.

Trading in NASD took place over the telephone rather than on a trading floor. Sitting at their desks, those who wanted to buy or sell shares would call NASD broker-dealers (which were either stand-alone firms or divisions of big stockbrokers and securities houses) to obtain quotes for particular stocks; orders would be executed over the phone and clearing and settlement (the exchange of share certificates and money) were arranged by the accounting departments of the broker-dealer firm and the buyer or seller. Amidst the cacophony of telephone conversations was a very physical flow of paper slips – and in this flow, the SEC thought, surveillance was compromised. By comparison to exchanges where trading was centralized in a physical venue, the geographically dispersed over-the-counter market that NASD dominated was opaque and difficult to oversee. In 1963, the SEC's *Special Study of Securities Markets* saw automation as the solution. New computer technologies permitted, in particular, using 'a central computer to record and report interdealer quotations for some or all over-the-counter securities on a continuous basis', perhaps even 'wholly new means of matching buy and sell orders and even accomplishing their executions in some circumstances' (SEC, 1963, p. 668). Out of the *Special Study* came a dramatic transformation: in exchange for receiving broader enforcement powers, NASD adopted a version (albeit a limited one) of the SEC's recommendations on automation. NASD automated quote dissemination via NASDAQ: the NASD Automated Quotations system, introduced in 1971. Controlled by the broker-dealers of NASD, NASDAQ grew to become one of the largest markets in America, playing a fundamental role in configuring the emerging digital economy of the last decades of the twentieth century. The new companies at the heart of that economy typically chose to list their shares on NASDAQ, not the New York Stock Exchange.

While NASDAQ's electronic systems facilitated some forms of surveillance, they did little to erode long-established practices of broker-dealers. NASDAQ's structure was, by design, one that should have introduced competition in prices to the over-the-counter market. Unlike the NYSE, where a 'specialist' was the auctioneer for a specific security (with only one specialist for each stock), NASDAQ's market-makers were supposed to compete with each other: there are multiple broker-dealers in the same stock. That they did so only to a limited extent was, however, discovered by economists William

Christie and Paul Schultz (1994), who found that in many stocks NASDAQ broker-dealers avoided posting quotes – bids to buy shares, or offers to sell them – in odd eighths of dollars ($\frac{1}{8}$, $\frac{3}{8}$, $\frac{5}{8}$ or $\frac{7}{8}$). (In the early 1990s, the tradition in the United States of quoting securities prices in eighths of dollars was still in force.)

Avoiding odd eighths may sound like a minor aspect of the ‘cogs’ of financial markets, a mere numerical curiosity, but it had a substantial economic consequence. Retail investors wanting to buy or sell NASDAQ shares in effect had to do so – directly or indirectly – via the broker-dealers (small retail brokerages which were not broker-dealers transmitted customer orders to the latter), and while large institutional investors had some alternatives (notably Instinet, a system, owned by Reuters, designed to bring institutional buy and sell orders together), they also often in practice needed to trade via broker-dealers. Instead of the latter competing with each other to reduce the ‘spread’ between the price at which they would buy and the price at which they would sell shares to its minimum (an eighth of a dollar), NASDAQ’s broker-dealers implicitly colluded, by avoiding odd-eighth prices, to keep the ‘spread’ no lower than a quarter of a dollar – thus in effect doubling their per-trade income. (So profitable was the business that broker-dealers began to pay brokers for sending them retail customers’ orders, a practice introduced by a NASDAQ broker-dealer later to become a household name, Bernard Madoff.) Damning tape recordings of broker-dealers’ telephone calls to each other were discovered by the SEC and Department of Justice, and – in what was then ‘the largest civil antitrust settlement in history’ (Ingebretsen, 2002, p. 153) – the broker-dealers collectively paid a reported \$910 million to settle claims against them.

That the NASDAQ broker-dealers via whom one had to trade avoided odd-eighths price quotes (a practice that would have been visible to market participants, who could see these quotes on NASDAQ screens, before Christie and Schultz documented it) is one indicator of why those broker-dealers could be seen as self-interested, privileged insiders. However, the flash-point of the conflict out of which Island arose was a different aspect of NASDAQ, introduced by the broker-dealers in 1984: the Small Order Execution System (SOES), designed to reduce their labour costs by allowing retail brokerages to submit their customers’ orders electronically to a broker-dealer firm and have them filled at the prices it was quoting. During the 1987 stock market crash, with its precipitously plunging prices, some NASDAQ market-makers stopped processing SOES orders, and in response the SEC pushed NASDAQ to make broker-dealers’ price quotations compulsorily executable via SOES for orders of up to set sizes (for example, in the case of heavily traded stocks, 1,000 shares), a measure that came into force at the end of June 1988.

Quite unanticipated by either NASDAQ or the SEC, SOES almost immediately began being used for quite a different purpose: intra-day trading. A number of firms – first the small New Jersey brokerage Allstate Investment Group (Donlan, 1988), then others, often based in lower Manhattan, such as

Datek and Broadway Trading – started either employing traders or offering self-employed traders the capacity to use SOES to create trading positions in NASDAQ stocks that they would later quickly unwind, often at a profit. By the middle of the 1990s, over 2,000 people were doing this full time, many in and around Broad St.⁷ Visiting Island’s offices on the sixth floor of 50 Broad St, with its ‘cramped halls and stained ceiling tiles’ (Brekke, 1999), two *Forbes* journalists were also taken into second-floor rooms occupied by Broadway Trading. They walked ‘through a sparsely furnished office suite’ into ‘a dimly lit, makeshift trading room’:

There, from 9:30 a.m. to 4 p.m. each weekday, sit 50 people all males eyes firmly attached to monitors. The players are mostly under 30, wearing T shirts, blue jeans and baseball caps. They talk to one another even as they pound on the keyboards. More often they just stare intently or blurt insults at the screens. (Schiffrin & McCormack, 1998)

