Constructing a Market, Performing Theory: The Historical Sociology of a Financial Derivatives Exchange[1]

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This analysis of the history of the Chicago Board Options Exchange explores the performativity of economics, a theme in economic sociology recently developed by Callon. Economics was crucial to the creation of financial derivatives exchanges: it helped remedy the drastic loss of legitimacy suffered by derivatives in the first half of the 20th century. Option pricing theory—a "crown jewel" of neoclassical economics—succeeded empirically not because it discovered preexisting price patterns but because markets changed in ways that made its assumptions more accurate and because the theory was used in arbitrage. The performativity of economics, however, has limits, and an emphasis on it needs to be combined with classic themes in economic sociology, such as Granovetterian embedding and the way in which exchanges can be cultures and moral communities in which collective action problems can be solved.

INTRODUCTION

The most challenging recent theoretical contribution to economic sociology is Callon's (1998) assertion of the performativity of economics. The

economy, Callon (1998, p. 30) writes, "is embedded not in society but in economics." Economics does not describe an existing external "economy," but brings that economy into being: economics *performs* the economy, creating the phenomena it describes.[2] Sociology, Callon argues, is wrong to try to enrich economics's calculative, self-interested agents. Such agents do exist, he suggests; sociology's goal should be to understand how they are produced, and he claims that economics is key to their production.

Not surprisingly, Callon's argument has commanded considerable attention and has begun to attract sharp criticism. Thus, Daniel Miller defends classic economic sociology and anthropology in the tradition of Polanyi against Callon: "Contrary to his own claims, Callon's work amounts to a defence of the economists' model of a framed and abstracted market against empirical evidence that contemporary exchange rarely if ever works according to the laws of the market" (Miller 2002, p. 175).

Empirical material for examination of these issues is less rich than might be wished. Most of the studies collected in Callon (1998) are not informed directly by performativity, and they and subsequent discussions such as Slater (2002) focus largely on accountancy and marketing. That these "economic" practices play a constitutive role in modern economies is easy to establish but not a novel assertion.[3] The contributions of economists such as Faulhaber and Baumol (1988) to discussion of performativity have been missed in the sociological debate. The central case study of the performativity of economics in the narrower sense is the examination of the creation of a computerized strawberry market in the Loire by Garcia (1986), who demonstrates how a reasonable approximation to a "perfect market" was consciously constructed, in good part by the efforts of a functionary trained in neoclassical economics.[4] Though a delightful study, it is limited in its scope and has not, for example, persuaded Miller (2002, p. 232) of the case for performativity.

In this article, we explore performativity by examining one of high modernity's central markets, the Chicago Board Options Exchange (CBOE). The CBOE opened in April 1973; it was one of the first two

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[2] The term "the performativity of economics" is based on the notion of a "performative utterance": one that makes itself true by being uttered, as when an absolute monarch declares that someone is an "outlaw" (see Austin 1962; Barnes 1983).

[3] As Callon (1998, p. 23) acknowledges, the claim that double-entry accounting is critical to the emergence of capitalism goes back to Weber, Sombart, and Schumpeter (see Carruthers and Espeland 1991).

[4] Other broadly sociological case studies that raise the issue of the performativity of economics are Muniesa (2000a, 2000b) and Guala (2001).

modern financial derivatives exchanges ("derivatives" and other significant terms are defined in the glossary in table 1).[5] The Chicago derivatives exchanges were the prototypes of a wave of successors—the London International Financial Futures Exchange (LIFFE), the Deutsche Terminbörse (DTB, now Eurex), and many others—and part of a process of liberalization that has transformed global markets. In 1970, financial derivatives were unimportant (no reliable figures for market size exist). By June 2000, the total notional amount of derivatives contracts outstanding worldwide was $108 trillion, the equivalent of $18,000 for every human being on earth.[6]

The CBOE is an appropriate site at which to look for performativity because it trades *options*, which have a special place in modern economics. The theory of option pricing developed by Black and Scholes (1973) and Merton (1973) was a crucial breakthrough that won the 1997 Nobel Prize for Scholes and Merton (Black died in 1995). This theory allowed reformulation of a host of issues such as business decisions and the valuation of corporate debt, and it became the central paradigm—in the full Kuhnian sense—of financial economics: "Most everything that has been developed in modern finance since 1973 is but a footnote on the BSM [Black-Scholes-Merton] equation" (Taleb 1998, p. 35). Above all, option pricing theory enjoyed empirical success: "When judged by its ability to explain the empirical data, option pricing theory is the most successful theory not only in finance, but in all of economics" (Ross 1987, p. 332).

The study of the CBOE thus allows the question of performativity to be given a precise formulation. Why was option pricing theory so successful empirically? Was it because of the discovery of preexisting price regularities? Or did the theory succeed empirically because participants used it to set option prices? Did it make itself true? As will be seen, the answer is broadly compatible with Callon's analysis. The CBOE, however, also demonstrates (even in a case favorable to the discovery of performativity) limits to the argument that *homo œconomicus*, though "not to be found in a natural state," nevertheless "really does exist" (Callon 1998, p. 51). The very agents who performed option theory were not and did not become atomistic, amoral *homines œconomici*: if they had, they could not have constructed their market. So classic themes of economic sociology remain relevant, in particular Granovetter's embeddedness and the views of markets as cultures, moral communities, and places of political action (Granovetter 1985; White 2001; DiMaggio 1994; Abolafia 1996; Fligstein 2001).

[5] The other, the Chicago Mercantile Exchange's currency futures exchange, named the International Monetary Market (IMM), will also be discussed more briefly.

[6] Data are from the Bank for International Settlements (http://www.bis.org).

TABLE 1
Terminology

Term	Meaning
Arbitrageurs	Traders who seek to profit from price discrepancies.
Black-Scholes	The canonical *option* pricing model, in which the underlying stock price follows a *log-normal* random walk.
Call	See *option*.
Clearing	The process of registering and settling transactions. In Chicago, traders who are not members of an exchange's clearinghouse (which sets *margin* requirements and becomes the counterparty to all transactions) have to clear via those who are.
Cox-Ross-Rubinstein	An *option* pricing model similar to *Black-Scholes* but based on a discrete-time random walk.
Derivative	An asset, such as a *future* or *option*, the value of which depends on the price of another, "underlying" asset.
Future	A standardized exchange-traded contract in which one party undertakes to buy, and the other to sell, a set quantity of an asset at a set price on a given future date.
Implied volatility	The level of *volatility* of an asset consistent with the price of an *option* on the asset.
Log normal	A variable is log-normally distributed if its natural logarithm is normally distributed.
Margin	The sum (typically adjusted daily as prices change) that sellers of options or parties to a futures contract must deposit with the *clearing*house.
Market maker	In the options market, a market participant who trades on his/her own account, is obliged continuously to quote prices at which he/she will buy and sell options, and is not permitted to execute customer orders.
Open outcry	Trading by voice and/or hand signals within a fixed arena.

TABLE 1 (*Continued*)

Term	Meaning
Option	A contract that gives the right, but not obligation, to buy ("call") or sell ("put") an asset at a given price (the "strike price") on, or up to, a given future date (the "expiration").
Put	See *option*.
Short selling	Selling an asset one does not own, e.g., by borrowing it, selling it, and later repurchasing and returning it.
Skew	A pattern of option prices in which *implied volatility* is not independent of strike price (as it should be on the *Black-Scholes* model).
Strike price	See *option*.
Volatility	The extent of the fluctuations of a price, conventionally measured by the annualized standard deviation of continuously compounded returns on the asset.

We shall argue that to theorize how performativity articulates with these themes requires that conventional economic notions of the rational actor both be impoverished (in the sense of the acknowledgment of human cognitive limitations) and enriched. To study the articulation empirically demands, we claim, a historical understanding of markets. If the CBOE were examined at any one point in time, quite mistaken conclusions about performativity could be reached. This has determined our methodology, which is that of historical sociology, in particular use of oral-history interviewing.[7] We have tracked the CBOE from its origins to the present, taking advantage of the fact that interviewees can be found who have been active in the market throughout, or almost throughout; we have also interviewed the leading option theorists. Instead of following a set interview schedule, we led interviewees through their careers, tailoring our questions to their specific roles and how those related to the above theoretical issues. Interviewees are listed in appendix table A1; interviews lasted between one and four hours and were tape-recorded and transcribed.

Of course, this methodology has disadvantages. One is "survivorship bias": those available for interview were generally those who had built

[7] Interviewing was necessary because neither financial/trade press sources nor archival materials were sufficient to address the questions of interest to us. See MacKenzie (1990, pp. 12–14) for a discussion of methodological issues arising from a similar use of oral history for similar reasons.

successful careers, not those who had failed and anonymously left the market (this bias, however, is not entirely inappropriate for our purposes, since it is the CBOE's long-term participants who transmitted its culture to neophytes and who witnessed that culture changing). Another disadvantage is that, unlike studies that use participant observation (see, e.g., Abolafia 1996)—we have spent periods on the CBOE's trading floor but not long enough to qualify as genuine observation—there is a risk that actual conduct will be "idealized" in retrospective interviews. Certainly, interviewing (especially interviewing a sample of respondents who cannot be claimed to be representative) cannot approach the quantitative rigor of, for example, the best social network studies. Plain good fortune, however, allows us to make up for lack of rigor in one respect. As we researched option trading, incidental details in the classic financial-market network study by Baker (1984a, 1984b) revealed that his anonymous "Exchange" is actually the CBOE.

Six sections follow this introduction. The first explores the cultural and legal barriers to the creation of financial derivatives markets in the United States in the late 1960s and early 1970s and describes the role of economics in undermining those barriers. The second turns to the cultures and social structures of the Chicago markets, in particular using the question of collective action to probe issues of moral community. The third examines the complex and sometimes conflictual process by which the CBOE traders began in the 1970s to perform option theory. The fourth describes how theory is performed in today's CBOE and focuses on the presence of a phenomenon at variance with canonical option theory: the volatility skew. The fifth examines the events giving rise to the skew and the processes sustaining it. The concluding section returns to the powers and limits of performativity and its relations to the classic themes of economic sociology.

