A Price is a Social Thing: Towards a Material Sociology of Arbitrage

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Abstract

Arbitrage is a form of trading crucial both to the modern theory of finance and to market practice, yet it has seldom been the focus of study outside of economics. This article draws upon two initially separate ethnographic and interview-based studies to sketch a 'material sociology' of arbitrage. (The article follows financial market usage in viewing 'arbitrage' as trading that exploits discrepancies in relative prices, trading which is seldom the entirely riskless arbitrage posited by finance theory.)

Prices are physical entities, and the extent and speed of the mobility of these entities are crucial to arbitrage. Traders' bodies sometimes need to be trained to conduct arbitrage, and the relative placement of different bodies can be crucial. Arbitrage generally involves a theory of the similarity of different assets, and material representations of relative value are often required in order to check the theory's plausibility. Arbitrageurs need to convince themselves and others such as investment-bank managers – and sometimes traders working for different organizations – of the correctness of the theory. Amongst the reasons this is necessary is that an arbitrage position often incurs losses before it becomes profitable, and those who provide arbitrageurs with capital have to be persuaded that those losses are indeed temporary. Patterns of trust and information exchange amongst known others are thus consequential, and arbitrage also has wider social aspects, manifest for example in deliberately-constructed barriers to the short sales often required for arbitrage. Sometimes, too, arbitrage impinges on informal norms of proper conduct in markets.

Key words: arbitrage, social studies of finance, material sociology, hedge fund, investment bank.

A noteworthy recent development in the social sciences is the emergence of 'social studies of finance.' The field brings perspectives from the social studies of science and technology to bear upon financial markets. It has close relations to economic sociology and economic anthropology, but complements them because of its distinctive set of concerns (see, for example, the papers collected in Knorr Cetina and Preda 2005). The social studies of finance addresses the *technicality* of financial markets: the role played in those markets by technologies and by systematic forms of knowledge; the concrete, material practices of trading, risk management and regulation; and so on.

For example, productive analogies can be drawn between scientific laboratories – the sites of the classic ethnographics of science and technology studies (STS) – and trading rooms (Beunza and Stark 2004). Both are heterogeneous assemblages of human beings and technical devices, devoted to the production of workable knowledge. While it might be assumed that the theories set to work and tested in trading rooms are simpler and cruder than those deployed in laboratories, this is not necessarily the case. Financial mathematics is now as sophisticated as the quantitative apparatus of many of the other sciences (MacKenzie 2006), and trading rooms are amongst the sites of the most intensive computation in the modern world (MacKenzie 2001).

A theme prominent in STS in the last two decades is that science is far from always simply knowledge of an unchanged external world. Both laboratory science and science in practical applications outside the laboratory often require the scientist to 'intervene' as well as to 'represent' (Hacking 1983): to create material conditions in which theories and 'reality' can be juxtaposed and within which science will 'work'. Callon (1998) advances the analogous thesis for the case of economics. The economy is not an external object that economics analyzes, he argues. Market participants, regulators, and others often

draw actively upon economics, for example in formulating trading strategies or in designing the 'rules' within which economic action takes place.

Another classic STS theme is that 'artifacts have politics' (Winner 1980). Technologies reshape social action, rather than simply making existing forms of social action more efficient. The stock ticker (Preda forthcoming), or the now ubiquitous computerized price-dissemination systems and trading screens (Knorr Cetina and Bruegger 2002) did more than offer more timely representations of existing markets. They changed how market participants act in relation to each other and to markets, and also how they *think* about markets.

In this article, we seek to exemplify and to extend the social studies of finance by developing a material sociology of arbitrage. As discussed below, 'arbitrage' is a term with different meanings, but this article follows market practitioners in defining it as trading that seeks to make low-risk profits by exploiting discrepancies in the price of the same asset or in the relative prices of similar assets. A classic example historically was gold arbitrage. If the price of gold in Saudi Arabia exceeds its price in New York by more than the cost of transportation, arbitrageurs can profit by buying gold in New York and selling it in Saudi Arabia (or vice versa if gold is cheaper in Saudi Arabia). By buying and selling as close to simultaneously as possible, arbitrageurs avoid the risks of 'directional' trading: they profit irrespective of whether the price of gold goes on to rise or to fall.