In the opinion of NASDAQ’s broker-dealers, such traders were ‘SOES bandits’: professionals who were cutting into their profits by exploiting the requirement – designed to protect lay investors – that the SEC had placed upon broker-dealers to honour their quotes when orders were received electronically via SOES. It was, for example, typical for each NASDAQ stock to have an ‘ax’: a broker-dealer firm that monitored trading conditions in that stock most closely and altered its quotes appropriately. Other broker-dealers would then follow suit, but a ‘SOES bandit,’ monitoring his or her screens more intently than an employee of the broker-dealer, was often able to act more quickly, for example buying shares from one broker-dealer and later selling them to another at a higher price.⁸ NASDAQ broker-dealers tried and failed to use regulation to shut ‘bandits’ out of SOES: in December 1988, the SEC approved a proposal from NASD to prohibit the use of SOES by ‘Professional Trading Accounts’, but the rule was successfully challenged legally.⁹ Endless legal skirmishing continued, however, as did verbal aggression and even death threats to SOES bandits. Physical violence took place on at least one occasion. A member of staff of a NASDAQ broker-dealer located at 43 Broad St, infuriated at being ‘SOES-ed’ by Datek’s traders, crossed to 50 Broad St and barged into Datek’s trading room, screaming ‘You did it again, I’ll fucking *kill* you!’ He leapt at one of the Datek traders, and a more senior trader picked up a letter opener and stabbed him forcibly, fortunately only in the shoulder (Patterson, 2012, p. 87).

The expression ‘SOES bandit’ was, it seems, a deliberately pejorative coinage by the NASDAQ broker-dealers. However, not all the connotations of ‘bandit’ were entirely misplaced, because at least some of those involved did see themselves as outsiders, even rebels. Mike Bellafiore, a trader who worked for Datek in the late 1990s, told us:

[W]e were rebellious in the fact that we weren't working at names of banks that you knew ... and we were rebellious in the sense that we didn't have to go to work in a suit ... we were rebellious in the fact that we had a little bit more flexibility when we could come and go. ... [A]s long as you were making money, the firm didn't care much what you were doing. (Bellafiore interview)

Such trading could involve occasional gut-wrenching losses – ‘No one blinked when a chalk-faced guy doubled over a garbage pail and puked violently, never leaving his seat and trading right through the puke’ (Patterson, 2012, p. 113) – and certainly was not always easy. For example, while SOES could be used quickly to create a trading position, by the mid-1990s unwinding it at a profit typically required use of either Instinet (designed, as noted above, for trading by larger institutions) or SelectNet (Harris & Schultz, 1998). SelectNet was another NASDAQ system, in this case originally intended for broker-dealers to trade with each other by sending out bids to buy shares or offers to sell them, and there was no compulsion on broker-dealers to respond to these bids or offers when they came from ‘bandits’. So it was understandable that the latter often saw themselves as facing ‘a closed system’, (Bellafiore interview), run by NASDAQ broker-dealers to their own advantage. The ‘closed system,’ however, was about to be broken open decisively.

‘More evolved than designed’

As Josh Levine, Island’s original software architect and programmer, told us, the first version of Island, launched in February 1996, ‘was, like most code [computer programs] in the world, more evolved than designed’ (email, 21 May 2012). Island’s two founders were Levine (who, after having ‘[d]ropped out and/or failed out’ from an electrical engineering major at Carnegie Mellon, was earning his living writing software for the finance sector in New York) and Jeffrey Citron, originally hired by Datek as a clerk. Once there, Citron began to trade, eventually striking out on his own and recruiting Levine to a number of joint ventures, several of which involved the development of software to aid traders such as those working for firms like Datek and Broadway. Both Citron and Levine retained close links to Datek, with Levine remaining based in the firm’s 50 Broad St office.¹⁰

Amongst the systems Levine built was a program called FREDY, which gave traders an audible warning when one of their NASDAQ orders had been executed. While that now sounds like a simple feature to provide, the design of electronic trading systems such as NASDAQ’s in the early 1990s was predicated on the assumption of use by human beings not computer systems. (Indeed, NASDAQ originally banned direct connections to users’ computer systems [Steiner, 2012].) Users rented proprietary computer terminals from NASDAQ, viewed price quotations on their visual display screens and entered orders using their keyboard. Lists of completed trades were printed out onto

continuous form paper by a line printer connected to the terminal. To build FREDY, therefore, Levine wrote code that emulated a line printer. Another Levine system was MonsterKey, which helped traders enter orders into SOES more quickly by providing programmable ‘macros’ that greatly reduced the number of keystrokes needed, and eventually also had a facility that automatically calculated the price that gave the order the best chance of being executed.¹¹

Watcher, the program from which Island was born, was ‘[o]riginally built on the printer-emulating code of FREDY’. It began ‘as just a program to watch for incoming executions and keep track of a trader’s position’, but Levine gradually added further features that turned it into a full-blown trading system: giving traders up-to-date information on broker-dealers’ changing quotes and other market news, permitting traders to enter orders and allowing them to send messages either to particular other users or to all the traders using Watcher (email from Levine, 27 January 2012; Anonymous, n.d.; Anonymous, 1995–1997, 15 June 1995). As Patterson (2012, p. 90) notes, Levine’s Watcher, designed as it was by a programmer who knew traders’ practices and priorities intimately, far outperformed NASDAQ’s clunky proprietary terminals, helping Datek become pre-eminent amongst lower Manhattan’s ‘bandits’.

Initially, Watcher users could not trade with each other, but only with NASDAQ broker-dealers, via either SOES or SelectNet. However, Citron and Levine noticed that it was quite common for one Watcher user to want to sell shares at a given price and another to want to buy them at that price, but to be unable to do so because the NASDAQ broker-dealers ‘rarely allowed customers to trade inside the [usually 25 cent per share] spread, even if one customer was willing to pay the same price that another customer wanted to sell his stock for’ (Schiffrin & McCormack, 1998). ‘We saw people trying to sell stock at the same prices or overlapping prices, and their orders were going unexecuted’, Citron told journalist Dan Brekke. As Citron went on gently to put it (since this kind of behaviour by broker-dealers was at the centre of the ‘odd-eighths’ scandal): ‘There was tremendous inefficiency in the markets’ (Brekke, 1999).

Accordingly, Citron and Levine added to Watcher a facility (Customer to Customer Jump trades) that allowed users to circumvent NASDAQ broker-dealers entirely and trade directly with each other. ‘It worked like this’, Levine told us:

1. You and me are sitting next to each other. I hear you mutter that you are upset that you can[not] sell the 100 shares of INTC [Intel Corporation] that you are currently long.
2. I am actually trying to buy INTC right now, so I say to you ‘Hey, I’ll buy those 100 INTC from you [for] \$125/share.’
3. You want to sell your INTC, so you agree to do the trade.

