Making markets: infrastructures, engineers and the moral technologies of finance*

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How do markets change? Conventional sociological accounts answer this question by stressing the weight of social structures on the transactional core of the marketplace. This paper provides an alternative approach. Market change is identified as an infrastructural transformation in which novel market devices and classifications are defined as the legitimate platforms for exchange. Rather than focusing on the traditional subjects of sociological enquiry, this study looks at the developers of market infrastructures in order to appraise the evolution and reinvention of markets. Empirically, the paper focuses on four historical episodes relating to the invention and dissemination of the electronic order book, a device that is central to global financial capitalism. These show how infrastructural work was implicated in creating the politics and structures of modern finance by criticising established institutions, mounting competitive challenges against incumbent institutions, establishing expansive projects of marketization and integrating otherwise disconnected marketplaces.

1. Introduction

How do markets change? For Karl Polanyi (1957) as for many scholars since, this question is pivotal to our collective imagination. An account of market change is an account of modern societies, of the central features of capitalism and its varied institutional forms. Extant sociological studies have addressed market evolution by stressing the differential influence of social structures—in the form of networks, institutions, fields and cultures—on economic organization (see Beckert 2010). The research presented in this paper provides an alternative solution. It argues that market change is a transformation of infrastructures (cf. Bowker 1994) in which novel market devices and classifications are defined as legitimate platforms for exchange. Rather than focusing on the conventional objects of sociological enquiry, this study presents four histories of infrastructures to reveal how they configured markets, transformed exchange relations and re-invented the politics of economic life.

This article focuses on the history of the electronic order book, a central technology of modern automated financial markets: The history of such a simple device, which at its core consists of a list made up by the volumes and prices at which market participants are willing to trade specific financial instruments, is ostensively a history of financial transformation. The electronic order book grounded the single most important qualitative revolution in recent finance (e.g. Glostein 1994, Domowitz 1992, 1993, Clemons and Weber 1996): its adoption displaced trading from the floors of stock exchanges onto global electronic trading networks (Zaloom 2006, Muniesa 2003), changing the spatial scope and interactional character of the markeplace (Knorr Cetina

and Bruegger 2002; Preda 2006). Its adoption also transformed the speed and politics of financial markets, as illustrated by the rise of automated trading strategies that exploit the affordances of computers and communication networks to generate profits in fractions of a second (Lenglet 2011, author ref). Statistics by the World Federation of Exchanges underscore this transformation. Between 2000 and 2009, the aggregate value of trading in global stock markets grew by 61%; the number of trades, however, grew by 700%. Trades today are smaller than what they were ten years ago, and they take place at higher speeds—turnover velocity[1] in most mature markets is generally above 80% (the NYSE Euronex and NASDAQ are notable examples: their turnover velocities are 138.5% and 300% respectively; WFE 2012). Tied to the widespread adoption of the electronic order book, these patterns are at the core of current public debates on how to understand and govern global finance (CFTC/SEC 2010). Existing scholarship, however, mostly ignores the origins of order books and, as argued here, has thus missed a fundamental insight for the sociology of markets in general and finance in particular: that understanding market change requires examining how making market infrastructures altered the nature of exchange and the politics of markets.

Within the history of the electronic order book, this article concentrates on four historical episodes to understand how infrastructures transformed American and British stock markets. The four episodes differ across numerous dimensions but share a common theme: the markets involved were made not only through the work of 'traditional' economic agents (investors and financial intermediaries, regulators and economists); fundamentally, they were also made through the work of agents who altered markets through their organizational and technological expertise. These individuals—in many

ways the engineers of modern finance, 'keepers of the [financial] community's material welfare' (Veblen 1965)—are the subjects of this study. And so, to the question of how financial markets change, this paper answers: through the *infrastructural* work deployed by market engineers who create and reconfigure finance.

The episodes explored refer to four ways in which infrastructural work is implicated in the propagation of electronic order books. Discussions around these structure the theoretical argument. After locating the concept in the literature, the paper identifies four varieties of infrastructural work in finance: critical, competitive, constructive and integrative. This is followed by a brief methodological note that introduces the empirical case studies. The paper then introduces the four episodes and draws connections between infrastructural work and the broader literature on markets, organizations and society. It then concludes with a call for re-examining and expanding sociological understandings of markets.

2. Making markets through infrastructural work

Whilst few scholars have addressed the constitutive role of infrastructures in markets[2], these are nevertheless central to the sociological imagery of late modernity. For instance, writing little more than three decades ago, Daniel Bell considered that 'teletext-radio-computer systems would breakup old geographical habits and locations' bringing about a 'change in the nature of markets from "places" to "networks"' (Bell 1987; 12). In her discussion of the new geographies of finance, Saskia Sassen mentions the couplings between telematic technologies and social institutions that configure the new spatial organization of capital (Sassen 2001). For Manuel Castells, information and

communication technologies 'allow capital to be shuttled back and forth between economies in very short time', increasing the velocity, complexity and connectedness of global financial flows (Castells 2000; 103). And in Karin Knorr Cetina's and Urs Bruegger's pivotal article, the social microstructures and terse connectivities of global foreign exchange markets are predicated upon 'response-presence-based social forms [that are] bound together by electronic information technologies' (Knorr Cetina and Bruegger 2002; 909).

These authors correctly identify technology as critical to financial markets. Yet their analyses assume rather than examine the qualities of market infrastructures; they deal not with how these infrastructures came to be, but rather with the imbrications between devices, social institutions and economic practice (cf. Latham and Sassen, 2005). This approach thus black-boxes (Pinch 1992; MacKenzie 2005) infrastructures in the making of markets[3]. Answering the question of how markets change requires engaging with an obviated fact: infrastructures matter.

The challenge, then, is conceptualizing the relationship between markets as exchange-oriented settings and their constitutive infrastructures. In this study, the relation is analyzed through the work of agents that create and reconfigure market technologies. These agents perform *infrastructural* rather than transactional work to establish the material conditions upon which exchange is then realized.

By infrastructure, I will refer to collections of technological devices, standards, classifications, protocols and material arrangements that 'often [appear] simply as a list of numbers of technical specifications, or black boxes, wires and plugs' in the marketplace (Star 2002, 1). Infrastructures, as Edwards notes, are perhaps best defined in

the negative ‘as those systems without which contemporary societies cannot function’ (Edwards 2003, 187). Not all market technologies are infrastructural. Star and Ruhleder (1996) identify nine features of infrastructures; of these, two are pertinent to this paper: infrastructures are transparent insofar as they do not have to be ‘reinvented each time or assembled for each task’; and they ‘become visible upon breakdown’.

Note that the term ‘infrastructure’ is not interchangeable with ‘technology’. As Edwards (2010, 12) notes, infrastructures involve the interconnection of multiple systems in ‘a perpetual oscillation between the desire of smooth, system-like behavior and the need to combine capabilities no single system can yet provide’. They are not systems but rather webs or networks that seldom respond to a ‘single vision, practice or plan’ (Edwards 2012, 12). Infrastructures are thus not the type of representational devices (Lynch and Woolgar 1988) emphasized in the recent sociology of finance. Consider, for instance, the growing body of research on visualization technologies (Pryke 2010; Beunza and Muniesa 2005; author ref) and models in finance (MacKenzie and Millo 2003; Beunza and Stark 2004; Lenglet 2011). These studies have a similar logic: they analyze devices that represent the world for market actors. Whereas trading screens scope what is otherwise a dislocated market (Knorr Cetina and Bruegger 2002), models act as metaphors through which agents deploy strategies (Derman 2011; cf. Lakoff and Johnson 1980; Morgan and Morrison 1999). But these devices are opaque rather than transparent, to use Star and Ruhleder’s terminology, and they are punctual rather than networked, to use Edwards’ metaphor: trading screens and algorithms, like other representational devices of finance, are center stage to framing, valuation and exchange (Callon and

Muniesa 2005) and require constant re-invention, making them foci, rather than platforms, of action.

Infrastructural work has been studied elsewhere, particularly in reference to the production of information systems (networks, protocols, classifications) within heterogeneous organizational settings (Bowker 1994). In these studies, infrastructural work is identified as a 'set of organizational techniques (technical, governmental, and administrative) that create the conditions of possibility for a particular higher-order objective' (Carse 2012). Infrastructural work entails a co-constitution of two domains: one practical and problem-oriented; another one organizational and ends-oriented. Infrastructural work can be conceptualized as a form of 'back stage' action (cf. Goffman 1958; Pinch 2008) whereby structural features are created to produce the environments where front stage actors work (Bowker 1994). The dichotomy front stage/back stage is not straightforward. Considerable efforts are placed in embedding infrastructures in practices and technologies, generating a seamless presence that only becomes apparent in moments of failure (Bowker and Star 2000).

In the case of markets, we can distinguish four varieties of infrastructural work—and thus, four ways in which markets change through the production of their underlying technologies. These forms of infrastructural work are sensitive to the character of markets as competitive, price-sensitive systems where action is oriented towards economic valuations (Weber 1978, Smith 2007).

The first form of infrastructural work is *critical* and consists of efforts to change market arrangements in response to a perceived legitimacy crisis. Here, infrastructural workers orient their products to reintroduce legitimate means of exchange. In this form of

infrastructural work, ideologies are particularly prominent since they ground the cognitive and justificational templates (cf. Block and Somers 2005, Boltanski and Thevenot 2006) that inform the design of new market devices. While the success of these devices is not determined by their original ideological context of production, these are carried over into the broader narratives and cultural repertoires of the market. In a sense, critical infrastructural work adds to the cultural tool kit (Swidler 1986) of markets by making available alternative forms of exchange. Thus, an infrastructure may be developed at some time to introduce a particular form of justice within a market. The original idea of justice may not be achieved. But broader discussions about justice in the market are nonetheless altered.