DERIVATIVES, MORALS, AND ECONOMICS

The origins of the CBOE and IMM lie in Chicago's agricultural exchanges, which traded futures contracts that permitted producers and large-scale consumers of agricultural products to hedge against price changes, while allowing speculators to make profits by anticipating changes. The CBOE emerged from the Chicago Board of Trade (CBT), founded in 1848–49. Its "pits"—octagonal open-outcry trading spaces, stepped around the sides to maximize visibility—traditionally traded huge quantities of futures on grain and other commodities, but the tightly regulated agricultural markets of the 1960s were a difficult environment for it and its younger rival, the Chicago Mercantile Exchange (or the Merc). Government guarantees set price floors while surpluses prevented

prices rising much. The need to hedge diminished and speculation became unattractive. By 1968, traders were "sitting on the steps of the [soy] bean pit . . . reading newspapers" (Sullivan interview) because trade was so slow. With government shaping the markets, the CBT in 1967 hired a Washington insider, former presidential aide H. H. Wilson, to become its president. Wilson in turn hired Joseph W. Sullivan, a *Wall Street Journal* political correspondent, as his assistant. Sullivan began to explore the feasibility of futures on commodities such as plywood, scrap steel, and fish meal (Sullivan interview). At the Merc, Leo Melamed, a trader who had risen to leadership of the exchange, similarly explored futures on shrimp, potatoes, apples, and turkeys (Melamed interview).

None of these, however, seemed to guarantee a genuine revival, and in the late 1960s a more radical departure began to be canvassed: financial futures. They could serve the same interlocked interests in insurance and speculation, but their pursuit encountered barriers that were essentially moral, like the earlier barriers to life insurance (Zelizer 1979). One was the loss of legitimacy suffered by financial derivatives in the first half of the 20th century. Stock options and futures were integral to 19th-century exchanges (Weber [1894] 2000), but the 1929 crash and subsequent Great Depression reignited hostility to "speculation" in derivatives that looked like wagers on price movements. Even as late as the 1960s, market regulators such as the Securities and Exchange Commission (SEC; founded directly in response to the excesses and abuses of the 1920s) remained deeply suspicious of derivatives.

The most attractive foundation for a derivatives exchange was a futures contract on a stock market index such as the Dow Jones Industrial Average. That idea, however, fell foul of how the moral distinction between gambling and legitimate futures trading had been crystalized legally early in the 20th-century United States. A futures contract was legal, the Supreme Court ruled in 1905, if it could be settled by physical delivery of a commodity such as grain. If it could be settled only in cash, it was an illegal wager. Since an index was an abstraction, there was no straightforward way in which an index future could be settled other than in cash. In 1968, Sullivan and two leading members of the CBT consulted securities lawyer Milton Cohen about the feasibility of a Dow Jones futures contract. Cohen advised against proceeding: the contract would violate Illinois law (Falloon 1998, pp. 209–10).

With futures blocked, the CBT's Special Committee on Securities began to focus on options. They were legal: there was an underlying asset that could be delivered, stock certificates, and in New York a small ad hoc market (not an organized exchange) already existed. Options nevertheless remained culturally problematic. For a modest outlay (options normally cost much less than the underlying stock), a speculator could profit greatly

from a price rise by purchasing call options, or from a fall by buying puts. As CBT officials began to float the idea of options trading with the SEC in the late 1960s, they encountered what they took to be instinctual hostility, based in part upon corporate memory of the role options had played in the malpractices of the 1920s. Sullivan, for example, was told by one leading SEC official that he had "never seen a [market] manipulation" in which options were not involved. When the CBT invited SEC Chair Manuel Cohen and one of his officials to a meeting with Wilson and Sullivan in the Democratic Club, the official told them that there were "absolutely insurmountable obstacles" to their proposal, and they "shouldn't waste another nickel pursuing it." He even compared options to "marijuana and thalidomide" (Sullivan interview).

A key role in undermining this kind of opposition to options was played by economics. During the 1960s, price data and the computer power to analyze them came together with key conceptual innovations. Economists postulated that stock price movements could be modeled with reasonable accuracy as random walks and that the U.S. stock market was "efficient" (responded to all publicly available information). In this burgeoning literature, increasing attention was paid to the valuation of options and similar derivatives. Amongst contributors were the Princeton economists Burton Malkiel and Richard Quandt, who argued that options' reputation "as the 'black sheep' of the securities field" was undeserved. Their use was "a very desirable strategy for most investors" and "wholly rational," although the ad hoc New York options market was "relatively inefficient" (Malkiel and Quandt 1969, pp. 6, 163, 165, and 167).

It seems that reading about this economic analysis of options in the magazine *Institutional Investor* (Malkiel and Quandt 1968) was what drew the attention of a key member of the CBT, grain trader Edmund O'Connor. Options were desirable but traded only ad hoc: might the CBT not profitably standardize them and trade them in a busy, efficient Chicago pit? To help explore and build legitimacy for this idea, the CBT hired consultants, Robert R. Nathan Associates, who had studied the grain futures market for the Department of Agriculture. Nathan Associates turned to Malkiel, Quandt, and their colleague William Baumol for a report on the impact of an options exchange on "the public interest." Options, the trio argued, "enrich the investor's repertoire of strategies by allowing him to realize a different set of payoffs than he would have realized in their absence." Just as the possibility of carrying an umbrella was an advantage to the pedestrian, "the more strategies are available to the investor, the better off he is likely to be" (Nathan Associates 1969, vol. 2, pp. 14 and 20).

The Nathan report, in turn, made it possible for the proposal for an options exchange to gain its single most crucial recruit, Milton Cohen.

He had originally not wished to be associated with the proposal, but the report made it "legitimate enough" that he agreed to become special counsel to the CBT and to lead its negotiations with the SEC (Sullivan interview). Cohen had been a key official at the SEC and was arguably the preeminent securities lawyer in the United States. No one was better placed to "make a record" with the SEC: putting proposals and getting responses. After two years, the record formed a stack of documents four feet high (Sullivan interview) but with no approval forthcoming. However, the election of Richard Nixon was changing the climate in Washington. In 1971, Nixon appointed venture capitalist and tax lawyer William Casey as chair of the SEC. Casey held Cohen in high regard, trying to lure him back from private practice to become his "personal mentor" (Sullivan interview; Rissman interview 1). Cohen arranged to meet Casey and presented the arguments for an options exchange. Casey, readily convinced, said, "Tell me what kind of order you need from the Commission to get started" (Cohen, in CBOE/OCC 1998*b*).

CULTURE, STRUCTURE, AND COLLECTIVE ACTION

The time-consuming, expensive lobbying, planning, and preparatory work that established the CBOE had many of the characteristics of collective action. The CBT was not a hierarchical corporation but a membership organization that elected its officials and voted on key decisions. CBT employees were paid for their work, but expenses were ultimately borne by the members of the CBT as a whole, and some members—Edmund O'Connor (the key original proponent of options), Irwin Eisen (chair of the Floor Procedures Subcommittee), and others such as David Goldberg, Patrick Hennessy, and Paul McGuire—took on substantial unremunerated commitments, which continued after the CBOE opened. O'Connor, Eisen, and Goldberg, for example, would sometimes lend newcomers the money (initially $10,000 but soon more) to buy a membership, with no certainty that the newcomer would succeed and be able to pay them back. On the Chicago Mercantile Exchange, similarly, Leo Melamed devoted large amounts of time he could otherwise have spent on profitable trading to leading its move into financial derivatives.

As Olson (1980) famously argued, collective action of this kind cannot satisfactorily be explained simply by the fact that it was in the collective interest of the membership of the agricultural exchanges. *All* their members benefited, even those who stood aside from it entirely. In such a situation, rational egoists—the individuals posited by the orthodox economic theory of financial markets—will free ride, leaving it to others to bear the costs of collective action, which will therefore not take place,

even if it would foster the interests of all involved. Hence the possibility of a delightful paradox: the very markets in which *homo œconomicus* appears to thrive cannot be created (if they require the solution of collective action problems, as in Chicago) by *homines œconomici*. Chicago practice (markets created by collective action) contradicts Chicago theory, orthodox economics as famously pursued at the University of Chicago.

Certainly, the accounts provided by central actors in the move to financial derivatives of their motivation are not those of rational egoists. Leo Melamed, for example, is in many ways the archetypal American capitalist and close ally of Chicago free-market economist Milton Friedman. (Friedman's analysis of the benefits of a currency futures exchange, commissioned by Melamed for $5000, was even more central in giving legitimacy than Baumol, Malkiel, and Quandt's analysis of options.) Asked why he devoted effort to collective projects, Melamed cited the influence of his father, a socialist and Bundist, who taught him to "work for society as a whole. My father had instilled in me [the] idea that you gain immortality by tying yourself up with an idea, or a movement, or an institution that transcends mortality" (Melamed interview). "We . . . never thought of even asking for reimbursement [for expenses involved in creating the CBOE]," says Eisen. "This was part of the concept that was inculcated into all of us: 'You owe it to your community.' We had all done very nicely, thank you . . . and we felt that we had an obligation to the Exchange and this is how you pay your obligations" (Eisen interview).

Of course, avowals of altruism sometimes mask self-interest, but for a rational egoist to embark on a project like the creation of the CBOE, in a context in which all others are rational egoists, is implausible. A risk-neutral egoist would need to be confident that the expected personal benefits of the creation of the CBOE exceeded its total costs (others must be expected to free ride, so the founder must expect to bear all these costs); for a risk-averse egoist, the excess might have to be considerable. Given the substantial *ex ante* uncertainty whether the CBOE would prosper—many opposed it as a likely waste of money—these conditions are unlikely, and our interviews give no suggestion that they were met.