4. I enter a Jump Trade into my Watcher and we both instantly see our positions and P&L [profit and loss] updated – yours to reflect selling 100 INTC and mine to reflect buying 100 INTC. (email from Levine, 21 May 2012)

That way of proceeding, however, depended on happenstance one-to-one interactions, and Island was developed so as to facilitate trading more widely, initially amongst Watcher users: ‘the idea ... was just simply an “island” where investors could meet directly’ instead of having to go through the intermediation of NASDAQ broker-dealers (Andresen interview). ‘Island is here!’ Levine told users of Watcher on 16 February 1996. ‘If you put up 1000 shares ZXYZ at 22 3/8 [\$22.375] and someone else enters an Island order to buy 500 at 22 3/8’, then that buy order would be executed automatically. Correspondingly, if

you see 4000 shares for ZXYZ for sale at 22 1/2 on Island and you want to buy stock at 22 1/2. ... You would press <Shift 2> to enter an order to buy 1000 shares (2 lots of 500). ... Want to buy 2000 shares? Just press <Shift 2> twice. Fun. (Anonymous, 1995–1997, 16 February 1996)

At first an ‘island’ alongside NASDAQ, Citron and Levine’s new system quickly became a trading venue in its own right, an outcome that gained ‘legitimacy’ (interview, 18 April 2012) when in 1998 the Securities and Exchange Commission adopted Regulation ATS, regulating and defining the place of ‘alternative trading systems’ such as Island. Island was organized quite differently from NASDAQ or the New York Stock Exchange, the main share-trading venues in the United States. Instead of trading having to be conducted via human intermediaries (NASDAQ’s broker-dealers or NYSE’s specialists), Island’s users traded directly with each other with the intermediation only of Island’s computer systems. Those systems maintained an anonymous ‘electronic’ book of buy orders and sell orders, along with the prices and quantities bid for or offered. The ‘book’ was visible to all traders using the system.¹²

Island offered users far lower fees than existing trading venues, and Levine invented an incentive, ‘rebates’, that was to become widely influential. A trader who chose simply to take up a bid or offer in Island’s order book was charged a quarter of a cent for each share traded (Biais *et al.*, 2003, p. 6). However, a trader who provided liquidity by posting an order in the book that another trader then took up was *paid by Island* a tenth of a cent per share for doing so: in other words, was paid a ‘rebate’.¹³ Also distinctive – and far more important than the mere detail it first appears to be – is that prices on Island were denominated in 1/256ths of a dollar: as noted above, share trading in the US prior to Island was almost all done in eighths of dollars. Island’s much finer-grained price grid made it possible for those who traded on it – who, as described below, increasingly employed automated-trading systems – to

undercut NASDAQ broker-dealers' quotes by posting slightly higher bid prices and slightly lower offers.¹⁴

Previous efforts to automate exchanges had typically involved the exchange's computer system sending out information that was displayed in alphanumeric form on a proprietary screen designed for human beings to view; often, all that was displayed was the current highest bid price and lowest offer price. Again, Island's approach was different. Levine developed a computer protocol, ITCH, which was used continuously to disseminate all incoming displayable orders and cancellations of orders, leaving it up to the user's computer system to 'build the book on your side to figure out what the best price was' (interview, 18 April 2012). ITCH had a counterpart, OUCH, designed to permit computerized input of orders and cancellations of orders into Island's systems. Levine made the application programming interface (API) for Island, which facilitated interaction between its computer system and users' systems, publicly available on his website, *josh.com*. The experience of computerized interaction with Island was thus utterly different from interaction with earlier systems such as Instinet:

I mean people were screen-scraping the Instinet terminal in like, the late 90s, right. [They would take] the RS-232 cable from the modem that you're supposed to plug into the [Instinet] terminal, and they would ... plug it into another computer and interpret the ASCII codes that were drawing the rendering on the screen ... of prices and ... would send back [simulated] keystrokes ... just really obscure. (interview, 18 April 2012)¹⁵

Island also made it possible for those using automated trading systems to place their servers in 50 Broad St, in the same building as Island's own servers, and so avoid the inevitable delays in using wider computer networks to route orders and cancellations of orders to Island. Initially, this was an informal arrangement (among the many firms that occupied the building's warren of offices was a web-services firm that would host trading firms' servers [interview, 9 December 2011]), but again it was a harbinger of what was to become a widespread practice, now called 'co-location'.

As computer equipment was added by both Island and other 50 Broad St firms such as the web-services firm, the demands on the building's electricity supply grew. Originally, the building's electricity bill was simply divided up amongst its tenants according to the square footage of their offices, but that practice became untenable once tenants not involved in automated trading started to receive huge bills. Indeed, the heat generated by the multiple computers in Island's rooms started to become a real constraint on the addition of further machines (Andresen interview). Such issues were indicators of the new venue's success. By February 1998, when Island still had only four employees, it had captured 4 per cent of trading on NASDAQ, and was the third most important mechanism of such trading, after the broker-dealers themselves, who had a 78 per cent share, and Instinet (Schiffrin & McCormack,

1998). By February 2002, Island's share of NASDAQ trading reached 9.6 per cent, approaching Instinet's 12 per cent share (Biais *et al.*, 2003, p. 6).

'That's too bad, man, we could have changed the world'

In 1998, despite Island's still small size, Levine sought to appoint a chief executive to lead the business (Levine's original business partner, Jeffrey Citron, was moving on to other ventures). He approached Matt Andresen, who had moved to New York because he was a fencer and 'was the only guy in the top ten in the US that was not training in the New York Athletic Club'. Once there, Andresen had become a successful trader (in interview, he did not reject the label 'SOES bandit'), but otherwise had no business experience. Because of that, he initially said no to Levine's suggestion, but when Levine replied, 'That's too bad, man, we could have changed the world', Andresen changed his mind, describing it as 'my Pete Best moment' (Andresen interview).¹⁶

Levine's unconventional choice of CEO indicates that Island's success did not cause it to become simply another financial institution: it retained more the flavour of a dot.com start-up. There were 'piles of garbage' in its Broad St offices (interview, 10 December 2012). Another interviewee described to us joining Island and discovering that those offices housed both a makeshift turtle tank (he fed the turtles, but also had the less pleasant task of changing the water) and a computer-numerically controlled milling machine, which Levine wanted to use to make a jewellery box for his wife, and which another new recruit had to learn how to program (interview, 18 April 2012).