The second form of infrastructural work is *competitive* and seeks to create systems that challenge the position of market incumbents. Here, novel designs are driven by a pursuit of pecuniary rewards, for instance through lower operating costs, expanding business volumes, or reducing the market share of established firms. Note that this need not challenge prevailing schemas (i.e. it is not necessarily 'critical'). A new trading platform may be introduced merely to gain financial recompense without challenging extant conceptions of control (Fligstein 1996) or introducing novel ideological elements into market discourse.

A third form of infrastructural work is *constructive*, and implies generating devices upon which novel market mechanisms are built. Here, technology is enrolled to create organizational forms, regulate new market relations, and facilitate exchange. This form of infrastructural work entails building both organizations and devices. Similarly, it implies expanding the boundaries of the market through, for instance, the addition of new

participants or the production of standards and platforms that marketize previously illiquid, untraded instruments.

Finally, infrastructural work can be *integrative*, creating technical and organizational connections between previously unrelated domains. Arbitrage opportunities are products of this type of infrastructural work (Beunza, Mackenzie and Hardie 2006): using transatlantic cables to expedite communication between New York and London was, for instance, an integrative project that created a larger, more efficient stock market (Garbade and Silber 1978). Integration may involve broader forms of financial bricolage (Engelen et al., 2010) that make regulatory opportunities exploitable.

Emphasis on infrastructural work has three recompenses for the sociology of markets.

Firstly, it re-introduces technical change to markets by expanding the scope of significant agents to those involved in creating exchange infrastructures. This shift renders the evolution of microstructures endogenous to market institutions: rather than being late adopters that obtain resources from an exogenous set of technologies (as suggested, for instance, by business historians and economists; Cortada 2006), market institutions are re-conceptualized as responsive agents of innovation. This permits studying technical change as an intra-organizational development that blurs users and developers (Oudshoorn and Pinch 2005) and has concrete implications on 'traditional' financial innovations. The complex investment instruments described by MacKenzie (2012, forthcoming), for instance, could not have been without the co-evolution of computational resources and their associated valuation infrastructures within financial organizations.

Recognizing infrastructural work thus expands the sociology of financial innovation. 'Financial bricolage' (Engelen et al 2010), through which new tradable instruments are produced in response to regulatory changes, grows to encompass forms of material tinkering that involve altering exchange platforms. This renders financial bricolage as a broader sociomaterial strategy (Orlikowski and Scott 2008) that generates contractual innovations (traded instruments), representational devices (e.g. valuation systems) and infrastructural systems (e.g. trading platforms). From this perspective, financial bricolage (and infrastructural work in particular) involves a pragmatic positioning of action (Levi Strauss 1978; MacKenzie 2003b; Garud and Karnoe 2005), solving problems and contingencies that emerge within local organizational settings: systems are developed for surviving immediate conditions rather than long-term possibilities. This explicates path-dependencies and lock-ins that characterize technological innovation in finance (e.g. Bátiz-Lazo, Maixé-Altés and Thomes 2010; Arthur 1989, David 1985); it frames, in particular, patterns of innovation in which devices created within micro-contexts grow to become structuring elements of fields (Callon and Latour 1981, author ref)—as is shown, for instance, in Poon's (2009) study of the emergence of scorecards as sorting devices in mortgage and credit markets, or MacKenzie and Spear's (forthcoming) study of the Gaussian copula models that base evaluation practices in derivatives markets.

Infrastructural workers are hence systems builders, 'capable [of] imagining and bringing into being the large ensembles of techniques, practices, institutions, and other technologies needed to support and sustain' their inventions (Jackson et al 2007; Mackenzie 2003a). To use John Law's (1992) terminology, they are heterogeneous

engineers, seamlessly shifting action from technical to market and organizational domains. The expertise of these workers are multiple: they possess contributory skills in technology development (they are makers of financial infrastructures), but are also skilled in interacting with 'traditional' market agents and translating their concerns into specific designs (cf. Collins and Evans 2002). Dominance of these expertise characterizes a subset of infrastructural workers as 'market engineers': while not possessing group consciousness (they are not, after all, a class in a strict sociological sense), some infrastructural workers recognize their transformative capacities and frequently reflect upon how their identities are entangled with their experience in developing technologies, negotiating regulations, and occupying diverse organizational roles. They resemble, in this sense, Veblen's engineers, technological experts who 'determine, on technological grounds, what could be done in the way of productive industry, and to contrive ways and means of doing it' (Veblen 1965).

Second, infrastructural work extends discussions on the politics of markets. Market engineers are political agents that build visions of society through their innovations (Bjiker and Law 1992). The politics of markets are not located only in their embeddedness in ideational systems (Somers and Block 2005) and evaluative discourses of worth (Stark 2009; Boltanski and Thevenot 2006; Lamont 2012) maintained between norm-enforcing market agents and regulatory institutions (e.g. Abolafia 1996). Politics are also built into market arrangements through technical change: with critical forms of infrastructural work, for instance, devices that reshape the possibilities of front-stage action are introduced, modifying the distribution of power and capabilities in the marketplace (cf. Winner 1980; Riles 2010). Macro-structural accounts of market change

are thus added depth. The politics of markets are not fixed by the evolution of large ideological systems (be they the invisible hands of 'neoliberalism' or 'free market' fundamentalism; see Davis 2009, Krippner 2011, but also Polanyi 1957); they are shaped too by the implicit micro-politics of market devices (cf. Riles 2011). Histories of infrastructures reveal the importance of smaller controversies and surprises in shaping the organization of markets. This does not imply that the content of struggles is determined by the design of technology (technologies are flexible and interpretable; Bijker 1993) but points to the need for acknowledging the ideational texture of markets as weaved by threads of differing materials with varying strengths and girths.

Thirdly, recognition of infrastructural work signals the mechanisms through which market structures emerge and re-articulate: creating and maintaining market infrastructures entails harnessing technical and organizational skills that can inform future entrepreneurial action. In the case of integrative work, recognizing opportunities for recombining technologies, regulatory frameworks and organizational arrangements across domains may lead market engineers to create platforms that catalyze systemic change within the field (e.g. author ref). Having accumulated technological and organizational capital in setting up trading systems in the past, these market engineers create bridges across markets and organizations through which novel forms of financial activity emerge. In a concrete sense, the patterns of transactional work in the market are rendered possible by previous instances of infrastructural work: without the development of real-time price dissemination systems, for instance, derivatives markets would have quite possibly taken a different evolutionary path.

2.2 Telling infrastructures

The research presented in this paper combines a variety of sources on the historical development of electronic order books in Anglo-American finance. Organized around four cases, with the exception of the first case, the evidence derives mostly from semi-structured interviews with people involved in the automation of stock exchanges and other trading sites between c. 1965 and 2010. Interviewees were selected through an iterative process that combined research on the histories of firms and institutions with traditional snowballing: initially, research in specialist archives, trade publications and other periodicals on finance-and-technology was conducted to identify the names individuals involved in the automation of stock exchanges in Britain and America. Data from this phase was used to organize a first round of interviews leading to a second list of names not identified in the initial iteration. Archival research into this second set of names produced a new list of actors around which the second round of interviews was organized. This proceeded for five rounds until reaching saturation. The sample is predominantly male (only one woman was interviewed), and spans across the organizational hierarchies of financial institutions: 9 interviewees were senior managers of stock exchanges or brokerage firms; 24 were technology developers, some of whom also occupied senior management positions in the past; 7 were traders with some involvement in technology; 4 were economists and/or regulators; and 2 were journalists or consultants. The interviews took place between October 2006 and May 2012 in the United Kingdom. Three interviews were conducted over the phone. All interviews were recorded and transcribed by the author.

Studies of infrastructures are notoriously difficult to conduct: the taken-for-grantedness of these systems, the very transparency that gives them weight in everyday social life, makes identifying their creators and genealogies a cumbersome task. Indeed, perhaps the single most important methodological challenge of this study was gaining access to a field that is neglected within the financial industry itself. Until the recent prominence of high-speed trading technologies in finance, the type of infrastructural workers studied in this paper occupied modest positions within organizations. They were seen, for most of their careers and in most cases as 'fundamentally […] sort of plebs' (Buck interview), back-office workers far detached from the site of market action. The interviewees that informed this study were hence individuals who obtained some prominence within the market—people who started as trainees and, with time, became managers, and reached in some cases a seat in boards of directors. The histories they offer are thus tinted with heroic overtones. Such heroic narrative is, however, part and parcel of the approach taken to the four cases. As microhistories, they describe 'heroes' otherwise cast to oblivion, re-dimensioning large and conventionalized historical categories by placing them in the scale of every-day life (Revel 1995). The accounts presented in this paper, in this sense, purposefully stress the work of actors ignored in the literature on financial markets, attempting to highlight their historical import by their every-day vicissitudes and politics to broader patterns of economic organization.

The four microhistories here studied cover a 40 year period, from the mid-1950s to the late-1990s, and deal with developments in the United States and Britain. Each episode is used to reflect upon a particular dimension of infrastructural work. Although connected, the cases do not form an extended history of the electronic order book. The

episodes, rather, provide insights into the dynamics of infrastructures and infrastructural work in markets, showing how specific innovations were imagined, developed and disseminated.