The interviews do, however, provide evidence that the Chicago exchanges provided the kind of context that the extensive experimental evidence that has accumulated since Olson's (1980) work suggests promotes the solution of collective action problems: a context of ample face-to-face interaction and one that fosters "conditional co-operators" and "willing punishers" (Ostrom 2000, p. 162). Although the exchanges had and have large memberships (ranging from around 500 to 3,500), they are not anonymous places, and, like most exchanges, have some of the characteristics of status groups (Weber 2000). The division between in-

siders and outsiders is strict: one could and can trade on exchange floors only by purchasing or leasing a membership; memberships of the agricultural exchanges were often passed from father to son; numbers of memberships were and are carefully limited. Contracts involving large sums are entered into on the basis of verbal agreement or hand signals. Although there are systems for the written, and now computerized, recording of contracts, each participant enters details separately, when prices may move substantially in seconds. Misunderstandings and mistakes ("outtrades") are not unusual, and opportunism is obviously possible. Outtrades often have to be settled on a rough-justice, split-the-difference basis: to discover what "really" has been agreed upon in the tumult of a pit is normally impossible. Widespread opportunism would render open-outcry trading infeasible, but a simple sanction is available: refusal to trade further with an offender. At any given time, several traders will usually be offering the same prices, and while formal rules require trading with the first "heard" or "seen," participants do in practice have a degree of discretion as regards whom they "hear" or "see."[8]

   Trading-floor interaction often spills over into off-floor socializing and elaborate membership committee structures. One should not idealize: hostile encounters on trading floors are common, and physical fights break out (though punished by heavy fines); exchange politics is sometimes bitterly divided. The occasional intensity of negative interaction, however, points to the importance of *interaction*. Day after day, year after year, members of open-outcry exchanges trade with each other face-to-face. They have the incentive to monitor each other's conduct and (because so much of this conduct occurs in a public arena) have the capacity to do so closely. Infractions are remembered, sometimes for decades. The result is a moral economy as well as a financial one: "This [Chicago] is a place where people think very simple in terms of people and markets. Black. White. Good. Bad. There's an invisible sheet with an invisible line down the middle of it. This is a good guy. This is not a good guy. Nobody's on that line. They're either a good guy or a bad guy. Very long memories" (Power interview). Actions that are seen as unduly opportunistic are punished by "freezing out," and actions that are perceived as in the common good are rewarded with "respect" (Melamed interview). Reciprocity is practiced intergenerationally, not just in the hope of personal reward:

> I . . . came to the Board of Trade as a clerk at the age of 20. . . . One of my mentors was an Irishman by the name of Jim McKerr. . . . He brought me in as a clerk, financed me, loaned me . . . the money to buy the mem-

[8] See, e.g., Hull interview. Abolafia (1996) describes similar phenomena on the New York Mercantile Exchange.

> bership. . . . When I came back from the service (Korea), things were tough then. I went to work for another Irishman, Bill Haggerty senior. . . . They were wonderful to me and when I got my membership back he wanted me to clear through him. I told him: ". . . I have an obligation to Jim McKerr, and I'm going to clear and be his customer, not yours." I expected him to say: "That's very nice, here's the door, goodbye." Instead he said: "I can understand that. As a matter of fact, I respect you for it, your job here is secured." . . . So I remained McKerr's customer. I felt obligated. In about two years I developed into a pretty good trader . . . but I realized the only way I could survive and compete was to become a [clearing] member. I still didn't have any money because in those two years I was paying lots of debts. I was now even. I went to Jim McKerr (that was in 1956) and said: "I'm going to start clearing." He said: "That's wonderful . . . but what are you going to do for money?" . . . My share was $15,000 in order to start a clearing firm and Jim said: "Okay" and reached in his pocket and wrote me a check for $15,000. I didn't even ask. I said: "How in the world can I ever thank you?" And he said: "You have a debt, but the debt is to youngsters that come on after you. You can repay me by helping other kids." . . . Many years later, when the Options Exchange was in existence, I was a clearing member and I was taking a lot of young floor traders as customers. One day Jim McKerr came visiting from Florida . . . he was 80 years old. . . . One of the kids jumped and gave him a big hug. Jim looked at him—he was rather reserved—and said: "What's that for?" And the guy said: "Mr. McKerr, I owe my career to you. Whenever I came to Corky [Eisen] to thank him, he told me about you and he said that he was returning your help." When I took him down to lunch there must have been 20 people who shook his hand, people he had never seen or heard of. But this was his legacy and we have passed it on. (Eisen interview)

"Respect" and "obligation," in their turn, are resources for moral suasion. On the CBOE's first morning, its failure seemed an alarming possibility. "There were two traders on the floor," recalls Eisen. "Eddie [O'Connor] and I were running all over the floor making markets." They returned to the floor of the CBT: "We went around and we convinced everybody to come in at least when grains got a little slow, around 11.15, 11.30 . . . and then they'd go back and trade the close in grains" (Eisen, in CBOE/OCC 1998*b*). The success of IMM, similarly, initially seemed precarious: "Once the novelty wore off, the market liquidity completely dried up. . . . For most of the day . . . we just sat around playing chess and backgammon" (Randy McKay, quoted in Schwager 1992, p. 82). Like Eisen and O'Connor, though, Melamed was able to exercise moral influence: "I became an obsessed one-man enforcer—coercing, cajoling, admonishing, pleading with our . . . members to trade the currency markets. We needed liquidity, I begged. Everyone had to lend a hand. . . . And for the most part, the floor responded to my pleas. These were, after all, my guys" (Melamed and Tamarkin 1996, p. 198). "All chits were called in" by Melamed. Traders would show him their time-stamped trading

tickets to demonstrate that they had done the 15 minutes of trading per day on the nascent financial market he had demanded: they would be "ashamed not to" do this minimum for the collective good (Melamed interview).

Nor did the social structure of the Chicago exchanges cease to matter once the CBOE became a large and successful market (by 1978, more than 100,000 contracts were traded on an average day: Falloon 1998, pp. 225–27). Baker (1984*a*, 1984*b*) examined the pattern of trading and the behavior of prices in two CBOE trading crowds, one large and one small. After taking account of the volatility of the underlying stocks, Baker found that, contrary to the predictions of economic theory, option prices were more volatile in the larger crowd, an effect he explained by the tendency of this crowd to fragment into subnetworks when trading was intense. As one trader told him, "In the really large crowds that are really active, it's possible to get trading in very different prices. [Why?] It's noisy; you can't hear" (quoted by Baker 1984*b*, p. 786). The small crowd, in contrast, tended to remain stable in membership, and always small enough for easy communication. Prices in it tended to remain stable, even as trading became more intense. A trader active during the late 1970s, when Baker was studying the CBOE, explained to us that the cause was essentially collective action in the smaller "crowds" (see also Baker 1984*a*):

> The larger crowds were . . . really competitive and . . . sometimes egos would get in the way and . . . some guy would get a trade and the next guy would say "Well, I would have paid an eighth better for twice the amount," and there'd be screaming and shouting. But in some of the slower pits . . . there wasn't as much competition, then there would [be] more of a sharing basis, which was always a problem to some of the firms because they viewed them . . . somewhat as cliques and nobody would ever break rank in terms of pricing. If an order came in, and the market would be [bid] one-eighth, [ask] one-half, or something . . . nobody would ever sell it at three-eighths, nobody would ever break rank.[9]

There were, furthermore, ways in which small crowds could keep themselves small— for example, by always seeing or hearing an existing member "first" (Hull interview).

There is also anecdotal evidence of effects on pricing of differences between the structures of different options exchanges.[10] In January 1975, the American Exchange (Amex) also began to trade options but did not

[9] Similar points were also made in our interviews with Doherty and also Power. Prior to recent decimalization, prices on the CBOE and other U.S. securities exchanges were quoted in binary fractions. Options are denominated in lots of 100 shares, but the price quoted is per share. An option contract priced at $5\frac{3}{8}$, e.g., actually cost $537.50.

[10] The Amex data needed to test the conjecture are not public and may no longer exist.

use the CBOE's competitive market-maker structure. Amex "specialists" maintained "books" of buy and sell orders and matched those orders. On the CBOE, market makers quickly learned how to profit from discrepancies between put and call prices, and violations of put-call parity (Stoll 1969) were typically evanescent. In busy classes of options at Amex, however, it was found necessary to have two specialists (both members of the same firm), one taking responsibility for trading in calls, the other for trading in puts. There were many more breaches of parity, and these could be exploited by traders standing between the two specialists: "What a dream world that was . . . they didn't know . . . what each other [was] doing. They were doing okay on their own, but they didn't coordinate. . . . He's the call specialist, you're the put specialist. And you don't even stand real close to each other (Carusillo and Struve interview 1).

OPTION PRICING THEORY

The preceding sections have shown that economics was crucial in legitimating the establishment of an options exchange, but that the processes of establishment, and behavior after the CBOE was set up, involved action at odds with *homo œconomicus*'s rational egoism. We now turn to the impact of the option pricing theory of Black and Scholes (1973) and Merton (1973) on the CBOE. Earlier academic work on options (e.g., Malkiel and Quandt 1968, 1969) had involved either empirical, econometric analyses or elaborate theoretical models that contained parameters whose values could not be measured in any straightforward way. In contrast, Black, Scholes, and Merton's arguments were at their core simple and elegant. If the price of a stock followed the standard model of a lognormal random walk in continuous time, and other simplifying assumptions held (see below), it was possible to hedge any option transaction perfectly. In other words, it was possible to construct a continuously adjusted portfolio of the underlying stock and government bonds or cash that would "replicate" the option: that would have the same return as it under all possible states of the world. Black, Scholes, and Merton then reasoned that the price of the option must equal the cost of the replicating portfolio: if their prices diverged, arbitrageurs would buy the cheaper and short sell the dearer, and this would drive their prices together. This reasoning led to the famous Black-Scholes equation, where w is the price of the option, x the price of the stock, t time, σ the volatility of the stock, and r the riskless rate of interest:

$$\frac{\partial w}{\partial t} + \frac{1}{2}\sigma^2 x^2 \frac{\partial^2 w}{\partial x^2} + rx\frac{\partial w}{\partial x} - rw = 0. \tag{1}$$

The characteristics of a particular type of option enter as boundary conditions, and in at least some cases closed-form solutions for the option price can be found. Crucially, with the partial (albeit important) exception of σ, the values of all the parameters involved can readily be determined empirically. Black, Scholes, and Merton's fellow economists quickly recognized their work as a tour de force. It was more than a solution of a difficult technical problem: it showed how to approach a host of situations that had "optionlike" features; and it linked options to the heartland theoretical portrayal of capital markets as efficient and permitting no arbitrage opportunities. The whole weight of orthodox modern economics could now be deployed against anyone still claiming options to be disreputable:

> Black-Scholes was really what enabled the exchange to thrive. . . . It gave a lot of legitimacy to the whole notions of hedging and efficient pricing, whereas we were faced, in the late 60s–early 70s with the issue of gambling. That issue fell away, and I think Black-Scholes made it fall away. It wasn't speculation or gambling, it was efficient pricing. I think the SEC very quickly thought of options as a useful mechanism in the securities markets and it's probably—that's my judgment—the effects of Black-Scholes. I never heard the word "gambling" again in relation to options. (Rissman interview 1)