The contrast in self-presentation between Island and the longer-established, institution-oriented Instinet was sharp. Earlier, Instinet had been technologically very innovative, but it had become 'corporate'. Its headquarters was in one of New York's most conspicuous skyscrapers, the newly completed Reuters Building on Times Square, and 'the chairman of Instinet had this gorgeous corner office', says Andresen. '[A]t great expense', Instinet 'had installed a balcony overlooking Times Square'. In contrast, he says, Island was 'cold rice and rat meat'. The phrase invokes Coppola's *Apocalypse now* ('Charlie [the Vietcong and North Vietnamese forces] didn't get much USO. He was dug in too deep, or movin' too fast. His idea of great R&R was cold rice and a little rat meat'¹⁷), but mention of rats in 50 Broad St was not always hyperbole. Traders would often go outside to smoke in narrow, rat-infested New St, which ran behind the building. Island 'had bagel Tuesdays where we'd bring in day-old bagels for the firm, you know, "yay! Employee morale"' (Andresen interview). Little effort was put into cultivating customers in Wall Street's traditional manner (buying them dinner, etc.), but some distinctive forms of advertising were found. For example, Island distributed free yellow raincoats bearing its name. 'I always took great pleasure any rainy day ... you looked out of my office on Broad St and you'd just see hundreds of these: Island coat, Island coat, Island coat' (Andresen interview).

Island was also distinctive technologically: two of its newly recruited programmers were immediately struck by differences between Island's system and any other system in the finance sector they had seen: 'first of all, we didn't think it would work, except that it was up and running so clearly it worked' (interview, 18 April 2012). '[B]ack then people were still building things monolithically', in other words having an entire system run on an ultra-powerful, extremely expensive computer (Andresen interview). In contrast, Levine saw no need for expensive hardware and preferred to use not one machine but multiple, cheap PC central processor units: 'the first version of Island ... ran on an AST Bravo Pentium P90. ... We used those machines for everything, they were small, fast, and cheap' (email from Levine, 21 May 2012). 'Josh was like, "no, no, no, I don't want any piece of hardware that costs more than four grand"', says Andresen. The one major exception that was made was an ultra-large-capacity server 'to keep track of everything we've ever done' (Andresen interview).

Island's 'matching engine', the technical heart of its system, was an algorithm called the 'enter2order' procedure, which Levine wrote in FoxPro, a programming language for database management developed by Fox Software (Figure 2). Levine found a simple but hugely consequential 'trick' to speed matching. In Levine's later paraphrase, what the 'enter2order' procedure did when the Island system received a new order was to:

See if there was a record from a recently cancelled order that we can reuse for this new order. This is hugely important because that record will likely still be in the cache [fast internal memory] and using it will be *much* faster than making a new one. (Levine, n.d.)

After generating a 'sequence number and time stamp' for the new order, the algorithm then checked whether the order 'could potentially be filled' by matching it with orders already in the book. If so:

Start matching! Starting at the top of the book [if the new order was, e.g., an order to sell, the 'top of the book' is the existing buy orders with the highest price] until we either run out of shares or orders to match against. (Levine, n.d.)

Also crucial to the speed of the matching engine was a distinctive design decision that made it possible for the matching engine not to have to pause for 'two-phase commits'¹⁸ to check that changes in the order book were being correctly recorded in system memory:

the way he [Levine] did it was so radically different from anything I'd seen before ... the matching engine ... broadcasts out its messages in a stream that everyone reads, it assumes that if I wrote this thing on the wire that everyone else can be responsible for writing it to disk. (interview, 18 April 2012)

```

***** Enter order adds the audit, tries for a match, and if it don't work, books it.
***** Enter order assumes ostock and obuy_sell are the right length.
***** Also assumes that buy_sell has already been checked to be B or S.
***** Also assumes that the token is no already used

proc enter2order

    parameter oport,ouser,otoken,obuy_sell,oshares,ostock,oprice,otif,oshort,ommid,opa,odisplay,omin,oclearing,oflags

    if odisplay = "P"

        obasefirm = ouser

    else

        obasefirm = "####"

    endif

    && Get the working record
    if tnextdead > 0

        tlocate = tnextdead
        goto tnextdead
        tnextdead = SEQ

    else

        insert into ISLAND (LEAVES) values (0)          && Keep it out of the indexes for now
        tlocate = recno()

    endif

    tseq = tseq + 1
    awhen = str( tnow , 9 , 3)
    oleaves = oshares
    ofilled = 0
    aflag = .f.          && have we written the "A" message yet?
    if obuy_sell = "B"          && Buy order...

        set order to SSEEK

```

Figure 2 The start of the 'enter2order' procedure, the heart of Island's matching engine. Taken from the source code of the matching engine, available at <http://www.josh.com/notes/island-ecn-10th-birthday/>

It is worth noting that initially Levine was the sole architect and programmer of the Island computer system, making it possible for him simply himself to take technical decisions such as this that in other contexts in the financial sector might involve multiple meetings and protracted negotiation. The result of these decisions was that the response time of Island's system was hugely faster than that of existing systems.¹⁹ A user in the New York City area could send in an order to Island and receive a response from the system in around two milliseconds; the equivalent for an Instinet user could be as much as two seconds (email from Levine, 21 May 2012; interview, 9 December 2011).

Island's ultrafast matching engine had qualitative as well as quantitative effects, because it meant that in their pursuit of speed the nascent automated trading firms using Island (see the next section) started to focus on other sources of delay that were not salient when interacting with a slower system. For example, in around 2002 informal co-location in 50 Broad St became – for, as far as we can tell, the first time anywhere – a formal, paid-for arrangement when the automated trading firm Tradebot realized that the transmission delay (of the order of ten milliseconds, or a hundredth of a second) in the fibre-optic cables between its Kansas City office and New York was putting it at a disadvantage. 'We were excluded because of the speed of light', Tradebot's founder Dave Cummings told *The Wall Street Journal*: 'We had to move our computers' to 50 Broad St (Lucchetti, 2006).