The first episode concerns the invention of the first electronic order book in 1971. This case illustrates how the making of a novel trading platform was tied to a specific ideological critique of American financial markets. The first electronic order book never left the patent office but set the stage for further developments in financial markets. Thus, the second episode presents the early history of the American company Instinet, arguably the first firm to operate a commercially successful electronic order book. The development of Instinet's trading platform shows, in particular, how infrastructural work was implicated in competitive efforts to bypass incumbent exchanges in the United States. The case is relevant in a broader historical context: Instinet was also the first alternative trading system of its kind, a model for the organizational forms that altered finance in the 1990s and which included the electronic trading platforms that allowed for algorithmic and high-frequency trading (author ref). This episode also provides insights into how market engineers are implicated in disseminating financial infrastructures. By looking at the efforts of British institutions to import Instinet's model to the United Kingdom in the mid 1970s, the case shows how infrastructures travel across markets. The third case presents infrastructural work as a form of bricolage. Focusing on the development of an international stock market in London, the episode shows how making market technologies also implied re-creating organizations. Finally, a fourth case examines how infrastructural work led to the articulation of markets by studying the introduction of the electronic order book to British financial markets. The case shows

quite explicitly how the expertise of market engineers are transformative: by using the experience gained in developing systems at the incumbent London Stock Exchange in the previous decade, technologists created a novel trading platform that catalyzed systemic change in British (and European) finance. The four episodes are then linked through a discussion which advocates understanding markets through infrastructures rather than transactions, opening a new line of empirical enquiry for the sociology of economic life.

3. The invention of order

Like double-entry bookkeeping, order books are prominent technologies of modern capitalism (Weber 1978, Sombart 1924, Carruthers and Espeland 1991). Faced with asymmetric and unpredictable variations in supply and demand, market intermediaries developed a simple device that facilitated allocating goods across time. The device consisted of a list indicating the schedules of delivery from sellers and the orders submitted by buyers which, through a given rule, established how items were to be distributed.

The history of this device is rather imprecise—it is, after all, so widespread a technology and so simple a design. We know, however, that it is an old solution. As William A. Shaw wrote in *The Economic Journal* in 1906, one of these devices was already central to the financial organization of Restoration England between 1660 and 1667, when the Treasury of Charles II installed an order book to control the supply of government credit. The problem faced by the Treasury the discontinuity of cash flows. Previous ways of tallying credit and debt were riddled with bureaucratic complexities, and whereas revenue trickled into the Treasury's coffers gradually, expenditure was

abrupt and clustered at the beginning of the fiscal year (Shaw 1906). By recording the demand and supply of money through the order book, credit could thus be planned and managed through time.

In different guises, the order book was reinvented across several sites of economic activity as a mundane yet critical device. In financial markets it acquired salience amongst stock exchange intermediaries involved in so-called 'making markets', agents that trade on their own accounts, set the prices of traded instruments, receive orders from brokers, and match trades accordingly (O'Hara 1995). By bearing the risk of short-term price fluctuations, market makers provided liquidity to brokers at the expense of a spread in prices: they bought at lower rates than they sold. This required managing the flow of orders that entered the market. Orders to buy and sell stocks arrived asymmetrically, providing an incentive for using an inventory of sorts. The order book thus became central to the operation of the market, allowing market-makers to control inventories and adjust prices of stocks according to demand and supply. Like many of the early recording technologies of finance, the original order books were made of paper and ink, updated copies of which were kept close to the market maker's pitch on the trading floor. Their import was reflected in language: by the early twentieth century, 'keeping the book' was synonymous to making a market in a particular security, be it among New York's specialists or London's jobbers.

An important feature of these early order books resided in how they were controlled. Information on the state of the order book was private to market makers who, in exchange for this privileged access to the ebb and flow of transactions, guaranteed liquidity to brokers and investors. Not all market participants sanctioned these forms of

privilege. In mid twentieth-century America, and inspired perhaps by the earlier rise of public discourses of financial democracy (Ott 2011, Krippner 2011), criticisms of traditional market makers grew in prominence. Some were echoed by regulators—including the US Securities and Exchange Commission. Increased operational efficiencies, argued the SEC, would benefit investors by reducing the overall costs of trading. For SEC, automation of the order books of specialists would make possible '[a] system which would select the best bids and offers, execute orders, and clear transactions […] Wholesale dealers and other broker-dealer subscribers could enter quotations (and size of market) into a central computer for indexing under the appropriate security and could interrogate the computer to determine the highest bid and lowest offer, selected by the computer, together with the number of shares bid and offered at such prices' (SEC 1963). Such system emerged in over-the-counter markets and became the foundation of NASDAQ (see Ingebretsen 2002). Yet it did little to erode the position of established market-makers who remained in control of their order book; they automated to lower operational costs, but remained firmly in control of price formation and information flows. For other critics, market makers altogether needed eliminating. Automation should replace, rather than simply discipline, the exchange intermediary (see, for instance, the visions presented by Fisher Black, a founder of modern financial economics and a prominent advocate for financial automation; Black 1971, see also Mehrling 2005).

Such opposition to the intermediary was the political rationale for the invention of the electronic order book. Issued in 1971, the patent for the first modern electronic order book was created by Frederick Nymeyer, an American consultant and industrialist from South Holland, Illinois. Born in 1897 and trained in economics in the 1920s, Nymeyer

epitomized the ideological mélange of post-war America. A relatively obscure historical figure, Nymeyer is best known for his role as apostle of Austrian economics in the United States. After reading Ludwig von Mises' *Theory of Money and Credit* and *Omnipotent Government* in 1946, Nymeyer wrote to the former asking for clarification of a particular passage (Greaves 2006). Mises replied, thanking Nymeyer for his 'thoroughness and critical acumen', starting what became a longer conversation. Through multiple exchanges, Mises introduced Nymeyer to the broader works of Austrian theorists. Nymeyer reciprocated, providing ample support for Mises and his colleagues. In 1955 he founded the Libertarian Press, a '"specialist" publisher, with a limited objective dedicated to making known in the English-speaking world the *revolutionary* ideas of the Austrian Neo-Classical economists' (Nymeyer in Mises 1974). Through the Libertarian Press the work of Austrian economists was translated, published and disseminated (Sennholz 2007), introducing a novel political ideology to American audiences[4].

Austrian economics had a prominent position in Nymeyer's worldview. It was, at one level, of technical significance: the patent application for Nymeyer's electronic order book cited Bohm-Bawerk's *Capital and Interest*, a seminal reference in the Austrian repertoire (USPTO 1971a).

At another level, though, Austrian economics was an instrument for achieving moral perfection, as exposed in Nymeyer's reflections in *Progressive Calvinism.* First published in 1955 as the official pamphlet of the Progressive Calvinism League, *Progressive Calvinism* (later changed to *First Principles of Morality and Economics*) was a 'hybrid—a cross between Hebrew-Christian ethics and neoclassical economics' (*First Principles* 1960). The pamphlet sought to explore and understand 'the relations of men to

men [...] and the relations of men to things'—the moral relations founding society. Throughout its pages, Nymeyer wrote not as a theologian but as a '*practical* social science [man]' who saw in business an activity that 'solves correctly and naturally many important matters about which professional social scientists have impractical and even dangerous ideas' (*Progressive Calvinism* 1955, p. 2-3). The practical social science which *Progressive Calvinism* predicated had clear ideological overtones: it sought to uphold 'awareness of the limitations of the human mind [to] promote true humility; and [resisting] the arrogance of all attempts at universal planning, that is, all attempts at pretending we are as God, and all Comptian Positivism' (p. 10). Such critique and moral reconstruction found support in Austrian economics. By embracing valuation as a subjective process, uncertainty as irreducible, and market interaction as a bounded cognitive process (cf. Hayek 1948), the theories of the Austrians were natural instruments for Nymeyer's theological cause.

The connections between these theological motifs and Nymeyer's invention of the electronic order book are clearly delineated in the final issues of *First Principles*. Insofar as *Progressive Calvinism* was concerned with the 'relations of men to men', it sought to understand the nature of 'brotherly love' which, argued Nymeyer, was the basis of social organization. Yet the backbone of brotherly love 'CANNOT be charity', contended Nymeyer; 'instead it MUST be mutual exchange, or trade, or buying and selling [...] Charity can only supplement exchange' (*First Principles* 1960). And if exchange mattered in brotherly love, investigating the moral dimensions of prices was of the foremost import.

At the core of the Nymeyer's approach to justice lied a debate on the morality of prices, a central feature in the reconfiguration of economic spheres (Zelizer 2010). As Nymeyer wrote,

> [a] thorough analysis of the price-determining process will at the same time be thorough analyses of the questions: (1) what is wrong between men, (2) what is so-called justice, (3) what is so-called brotherly love. Understanding *price determination* will go a long way toward definitely answering what is or is not "brotherly love" (*First Principles* 1960).

For Nymeyer, the problem was finding a price that would efficiently and fairly clear the market, a 'single price for all. Probably most people would agree that that is "justice"' (*First Principles* 1960). Under such conditions,

> no buyer coerces a seller beyond the limits that the seller is willing to go; and vice versa, that no seller coerces any buyer beyond the limits that the buyer is willing to go. [...] Every buyer and seller, by this definition, himself wishes to be a buyer or seller at the price that prevails. Every actual buyer and seller prefers to pay the price he is paying or receiving, versus not trading at all. Every buyer and seller, according to his own estimation, gains by the transaction. He trades willingly. The market he creates or helps create is, in that sense, a free market (*First Principles* 1960).

Yet, as Austrian economists argued, single market-clearing prices rarely occur. Rather, markets are cleared along a range of multiple prices (see Figure 1). Anything within the range is 'just'; the ultimate market price is determined by the negotiating skill of either

buyer or seller (Bohm-Bawerk 1890), by judgment and power of coercion, things considered both unjust and undesirable in Nymeyer's view. A remedy existed: following Bohm-Bawerk, Nymeyer argued that increased competition narrowed the range of possible prices. Competition, he wrote, 'which is no respecter of persons, is the most influential factor in the world for promoting justice' (*First Principles* 1960).