Arbitrage requires technological resources, sustained effort and expertise beyond the capacity of nearly all lay investors in financial markets. It is the preserve of market professionals, and is a crucial form of trading. (To bring the topic close to home for academic readers in the U.S., we would note that the most successful of large endowment

funds, such as Harvard's, are often skilled practitioners of arbitrage.) Indeed, arbitrage *constitutes* markets, for example helping to determine their scope and the extent to which they are global: that international gold arbitrage is possible creates a world market in gold with a 'world price', rather than geographically separate markets with different prices. Arbitrage links asset classes, creating systematic connections between the prices of stocks and of stock-index futures, of options and their underlying assets, of bonds of different maturities, and so on. (A stock-index future is a contract that yields a pay-off that follows the prices of the stocks making up the index. Options are contracts that give their holders the right, but do not oblige them, to buy – or, in an alternative form of the contract, to sell – an asset at a set price on, or up to, a given future date.)

In constituting markets, arbitrage has wider consequences for economies and political systems. For example, in the late 1990s arbitrageurs in hedge funds and investment banks began to perceive growing similarity between the bonds issued by the government of Italy and those issued by other European countries, notably Germany. For a variety of reasons (including distrust of the fiscal efficiency of the Italian state and consequent fears of it defaulting on its bonds), the prices of Italian government bonds had traditionally been low relative to those of countries such as Germany, thus imposing high debt-service charges on Italy. As arbitrageurs began to buy Italian bonds, their relative prices rose and the proportion of Italy's government expenditure devoted to debt service fell. The process – which was assisted by the liquidity created by the MTS electronic bond-trading system, set up by the Italian treasury in 1988 and discussed below – helped Italy meet the Maastricht criteria for European Economic and Monetary Union (EMU). Arbitrageurs' beliefs thus had a self-validating aspect – they prompted trading that made more likely the event, Italy's qualification for EMU, on which the beliefs were predicated

(MacKenzie 2003) – and arbitrage helped to create a European government bond market, rather than separate national markets.

The failures of arbitrage can be as consequential as its successes. Such failures were at the heart of two of the most serious crises of the post-war financial system: the 1987 stock market crash and the 1998 turmoil surrounding the hedge fund Long-Term Capital Management (LTCM). A crucial aspect of the former was the breakdown of the link – normally imposed by arbitrage – between the stock and index-futures markets (MacKenzie 2004). In the case of LTCM, the forced unwinding of arbitrage positions caused huge, sudden, highly-correlated price movements across the globe in apparently unrelated assets, bringing some markets close to paralysis (MacKenzie 2003).

There is an enormous disciplinary imbalance in regard to arbitrage. It has received almost no sustained attention in economic sociology, in economic anthropology, in economic geography, or in the strand of political science known as international political economy, even in the subsets of those specialities that deal with financial markets (the limited exceptions include Miyazaki 2003, Robotti n.d., Beunza and Stark 2004, Hardie 2004, and MacKenzie 2003). In contrast, the central theoretical mechanism invoked by modern financial economics is 'arbitrage proof'. The field posits that the only patterns of prices that can be stable are those that permit no opportunities for arbitrage. Particular patterns of prices are then shown to be necessary by demonstrating that if prices deviate from that pattern arbitrage is possible. The entire modern theory of asset pricing – especially the theory of the pricing of derivatives such as options – relies on 'arbitrage proof' of this kind. Paradigmatic is the Nobel-prize-winning theory of options developed by Fischer Black, Myron Scholes and Robert C. Merton (Black and Scholes 1973; Merton 1973). In their model, the price of an option is determined by the fact that it can be

replicated exactly: it is possible to construct a continuously-adjusted portfolio of holdings or borrowings of the underlying asset and cash that will have the same pay-off as the option in all states of the world. The price of the option must equal the cost of this replicating portfolio, for otherwise arbitrage is possible.

The conceptualization of 'arbitrage' in the work of Black, Scholes and Merton, and in mainstream financial economics more generally, differs from the arbitrage as market practice that is the focus of this article. Orthodox economists define arbitrage as demanding no capital and involving no risk, while in market practice arbitrage seems always to require some capital and involves some risk, even if the risk is only that a counterparty to a transaction will not fulfil its obligations (Hardie 2004). Indeed, a purist would argue that the trading we consider in this paper should not be considered 'arbitrage'. (Such a purist should replace the word 'arbitrage' in what follows with 'relative-value trading'.)