Levine protected the simple, fast elegance of Island's system. Only a very limited number of order types were implemented in the system: essentially, just bids to buy shares at or below a limit price, and offers to sell them at or above a limit price. (Later, more complex forms of order were sometimes added to other systems as a way of attracting customers who wanted to employ them, a practice that is now under investigation by the SEC, because of allegations that it is an unhealthy aspect of the symbiosis – outlined in the next section – between trading venues and automated trading firms.) 'Josh was very, very rigorous, you know: "why do you want that order type, and why is it fundamentally different from a limit order?" ... [H]e could push back in a very articulate way' (interview, 18 April 2012).

So the bricolage involved in first developing Watcher, and then developing and evolving Island, was never simply random or opportunistic bricolage, a mere response to immediate demands and opportunities. Some of what guided it could be described as a 'programmer's aesthetic': a preference for the cheap, simple and fast over the expensive, complex and cumbersome. 'I write programs to solve problems', Levine told journalist Dan Brekke. 'I enjoy writing elegant programs. Island's an elegant solution to an annoying problem' (email, 22 March 1999). As that understated 'annoying' suggests, however, more was involved than simply a preference for technically elegant solutions. It is striking, for example, that Island did not simply make its order book visible to its customers, but also did something no exchange previously had: Levine wrote a program, 'BookViewer', that allowed anyone with internet access to see the contents of Island's order book in close to real time. He made himself (and

Peter Stern, Datek's Chief Technology Officer) visible via webcam and his site josh.com:

In 'Josh's Corner' [of josh.com] you'll see a bullet-headed, pale, dark-haired young man wearing a T-shirt and tapping away at a computer amid a dumpster-like heap of bottles, cans, take-out food containers, papers, and books. (Brekke, 1999)

As Brekke reported, Levine and Stern would even get up and dance if visitors to josh.com pressed an electronic 'bell'.

Although we have not found an instance of his use of the actual phrase, Levine's actions, as Patterson (2012) notes, indicate his commitment to the famous slogan first coined at a 'Hackers' Conference' in 1984 by Stewart Brand, who linked Silicon Valley to San Francisco's counterculture: 'information wants to be free'. (Anonymous, 1985, p. 49; see Turner, 2006). A 'hacker' was both a skilled, dedicated programmer, for whom writing software was a – sometimes obsessive – pleasure, and also a believer in opening up closed systems (see Levy, 1984). Although his work made him rich, Levine – like many hackers – seemed little guided by personal monetary reward. '[T]here's that whole hacker ethos of "I'm above money",' but unlike in many cases in which 'they affect it because it's considered cool', Andresen found it to be genuine in Levine's case: 'I'd be like, "Josh, here's your bonus cheque", [and] he was like, "ah, give it to those guys"' (Andresen interview).²⁰ Levine provided crucial technical help, free of charge, to what became Island's perhaps most potent rival: the new Chicago-based electronic trading venue, Archipelago. He not only spent many phone calls advising its founder Jerry Putnam, but even sent, gratis, segments of Island's software (Patterson, 2012, p. 144).

What Andresen remembers Levine telling him in 1998 ('we could have changed the world') shows that by then Levine had a broader ambition than making money or even simply designing an elegant technical system, and the occasional presence in Levine's phraseology of the turn of phrase of the social activist was, perhaps, not entirely accidental. Trying to persuade the journalist Dan Brekke to focus less on his biography and more on the structure of markets, Levine wrote: 'The people need a good flowchart' (email to Brekke, 12 April 1999). Exasperated by a vexatious lawsuit by an 'unhappy daytrading customer' (and perhaps also by journalists continuing to focus on 'matters of personalities as opposed to facts') he told Brekke: 'It's likely that I will soon remove and destroy the josh.com website and stop trying to help the people altogether' (email to Brekke, 27 April 1999).

In his 1999 correspondence with Brekke, '[a]fter about three minutes of thought', Levine spelled out 'seven steps to building a good market':

I think that pure auction markets are the best way to price and trade stocks (and some other things too).

A market should be fair and that fairness should be obvious from [its] design rather than something that needs to be monitored and regulated externally.

A market should encourage the creation and free dissemination of information. A market's usage fees should be reasonable and cost-based and should encourage participants to behave in ways that are good for the market as a whole.

A market should have low barriers to entry.

A market should be inclusive, not exclusive. The more participants, the better for everyone.

A market's technology should be fast, simple, robust, and scalable. (email to Brekke, 22 March 1999)

Island becomes a continent

By 1999, these precepts seemed 'mostly common sense type stuff' to Levine (email to Brekke, 22 March 1999). We have to be careful, however, not to read this 'common sense' backwards in time, as a preformed vision he had always held, nor to over-intellectualize it as, for example, a crystallization of free-market economics.²¹ Asked by us what had led him to it, Levine gave us not a systematizer's abstract answer but a *bricoleur's* concrete one, citing his accumulated experience rather than, for example, any author:

With Watcher, we had a lot of experience interacting with markets that were unfair, inefficient, and poorly regulated so we certainly knew what we wanted to avoid. (email from Levine, 21 May 2012)

It would certainly be quite wrong to read Levine's precepts forward, as a blueprint for what was to come. The 'information libertarian' aspect of them largely did not survive: information might have wanted to be free, but capitalism had other priorities. No exchange or other trading venue of which we are aware now offers an equivalent of Levine's BookViewer, allowing anyone real-time sight of its order book. The data feeds from trading venues are not free: indeed, they are a vitally important source of revenue for venues. Similarly, Levine might have wanted to stick to a small set of simple order types, but order types have subsequently proliferated and have become far more complex. Island was an influential exemplar, but an exemplar is not a template, and bricolage is not simple copying.

How, then, did Island's exemplar become influential? Limited space means that we can do no more than sketch an answer to that question, but at least three processes were involved. The first is the most straightforward: the diffusion of people and of technical designs. Island did not survive for long: in

2000 its owner, Datek Online Holdings, sold it to a group of investors including Bain Capital (co-founded by Mitt Romney), and in 2002 those investors sold Island to the trading venue to which it was the most direct threat, Instinet. In 2005, NASDAQ – the system that Island was created to circumvent – bought the US business of the merged entity. However, although the two takeovers each involved a bigger, richer company buying up a smaller rival, that rival's staff and approach to technical systems substantially changed its new owner. Island programmers rewrote Instinet's antiquated system, preserving its familiar interface ('the green screen', as traders called it) but discarding the old, slow matching engine in favour of a design that was essentially Island's.