[INSERT FIGURE 1 HERE]

In mid twentieth century American stock markets, however, competition between investors need not result in 'just' prices: Nymeyer argued that the mechanics of trading—whereby specialists manually generated prices through the matching of orders from brokers—meant that the benefits of competition were not reflected in prices; the structural features of the NYSE, where the monopolistic specialist controlled the transaction by controlling the order book, meant that prices could stay artificially wide. As he wrote in his patent,

> The maintenance of a fair and orderly market becomes difficult in direct relation to the increasing complexity of business structure upon which the markets are based […] the increase in the number of individuals participating in the markets but not directly present increases the possibility of manipulation of market prices by those persons, such as the stock specialists actually present at the exchange and actively engaged in making market price determinations (USPTO 1971a).

The solution Nymeyer found was to detach order books from specialists, creating conditions through which trades could be effectuated without their seemingly pernicious involvement. Filed three years earlier in 1968, and based on an abandoned patent

application from 1963, Nymeyer's invention presented a 'new and improved computation system for commodity exchanges, stock exchanges, and similar auction markets [for] establishing exchange prices for any form of fungible goods [...] without requiring the exercise of human judgment as a substantial factor in price determination' (USPTO 1971a).

The ideological content of Nymeyer's infrastructural work is clear. His was a critical effort to construct a system that allowed exchanging financial instruments without a human auctioneer, without a specialist, without the differentials of judgment or the erosion of competition in the marketplace. It was a market materialized in cables and processors that collected the subjective evaluations of many agents in a single site. Its computational, impersonal character was relevant: the system determined price with no other human intervention; such intervention was after all gratuitous, as in Nymeyer's view it would have required knowing 'in a Godlike manner, the marginal utility of each unit of goods to be traded, for every potential buyer and seller, and then to match such data so perfectly that the ideal price, presumably the 'just price," is arrived at' (*First Principles* 1960). As a moral technology, Nymeyer's patent illustrates the ideological dimensions of infrastructural work, for his was not simply a commercial opportunity; it was a spiritual quest materialized, proof that divine justice could be built through the tools of science, technology and economics.

4. Re-inventing Anglo-American finance

Nymeyer's patent was never implemented, surviving as a curious historical example of how ideology and infrastructures co-evolve in the making of markets. The same cannot

be said of a patent issued in the same year as Nymeyer's to the recently formed Institutional Networks Corporation (Instinet).

Instinet's designers were solving a problem that echoed Nymeyer's concerns. The rise of institutional investors[5] in the 1950s and 1960s presented a problem to the stock market. In particular, this class of investors was captive to the structural forms of market opposed by Nymeyer whereby specific intermediaries (such as NYSE specialists) had considerable privileges. Selling securities in the New York Stock Exchange, for example, required dealing through a broker who charged a commission on sales; it then entailed accepting the prices offered by market-making specialists on the floor of the Exchange; and, finally, such an intermediated trade increased the risk that information about the transaction could be leaked leading to an adverse price movement. For institutional investors, the situation was unwarranted particularly in light of the fact that, by the mid-1960s, they had already internalized research and portfolio management which traditionally added most of the value to intermediation. Why pay so dearly for trading? Paying for intermediation was exasperating at best, immoral at worst. Institutional Networks Corporation emerged from this competitive struggle for legitimacy.

The company and its trading platform, Instinet, were also collateral effects of Wall Street's automation. Economic growth in the post-war period made evident the operational fractures and bottlenecks of American financial infrastructures. The most notable was the heavy reliance on humans in the back-offices of brokers and stock exchanges to confirm and settle trades. As trading volumes grew in the 1950s and 1960s, the limits of this human computer were reached, leading to a virtual operational collapse of Wall Street in 1963 (Wells 2000). The event became national news and the US

Congress intervened, calling for firms and stock exchanges to invest in a new generation of mechanized systems. Electronic computers were enrolled, taking over a host of routine tasks in the back-offices of banks, brokers and exchanges.

At the time, computers were expensive to purchase and maintain, and so the business of time sharing emerged. Rather than installing systems of their own, companies would rent computer time from secondary providers (Cortada 2006). Among the first such firms to offer time-sharing was Keydata Corporation (Manns interview)[6].

Setting up Keydata required engineering a 'traditional' type of financial infrastructure: venture capital from Wall Street. This included importing specific expertise and resources that would enable the organization to grow beyond its technical origins. Financial expertise came through two 'investment banking types', Jerome M. Pustilnik and Herbert R. Behrens. And in setting up Keydata, Pustilnik and Behrens recognized an opportunity:

> they thought to themselves, 'wouldn't it be interesting to use this technology to let people trade with each other directly instead of going through these thieves at the New York Stock Exchange'. So, they actually did start Instinet in 69, has a real live trading system. It ran on Keydata. […] Instinet got on the air in 1969 with about 60 or 70 institutional trading rooms connected, one broker-dealer, Weeden & Co. […] Charlie Adams had patented some of the basic ideas of electronic trading. So there was an Adams patent. That incarnation of Instinet ran quite successfully for several years (Manns interview).

Like Nymeyer's, Instinet's patent responded to a problem of 'just' prices. The system was the first functional electronic order book, 'an apparatus and method of automatically, anonymously and equitably buying and selling fungible properties between subscribers' that permitted 'institutional investors to communicate anonymously with each other for the purpose of arranging block trades' (USPO 1971b). It thus allowed both bypassing the agents of the New York Stock Exchange and provided an anonymous system of exchange that reduced the risks of information leakages in institutional transactions. The prices it provided were free from the constraints of the NYSE and the intervention of its specialists. It was, in this sense, an instrument for and of competition, a form of competitive infrastructural work.

The system was attractive not only in the United States but also abroad. In Britain, where financial markets were controlled by the London Stock Exchange (Michie 2001), Instinet's platform was appropriated as the cornerstone of a private competitive struggle between large banks and the exchange. In London as in New York, the stock exchange was a central referent for trading: not only did it control the primary market for new issues, but it also commanded the majority of secondary stock trading in Britain. Yet precisely because of its centrality, buying and selling securities in London necessarily implied going through the heavily intermediated and costly arrangement of the stock exchange: restricted access to the trading floor, fixed broking commissions and the absence of alternative trading venues meant that large investors often paid a high price to trade.

Motivated by the high costs of trading, a group of British investment banks announced in 1971 that they would create an electronic competitor to the London Stock

Exchange. Their project, known as Automated Real-time Investments Exchange (ARIEL), was at the forefront of financial technology at the time of its launch in 1974.

Implementing ARIEL proved difficult, though. Developing a system from scratch was an expensive option, and so the seventeen banks that financed ARIEL looked to adopt a new version of the block-trading system pioneered by Instinet (Littlewood, 1998). Like Instinet, each subscriber to ARIEL would have been equipped with a terminal consisting of a screen, keyboard and a printer. The terminals would connected to a central computer that '[kept] a "book" for each security in the system into which subscribers may enter their buying and selling interests, [which are] normally broadcast to all other subscribers' (Clay and Wheble 1976 p. 66). Negotiations on particular transactions would then take place anonymously through the central computer. With this design, ARIEL meant to provide 'an inexpensive efficient trading market which will transcend National boundaries' (Kynaston 2001).

In procuring Instinet's know-how, a team from ARIEL travelled to the United States in 1971 (Clay and Wheble 1976). They soon realized that intellectual property over the market's design was critical. As David Manns, one of ARIEL's key developers recalled,

> they needed to be careful with the patents and so on. Pustilnik sold them a license to use the [intellectual property] in the patent. […] There was a user guide, which nobody ever looked at […]. But there was basically nothing. [These] bankers came back to London all chuffed with themselves that they had gotten an 'off-the-shelf' system to do this stuff. But they quickly realized that they didn't actually

> know what they'd bought and there was nothing defining what they'd bought. This system was totally undocumented. So they hired some consultants to go and document it. This friend of mine […] went out to the States to document this thing [and] he pointed out to them that they really had to start from scratch to build something because there was just no way this was going to be of any use to them. […] And in the meantime, over in the States, the Instinet people realized they had to totally replace what they had, and get it onto screens, get out from under the time sharing service which was a huge constraint in all kinds of ways. [I joined ARIEL at the time, as] the real technical guy to take over this thing as it was built by [Capgemini] and handed over (Manns interview).

Hired to develop ARIEL's trading system, David Manns had to reinvent the electronic order book. Then still in development, Instinet's second system (Instinet II) proved to be nothing more than a demonstration

> […] it was all smoke and mirrors, and we actually suggested that we build the engine for it, the actual central piece, the matching system itself [in London] on a contract basis for them. Because we had started hiring some programmers at ARIEL and this was something for them to do and it could actually make us money. So, I had a team of about five people in London working on [Instinet's second] trading system' (Manns interview).

The system that Manns and his colleagues reinvented in London as part of a targeted competitive effort against the local stock exchange thus became Instinet's core technology for years to come. But perhaps more importantly, it provided a proof of

concept, a technical and organizational roadmap for the automation of order books elsewhere[7]. Soon after the release of Instinet II in 1975, American stock exchanges increasingly adopted electronic solutions for trading. Notably, a small yet influential group of investors associated to Instinet set out to buy and automate an American exchange, and did so by 1978 when the Cincinnati Stock Exchange became a fully electronic marketplace. Mirroring Instinet, Cincinnati was an 'exchange without walls', a stock market that occupied two inconspicuous rooms in the Dixie Terminal buildings (The Miami News 1978). And like Instinet and ARIEL before it, Cincinnati revealed the beginning of a trend that became critical to financial markets in the 1990s: the emergence of alternative trading systems and electronic communication networks that eroded the position of traditional stock exchanges and constituted the foundation for computer-based and automated trading (author ref, Beunza and Millo forthcoming).

In the context of infrastructural work, the to and fro between Instinet and ARIEL exemplifies the competitive quality of technological innovation in finance. The device was built for competition and, in performing its role, it altered the politics of markets in both Britain and America. In the former, ARIEL was explicitly designed as system to induce lower broking commissions in the LSE. The banks were 'using technology as a political leaver […] over institutions like the Stock Exchange [and] Bank of England' (Manns interview). In the latter, the infrastructures of Institnet opened the possibility of competition. The electronic order book of Instinet provided a working example of how to automate trading, and as regional exchanges learnt the lessons from New York and London, they digitalized.