Black, Scholes, and Merton's work was, however, theoretical rather than empirical. In 1972, Black and Scholes tested their formula against prices in the pre-CBOE ad hoc options market and found only approximate agreement. For example, as against the model, "contracts on high variance securities tend to be underpriced, and . . . contracts on low variance securities tend to be overpriced" (Black and Scholes 1972, pp. 414–15). Nor did the opening of the CBOE immediately improve the fit. Mathew L. Gladstein of Donaldson, Lufkin and Jenrette Securities Corporation contracted with Scholes and Merton to provide theoretical prices ready for its opening:

> The first day that the Exchange opened . . . I looked at the prices of calls and I looked at the model and the calls were maybe 30–40% overvalued! And I called Myron [Scholes] in a panic and said, "Your model is a joke," and he said, "Give me the prices," and he went back and he huddled with Merton and he came back. He says, "The model's right." And I ran down the hall . . . and I said, "Give me more money and we're going to have a killing ground here." (Gladstein interview)

Measuring how long this situation persisted is problematic. Black-Scholes prices are extremely sensitive to the value chosen for σ. Calculating previous "historical" stock price volatility is straightforward, but "the [future]

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volatility of the stock must be estimated. The past volatility . . . is not an infallible guide" (Black 1975, p. 36). However, the empirical validity of the Black-Scholes formula can be tested indirectly by investigating whether investment strategies are available that yield excess profits: if they are, either the formula or one of its assumptions (for example, of an efficient market) has failed. When Scholes's student Dan Galai applied such tests to the first seven months of the CBOE, he found that "some above-normal profits could have been made" (Galai 1977, p. 195). These profits "were even greater than those found in our original tests" (Scholes 1998, p. 486), indicating a poorer fit of the model to the CBOE than to the earlier ad hoc market.

Soon, however, the fit began to improve. The most thorough tests of fit were conducted by Rubinstein (1985), using a data set of all CBOE price quotations and transactions between August 1976 and August 1978 for the 30 stocks on which options were most heavily traded. Rubinstein judged the fit of the model without independently estimating σ, by constructing from sets of matched pairs of observed option prices the estimate of volatility that minimized deviations from Black-Scholes values. He then calculated the largest deviation from the Black-Scholes prices implied by that volatility, finding typical deviations of around 2%. He later repeated the exercise for the index options that the CBOE began to trade in 1983, finding that by 1986 typical deviations had fallen to less than 1% (Rubinstein 1994, p. 774). By any social science standards it was an excellent fit.

This empirical success was not due to the model describing a preexisting reality: as noted, the initial fit between reality and model was fairly poor. Instead, two interrelated processes took place. First, the markets gradually altered so that many of the model's assumptions, wildly unrealistic when published in 1973, became more accurate. Consider, for example, the assumptions made by Black, Scholes, and Merton about the construction of a portfolio of stock and cash to replicate an option: that it could be constructed using entirely borrowed funds and/or stock; that it could be adjusted instantaneously; and that its construction and adjustment entailed no transaction costs. In the mid-1970s, stock could not be bought entirely on credit: the Federal Reserve's Regulation T limited credit to 75% of the stock price. Borrowing stock was often difficult and always expensive: stock lenders retained the proceeds of short sales as security and typically refused to pass on any of the interest earned. If an options trader did not belong to a member firm of the New York Stock Exchange, stock transactions incurred significant commissions. The information on stock price changes needed to adjust a replicating portfolio was often not available quickly (the electronic feed from New York to the CBOE was slow), adjustments took time, and "to place a stock order, a marketmaker

must leave the options trading crowd (or at least momentarily divert his attention from options trading activity), and, as a result, may lose the opportunity to make an advantageous options trade" (SEC 1979, pp. 139–40).

Gradually, though, many of the model's assumptions gained greater verisimilitude. Regulation T was waived for bona fide hedging by options market makers, with the model used, performatively, to determine the quantity of stock purchases that constituted a bona fide hedge (Millo 2003). Stock borrowing became more respectable (short sellers had in the past often been blamed for price declines), and the balance of market power began to shift, with borrowers obtaining increasing proportions of the interest on the proceeds of short sales (Thorp interview). Fixed commissions on the New York Stock Exchange were abolished in May 1975. The data feed to Chicago was improved, and better communications and growing automation made it quicker and easier to adjust the replicating portfolio.

To the increasing veracity of the Black-Scholes-Merton model's assumptions was added the second process: the model's growing use as a guide to trading. If that use had been as rapid and widespread as later accounts (e.g., Passell 1997) have suggested, it would raise the possibility that the model's success was a simple self-fulfilling prophecy. Matters were, however, slower, more complex, and more interesting than that. It was not immediately clear to all participants that one needed an option pricing model. Initially, the CBOE traded only call options and did so in a bear market, in which calls with high strike prices seemed always to expire unexercised, because the stock price remained below the strike price. A good income could therefore be earned by selling those calls without bothering with theory or hedging. "Sell the 280s and drive a Mercedes," became the motto of at least some traders, referring to high-strike-price ($280) calls on IBM, then the stock on which options were most heavily traded (Doherty interview). Sophisticated models might not seem necessary even for options for which the probability of exercise was higher. Participants could, for example, turn to rule-of-thumb pricing heuristics like those used in the ad hoc options market.[11] One manager, Michael Greenbaum, tried to teach pricing theory to market makers: "He'd stay late to give seminars and two people would show up, and it would be Joe Doherty [Sullivan's deputy, who became a CBOE trader] and somebody else, and they were already fully sold disciples. . . . He's trying to bring in some new technology [option pricing theory] and nobody would use it or pay for it" (Carusillo and Struve interview 1).

[11] Kassouf interview. Kassouf recalls that for options with strike price equal to current stock price, the rule of thumb was to price a 90-day call at 10% of the stock price.

Even those who accepted the need for a pricing model did not all accept that Black-Scholes-Merton was correct. Its theoretical elegance was not a factor that could be expected to weigh heavily with practitioners. With plausible estimates of volatility, the Black-Scholes-Merton model tended to generate prices significantly lower than early CBOE market prices and thus also lower than those generated by models more directly fitted to those prices. That might imply (as Gladstein had been persuaded by Scholes) that the market was overpricing options. Alternatively, it could mean that the Black-Scholes-Merton model had a tendency to underprice options because of its unrealistic assumptions, as was argued by Gastineau's widely used *Stock Options Manual* (Gastineau 1979, pp. 248–50).

Furthermore, even those who agreed on the virtues of Black-Scholes-Merton faced practical difficulties. Calculating a theoretical price involved taking natural logarithms, finding values of the distribution function of a normal distribution, and exponentiation. It could not plausibly be done by hand in the hurly-burly of trading. Implementing the model on a mainframe computer and making the results available via terminals were straightforward. But such terminals could not be used on the trading floor.[12] Electronic calculators programmed with Black-Scholes solutions did quickly become available, but, despite what others have written (e.g. Passell 1997), they were used only very occasionally on the CBOE floor: even the few seconds it would take to input parameters and wait for a result made them unattractive in fast-moving trading. More attractive was to print theoretical prices on sheets of paper that could be carried on the floor, often tightly wound cylindrically with only immediately relevant parts visible. Particularly widely used was a subscription service of Black-Scholes price sheets that Fischer Black began in 1975. Trading with the help of sheets was, however, initially not universally well regarded on the CBOE. Chicago was a "macho environment" where fellow traders "would laugh at you and try to intimidate you out of the pit, saying, 'You're not a man if you're using those theoretical value sheets.' They'd take your sheets and throw them down on the floor and say, 'Be a man. Trade like a man. . . . You shouldn't be here. You're not a trader. You can't trade without those'" (Hull interview).

Interlocked economic and cultural processes gradually reduced the various barriers to the use of models. A sudden surge in stock prices in April 1978 caused huge losses to market makers who had sold large numbers of insufficiently hedged calls, and some were forced out of the market: those who had sold the 280s lost their Mercedes, so to speak. Gradually,

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[12] It was against the CBOE's rules during most of the 1980s to have a computer terminal on the floor (Hull interview). Such a terminal would in any case have been unattractively cumbersome.

the CBOE market makers began to develop a distinct self-identity in which careful pricing and hedging were important. On the agricultural exchanges, the stereotypical belief was "I got the trade 'cos I'm faster than you, buddy." In New York, it was "I got the trade 'cos I'm here," because I am the designated specialist. In the CBOE's growing self-perception, it was "I got the trade 'cos I thought it out" (Doherty interview).

As the CBOE prospered, individual market makers and small firms were gradually displaced by larger firms, such as O'Connor and Associates, set up in 1977 when Michael Greenbaum (whose poorly attended classes on options theory were described above) persuaded Edmund O'Connor to support him in establishing a firm to trade in all the U.S. options markets. In the 1970s, options on a given stock were traded on only one exchange, so if one wished, for example, to take a position on an entire industrial sector it had to be implemented across exchanges. Seat-of-the-pants trading or simple heuristics could not suffice when implementing a position across several markets and carrying dozens or hundreds of such positions. Pricing models were necessary for risk management and, crucially, offered a way of communicating and coordinating activities, of *talking* about options.

Central was the notion of "implied volatility," calculated by running the Black-Scholes model "backward": using observed option prices to infer, by iterative solution, the stock volatilities they implied. "Implied volatility" reduced the complexity of option trading (different stocks with different, changing, prices; puts and calls; different expirations and strike prices) to a simple common metric. O'Connor traders in the different options exchanges used their "sheets" to calculate implied volatilities and reported them by hand signals to the O'Connor booth beside the trading floor and thus to the firm's headquarters: for example, "I can buy [oil company] Arco on a 15," in other words, purchase options the price of which implied a 15% per annum volatility of Arco stock. There would be "two or three people sitting upstairs saying 'Mickey can buy Arco on a 15. Someone in San Francisco can buy Santa Fe on a 13.' They're both big oil companies . . . if you thought all oil stocks were similar . . . you'd certainly rather buy one on 13 than a 15. . . . [So] they'd say, 'Don't buy any.'" (Carusillo and Struve interview 1). Gradually, what was being bought and sold in an options market was reconceptualized: it was the Black-Scholes-Merton model's key parameter, *volatility*. If stock volatility increased, options became more valuable; if it decreased, they became cheaper (see, e.g., Dunbar 2000, p. 167). Strategies involving a multiplicity of different transactions could be talked about very simply: "We would have a morning meeting, and Greenbaum would say, 'The book isn't long enough volatility. We're looking to buy some,' or 'We bought too much

yesterday. We're looking to be less aggressive'" (Carusillo and Struve interview 1).