NASDAQ, too, was transformed into something more like Island, although in its case the process had begun before 2005. Gone was the broker-dealer oligopoly: in its place, an electronic order book. A version of Levine's code – albeit by now much rewritten – still runs in the matching engines of NASDAQ, the second largest share-trading venue in the world. Although there are other, slower ways to interact with those engines, NASDAQ offers ITCH and OUCH to those who want speed, and those protocols, or minor variants of them, are used by many other trading venues. The considerable bulk of share trading in the United States now resembles trading on Island far more closely than it resembles 1990s NASDAQ or New York Stock Exchange. The established order in Europe, dominated by centuries-old institutions such as the London Stock Exchange and Paris Bourse, has also been transformed, and a crucial vehicle of its transformation was Chi-X, a new trading venue set up in 2007, with a matching engine written by two former Island programmers.

A second, more general factor causing share trading at large to become more like trading on Island is that the regulators of this trading, first in the United States and then in Europe, have deliberately sought to promote competition between trading venues. What Burchell (1996) says of neo-liberal thinkers holds directly here:

[T]hey do not regard the market as an existing quasi-natural reality ... Rather, the market exists, and can only exist, under certain political, legal and institutional conditions that must be actively constructed by government. (Burchell 1996, p. 23)

Historically, the 'quasi-natural reality' of financial markets has overwhelmingly been oligopoly of the kind exemplified by NASDAQ or de facto monopoly of the kind enjoyed by the New York Stock Exchange (see Preda, 2009 on the 'social closure' of stock exchanges). It has taken powerful regulators – above all the US SEC, since European regulation has largely followed the lead of the SEC in this respect – to create what might aptly be called a 'market for markets' (Schwartz, 2010, p. 18). Trading venues – now nearly all corporations, not membership-owned organizations – have to compete with each other for business, and the competition is often fierce.

The existence of competition amongst markets, however, does not in itself determine what market form will triumph, and in the 1990s new electronic forms of market quite different from Island were created (notably the Arizona Stock Exchange, with its discontinuous call auctions [see Muniesa, 2011]), as well as several other venues that more closely resembled Island. Here a third factor is important in Island becoming the most influential exemplar: Island's close links to a crucial category of user, the nascent automated-trading firms. 'Everything we did', Levine told us (email, 21 May 2012), 'was a collaborative effort between us and our users. Almost all of the good ideas came from the outside, we just listened and implemented them'. (Like the pervasiveness of bricolage, the role that users often play in innovation is an important theme of the sociology of technology [see, for example, Oudshoorn & Pinch, 2003].) As noted above, trading venues before Island at most tolerated automated trading, doing little or nothing to facilitate it. With its downloadable API, its fast matching engine, ITCH, OUCH, its fine-grid prices and its rebates, Island was utterly different. Only a handful of automated-trading firms pre-date Island, and one of the oldest of them, Automated Trading Desk, set up in Charleston, SC in 1988, 'was the first firm to sign up with Island' (Wipperfurth, 1999). The newer automated-trading firms created in the late 1990s, such as Tradebot and the Chicago-based Getco, also flocked to Island.

Above all, Island's technical system (for example, its ultrafast matching engine) enabled the development of a form of automated trading that had been difficult if not impossible on earlier venues: electronic market-making. In this, an automated-trading firm's technical system constantly kept keenly priced bids to buy shares and offers to sell them in Island's electronic order book, with smaller 'spreads' between the bid and offer prices than quoted by NASDAQ's broker-dealers. Co-location, fast feeds and a fast matching engine enabled automated-trading firms to minimize the main risk of market-making: being 'run over', as market-makers call it, in other words caught holding shares (or a short position in them) when prices move adversely. A co-located computer server processing the ITCH feed direct from Island's matching engine (and using other sources of information as well, such as price movements in the stock-index futures traded on the Chicago Mercantile Exchange's Globex system) could normally detect such movements fast enough to avoid being badly 'run over', using OUCH to cancel its exiting bids and offers before they were filled and resubmit them at different prices.

A kind of symbiosis thus developed between Island and electronic market-making firms. Island's speed and its rebates (which provided market-makers with a source of income additional to the 'spread' between bid and offer prices) gave them what they needed to conduct their business profitably and with reasonable safety, while their constant presence in the order book gave Island the liquidity and the tight 'spreads' that made it an attractive place for trading. Other venues competing with Island thus had little option but to develop a form of symbiosis of their own. Despite Levine's help, Archipelago, for

Table 1 Distribution of trading of US shares by venue, March 2012

NASDAQ (inc. NASDAQ OMX BX and PSX)	21.9%
New York Stock Exchange (inc. NYSE MKT)	12.5%
NYSE Arca	11.7%
BATS (BZX and BYX)	10.9%
Direct Edge (EDGX and EDGA)	9.0%
All other exchanges	1.0%
Lava Flow (electronic communications network)	1.8%
Dark pools	13.2%
Broker-dealer internationalization and over-the-counter	18.0%
	100.0%

Source: CFA Institute (2012). Dark pools are trading venues in which the order book is not visible to participants. Internationalization is when a broker-dealer itself directly executes (i.e. acts as the counterparty to) customer orders.

example, was initially handicapped by having a matching engine far slower than Island's, an engine that was also limited in its capacity to handle large volumes of orders. Amongst dissatisfied customers was Tradebot's founder, Dave Cummings, who told Jamie Selway, Archipelago's Chief Economist: 'I can't manage that risk', i.e. the danger of being 'run over' in the one or two seconds it could take Archipelago's system to process orders and cancellations. Selway told *TheWall Street Journal* that he then spent 'a hundred hours on the phone' with Cummings – who, like Levine, was a skilled programmer – discussing how to make Archipelago's system faster and better able to cope with high volumes (Lucchetti, 2006).

The effort was successful: like Island, Archipelago became a formidable competitor to the established venues, and, like it, Archipelago too was bought by one of those venues, in its case the New York Stock Exchange, which drew on its technology in rebuilding the NYSE trading system and offered NYSE Arca, as it renamed Archipelago, as an alternative to that system. The takeovers, however, did not remove the pressure from NASDAQ and NYSE. Their most successful competitors are now Direct Edge (which in its first manifestation was a trading venue called Attain, set up by Domestic Securities, the firm of the pioneer of SOES banditry, Harvey Houtkin) and BATS, launched in 2005 by Dave Cummings and a team from Tradebot. Together, Direct Edge and BATS almost rival the market shares of NASDAQ and NYSE/NYSE Arca (Table 1).