Less obvious are the complex trajectories generated throughout the life of market technologies. Devices invented in one market and for a specific purpose (bypassing the NYSE) were copied, transformed, adapted and reconstructed elsewhere with an altogether different end (political leverage). This process was not only a change of context. It was also a change of contents: forced to create a system from scratch, ARIEL produced novel expertise for the marketplace. Engineers involved in the development of ARIEL eventually disbanded, taking and applying their knowledge elsewhere.

5. Building technology, expanding markets

When ARIEL was announced in 1971, the London Stock Exchange reacted by accelerating the production of its proprietary information dissemination system. The system, which provided mid-prices of the market's most traded stocks through closed-circuit television, did not alter the mechanism of price formation in London. Prices remained on the floor, controlled by competing market makers (known as jobbers) who bought and sold securities on their accounts. Market Price Display Service, as the information system was known, merely provided an indication of the prices that could be obtained from a selection of jobbers. Yet despite its simplicity, it was quite a success. For the organization, it was an important source of revenues. And for its users, it offered a convenient and flexible market technology. Rather than calling the trading floor, brokers could simply turn the dial on their television sets to get a sense of the state of the market. And when conditions were calm, they could also tune into cricket matches during the trading day—a quality of the system that seems to have given it particular appeal (Bennett interview).

But when ARIEL went live, the threat of an alternative trading platform built with computers catalyzed a change in mentality, if not among all certainly among an important and influential set of members and workers of the London Stock Exchange. An additional market information service would not suffice. A different approach to technology was needed, one that did not see devices as mere facilitators, as tools to cheapen costs and expedite processes, but rather as strategic elements, the foundations for the future of the organization. What was needed, recalled the then head of the LSE's Information and Communications Committee Patrick Mitford-Slade, was a system that could handle 'an unlimited amount of information' (Mitford-Slade interview). And for this they required an army.

And so the LSE internalized research and development in 1976. The newly created Directorate of Information Systems and Settlement—which developed front and back office technologies—was given to George Hayter, a technology specialist recruited from the British Overseas Airway Corporation where he had managed the development of one of Europe's first real-time flight reservation systems. The employees who had joined the LSE previously to maintain and expand its growing information systems rose too in prominence, becoming leaders of a host of projects. Among these Peter Bennett, who had joined in the late 1960s to work on the LSE's first computer systems, acquired a particularly central role. Indeed, from 1976 to the late 1980s, the LSE was altered through the type of structurating work involved in reconfiguring organizations through technology (Orlikowski 1992). As its services expanded (MPDS was overhauled in the late 1970s, seeing the introduction of TOPIC, an extensive price visualization system, EPIC, a real-time electronic price database, and TALISMAN, a robust and resilient

paperless settlement system), so did the technical teams that produced them. To reconstitute the market through technology, the Stock Exchange amassed a small army of technologists. From a dozen technologists and engineers in the mid-1960s, by 1986 the LSE employed between 3300 and 3500 people in technical services, becoming perhaps one of the largest sites of information-technology development in corporate Europe (Sheridan, Bennett interviews). The core group of a dozen technologists that had joined the organizations a decade earlier to develop the LSE's first systems (including MPDS) grew 'to a couple of hundred, three hundred probably' (Buck interview). George Hayter alone oversaw between 2,000 and 2,200 employees whose responsibility was to 'run the market and [make innovations] operational' (Bennett interview). Programmers, developers, engineers, analysts, managers, marketing specialists and clerks overflowed the Stock Exchange's tower, requiring up to 14 buildings distributed across the City of London that housed offices, restaurants and back-up systems (Scannell interview).

In these changes resided an intriguing reconfiguration of the stock exchange technologists. Some, particularly those who possessed both seniority and demonstrated technical expertise in the organization, were no longer merely making systems. They were, quite fundamentally, making markets. These engineers transformed British finance by developing the system that replaced the trading floor of the Stock Exchange with screens and telephones (author ref). Those changes, however, did not modify the mechanics of trading (the roles of brokers and market makers persisted). On the contrary, the system folded flesh onto silicon (Muniesa 2003; Beunza and Millo forthcoming), replicating the model that had prevailed in the Stock Exchange for over a century. Unlike an order book-driven market where users submit orders anonymously to a central

mechanism for matching, the LSE's systems were 'quote-driven'. Prices were obtained by brokers from the competing quotes of market-makers, as they are on NASDAQ and other organizations modeled after over-the-counter marketplaces. The difference is critical: by providing liquidity, market makers gained clout and, in a very tangible way, controlled the politics of the organization.

The remaking of technology was also heavily influenced by regulation. In 1986, pressure from the government induced a series of legal and organizational modifications to the rules and regulations of the stock exchange that included dismantling fixed commissions, modifying the structure of trading, admitting foreign firms (Michie 2001).

Regulatory intervention had other consequences: the systems adopted in 1986 were not what the elegant, ambitious and revolutionary roadmaps that LSE's engineers had outlined in the late 1970s. Hayter and Bennett originally envisioned reassembling LSE's many information systems under a single system umbrella, creating a general-purpose network to replace those in place. The so-called Integrated Data Network (IDN) would have 'a widespread impact on the working of the Securities Industry over many years', wrote Hayter (1983), permitting interoperability and providing 'faster, easier and cheaper communications' through 'a common data network operating to a set of recognized international standards' (Hayter, 1983). IDN would have been a tremendous technological feat, had it come to fruition. It would have integrated the 'IBM personal computer, or one of its look-alikes [as] the basis for [a new] terminal system'. Brokers, market-makers and clients of all types would have been able to 'use a single terminal, or a limited range of terminals, for a multiplicity of functions'. IDN would have freed user from 'the cost and time involved in building and maintaining his own communications

networks' (Hayter, 1983). The system was no less than visionary: in design it would introduce the multi-purpose trading screen to London at a scale not seen before. Yet this 'set of standardized and versatile networking and information systems building bricks' (Bennett, 1984) would do so much more: it would be coupled to the creation of a globally accessible electronic order book, tantamount to a radical transformation of London's stock market.

Resistance from market-makers was intense, costs high, pressure from the government relentless, and so IDN never was. The audacity of its promise remained, though, and became a foundation for other equally important projects. Here, I will focus on one: how, through the organizational capital (Brynjolfsson and Hitt 2000) gained in planning for IDN, engineers created an entirely novel market. The case concerns the institution of a highly successful trading system for overseas securities in London known as SEAQ-International.

International markets were a vast frontier for exploration in the 1980s. Aside from the Eurobonds market that thrived in Britain[8], exchange controls set up during and after the Second World War had made trading in overseas shares prohibitively expensive. When these controls ended in 1979, the gates opened to a new world of possibilities.

But international markets were a frontier in more than one sense: they were an established site of computing and telecommunications technologies. Seizing the end of fixed exchange rates in 1972, for instance, Reuters had built a global information system for the foreign exchange market[9]. And when exchange controls ended, Reuters entered

the British market, posing a threat to the international expansion of the Stock Exchange. As Hayter noted,

> Reuters sensed there was an opportunity for them to move in and be the market in some major respect. In the same way that they had already become the trading mechanism for foreign exchange, they wanted to do the same thing for equities. And the first area that they started in was in was foreign equities that were not listed in London. [..]And so they set up pages that looked a bit like SEAQ, in black and white, on their Reuters monitor screens, company by company, and [in these] you could see all the market-makers quotations. [They] thought 'Well, this is our opportunity to corner, to provide the electronic infrastructure for the foreign securities market in London' (Hayter interview).

Seeking to attract trading in international securities, the LSE pursued an aggressive strategy. 'I put Peter Cox in charge of competing with Reuters on this', recalled Hayter, 'and we succeeded in creating a primitive market that actually beat Reuters at their own game' (Hayter interview).

An engineer by training, Cox was involved in at least three of the Stock Exchange's largest projects. Having previously worked at IBM, he joined LSE by secondment in 1976 to develop the settlement system TALISMAN. Cox's experience in reassembling back-office operations gave him insights on the market that contributed to the development of SEAQ-International. Working out the 'functionality that would suit the market [was] not a foregone conclusion in those days' (Cox interview). It required skill and judgment, taking into account numerous organizational scenarios; at the time

there weren't any 'models which [had] been proven in the market, when you design[ed] an electronic market' (Cox interview).

There were some clear templates of electronic trading systems: Cox's team, for instance, considered building a market through a license of Instinet's systems (the same systems that were the technical backbone of ARIEL). Such choice would have effectively locked-in the type of market selected for the trial.

> The idea was that, since we were running Instinet technology and all their expertise were in American securities and [that] there [was a] market in American securities in London, [we should] start a market in [these] running on the Instinet system and then, if successful, roll it out into other markets[,] potentially into the UK equity market (Cox interview).

The experiment did not materialize. Research conducted by LSE showed clear hostility from traders in American securities, notwithstanding the selection of Instinet.

> Hardly any of [them] were members of the Stock Exchange. They were almost all big [investment banks], Morgan Stanley, and Shearson Lehman, Merrill Lynch. […] We [told them] 'We have this great idea. We want to launch a European time zone market in American shares. You guys are in the business, you're doing it right now, it'll be great. And just sign up being alongside us with this pilot'. And they said 'Oh, that's a stupid idea. You're talking about putting a sophisticated system which runs in the most structured and regulated market in the world out here in Europe, where this American shares market runs with no regulation at all, and nobody has oversight of it. [London is] a bit of a Wild West market. And you

> want to put all this sophisticated transparent technology in there. Well that's a daft idea, and we're not going to do it' (Cox interview).