Purism, however, has its costs – a purist definition of 'arbitrage' excludes the real-world counterparts of the canonical arbitrages of finance theory, such as the arbitrage that imposes Black-Scholes-Merton option pricing – and purism is not the only possible response. Recently, financial economists – especially 'behavioural' economists such as Andrei Shleifer – have begun to investigate the consequences of making the definition of arbitrage more realistic (see, for example, Shleifer and Vishny 1997). These economists rightly see the topic as a crucial one. Since, in orthodox views, it is above all arbitrage that makes markets efficient, the existence of limits to arbitrage casts into doubt the full validity of the central tenet of modern financial economics: the efficient market hypothesis, according to which prices in mature capital markets fully reflect, effectively instantaneously, all available price-relevant information. As we shall argue, there are

potentially productive linkages between the emerging literature in economics on the limits of arbitrage and the 'material sociology' of arbitrage that we advocate.

Material sociology pays attention to the role played in social relations by artefacts and other physical objects and entities (including human bodies viewed as material entities). Since that role is of course pervasive, all sociology should be material sociology, yet social theory frequently abstracts away from material entities and empirical enquiry often does not focus on them. Material sociologists who have highlighted the constitutive role of objects and artefacts in social relations have included Karl Marx, but prominent in the recent 'turn to things' (Preda 1999) in sociology has been the actor-network theory developed from within STS by Bruno Latour and Michael Callon, the latter of whom has been a particularly strong influence on social studies of finance. (Readers of *Organization Studies* can find references and a useful account of the theory in Munir and Jones 2004.)

In developing a material sociology of arbitrage, this article draws upon two separate research projects. The first author spent 34 months in a participant-observation study of an investment-bank arbitrage trading room in New York. The second and third authors are conducting an interview-based study of traders in a variety of locations, supplemented by the much more limited participant observation drawn on in the second section of this article.

Our goal here is not to report systematically on the empirical studies underlying this paper, which have many aspects beyond those discussed here (see Beunza and Stark 2003 and 2004, MacKenzie 2003 and 2004, and Hardie and MacKenzie 2005). In the second section, we present one of the many arbitrage trades we observed in our fieldwork, but the example is chosen for its simplicity, not because it encapsulates all the issues we

wish to discuss – no single example does. The article's aim is to outline a material sociology of arbitrage consistent with our observations and interview data, and also with the results of others in the social studies of finance who have touched upon arbitrage. This we do in the article's third section – which discusses the materiality of arbitrage – and fourth section, discussing arbitrage's sociality. (The separation of the sections is for convenience of exposition alone: fundamental tenets of any properly material sociology are that the social *is* material and that the material world, at least as comprehended by human beings and configured technologically, is social.) The fifth section is the article's conclusion.

Brazil 14s and 40s

January 5, 2005: the second and third authors are observing trading in a hedge fund. (More lightly regulated than traditional investment companies, hedge funds are prohibited from advertising, but have greater freedom of action, in particular to use borrowed capital in order to enhance returns, and to short sell, in other words to sell assets they do not own, for example by borrowing them and later repurchasing them and returning them.)

With traditional investment vehicles producing poor returns, hedge funds have been growing rapidly in number and in capital. They tend to cluster in particular places, notably Greenwich, Connecticut, and in and around Mayfair in London's West End, where the fund in whose trading room we are sitting is based. It was set up by partner A, who takes primary responsibility for the fund's trading and is referred to below as 'the trader', and partner B, who helps set the fund's overall strategies, markets the fund to investors,

and also does some trading. A and B then recruited partner C, an economist (he is at home ill on January 5 but gives his opinions by phone); partner D, the fund's administrator; and an assistant to the trader, who for example helps to perform quantitative analyses.

The fund's trading room is quiet: it faces off the street, and often the only noises to be heard are typing on keyboards and the hum of the fan cooling the fund's powerful computer server. Yet the world is continuously being brought into this modestly-sized room. At noon, Europe's three-minute silence to commemorate the victims of the Asian tsunami is observed. Electronic mail from other market participants, often at major investment banks, arrives frequently: it brings electronic traces of prices and other news; analyses of markets; confirmation of trades; and so on. Screens continuously display numbers representing indicative prices in the markets in which the fund concentrates: emerging-market government bonds, derivatives of those bonds (especially 'credit default swaps', which provide protection if a bond-issuer defaults) and currencies. A scrolling 'ticker' lists major transactions in emerging-market bonds. Telephone conversations take place. Most are brief: often, the trader is seeking price quotations, and if the numbers he is quoted down the telephone line are attractive, a purchase or sale worth as much as $5 million is completed in a further few quick words. At one point, the speaker phone is switched on to listen to staff at an investment bank answering questions about their views on particular emerging markets.