Conclusion: cogs matter; does history?

It would take a deep commitment to what Lie (1997) calls 'ontological indeterminacy' – to the idea that the material form taken by markets does not matter much – to deny that the transformation of share trading in the United States (and elsewhere) is important. Twenty years ago, share trading in the

United States was still almost entirely human-mediated and mostly took place in just two market-places: NYSE and NASDAQ. Now, there are 13 exchanges and more than 50 other trading venues. Only a very small minority of deals are now consummated by human beings: the heart of trading is tens of thousands of computer servers, in often huge data-centres linked by fibre-optic cables carrying millions of messages a second.

Share trading in the United States has thus become a giant, partially integrated technical system. The most dramatic demonstration of its potential vulnerability is the ‘flash crash’ of the afternoon of 6 May 2010: in around 20 minutes, overall share prices in the United States plunged precipitously and then recovered almost as quickly, with bizarre fluctuations in some stocks, some falling in price to a cent, and others rising in price to \$99,999.99 (see, e.g., CFTC/SEC, 2010). The trigger of the crash was not an electronic market-making algorithm of the kind perfected on Island, but a simpler sell algorithm set in motion by a mutual fund. However, that afternoon’s events show the potential for instability in the new material infrastructure of share trading. While regulatory measures – such as ‘circuit-breakers’ that pause trading in a stock if its price moves very sharply – have been introduced in the United States to reduce the chance of a repetition, it is too early to say whether they will prove successful. Fierce controversy has also erupted in Europe over automated trading. In September 2012, for example, the European Parliament voted for a compulsory half-second minimum ‘resting time’ in which an order cannot be cancelled, and the German government adopted a draft *Hochfrequenzhandelsgesetz* requiring algorithm-generated orders to be earmarked as such and high-frequency firms to be licensed. If implemented, the resting-time requirement in particular would be a dramatic change in the market ecology whose evolution we have sketched here.

The cogs, we would argue, are clearly important. Does their history matter? That is a conjecture, and it could be false. Perhaps the form of market first fully brought into being on Island is a kind of ‘attractor’, a form towards which trading would be drawn irrespective of local struggles, local culture and path-dependent bricolage of the kind discussed in earlier sections. Something akin to that was argued by the economist Lawrence Glosten in 1994, before Island was even established. ‘Is the electronic open limit order book’ – the generic kind of market of which Island was a particularly influential variant – ‘inevitable?’ asked Glosten, and he answered the question with at least a tentative ‘yes’. ‘[T]he open limit order book’, his theoretical analysis suggested, ‘is a stable institution and, within the set of economic environments and trading structures considered, the only stable institution’ (Glosten, 1994, p. 1128). It was, in other words, an attractor.

Taken on its own, the history of share trading over the past two decades is compatible with the ‘attractor’ hypothesis as well as with our ‘path-dependent bricolage’ hypothesis. It is worth noting, however, that while Island became a continent, it has not become the world. While shares, futures and to some extent options, at least in North America, Western Europe and much of East

Asia, are now generally traded on markets similar to Island, the same is not true of other asset classes such as bonds. (Foreign exchange is a kind of intermediate case, and while regulators have been pushing for interest-rate derivatives and credit derivatives to move onto electronic order books, that effort is still far from complete.) True, in some cases bonds have features that make trading in the style of Island difficult: the bonds issued by corporations are much more heterogeneous than their shares, limiting the liquidity of corporate bonds. That is, however, certainly not the case for US Federal government securities (Treasury bills, notes and bonds), especially ‘on-the-run’ (the most recently issued securities). These securities are generally seen as the most liquid financial instruments on the planet, yet to a large extent they are traded in a way that much more closely resembles 1980s NASDAQ than Island (although, at least so far, without a scandal on quite the scale of ‘odd eighths’). There are 21 officially designated primary dealers in US Federal government securities, 20 of them well-known banks or subsidiaries of such banks, and the other a big inter-dealer broker, Cantor Fitzgerald. Although there are electronic platforms on which Treasury securities can be traded, it is still largely a ‘dealer market’. It is, for example, the primary dealers who buy nearly all Treasury securities, sell them on into the secondary market and play a large role in trading in that market.

There is no clear sign here of an Island-style open electronic order book being an attractor, even though the trading of government securities falls within the remit of the Securities and Exchange Commission, just as share trading does.²² Although the reasons for the difference remain to be researched, they may include a ‘big culture’ factor – that ‘mom and pop in Peoria’, the archetypal small investors of the American imaginary who need the SEC’s protection, are envisioned as buying and selling shares, not bonds – along with two more specific factors: the absence in the government bond market of any concerted move ‘from below’ against dealer hegemony analogous to the rebellion of the SOES bandits and Island against the NASDAQ broker-dealers; and a political-economy consideration absent in share trading. There is an almost explicit bargain in which, in return for their central position in the market, the primary dealers take on obligations. As the Federal Reserve Bank of New York, operating arm of the Federal Reserve system, puts it, primary dealers are ‘required to participate in all auctions of U.S. government debt’ and have to ‘provide the New York Fed’s trading desk with market information and analysis helpful in the formulation and implementation of monetary policy’.²³ There is an informal obligation, one interviewee suggested to us, on the primary dealers to make sure that no auction of US Federal debt fails.

A capitalist, neo-liberal world thus sustains multiple forms of market, and quite possibly may continue to do so: the open electronic order book is not an all-powerful transhistorical attractor. Our argument is not that outcomes such as this are the result only of small actors and local contexts: big actors and global processes also play their part. But we remain emphatic that historical change can involve a shift in scale. In this paper, we have focused on a small actor

becoming big, on Island becoming a continent. However, we could equally have told a story of big actors becoming small, for example of the New York Stock Exchange, once a proudly autonomous social world that dominated share trading in the United States, becoming one venue among several (Table 1), subject like all other venues to the pressures of competition and the need for a symbiosis with automated trading: in other words, a story of NYSE becoming simply one part of the large socio-technical system that share trading has become.²⁴ (In December 2012, that status was underlined by the announcement that an upstart electronic commodity-futures trading venue, the IntercontinentalExchange, was buying NYSE.) NYSE was a car, and has become a cog. Island was a cog that became a car, the archetype of the new socio-economic and socio-technical environment within which even the longest-established stock exchange now has to operate. Scales are indeed not stable, and cogs – and their histories – matter.