If foreign firms saw the market for American securities as 'a bit of a wild west', Cox pondered, perhaps the solution was to erect a novel institutional framework in London, a new market made from scratch. 'Why don't we organize a market in these shares', recalled Cox. 'We don't have to put all the sexy technology in place, but just try to organize a market for these players' (Cox interview).

Creating a market required trust binding participants, an extension of the LSE's *Dictum Meum Pactum* (My Word is My Bond) which had held together British markets since the early 19ths century:

> [In designing the market,] we went right back to first principles. What are stock exchanges? Why are there stock exchanges? Stock exchanges started because these people were buying and selling shares in rooms like this centuries ago [and] suddenly there were rogues amongst them. And the good guys got together and said 'Well we'll form a club of good guys and we'll sign up to a code of conduct that says we're good guys and [when] somebody slips up and doesn't meet the code of conduct, we'll throw him out and that way we'll gain confidence, you know, a market'. And that was exactly the situation we were in with these international dealing guys. They were doing the business but not everybody was quite playing by the rules (Cox interview).

Indeed, a salient feature of Cox's work is the fact that, rather than seeing markets as technical solutions, stock exchange technologists understood them as social institutions.

The creation of an orderly market hinged on reaching agreements between the traders, on standardizing and regulating their activities. As George Hayter later recalled, such standards were 'generated by the dealers in conjunction with the Stock Exchange. We allowed them to set the rules for how these quotations were to be interpreted. And things like what the standard size would be for the quotations, what currency they should be quoted in, what settlement house would be used for the clearing process. These were not universally accepted, they were not standardised, until we got these people together in a room' (Hayter interview). The work of market engineers was not aimed at reducing the social from the marketplace but rather, as Cox wrote in 1985, to create 'confidence in the market place, [allowing] for it to reach its full potential' (Cox 1985). Even if the business of 'buying and selling securities [were] to be heavily computerised and based upon large scale networks', as Cox wrote in 1985, the future of the market did not lie 'entirely in the hands of the technologists' (Cox 1985).

A market in overseas securities needed more than trust and regulation, though. The market lacked a 'uniformity of presentation, [instead] working according to how each individual firm interpreted it' (Cox interview). Uniformity was achieved with a simple electronic price bulletin board available to all members of the newly constituted market, a public order book of sorts. And as Cox's team continued to structure the new international market in London, they 'went from creating a sort of […] bulletin board to being a market department which regulated the market, wrote the rules, and also created a membership scheme for foreigners' (Cox interview).

The outcome, SEAQ International, cobbled together existing systems. It was financial bricolage of a sociomaterial variety (Engelen et al., 2010, author ref). But this bricolage was not uniquely technical. Critically, it was organizational. In negotiating standards, creating devices, formatting information, endearing trust and expanding the limits of the market, SEAQ International modified the Stock Exchange itself. It was prolific investment. As SEAQ-I expanded into a wider variety of shares it commanded a larger segment of the European market. In the late 1980s, SEAQ-I captured between 26% and 60% of the trading in the shares of the 250 largest European companies by capitalization. By 1990, trading in French shares on SEAQ-I represented as much as one fourth of the volume traded on the Paris Bourse (Jacquillat and Gresse, 1998). SEAQ-I 'sucked liquidity from the continental market centers', recalled Bennett (Bennett interview). It made London, once again, a pivot of the global financial marketplace.

6. PIPE Dreams

SEAQ-International proved that markets could be made through sweat, technology and trust. But it also proved the uniqueness of market engineers like Cox, Bennett and Hayter. Theirs was not a supplementary role; it was transformative (Veblen 1965). And what these engineers didn't implement, they dreamt.

It was precisely through the visionary work of these agents that the modern order book arrived to London: the first commercially-successful, fully-functional electronic order book in Britain was installed not by the LSE but by a splinter group of engineers who left the Stock Exchange in 1990. When the market crash of 1987 affected trading volumes at LSE, income fell and in late 1989 the Stock Exchange incurred a loss. The

first casualty was research and development. To control costs, technology was outsourced. George Hayter left in December 1990 – '[If] you're going to outsource to Arthur Andersen, you don't need a director who's responsible for internal IT services', he recalled – going off to 'develop stock exchanges in Eastern Europe' (Hayter interview). Peter Bennett departed in 1990 too and, for a time, earned 'his bread and butter' by convincing 'the top exchanges in Europe to agree that there was a need for a European price dissemination system' (Bennett interview). Bennett's project provides a particularly stark example of the articulations created through infrastructural work

Bennett's European price dissemination system was part of the same genealogy of technologies that inspired Integrated Data Network. It was, equally, shaped by regulatory imperatives. European regulators had set 1992 as a deadline for implementing the free flow of financial services between the then twelve member states of the European Union. An opportunity for creating communications infrastructures thus emerged, as Bennett's colleague, Michael Waller-Bridge, recalled:

> we [Bennett, Waller-Bridge and Steven Wilson] generated […] the idea that there should be [a] cost effective infrastructure on a pan-European basis, not in a federalized sense but a set of cooperative arrangements [between national stock exchanges]. Peter and I and others in the group were assigned to it. And this became a joint venture. It was a joint venture between the principal stock exchanges of the then 12 member states. Peter was in charge of the technology. I was in charge of the joint venture discussions and was put in charge of the joint venture company.

The project, known as Pan European Market Information Network (PIPE), was ambitious, contemplating first, 'a central information capture and delivery point for regulated and strategic securities market information, and the dissemination of this information in real time throughout Europe'; second, 'a network capable of providing interactive access to market systems operated by Exchanges, third parties and the PIPE database'; and third, 'a central point for automated trade execution, trade confirmation and settlement message routing' (Federation of Stock Exchanges in the European Authority 1990). It was, in sum, a version of London's IDN at a European scale. 'The inspiration', said Waller-Bridge, 'had really been the Consolidated Tape in the United States which was enacted by congressional fear in 1975 to insure that there was equivalent access to data across America' (Waller-Bridge interview).

Like IDN, PIPE failed. Opposition from the London Stock Exchange cancelled the project, and '[even] the idea of the joint infrastructure on a [European] scale went out' (Waller-Bridge interview).

> [We] felt we really couldn't operate in that environment. Peter and I and [Wilson] then left and started a consulting company. And from that consulting company, which was called Bennett, Waller-Bridge, Wilson, or BWW, we started worked on consulting work, but we also had a plan to say that European wide infrastructure could work. It really was going to work, it could lead to a system. [But] we were no longer within the institution. We were outside, so we decided to do this as a venture. And by 1991 we had actively decided that we could do this, if we could raise capital and if we could move forward (Waller-Bridge interview).

The course taken by Bennett and colleagues was bold. To build a European infrastructure, to articulate markets across the region, they needed institutional support. Their company, a small consultancy set in London, was not sufficient. They needed an exchange. So they built one, in Thames Wharf.

> [That's] where all the creative work was done […] what were the market constructs, what the technology was, what the regulatory structure was et cetera, et cetera. And that was really the genesis of the whole thing that became Tradepoint. [It] took us the best part of five years [to launch Tradepoint] [You've] got to remember that when we started we were literally three guys, a bunch of packing boxes and an assistant answering the phone, some IKEA tables and chairs, one phone line trying to think 'right, how are we going to do this' with literally a clean sheet of paper (Wilson interview).

The project was controversial. 'At the time', recalled Wilson, 'the idea [of competing] with the Stock Exchange' was unthought-of. 'Because, why would you? The rules somehow don't allow it because, of course, there can only be one stock exchange. You have the London Stock Exchange, the Paris Stock Exchange, the Frankfurt Stock Exchange, the Milan Stock Exchange. They are a bit like the village pub or church. You have one. And there is no concept of competition' (Wilson interview).

Competition was, however a priority for the Treasury, the key economic regulator in Britain which saw in the growth of European markets a threat for London's historical position (Interview with Treasury official). The Stock Exchange was 'seen as really very slow-moving' (Wilson interview). Change had to come from elsewhere, and so in 1992

Tradepoint was authorized to operate as a Recognized Investment Exchange in direct competition with the LSE.

Tradepoint offered something that the LSE did not, a 'different market construct' based on a public electronic order book. Tradepoint's fortitude was competitive: like ARIEL before it, it sought to narrow spreads and drive down end costs for investors (Wilson interview).

> [Our] view was that we needed really embrace institutional access to markets and actually make it more attractive for them to get direct access to the London marketplace. [There] was absolutely no heritage, no one in the UK market at the time had any real knowledge or experience of order book trading. It was a completely foreign construct whereby you physically put an order into the market rather than trading on the phone and reporting it using some kind of price discovery. It's a bit like the difference between riding a motorbike and driving a car (Wilson interview).

The differences were clearly drawn across ideological lines. Unlike the LSE's market-making system, Tradepoint was 'consumer led at the institutional level' (Waller-Bridge interview). Investors would 'have equal access to the price formation mechanism, which would then bring along competition, lower charges, be better for the pension funds, better for the savings. We even thought of calling it 'The People's Exchange' […] in the sense that it would be working very much at a neutral stance of the institutions' (Waller-Bridge interview).

In my conversations with the founders of Tradepoint, I encountered a strong sense of accomplishment in having challenged the LSE's market position. This identity was not the result of technical success. Technologists clearly noted, for instance, that Tradepoint was an off-the-shelf solution, licensed from the Vancouver Stock Exchange (Wilson, TCAM interviews). Their pride came from having opened a hitherto closed marketplace built on the prestige of a gentlemanly class. It was the accomplishment of democratization, rather than of technical or economic success, which foregrounded their sense of triumph.

And successful they were: Tradepoint effectively transformed the market. When the system went live in 1995, regulators and international users (particularly American investment banks) placed additional pressure on the LSE's management. And so, in 1997 the LSE released its own electronic order book, SETS. And while it is likely that the order book would have arrived independently of Bennett's efforts, Tradepoint accelerated its delivery (Waller-Bridge, Smyth-Osborne, Barnes interviews).