The matters that attract attention, in the form either of conversations or of close scrutiny of computer screens, are heterogeneous: the minutes of the U.S. Federal Reserve's Open Market Committee, released the previous evening in London time, which are taken as indicating that further interest-rate rises are on the way; the prices of the

government bonds of the Philippines, which have defied a sharp global decrease following the release of the minutes; the soon-to-be-announced figure for U.S. non-farm employment; the exchange rates of the Mexican peso and South African rand; politics in Ecuador; price quotation conventions in the Turkish bond market; and much else.

At 9.00 am every working morning, the fund holds a meeting, attended on January 5 by the trader, partner B, and the trader's assistant. Just after the morning meeting, partner B notices an oddity in the Brazilian government bond market. Although the release of the Federal Reserve's minutes has led to general price falls, the '14s' (an issue of dollar-denominated bonds that mature in 2014) are 'trading up': their price is high relative to other bonds. 'Hit the bid' (sell them), he suggests.

The trader does not respond immediately, but he goes on to ask his assistant to produce a chart of the prices over the last three months of the '14s' and the '40s' (Brazilian government dollar-denominated bonds that mature in November 2040). As the day proceeds, the trader takes a position in the 14s and the 40s, short selling the former and buying the latter. He also sends a contact in an investment bank the Excel file containing the price chart produced by his assistant, encouraging his contact to circulate it to others.

A bond maturing in 2040 seems very different from one maturing in 2014: much could happen in the quarter century between the two dates. But the bond maturing in 2040 is 'callable': the Brazilian government has the right to recall the bond by repaying the principal early, in 2015. If Brazilian bonds continue to trade at anything like their current prices, it will be in the government's interest to do so, since it will be able to replace the

borrowing more cheaply. The '40s' thus in effect mature in 2015 and so, despite appearances, a '14' and a '40' are quite similar.

On the morning of January 5, none of this is said explicitly: it is part of what the trader and partner B, like all sophisticated participants in the Brazilian bond market, simply 'know'. (The second author was an investment banker before returning to academia, and was involved in the initial sale of the '40s' on behalf of the government of Brazil, so he knows it too, though he needs to whisper an explanation to the third author.) Nevertheless, the chart produced by the trader's assistant is a material representation that makes visible the reasoning underpinning the trade. Once he has configured the chart according to the trader's wishes – initially, it shows the prices of the 14s and the prices of the 40s, when the trader wants it to display the *difference* in prices – the prices of the two bonds can be seen to follow each other closely, as would be expected, but with the 40s almost always slightly more expensive than the 14s. Again, the reason is common knowledge amongst aficionados. The 40s are the most liquid of Brazilian government bonds, the ones most readily bought and sold, and thus the most attractive, for example to those who wish to create and to exit positions quickly. Indeed, in a later interview partner C describes the Brazil 40s as the 'asset-class benchmark' for emerging-market government bonds as a whole: 'if people are negative/positive on emerging markets, they buy or sell that specific issue'.

In order to read the trader's assistant's chart correctly, one needs to realize that on it 'time' flows from right to left (the earliest dates are on the right). Once that is grasped, however, someone viewing it can clearly see what the trader has seen: in recent trading days the 14s have become more expensive than the 40s, with the difference increasing sharply the previous day (January 4). The trader knows his market well enough to infer a

cause that is confirmed only later in the day in a telephone conversation with the above-mentioned investment bank contact. The sell-off triggered by U.S. Federal Reserve's minutes has concentrated in Brazil's liquid 40s. Indeed, as the contact tells the trader, unusually 'the real money guys [traders not in hedge funds but in bigger institutions] shorted 40s'.

The trader thus confidently assumes (and makes explicit in a telephone conversation with his contact) that the fact that 14s are more expensive than 40s is a price discrepancy that will be temporary. By short selling 14s and buying 40s, he – and indeed others – can perform an arbitrage. The discrepancy would be expected to vanish in the normal course of events, but especially if others choose also to exploit it (perhaps because the investment bank contact circulates the assistant's chart to them), the process will be hastened, maybe considerably. By early afternoon, the trader has accumulated some $13 million of short sales of 14s and another $13 million of purchases of 40s. By mid afternoon, he is able to say 'it's moved in my favour' – the discrepancy has started to reduce – 'but not enough to unwind': he keeps the position on, expecting further reductions in the discrepancy. Only at the end of the week does he liquidate his position, earning a healthy profit.