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Notes

- 1 The set of panels looks like concrete but is ‘actually painted foam. You could pick it up with one hand. It is glued onto the façade’. (email from Josh Levine, 1 September 2012)
- 2 As Kuhn (1970, p. 145) notes, the notion of the paradigm as the successful exemplar, the ‘concrete puzzle-solution’, is ‘[p]hilosophically ... deeper’ than what became its standard interpretation as a constraining framework of thought. Exemplars are crucial because they are key cultural raw materials of ‘bricolage’ (see below).
- 3 In everyday French, ‘*bricolage*’ is ‘do-it-yourself’ or tinkering. ‘*J’ai bricolé une bibliothèque*’ would ordinarily mean ‘I knocked together a bookcase.’ The term was introduced to the Anglophone social sciences by Lévi-Strauss (1966), and although he sought to separate the scientist from the myth-making *bricoleur*, sociologists of science seized on ‘bricolage’ as a fertile metaphor for the way innovators ‘redeploy ... pieces of culture in new ways to perform new tasks’ (Barnes, 1974, p. 58).
- 4 Riles, for instance, is right to dismiss the ‘notion of the financial market as an offshoot of science’ (2010, p. 796). That version of the performativity of economics – the idea that economics, even in the narrow academic sense, is sometimes actively

drawn on in the very construction of markets, rather than simply providing passive ‘external’ representations of them – is clearly incompatible with the bricolage hypothesis. This is not the place for an extended discussion of recent critiques of performativity such as Riles (2010) and Bryan *et al.* (2012), but let us briefly say that it should not be read as a version of the simplistic linear model of technological innovation, which does indeed see technological change as an ‘offshoot of science’. The arguments against the linear model are, e.g., briefly summarized in MacKenzie and Wajcman (1985, pp. 8–9).

5 Unfortunately, messages before March 1995 appear no longer to be extant.

6 Because these Island employees went on to work for automated trading firms, and that is a publicity-shy sector, we draw on those interviews anonymously, citing only the date of the interview. Island’s co-founder, Jeffrey Citron, did not respond to our request for an interview.

7 The estimate of over 2,000 comes from James Lee, then President of the Electronic Traders Association (Harris & Schultz, 1998, p. 41).

8 This was not the only trading strategy of the ‘bandits’: others included ‘momentum trading’ (identifying rises or falls in prices that were likely to persist for at least a short period) and spotting when a large institutional order was being ‘worked’ and e.g. buying shares ahead of it (GAO, 1998, pp. 10–11).

9 William Timpinaro *et al.* *v* Securities and Exchange Commission, 2 F.3d 453 (US Court of Appeals, 1993).

10 Email from Levine, 27 January 2012; Brekke (1999). Citron’s role was primarily the business side of his and Levine’s joint ventures, but he did some of the early programming, and Levine testifies to his influence: ‘pretty much everything I did was ... shaped and guided by the long and deep arguments we would have’ (email from Levine, 21 May 2012).

11 Emails from Levine, 27 January and 21 May 2012. SOES orders were always filled at the broker-dealer’s quote, but for example inputting a sell order with a price well below the broker-dealer’s bid increased the chances of the order being filled (but also carried the risk that the broker-dealer’s quote would have changed by the time that happened).

12 Later, a facility was added to permit users to submit orders that would not be displayed in the order book, although in the matching process described below undisplayed orders had lower priority than visible orders.

13 Initially, Island offered a ‘order-entry rebate’ that went to those who ran the trading systems from which orders were sent, in order, Levine told us, to ‘incentivize’ them to implement and support the technical interconnection as well as possible. The rebate structure was later changed to that described in the text following Levine’s thoughts about the ‘*price of immediacy*’ (the cost to a trader who simply took up an existing bid or offer) and ‘*price of liquidity*’, the cost to a trader who posted a bid or offer in the order book and thus gave other traders an implicit option (in the financial-market sense): the right but not obligation to take up that bid or offer (email from Levine, 21 May 2012; emphases in original).

14 This pattern of price setting on Island is clearly documented by Biais *et al.* (2003).

15 RS-232 was a set of standards for the interconnection between computers and peripheral devices, now largely superseded by USB (universal serial bus). ASCII is the standard way of encoding English-language letters, digits and other characters.

16 Best was the original drummer of The Beatles, later replaced by Ringo Starr.

- 17 http://en.wikiquote.org/wiki/Apocalypse_Now, accessed 4 November 2012, quotation corrected. The United Services Organizations (USO) provide entertainment to US forces; R&R is ‘rest and recuperation’.
- 18 A ‘two-phase commit’ is the procedure by which a system writes information onto a disk or other form of memory and receives back a message acknowledging that the information has indeed been written.
- 19 Island’s was not the first electronic order book. Earlier examples include exchanges in Toronto, Paris, Frankfurt, Chicago and Cincinnati, as well as the Instinet system touched on in the text (see, e.g., Muniesa, 2003).
- 20 ‘Those guys’ were the programmers who had taken over much of the programming burden from Levine (email from Levine, 1 September 2012).
- 21 Patterson (2012, pp. 90–91) reports that in the mid-1990s Levine did read work on the economics of market microstructure, in particular Schwartz (1993). However, Schwartz (1993) shows only limited enthusiasm for a market form such as Island, instead advocating discontinuous call auctions, such as those implemented in the unsuccessful Arizona Stock Exchange (Schwartz, 1993, pp. 196–207; Muniesa, 2011).
- 22 There is, however, what may be a harbinger. In April 2013, NASDAQ bought the electronic bond-trading platform eSpeed from its owner, the interdealer broker BCG.
- 23 http://www.newyorkfed.org/markets/pridealers_current.html, accessed 6 November 2012.
- 24 For a sociological portrait of NYSE on the brink of the process of change discussed here, see Abolafia (1996). For NYSE’s limited but partially successful attempt to ‘fold’ the social world of its specialists into algorithms, see Beunza and Millo (2012).

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