More important were the articulations introduced by Tradepoint's order book. Bennett and his colleagues never built the European infrastructure that initially inspired their efforts. Such infrastructure, rather, emerged organically. As order books were adopted in Britain and across Europe, incentives for communicating markets became stronger. The forces of isomorphism were set in motion, leading the order book to become the key technology of finance.

In its expansion throughout the world, the electronic order book created novel opportunities. Fragmented across different trading sites, financial markets could be linked

through proprietary information networks allowing automated systems to collect data from different order books and providing investors with aggregate views of the market. These technologies permitted to 'not only see a consolidated view of a fragmented, physical market but [to] seamlessly [...] interact with the limit orders on these different places' (Barnes interview). The next step was seamless: as computerized solutions, dispersed order books were best coordinated through algorithms and their associated automated trading strategies. Without the electronic order book, financial markets would move at an altogether different pace.

7. Discussion and conclusions

This paper set out to examine the question of how markets change. In doing so, it explored four episodes in the development of the electronic order book. How are these episodes relevant? In what ways do they expand the state-of-the-art?

Despite the wealth and scope of the sociological literature on markets (Swedberg 2003, Beckert 2010, Fourcade 2007, Fligstein 2001), relatively little has been accomplished in re-thinking the modern ontology of markets forms (Lie 1997). Sociological definitions of markets are not radically different from those found in other disciplines, including economics. Markets, we read, are social arenas (Durkheim 1976; Beckert 2009) constructed through dyadic, short-lived exchanges (Thomas 1991, Callon 1998), formatted by relational networks of interactions maintained between agents that are engaged in a competitive struggle (Simmel 1955, Weber 1978, Hayek 1948). What governs sociology is hence a *transactional* definition of markets, one that defines their ontological constitution primarily in terms of exchange relations. The sociology of markets has thus grown as a series of claims on either how exchange relations are

conditioned by an *a priori* social space (e.g. Granovetter 1985) or how, through their performance and formatting, they reconfigure the social world they inhabit (Callon 1998).

This transactional account of markets is far-reaching and is perhaps the most vivid reminder of sociology's disciplinary origin (Stark 2009). In Weber's synthesis, for instance, markets were presented as archetypes 'of all rational social action […] a coexistence and sequence of rational consociations, each of which is specifically ephemeral insofar as it ceases to exist with the act of exchanging the goods' (Weber 1978, 635). Despite his fervent opposition to his economic contemporaries, Durkheim also described markets as exchange-oriented institutions (Durkheim 1976). Decades later, the transactional account remained unaltered. Harrison White's contribution reproduced the paradigm, defining markets as 'self-reproducing social structures among specific cliques of firms' (White 1981; 518); markets are thus formed by agents that produce and exchange goods and services—that is, by agents whose identity is defined through transactions. Granovetter (1985; 502) too preserved the transactional metaphor: his is not a challenge to the exchange-oriented conceptualization of markets but, rather, a proposal for explaining allocation outcomes in terms of 'personal relations and networks of relations between and within firms'; note that his is a theory of the embeddedness of transactions in economic relations, rather than a challenge to the classical conceptualization of markets as essentially transactional institutions. The situation is similar in Fligstein's (2001) work, where markets are conceived as 'situations in which some good or service is sold to customers for a price that is paid in money'. Zelizer (1988) also sees markets as 'institutionalized type of social relations involving

consumption, production and exchange' (p. 618). This account is consistent across sociological traditions: For Bourdieu (2005), markets are 'the product of a twofold social construction […]: the construction of supply […] and the construction of demand' (p. 16). Slater and Tonkiss' (2001) review identifies markets as 'the buyers and sellers of a particular good or service [comprised by] supply […] demand […] and price' (p. 38). And Aspers' (2011; 4) recent tome on the subject defines markets as social structures 'for the exchange of rights in which offers are evaluated and priced, and compete with one another'. As Swedberg (2005; 233) writes, sociology has 'suggested new ways of conceptualizing how markets operate' (see also Krippner 2001). But it hasn't entirely escaped the historical absolutization of the market (Barber 1977), conceptually separating physical marketplaces from the abstract, eminently transactional market process.

So how are the four histories of the order book relevant? In a sense, they matter because they examine an often ignored dimension of market making. As they show, markets were built not only in a transactional plane but hinged on back-stage efforts that brought into being novel platforms for exchange. This empirical shift in the study of markets is, indeed, rewarding. Previous studies, including those in the burgeoning performativity programme (Callon 1998, MacKenzie 2003, Pinch and Swedber 2008), have mostly concentrated on agents close to the transactional interface of the market process, those involved in exchange be they producers, consumers, intermediaries or the regulatory institutions that give legitimacy to transactions. This is notable in the sociology of finance, where focus is placed on 'market-makers'. Thus, Baker (1984) studied options traders in a Chicago trading floor. Abolafia (1996) looked at bond traders and New York Stock Exchange specialists as those 'involved in "making the markets"'

(p. 12). And the informants in Zaloom's (2006) fine ethnography of the technologies of finance in Chicago and London were futures traders. The hallmark of these and similar studies is their resolve in demonstrating that markets are socially constructed institutions (cf. Abolafia 1996, Smith 1989, Garcia Parpet 1986). But in these studies as elsewhere, markets are the constructs of a specific type of market makers; agents that, like Adam Smith's archetypical capitalists, are engaged in 'truck, barter and exchange' (Smith 1776)[10]. Market engineers find little space in these stories, yet as the episodes explored in this paper show are foundational to operation of finance.

Hence, when describing the evolution of markets, scholars focused on the work of these transactional agents. Theories of markets as networks (Granovetter 1974, White 1981, Brut 1992, Uzzi 1997) explicate change from the 'outside' (Krippner 2001), referring to underlying transformations in the relational patterns established between market agents. Depending on how specific networks are conceptualized, changes in relational structures are seen as determinants of new patterns of information access, group formation, performance, and resource distribution. In analysing these structures, furthermore, they focus on relations between 'traditional' market agents, whether individual traders (e.g. Baker 1984) or firms and corporations (Baker 1990, Davis and Greve 1997, Haunschild and Beckman 1998, Biggart and Castanias 2001). The literature on institutions and organizations echoes this approach (DiMaggio and Powell 1983, Dobbin 1994, Fligstein 2001, Carruthers 1994). There, market processes are represented through the cognitive frameworks of agents and their associated socio-institutional arrangements (cf. Zuckerman 1999; Beckert 2009, Beckert 2010, Aspers 2011); they consequently attribute the origins of both market stability and change to social

institutions (cf. Fligstein 2001). Whether culture (Carruthers 1999, Zelizer 1979) or politics (Fligstein 2001, Dobbin 1994), market change is explicated as the effect of broader macrostructures that impinge upon the transactional space[11]. The consequent lack of accounts of innovation in market infrastructures curtails our collective imagination: their critical role is obviated, and so are their effects on market politics and the shape and content of exchange relations.

So, how do markets change? Certainly transactional agents play a role. Had brokers not used the order book, had regulators sustained the privileges of market makers, this technology would have surely disappeared. This was, in fact, a possibility faced by Tradepoint in its early years. Its systems were 'too fast' for manual traders, who were used to dealing with market-makers over the phone (Smyth-Osborne interview; the company was eventually rescued by the Swiss Stock Exchange, who used it as a platform for accessing the British stock market; Barnes interview). Technologies of trading, like those elsewhere, are irrelevant unless adopted. And in fomenting use, historical context played an important role: the lower transaction costs of electronic order books and their greater control over anonymity were attractive to derivatives traders and hedge funds that required frequent and seamless modifications in their portfolios (Financial Times 1995a, 1995b). Without the traders, without the acquiescence of these transactional workers, markets would not have changed.

But change would not have happened without the intervention of engineers who in creating devices for the market also created novel institutional forms (e.g. SEAQ- I) and possibilities of action (e.g. computer-based trading). The history of financial organizations, long told through the narratives of investors, regulators and market

intermediaries, lacks in its analysis of infrastructures and their producing agents. We miss, in a sense, the role of the 'corps of technological production specialists, into whose keeping the due functioning of the industrial system has now drifted by force of circumstance' (Veblen 1965). Recognition of the constitutive role of market engineers and other infrastructural experts in the making of modern markets is a point lacking in the literature—and which sets the stage for new directions in research on markets and economic life. Consider, for instance, conventional models of market emergence presented (e.g. Aspers 2010): for these, markets are either outcomes of the mutual, self-organized adjustment of transactional agents, or inventions of institutions and state regulatory. Markets in this conventional sense are 'interpenetrating networks of exchange and competition' that exist independently to particular spatial constraints (Quack 2009). This perspective is inherently restricted to the study of transactional spaces and cannot explain, for instance, the emergence of markets at the hands of technologists, or externalities of recombining and disseminating expertise in making a trading platform. A robust theory of market emergence and change must deal with these infrastructural dimensions.