As the options markets grew, and the SEC relaxed, options were traded on more stocks, some no longer "blue chip" corporations but high volatility newcomers. More expensive errors made pricing models seem indispensable: "I'll stand in a pit with [options on] 16 stocks that each trade two [expiry] months and five strike prices and I'll take anybody on: turn off the lights, I want to trade with no electronics. But when you get to multiple expirations, strike prices, higher volatility stocks . . . well, volatility changes by 10%, Arco goes from a 15 to a 13.5 [annualized percentage implied volatility], I can do that math in my head. [With a high volatility stock] 150 to 135 seems like it ought to be similar but . . . I've got too much money at risk if I'm wrong in my mental calculations" (Carusillo and Struve interview 1).

The increasing use of models seems to have begun to have direct effects on prices. That the Black-Scholes-Merton model had, in the CBOE's early years, a tendency to price options lower than its competitors gave it a certain general selective advantage, so long as it did not expose those using it to undue risks (a topic to which we return below). Above all, though, the model could readily be adapted for a simple arbitrage (feasible even for individual market makers) that had been used since the CBOE's foundation: spreading, looking for discrepancies in the prices of different classes of options on the same underlying stock, buying relatively under-priced options and selling overpriced ones (Galai 1977). The offsetting positions insulated the spreader from many forms of risk, without demanding that one hedge using stock. Pricing models soon began to seem an "inherent part" (SEC 1979, p. 137) of spreading, and the strategy's popularity helps explain why, by 1976–78, the fit between prices on the CBOE and the Black-Scholes-Merton model was so good on the crucial econometric test by Rubinstein, described above. A key aspect of what Rubinstein did was to check the empirical validity of a basic feature of the model: "that all options on the same underlying asset with the same time-to-expiration but with different striking prices should have the same implied volatility" (Rubinstein 1994, p. 772), in other words that the graph of implied volatility against strike price should be a flat line. When spreaders used Black-Scholes to identify discrepancies, it would be precisely deviations from that flat line that their activities tended to arbitrage away. The model was, therefore, helped to pass its central econometric test by the market activities of those who used it.

Gradually, models became not just private resources for some traders but the public property of the entire floor. This began with the start of trading of options on stocks on the National Association of Securities Dealers Automated Quotation system, or NASDAQ, which has no trading

floor: transactions are dispersed among large numbers of NASDAQ dealers buying and selling via computer screens and telephones. CBOE market makers soon learned that stock prices on NASDAQ screens were, in practice, indicative only. One could not be sure of a genuine price for a large transaction until one telephoned a dealer, and there were suspicions that at crucial moments telephones were left unanswered for critical seconds. Black, Scholes, and other options theorists had implicitly (the matter was never expressly discussed) assumed that the price of the underlying stock was known. With NASDAQ, that pervasive assumption failed. So, in 1986, the CBOE launched its first "Autoquote" system. In the crowds within which NASDAQ options were traded, CBOE employees would feed in the prices of the most liquid options, those with strike price close to the current stock price. Autoquote software implementing the Black-Scholes equation would then generate the price of a "synthetic underlying," in other words, calculate the stock price compatible with those option prices. From that it would generate and make public to traders the Black-Scholes prices of the full range of options being traded, including the less liquid ones for which preceding market prices might be a poor guide (Knorring interview).

THE VOLATILITY SKEW

By the late 1970s, then, Black-Scholes was widely used by CBOE traders, and in the 1980s it began to be incorporated into the CBOE's informational infrastructure. Gradually, "reality" (in this case, empirical prices) was performatively reshaped in conformance with the theory. However, perhaps the Black-Scholes formula came to be adopted, and came to describe prices accurately, simply because it was "right," because it gave the correct way to price options? Perhaps the poor early fit of the formula was just a passing consequence of an inefficient market, fated to diminish as the CBOE reached efficiency? If that were so, a claim of performativity would be an empty gloss on a process better understood in conventional economic terms.

Here a historical perspective becomes crucial. Let us fast-forward to our most recent observations of the CBOE in November 2000. In 1986, human beings were still at the center of the market, and technical systems were their aids. By 2000, the balance had shifted. By then the CBOE traded 104,000 option classes. Inevitably, trading in some is quiet—in 2000, despite record overall trading volumes the average class was trading only 13 contracts per day—but Autoquote, now pervasive, continuously generates prices for all classes of options, no matter how sporadic actual transactions are, and distributes those prices to the vast array of electronic

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displays on the trading floor and through worldwide computer networks. Autoquote prices are firm, at least for public orders of modest size. If such orders can be filled at these prices, the contract can be executed without human intervention: the other side is assigned at random to "a market maker who has volunteered to accept such orders" (Options Institute 1999, p. 241). Most market makers now carry handheld computers, linked by infrared and microwave communication links to the CBOE's central systems. These register the automated fill of an order, and if the market maker wishes to hedge the resultant position (as now almost all will wish to do), earlier difficulties are no more: the handheld computer calculates the requisite hedge, and the trader can make the necessary stock purchases or sales simply by punching buttons.

Such is the array of screens, computers, and communication systems on the CBOE's trading floor that other heating is needed only when the Chicago temperature drops below $-10°F$ (Options Institute 1999, p. 232). Dotted inconspicuously among all this automation are the touch screens used to set Autoquote working. Once these screens have been used to set parameters such as volatility, Autoquote receives stock prices and index levels from other markets and, as these inputs change, continuously updates option prices. Two words at the top of each screen reveal how it is done: "Cox-Ross." The Cox-Ross-Rubinstein model (similar to Black-Scholes-Merton but more flexible and in many cases computationally more tractable) is used to generate prices. Human beings remain in ultimate command: by pressing on the section of screen marked "lean," traders can manually override model values, and, furthermore, the ebb and flow of orders in actively traded option classes do move prices. Nevertheless, such human interaction is now merely one aspect of a larger technosystem.

It can reasonably be said of this technosystem that it performs theory. That the model employed is Cox-Ross-Rubinstein, rather than Black-Scholes-Merton, is not in itself significant: the latter is a limit case of the former.[13] A crucial aspect of the Black-Scholes-Merton model, however, is now almost never present. As noted above, in that model the relationship between strike price and implied volatility is a flat line. In the fall of 1987, however, the flat-line relationship, empirically manifest in the late 1970s and early 1980s, disappeared and was replaced by a distinct "smile" or "skew." Figure 1 shows the shift in typical pattern for index options. The earlier flat line has not returned subsequently (see, e.g., Jackwerth 2000): indeed, the skew continued to grow at least until 1992 (Ru-

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[13] The Cox-Ross-Rubinstein model assumes that stock prices follow a binomial process in discrete time. In the limit in which time periods become infinitesimally small, the binomial process becomes the Black-Scholes-Merton model's log-normal random walk in continuous time.
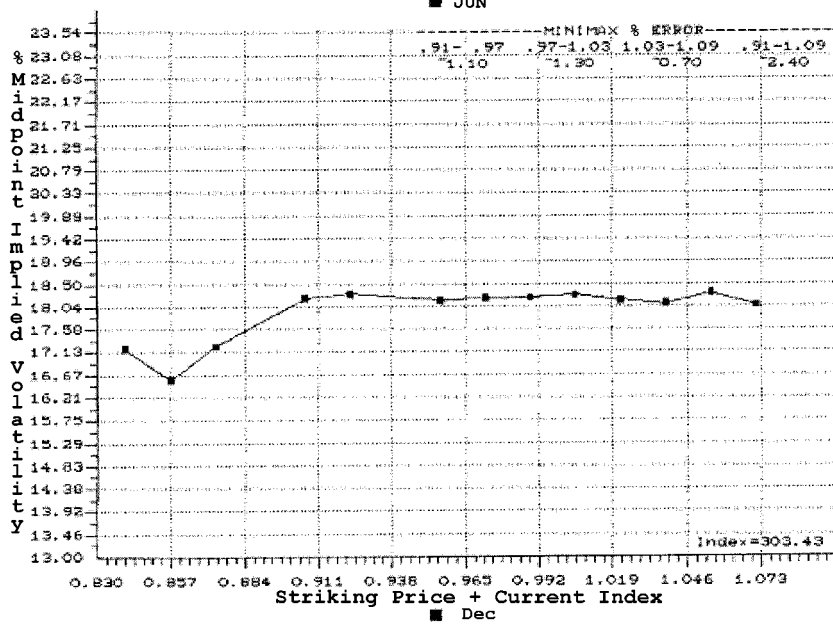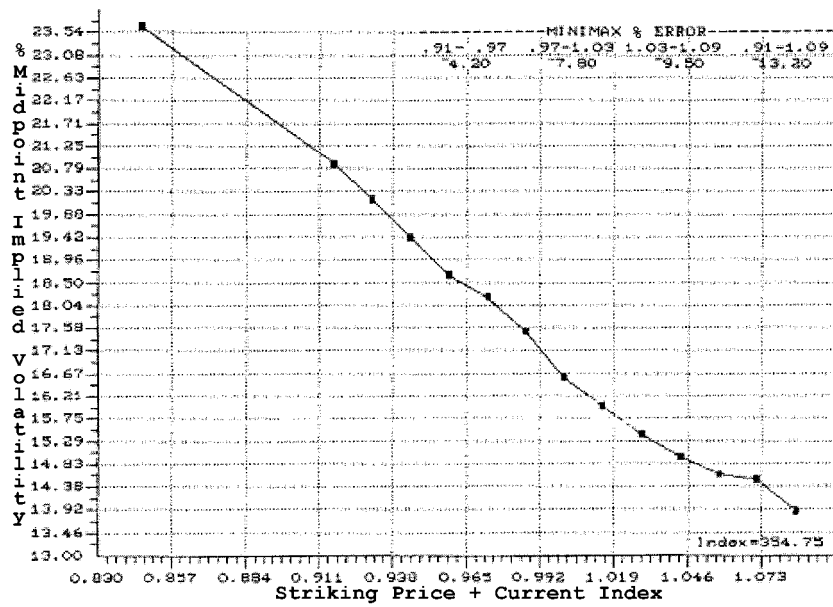
FIG. 1.—Volatility skew of CBOE S&P 500 index options, 9:00 A.M., July 1, 1987 (lower graph), and 10:00 A.M., January 2, 1990. From Rubinstein (1994, pp. 776–77); used with permission of the author and Blackwell Publishers.

binstein 1994, pp. 772–74). The direction of the skew has been stable: puts with strike prices well below current stock index levels have higher implied volatilities—are relatively more expensive—than puts with higher strike prices, and put-call parity relations imply that the same is true of calls. Similar, if less intense, skews are also to be found in options on individual equities (Toft and Prucyk 1997, p. 1177).

The empirical history of option pricing, therefore, falls into three distinct phases.[14] First is the phase prior to the opening of the CBOE and in its first year or so, when there were substantial differences between observed prices and Black-Scholes values. The second is a phase that had begun by 1976 and lasted until summer 1987, in which the Black-Scholes-Merton model was an excellent fit to observed prices. Third is a phase from autumn 1987 to the present, when the model's fit has again been poor, especially for index options, in the crucial matter of the relationship between strike price and implied volatility. There is little doubt which event separates the second and third phases: the stock market crash of October 1987, particularly Monday, October 19, 1987, when American stocks suffered their largest ever one-day fall. That day, the Standard and Poor's (S&P) 500 index fell 20%, and the S&P 500 two-month future on the Chicago Mercantile Exchange—probably a better indicator because of trading disruptions in New York—fell 29% (Jackwerth and Rubinstein 1996, p. 1611).

Qualitatively, the emergence of the skew is close to consistent with standard notions of rational learning.[15] On the log-normal model, the fall in the S&P future price on that dreadful Monday was a -27σ event; its probability was 10^{-160} (Jackwerth and Rubinstein 1996, p. 1612). Any doubts arising from 1987's uniqueness seem to have been removed in practice by the 6% fall of the S&P 500 index on October 13, 1989, a -5σ event. Jackwerth and Rubinstein have shown how to infer backward from observed skews to what they imply for the probability distribution of the underlying index. Slightly left-skewed and platykurtic (flat-topped) distributions prior to the 1987 crash have been replaced by more or less consistently left-skewed and leptokurtic (more peaked and long-tailed) distributions (see fig. 2). To put it simply, the options market does not expect changes in the S&P 500 index to be log-normally distributed, and large downward movements have implied probabilities far greater than

[14] Interviewees generally agreed that this was the case (with some dispute as to how flat the implied volatility-strike price relationship was prior to 1987), but the prime evidence here is econometric, not interview based.

[15] The one qualification is that by 1987 econometricians already knew that stock price movements were not log-normal. However, although this was noted by Gastineau (1979) as an objection to the Black-Scholes-Merton model, it took 1987's drama to give it practical force.
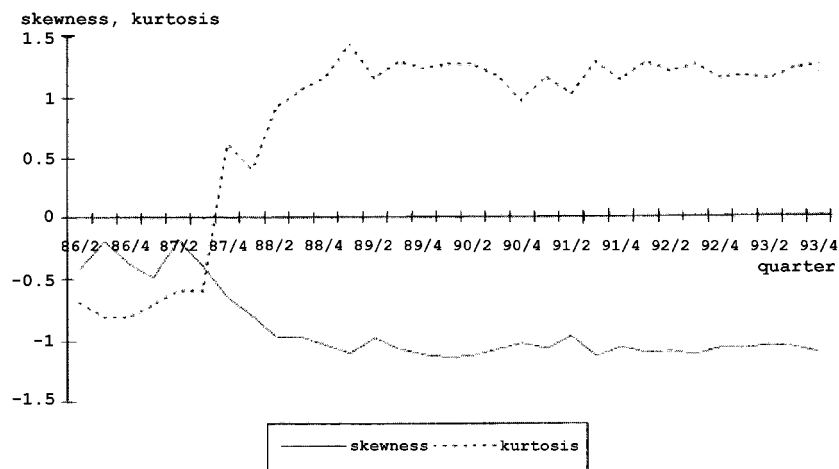
skewness, kurtosis

FIG. 2.—Median daily skewness and kurtosis of probability distribution of S&P 500 index implied by CBOE S&P 500 option prices, for each quarter from April 1986 to December 1993. From Jackwerth and Rubinstein (1996, p. 1629); used with permission of the authors and Blackwell Publishers.

on log normality. After October 1987, the market has come to expect crashes, and it prices options accordingly: puts with low strike prices, which will be exercised only if the underlying index falls considerably, are relatively much more expensive than if the market believed that price changes followed the log-normal assumption of Black-Scholes pricing.

What is now performed on the CBOE, therefore, is no longer classic option pricing theory. That theory has become part of the market's vernacular: whenever a participant talks of "implied volatility," he or she implicitly draws upon it. Upon that communicative idiom, and upon the algorithms of the Cox-Ross-Rubinstein model, is, however, placed a layer that mixes market processes and practitioner know-how. On the morning of every CBOE trading day, DPMs (designated primary market makers) set the skew for the options for which they are responsible. As the underlying stock price or index value changes, Autoquote uses this skew and the Cox-Ross-Rubinstein model to generate prices. If trading conditions shift markedly, the DPM can reset the skew during the day, but this by no means always happens. The skew has become arguably the central cognitive aspect of options trading:

> When experienced traders . . . move to a different pit . . . say they're trading [options on] telephone [stocks] and now they're going to trade AOL [America Online], the first thing they want to know when they walk into a pit is, "What's the skew like?" To them that tells them lots. And it's the most vital information, more than what's the potential earnings of AOL

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> and who their competitors are and any fundamental kind of stuff; it's, well, "How does this pit trade this thing?" . . . They still have competing bids and offers. . . . So . . . if you look at the actual skew relative to prices it's kind of choppy, but if you look at it consistently it really does kind of become . . . a function that's relatively smooth. . . . It's amazing, people just talk about volatility skew, I mean, that, that is the market. And the sophistication of how that [the skew] changes. . . . Different . . . people will say, "This is what I think the skew should be," "It's a little bit different today, is it enough different for a trading opportunity?" . . . "Here's how I think that skew will react to different scenarios." . . . So people certainly have their opinions. But what the floor in general seems to [believe] is . . . "Here's what the consensus kind of [skew] is." (Hinkes interview 1)

THE SKEW AND THE MEMORY OF THE MARKET

The volatility skew described in the previous section is qualitatively consistent with standard models of rational learning, but quantitatively the options market has overlearned. For a prolonged period, excess risk-adjusted profits have been available from selling index puts at the market prices that have prevailed since 1988. Remarkably, this is the case even when artificial crashes of 20% in a month are introduced into the computation with probabilities as high as one every four years (Jackwerth 2000). Nor is this simply a theoretical finding. Market participants reported to us that healthy returns could be earned in practice by "betting against the skew," that is, by selling low-strike-price puts with their high implied volatilities. To explain observed index option prices since 1988 requires artificial addition of crashes of almost 1987 severity more frequent than one every four years, when "even a 20% [one-month] crash every 8 years seems to be a rather pessimistic outlook" (Jackwerth 2000, p. 447). "The most likely explanation," Jackwerth concludes (p. 450), "is mispricing of options in the market."

If true, this is a striking finding: participants in one of high modernity's most efficient, sophisticated markets have been behaving irrationally. Such a conclusion, however, seems to us to involve too narrow a view of rationality. Because the 1987 crash had remarkably little direct effect on the wider economy, and because many investors lost only what they considered to be "paper" gains (the result of earlier stock price rises), it is hard now to recapture just how traumatic 1987 was to those most directly involved. On October 28, 1929, the worst day of the Great Crash, the Dow fell 12.8% (Brady Commission 1988, p. 1). A collapse in a single day of twice that severity lay almost outside the bounds of the conceivable. Arbitrageur Eric Rosenfeld, then at Salomon Brothers, recalls "sitting at the [trading] desk and wondering about the end of the whole financial

system" (quoted in Dunbar 2000, p. 97). Others, like trader Mary Schwartz, acted on such feelings: "I got out of most of my positions and protected my family. Then at 1:30 P.M. [on October 19, 1987], with the Dow down 275 points, I went to my safe deposit box and took my gold out. Half an hour later, I went to another bank and started writing checks to get my cash out" (quoted in Schwager 1993, p. 268). Fearing that the crash might partly have been caused by the widespread adoption of the "portfolio insurance" technique (the creation of synthetic put options) he and his Berkeley colleague, Hayne Leland, had developed, Mark Rubinstein entered two weeks of what he now regards as clinical depression: he could not rid himself of the fear that the weakening of the American markets could lead the Soviet Union to a Cuba-style challenge and that nuclear war might ensue (Rubinstein interview).

Nowhere was the trauma more sharply felt than in the CBOE and the Merc. The unprecedented market movements called for huge sums of collateral to change hands, and there was a very real fear that major participants would be unable to meet their obligations. Clearers inherited the obligations of those for whom they cleared; if one clearer failed, the others became responsible for its debts; if they could not honor them, the entire clearing system, and thus the exchange, would collapse. As the Merc (by 1987 tightly linked to the CBOE by the use of its index futures to hedge index options) closed on Monday, October 19, Leo Melamed "said a silent prayer. I didn't know whether we had survived." After a prearranged dinner meeting, he returned to the exchange just before midnight and learned that "the longs owed the shorts some $2.5 billion," more than 20 times the normal settlement sum. In the middle of the night, "with sweating hands," Melamed began to return the telephone calls that his secretary had received, beginning with the chair of the Federal Reserve, Alan Greenspan. Melamed could not promise Greenspan that the exchange would be able to open the following morning. Frantic activity by Melamed and his colleagues throughout the night (including a call to the home of the chief executive of Morgan Stanley at 3 A.M.) achieved the transfer of $2.1 billion, but as morning approached $400 million was still owed by a customer of Continental Illinois Bank. Around 7 A.M., Melamed called Wilma J. Smelcer, the bank executive who ran its account with the exchange:

> "Wilma . . . you're not going to let a stinking couple of hundred million dollars cause the Merc [Mercantile Exchange] to go down the tubes, are you?"
>
> "Leo, my hands are tied."
>
> "Please listen, Wilma; you have to take it upon yourself to guarantee the balance because if you don't, I've got to call Alan Greenspan, and we're going to cause the next depression."