Emphasis on infrastructural work also revisits market politics. As illustrated by the efforts of Nymeyer, Instinet, ARIEL and Tradepoint to create functional electronic order books, discussions of fairness, justice, efficiency and transparency in markets were also debates about their technical makeup. Markets are, indeed, distributed calculative agencies that entangle social, technical and political components (Callon and Muniesa 2005). But perhaps additional theoretical traction is gained by not only acknowledging market infrastructures but, more fundamentally, conceptualizing markets as

infrastructures themselves that perform non-calculative operations on their immediate social worlds and in specifically moral ways (Bowker and Star 1999). This shift may allow, for instance, investigating how infrastructural arrangements shape the types of relational work that constitute market transactions (Fourcade 2007, Zelizer 2012). Like Goffmanian props, infrastructures provide grounds upon which relations are performed (Pinch 2000) and thus exert influence on the content, rather than merely the context, of action. This departs significantly from macro-structural approaches that study the propagation of markets through the pressure of wider ideological forces. As this article showed, histories of infrastructures reveal that the cultural repertoires of markets are equally shaped by the type of macro-structural forces referred to, for instance, in the literature on economic globalization (e.g. Bandelj 2008) and the micro-structural contexts of infrastructural work. Order books were clearly political projects, yet they were limited in scope; each design sought to change a defined marketplace by bringing into being specific visions of society within the boundaries of a specific institutional field: Nymeyer's patent critiqued the financial model of the NYSE by seeking to create just prices; Instinet's model was a competitive reaction by institutional traders to the oligopolistic practices of New York's specialists; SEAQ-I was a constructive project of expansion and domination; and Tradepoint was an overt attempt to challenge the predominance of the London Stock Exchange and articulate new modes of financial action. None tried to transform the world—and, aside from the odd connection to Austrian economists in Nymeyer's case, none of these projects drew inspiration from broader ideological schemas. They were, rather, practical solutions to local concerns on

the legitimacy of markets. There seems to have been no single master plan, no theory or discourse that was performed (Callon 1998). And yet, they transformed the world.

The question of how markets change continues to challenge our sociological imagination. Echoing Zelizer's (1988) call to think of markets in the plural, the histories of electronic order books beg investigating the varied infrastructures through which concrete markets come into being. Complementing Zelizer, this article proposes expanding sociological enquiry by moving beyond the transactional core of market processes and studying the systems and infrastructures upon which 'meaningful and dynamic interpersonal transactions' take place (Zelizer 2012, 149). Even when understood as eminently social forms of relational work, transactional accounts provide partial explanations of markets. They neglect, in particular, the material weight of markets in modern societies. Karl Polanyi was correct in highlighting market societies as political projects. He was right, too, in showing economies as achievements of social organization. Yet in re-imagining markets as formed by transparent and patently material infrastructures forged through small-scale political struggles, his substantivist approach—too often echoed in the sociological literature on markets and economic life—seems limiting. Perhaps market societies exist, not as grand utopias but crystallized in cables, silicon and sweat.

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NOTES

[1] Turnover velocity refers to the percentage of shares (stocks) of a particular corporation that are traded during a time interval (generally, per year). Thus, an 80% turnover velocity would imply, for instance, that 800,000 shares of a company with 1 million shares outstanding were bought and sold throughout a year.

[2] There are few studies concerned with infrastructural market technologies. Prominent examples are Muniesa's 2003 study of the Paris Bourse; Poon's 2009 study of credit score cards; Preda's 2008 research on the stock-ticker; Knorr Cetina and Grimpe's (2008) analysis of two global trading systems; and the edited volume by Kyrtis (2010), which presents some discussions on financial technologies.

[3] Where infrastructural technologies are studied, they are evaluated in terms of their 'impact on representations, skills and tacit knowledge, as well as on attitudes to financial objects' (Kyrtsis 2010). Thus, they remain appendices of traders, economists and managers rather than structures upon which markets are constructed.

[4] Nymeyer's support of Austrian economics went beyond his epistolary relation with Mises: he was also involved in Friedrich von Hayek's appointment to the University of Chicago and seems to have had a small thought relevant role in raising funds for the initial meetings of the Mont Pelerin Society (Hulsman 2008).

[5] Institutional investors are financial organizations that control large pools of capital and may serve a number of shareholders. Thus, insurance companies, pension funds, mutual funds and banks are classed as institutional investors.

[6] Keydata had an illustrious lineage: it was founded and led by Charles Adams, 'one of the MIT project Whirlwind pioneering developers'. Whirlwind was the predecessor of modern computers: it was the first digital, real-time processing system with video displays for outputs (Ceruzzi 1998; Edwards 1997).

[7] Instinet arguably served as an inspiration for the automation of Toronto in the late 1970s, which provided the blueprint for the automation of the Paris Stock Exchange in the 1980s. Similarly, some of the engineers at Instinet became involved in the development of alternative trading platforms as late as the 1990s. Of these, the most prominent are Island and Chi-X, which catalyzed the dramatic rise of electronic trading in America in the past two decades.

[8] Eurobonds are debt securities that pay interest to their holders and are denominated in a currency different from the country where they were issued. Thus, a bond in dollars issued in Great Britain is a Eurobond. Eurobonds thrived in the second half of the twentieth century since they allowed investing in foreign currencies and bypassing the strict exchange controls that characterized European monetary policies from 1945 to the early 1980s.

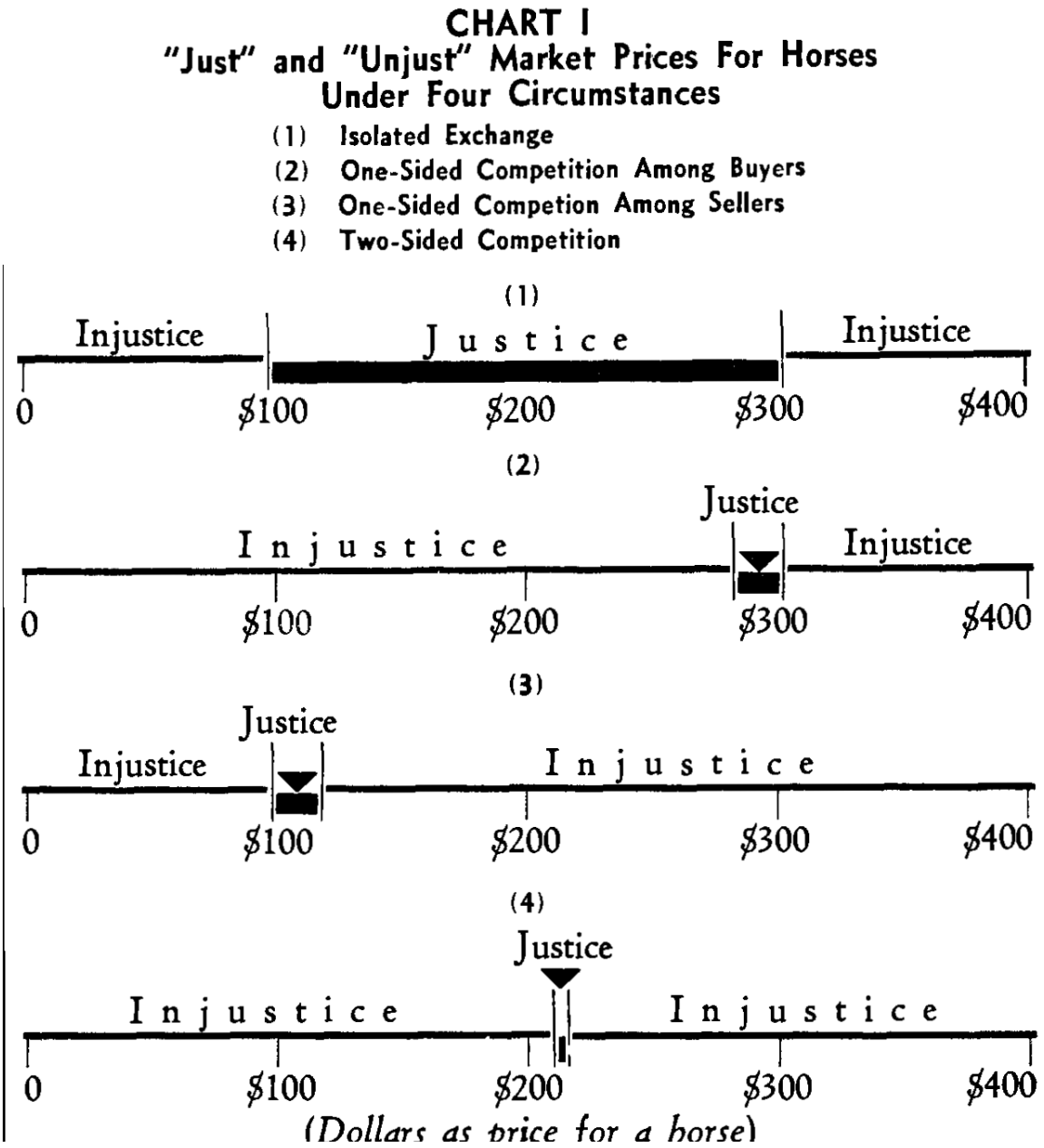
[9] A possible insight into how market engineers are pivotal in connecting financial infrastructures at a global scale is provided by David Manns' prolific career. In addition to setting up Instinet, Manns was also involved in the development of the first generation of Monitor, Reuter's global trading network for foreign exchange. The linkages and articulations between stock markets and foreign exchange markets were drawn, in this sense, at the level of concrete trading infrastructures as early as the 1970s.

[10] Like the selection of relevant actors, extant treatments of technology in markets echo the transactional account. The 'performative turn' in economic sociology is notable in this respect: whilst it has stressed materiality (Pinch and Swedberg 2008), the devices upon which it focuses are considered insofar as they act as prostheses that 'equip individuals in such a way as to give them a capacity to act and move' in the marketplace (Callon 2008). This explains, in particular, the overwhelming attention that performativity scholars have placed on a particular type of technical agents—economists—in their studies.

[11] Note that macrostructures are defined in a transactional idiom. Fligstein (2001), for instance, identifies property rights, governance structures and rules of exchange as key institutions of capitalist economies. These only have significance, however, if placed in the context of exchange: property rights define claims on what can be traded and who is to benefit from trade (Carruthers and Ariovich 2004); governance structures are formal and informal arrangements that sanction the limits of competitive and cooperative behaviors in a trade arena (Williamson 1981, Granovetter 1985); and conceptions of

control are agent-orientated worldviews that allows ‘actors to interpret the actions of others and a reflection of how the market is structured’ (Fligstein 2001, p. 35).

FIGURE 1



Four ideal market scenarios, as represented in Nymeyer's *First Principles* (1960)