> There was silence on the other end of the phone. . . . Suddenly, fate intervened. "Hold it a minute, Leo," she shouted into my earpiece, "Tom Theobald just walked in." Theobald was then the chairman of Continental Bank. A couple of minutes later, but what seemed to me like an eternity, Smelcer was back on the phone. "Leo, we're okay. Tom said to go ahead. You've got your money." I looked at the time, it was 7:17 A.M. We had three full minutes to spare before the opening of our currency markets. (Melamed and Tamarkin 1996, pp. 358–59 and 362–63)

In only slightly less dramatic circumstances, John Hiatt and his colleagues at the Options Clearing Corporation stayed awake not just on Monday, October 19, but on the next two nights, and then spent the entire following weekend in their offices dealing with a particular problem case (Hiatt interview 1). Option prices rose to levels that defeated the nascent automated systems, many of which could cope only with double-digit dollar prices. When option prices rose to $106, "it appeared on your sheets as . . . $6. . . . So your account [with the clearing firm] was off by $20 million the next day. . . . Nobody knew where they stood" (Hull interview). Enormous margin payments were owed to clearing firms by market makers who had sold options that had suddenly shot up in value, and by the firms to the Clearing Corporation. First Options, the leading CBOE clearer, absorbed huge losses from market makers who could not meet their obligations. Its failure would have been a calamity, but it had shortly before been bought by Continental Illinois, and the Federal Reserve permitted the bank to draw upon its capital reserves to replenish First Options' funds.

What was learned in October 1987, therefore, was more than that stock markets could suddenly fall by previously unthinkable amounts: it was also that the consequences of such a fall could threaten the very existence of derivatives markets. Nor were all the effects of the crash short-lived: it was 1995 before stock options trading on the CBOE recovered to precrash volumes (CBOE/OCC 1998a, p. 12). It is this collective trauma, we conjecture, that sustains the skew. It is, for example, noteworthy that it has largely been an American phenomenon. The British options market did not respond to 1987 by developing a similar skew (Gemmill 1996). Although stock markets in the United Kingdom and around the world also crashed, the effects on the then-tiny British derivatives markets were nothing like as devastating. When a consistent skew did emerge in Britain in the first half of the 1990s, and also in Japan, it was only a third as intense as in the United States (Gemmill and Kamiyama 2001).

When asked to explain the skew, U.S. interviewees differed in the precise mechanisms they cited, but all led back to October 1987 and to dangers involved in selling low-strike-price puts, such as their lack of liquidity, which made exiting a position in them hard, and the inadequacy,

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in a precipitous market fall, of theoretical hedging ratios.[16] Those who sold such puts without hedging them faced moral obloquy—"We call them the shit-sellers!" (Hinkes interview 1)—but 1987 taught market participants how difficult it was to construct a hedge that would be adequate in extremis. Simultaneously, however, 1987 revealed the desirability of *owning* such puts (the synthetic puts offered by portfolio insurance had in many cases failed adequately to protect investors), so they would still be bought even at sharply increased prices.

Why has the skew not attenuated with the passage of time, even though "someone who just looks at the math will just say, 'Just do it' [sell puts]" (Carusillo and Struve interview 2)? In part, the memory of 1987 has been institutionalized as a shift to margin requirements based explicitly on levels of risk, requirements that are underpinned not by the log-normal distribution of Black-Scholes-Merton pricing but by stable Paretian distributions with infinite variance, in which the probability of extreme events is much higher. As the key figure in the technical development of these requirements puts it,

> The shit-sellers cannot trade the way they used to. Either their capital requirement will be higher than it was or the clearing firm will pay more margin to [the Clearing Corporation] than they used to. . . . The exchanges . . . wanted better risk management tools than the old systems had allowed but they didn't want to kill the market either. . . . [The new systems] gave them [the clearing firms] ammunition to rein in traders that they were always nervous about. The problem before was . . . if you sat on a guy too hard he'd go somewhere else [to a different clearer]. And you can make a lot of nice money in two or three years when there's not a crash. And a lot of nice fees for the clearing firm. [But] when there's a kind of new minimum floor . . . you can be tough on a guy and he can't go somewhere else and get a hugely better deal. (Hinkes interview 1)

These centralized, formal risk controls help reinforce an informal cultural understanding, still strongly held by older traders and risk managers who had "that experience of being in a hurricane" in 1987 (Power interview), of the dangers of low-strike-price puts. Certainly, the combination of formal risk controls and cultural memory has proved robust, surviving the crises of August and September 1998 and September 11, 2001, with no repeat of the trauma of 1987.[17]

[16] Power (interview) and Wenman (interview) were particularly eloquent in these respects, but the sentiment seemed widely shared.

[17] Because the hedge fund Long-Term Capital Management (LTCM) was at the heart of the 1998 events, and because its partners included Merton and Scholes, a spurious connection is often drawn to alleged errors in option pricing theory (see MacKenzie 2003).

CONCLUSION

> It takes planning, calculation, arm-twisting, and tenacity to get
> a market up and going. Even when it's chugging along, it has
> to be cranked and pushed. (Melamed and Tamarkin 1996, p.
> 295)

The development of the CBOE and (in a different way) of the Merc is a small but significant thread in the emergence of high modernity. As noted above, replicants of the Chicago financial derivatives markets have sprung up around the globe, copying and adapting Chicago's products, its trading procedures, its technical systems, and even its culture. Options trading, with its cognitive complexity and mature mathematical models, has been a central driver of the marketized, mathematicized risk-evaluation culture of the contemporary world. For example, O'Connor and Associates, with its expertise in cross-market arbitrage and enterprisewide computerized risk-control models, has been one of the vehicles of this diffusion. In 1989, the firm began to sell its risk-control and trading expertise to Swiss Bank and was purchased by it in 1993. O'Connor partners moved to senior positions at Swiss Bank, and, as the latter bought the British merchant bank Warburg and merged with the Union Bank of Switzerland, "Chicago culture" became transplanted into the very heart of European banking. The CBOE also indirectly spawned other options exchanges, such as OM (Optionsmäklarna), set up after his return to Sweden by CBOE broker Olof Stenhammar. OM—privately owned and focused on telephone and electronic trading—became a major force "technologizing" exchanges in Europe and elsewhere, taking over the venerable Swedish stock exchange and narrowly failing to take over the London Stock Exchange (Larsson interview).

The historic clash between the capital-market-based systems of the United States and the United Kingdom and the relationship-based financial systems of continental Europe and Japan (see, e.g., Zysman 1983) has not yet ended in a decisive victory for the former, but the recent trend has been in that direction, and the transplantation of Chicago culture has been part of the process. There is even an intriguing personal connection between the CBOE and the rapprochement between left liberalism/social democracy and the financial markets so prominent in the 1990s. Robert Rubin, Clinton's treasury secretary, was a member of the CBOE's original board.

The development of the CBOE, then, is of importance in its own right as one of the transformative processes of our times. Its chief theoretical interest is as a study in the performativity of economics. Economists (Baumol, Malkiel, and Quandt in the case of the CBOE; Friedman in the case of IMM) helped make the Chicago financial derivatives markets

possible by providing legitimacy; Black, Scholes, and Merton provided the capstone, decisively undermining the regulatory view that derivatives were morally dubious instruments of gambling. To this general performative role of economics was added the specifically performative nature of option pricing theory. Black, Scholes, and Merton's model did not describe an already existing world: when first formulated, its assumptions were quite unrealistic, and empirical prices differed systematically from the model. Gradually, though, the financial markets changed in a way that fitted the model. In part, this was the result of technological improvements to price dissemination and transaction processing. In part, it was the general liberalizing effect of free market economics. In part, however, it was the effect of option pricing theory itself. Pricing models came to shape the very way participants thought and talked about options, in particular via the key, entirely model-dependent, notion of "implied volatility." The use of the Black-Scholes-Merton model in arbitrage— particularly in "spreading"—had the effect of reducing discrepancies between empirical prices and the model, especially in the econometrically crucial matter of the flat-line relationship between implied volatility and strike price.

Gradually, then, the CBOE participants began to price options as economists suggested *homo œconomicus* should. In the ad hoc New York market, and in the early months of the CBOE, prices were often set following simple rules of thumb. Participants then were more like the heuristic followers, with bounded rationality, posited by Herbert Simon (e.g., Simon 1955) than fully rational neoclassical *homines œconomici*. But even those participants who were not convinced by, or entirely ignorant of, Black, Scholes, and Merton's elegant reasoning were pushed toward Black-Scholes-Merton pricing as increasing numbers of other participants used the model. As far as pricing is concerned, the process, at least until 1987, nicely fits Callon's formulation: "Yes, *homo economicus* does exist, but is not an a-historical reality; he does not describe the hidden nature of the human being. He is the result of a process of configuration. . . . Of course it mobilizes material and metrological investments, property rights and money, but we should not forget the essential contribution of economics in the performing of the economy" (Callon 1998, pp. 22–23).

Callon's critic Miller is wrong when he suggests that economic sociology and anthropology should "radically separate out the market as a ritual and ideological system constructed by economists and the actual practice of economics" (Miller 2002, p. 224).[18] Economics and the "actual practice"

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[18] Miller's own theory of "virtualism" suggests a certain performative power of "economics and other abstract models . . . to transform actual economic practices, making them accord more with these same models," but ultimately he retreats to a sharp

of the CBOE and other derivatives markets were and are interwoven so intimately that such a separation is impossible.

The performativity of classic option pricing theory was, however, not a matter of simple self-fulfilling prophecy (see Merton 1949) or of the discovery of the correct way to price options. It was a contested, historically contingent outcome, ended by a historical event, the 1987 crash. No feedback loop of performativity stabilized the assumption of lognormal stock price movements.[19] The crash was a grotesquely unlikely event on such an assumption and thus undermined its credibility. Nor, as we have seen, was the market reaction to 1987 a simple matter of rational learning from the rejection of the null hypothesis of log-normality. The strength and persistence of the skew becomes understandable only once 1987's threat to the very existence of derivatives markets is grasped. No economist—indeed no identifiable person—invented the skew; economists have yet to reach any consensus on how best to theorize it. It was, we have argued, the upshot of a collective trauma, held in place subsequently in part by a concern that has an edge of morality to it. Its emergence, however, does validate another of Callon's claims: that we should talk only of "the laws of the markets," not of "the market" (Callon 1998, p. 47). His examples are primarily markets in different contemporary contexts, but the skew demonstrates variability across time as well as space: it demonstrates the historicity of economics. A mature, efficient market (which the CBOE had certainly become by the mid-1970s) priced options one way until 1987 and differently thereafter, and the change was driven by a historical event.

"Performativity" is a helpful addition to economic sociology's conceptual tool kit, and Callon has usefully shown the insights that can be gained by reversing the field's normal approach: instead of showing how market participants are more complex and more embedded than economics assumes, show how economics and its associated practices simplify and disembed them to the extent that economics becomes applicable. Yet even here matters were not as straightforward as a simple reading of Callon would suggest.[20] Economics indeed facilitated the emergence of deriva-

distinction between economics as a "culture of representation" and "ordinary economic . . . practice" (Miller 2002, pp. 229–30).

[19] There is a tempting argument that the assumption of log-normality was self-undermining, via its incorporation in the techniques of portfolio insurance. Unfortunately from the viewpoint of analytical neatness, however, the extent of the contribution of portfolio insurance to the 1987 crash is unclear.

[20] Although there are passages in Callon's work that suggest that "framing" and "disentanglement" indeed create *homo œconomicus*, other passages are more dialectical, noting the generation by framing and disentanglement of noncalculative overflowing and the "inextricable mixture" of noncalculative and calculative agencies "where we least expect it: at the very heart of the financial institutions" (Callon 1998, p. 39–40).

tives markets by disembedding derivatives from the pervasive moral framework in which they were dangerously close to wagers. However, neither economists on their own nor the unaided persuasive power of economic theory created the CBOE and the IMM. In the United States in the late 1960s and early 1970s, economics had persuasive force, particularly with the Nixon administration, committed as it was to freeing markets from their Rooseveltian shackles. In Malaysia in the late 1990s and early 2000s, in contrast, a similar battle to legitimize derivatives trading was fought, but those engaged in it appealed for legitimacy to Islamic jurisprudence, not to neoclassical economics (Kamali 1997; Maurer 2001). Even in the United States, furthermore, economics's persuasive power flowed through a Granovetterian network: in the case of the CBOE, from Baumol, Malkiel and Quandt, via Edmund O'Connor and Nathan Associates, to Milton Cohen, to William Casey, and into the Nixon administration; in the case of IMM, from Friedman to George Shultz (a Chicago economist, and colleague of Friedman's, who became Nixon's secretary of the treasury; see Melamed and Tamarkin 1996, p. 195), economist Arthur Burns (chair of the Federal Reserve and Friedman's former mentor), and others. Nor did the significance of embedding cease once the CBOE and the IMM were established. Baker's work demonstrates its economic significance for the CBOE; without the network of interpersonal connections mobilized by Melamed on the night of October 19, 1987, the American derivatives exchanges might have ceased to exist.

Callon acknowledges Granovetterian embedding (Callon 1998, pp. 8–12), and, given the origins of Callon's analysis of economics in his and Latour's actor-network theory (e.g., Latour 1987), there is no great barrier to integrating performativity and embedding in "networks of interpersonal relations" (Granovetter 1985, p. 504). Actor networks link human and nonhuman actors or "actants," so they are *not* sociometric networks, but the topology, so to speak, is similar. A potentially deeper difficulty—which has its roots in the sometimes narrowly semiotic view of "culture" in actor-network theory—concerns moral community. In one critical aspect, option market participants did not become *homines œconomici*. They might have priced options as economic theory said they should, but they never became morally atomistic. The reputation of an exchange member in the eyes of his/her fellows was and is significant. Open-outcry trading demands interpersonal trust, and it was "mutual *symbolic* sanctioning considered as an aspect of the communicative interaction that is normal and natural to us as social beings" (Barnes 1992, p. 263) that largely made possible the

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In his most recent writing (e.g., Callon and Muniesa 2002) the construction of *homo œconomicus* is deemphasized and more dialectical formulations prevail.

solution of the collective action problem represented by the very creation of the Chicago derivatives exchanges. Even the skew can in a sense be seen as the upshot of collective action. It could be perfectly rational for an individual trader to sell low-strike-price puts cheaply, at unskewed prices closer to the implied volatility of other options, without taking the difficult and expensive steps needed to provide a hedge that would be adequate in an extreme crisis. He or she could earn healthy profits; there has been no repeat of 1987; and, if there were, the losses of a bankrupt trader are borne by others. Yet if such trading were engaged in too widely it would create a systemic risk: another 1987 could undermine the very foundations of the options market. To trade that way is, even if individually rational, seen as immoral. It is to be a "shit-seller," and it has been kept in check by the options market, its clearinghouse, and its regulator, the SEC, through mechanisms such as risk-based margining. Throughout, it has remained important that Chicago is a place of rough-and-ready but economically significant market morality, a place with "an invisible sheet with an invisible line down the middle of it."

How should one theorize the articulation between performativity and markets seen as networks, cultures, and moral communities? The answer, it seems to us, must involve both impoverishing and enriching conventional economic views of the rational actor. A necessary impoverishment is the acknowledgment of humans' limited information-processing and calculational capacity and thus the recognition that a key role is played by simplifying concepts such as "implied volatility" and material means of calculation such as Black's sheets or Autoquote. That concepts and material means are constitutive of economic action—that economic action is distributed cognition in the sense of Hutchins (1995)—implies that the economic theory crystalized in concepts and devices can indeed be performative, even if not (as emphasized above) in any simple sense of self-fulfilling prophecy, but as the outcome of a conflictual, embedded process.

Enrichment of conventional models of the rational actor also seems necessary, even though Callon, as noted above, rejects it. As he himself concedes, the "cool[ing], reduc[ing] and fram[ing]" (Callon 1998, p. 50) of economic agents is never complete or stable. In consequence, "How can the emergence and formatting of calculative agencies be explained?" is *not*, as Callon asserts, "the only question worth posing" (Callon 1998, p. 51). The critical necessary enrichment is the recognition that the monetary economy is ultimately inseparable from the "economy of regard" (Offner 1997), at least in the Chicago derivatives exchanges and in almost all the markets in which the issue has been researched in any detail (even the geographically dispersed, electronically mediated market studied by Knorr

Cetina and Bruegger [2002]).[21] Even in financial markets, the apparent epitomes of self-interested, rational individualism, human beings have remained mutually susceptible (in the sense of Barnes 1992), and reputation and respect have mattered. With the aid of economic theory, of technology, and of much else, a passable version of *homo œconomicus* can be and has been configured cognitively, so to speak. Whether he can be configured morally, out of real men and women, remains an open question.

One should not posit an unchanging human essence: morally atomistic markets are conceivable. We are not, however, convinced that any actually exist, and it is possible that if they are to be created it may need to be in silicon, perhaps as autonomous software agents or as more mundane algorithms, not out of flesh and blood. But such agents or algorithms might well not (Mirowski 2002 argues they *could* not) simulate the cognitive capacities of *homo œconomicus* as conceived by orthodox modern economics. A partially configured actor (in the case of humans, cognitively configured, at least to a degree, but not morally configured; in the case of software agents, entirely amoral but perhaps not cognitively configured) is a looser, more open construction than fully configured *homo œconomicus* or his classic apparent negation, *homo sociologicus*.[22] An open construction of the actor, however, is precisely what is needed as the foundation for an adequate theoretical understanding of the "concrete organized markets" (Callon and Muniesa 2002) of high modernity, in all their diversity.

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[21] The classic case study of performativity by Garcia (1986) is not in sufficient ethnographic detail to stand as a counterexample. The 1980s' bond markets described by Abolafia (1996) are perhaps closest to morally atomistic, although our own current fieldwork on bond and bond-derivative markets (to be described elsewhere) suggests they have become *less* atomistic subsequently.

[22] See Granovetter (1985) and Callon (1998, pp. 10–19) for the underlying similarities between these two forms of *homo clausus*.

APPENDIX

TABLE A1
LIST OF INTERVIEWS

Name	Date	Location
Yigal Baruch	April 12† and November 10,* 2000	Chicago
Douglas Beck	March 28, 2000†	Chicago
Thomas A. Bond	November 9, 2000*	Chicago
Michael J. Carusillo and Clayton Struve	November 7 and 8, 2000*	Chicago
John Cox	September 25, 2001*	Cambridge, Mass.
David DeArmey	November 8, 1999*	Chicago
Joseph Doherty	December 4, 2000*	London
Irwin Eisen	April 6, 2000†	Chicago
Milton Friedman	October 9, 2001*	San Francisco
Mathew L. Gladstein	November 15, 1999*	New York
John Hiatt	April 12, 2000,† and November 7, 2000*	Chicago
Timothy Hinkes	November 8, 1999,* and November 6, 2000*	Chicago
Blair Hull	November 10, 2000*	Chicago
Sir Michael Jenkins	March 16, 2000*	London
Edward Joyce	March 29, 2000†	Chicago
Sheen Kassouf	October 3, 2001*	Newport Beach, Calif.
Thomas P. Knorring	November 10, 2000*	Chicago
Per E. Larsson	November 25, 2002*	Stockholm
Hayne Leland	June 12, 2000*	Berkeley, Calif.
Martin Liebman	April 5, 2000†	Chicago
Barry Lind	November 9, 2000*	Chicago
James McNulty	November 6, 2000*	Chicago
Leo Melamed	November 8, 2000*	Chicago
Robert C. Merton	November 2, 1999*	Cambridge, Mass.
William R. Power	November 10, 2000*	Chicago
Burton R. Rissman	November 9, 1999,* and March 30, 2000†	Chicago
Stephen A. Ross	September 24, 2001*	Cambridge, Mass.
Mark Rubinstein	June 12, 2000*	Berkeley, Calif.
Paul A. Samuelson	November 3, 1999*	Cambridge, Mass.
Lawrence Schneider	March 31, 2000†	Chicago
Myron Scholes	June 15, 2000*	San Francisco
Paul G. Stevens, Jr.	November 8, 1999*	Chicago
Joseph W. Sullivan	October 24, 2000*	Knoxville, Tenn.
Nassim Taleb	November 14, 1999*	New York
Edward O. Thorp	October 1, 2001*	Newport Beach, Calif.
David Weinberger	November 9, 2000*	Chicago
David Wenman	June 22, 2001*	London
Steve Youngren	March 31, 2000†	Chicago

NOTE.—An asterisk indicates that the interviewer was MacKenzie; a dagger indicates Millo.

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