Note what the trader is *not* doing in this trade. Like the gold arbitrageur, he is not taking a 'directional' view. He is not attempting to estimate the probability of bond default by Brazil, nor the future courses of interest rates or inflation, the other main systematic influences on prices in the bond market: because the 14s and the 40s are so similar, rises or falls in factors such as these will affect the prices of each bond roughly equally, and with the trader's matched 'long' and 'short' positions the effects will cancel out. Other specific factors such as the policies of Brazil's government are likewise of no

immediate import, and the trader does not expect to hold the position for very long. His position is not entirely free from risk – see below – but in its insulation from the major risk factors in his market it is low risk.

Asked by the third author about the rationale of the trade, the trader says (just as a financial economist would) that the fact 'that this trade has presented [itself] indicates [an] inefficiency'. Temporarily, prices are reflecting something other than merely the available information. Although the trader's motivation may simply be to earn money for his hedge fund, his actions are helping to eliminate a discrepancy and correct the effects of an 'inefficiency'. In that respect, his trading resembles arbitrage as conceived by financial economics.

The Materiality of Arbitrage

A price is a thing. Like all prices, those to which the trader was responding (and circulating in the form of the chart prepared by his assistant) were physical entities – patterns on computer screens and spoken numbers transmitted by telephone. The forms of embodiment of prices are various – the sound waves that constitute speech; pen or pencil marks on paper; the electrical impulses that represent binary digits in a computerized system or encode sound over a telephone line; hand signals in 'open-outcry' trading pits that are too noisy for voices to be heard; and so on – but are always material. If a price is to be communicated from one human being to another, or from one computerized trading system to another, it must take a physical form.

The materiality of prices matters to arbitrage because their physical embodiment affects the extent and speed of their transmission. Classical forms of arbitrage exploited the differences between prices in different places. The commodities and currency arbitrageur J. Aron & Company, for example, used to keep telephone lines to Saudi Arabia open constantly so it could as quickly as possible detect the emergence of discrepancies in gold or silver prices (Rubin and Weisberg 2003: 90-91).

The development of electronic price dissemination systems (especially the 'Monitor' system, introduced by Reuters in 1973) largely undermined the time-space advantages that firms such as Aron had achieved by the use of social networks and older communication technologies, notably the telegraph and then the telephone. It was much less likely, for example, that a trader could perform arbitrage by having two telephone lines open, selling an asset to one counterparty while buying it at a lower price from another, while making sure that neither counterparty could hear what was being said to the other. 'After the introduction of Monitor, prices [initially currency exchange rates, and later many other prices as well] suddenly became available globally to everyone connected to the system'(Knorr Cetina and Bruegger 2002: 395).

Electronic price dissemination does not, however, entirely eliminate differences in the speed of transmission of prices, and those differences remain consequential, even if they are now measured in seconds, not the minutes or hours of traditional arbitrage. For instance, as little as two seconds made the index arbitrage desk of a bank that competed with the bank studied by the first author lose millions of dollars. Index arbitrage (the form of arbitrage at the heart of the 1987 crash, for example) exploits differences between the prices of index futures, for instance on the S&P500 index, and the prices of the stocks making up the index. On the day in question, the numbers representing stock prices were

being transmitted by the competitor's Reuters server with small delays, while futures prices were arriving normally, giving the appearance (on a day on which the market rose consistently) of persistent, attractive mispricing. Seeing apparent opportunities, the competitor's arbitrageurs traded in huge volumes and incurred large losses. As a trader explained, 'while they were buying, we were selling ... the traders here were writing tickets until their fingers were bleeding. We made $2 million in an hour, until they realized what was happening' (Beunza and Stark 2004).

The way in which one of the traders in the bank studied by the first author configured his two Unix workstations and Bloomberg terminal indicates the importance of speeds of transmission and precise times. Every day, the clocks in his Unix workstations are synchronized to an atomic clock. Across the top of one of his three screens, he has a slash sign that rotates and moves from side to side. It is a 'pulse meter', used to gauge the 'price feed' – the speed with which information on prices is arriving – which stops moving when prices stop arriving. On the his other Unix workstation, the trader has five coloured squares that work as 'speedometers', indicating how quickly orders are getting through network servers: if they are green, everything is fine; if they are yellow, the network is congested and deals are delayed; if they are red, servers are clogged. Two 'CPU-meters' also measure congestion in the bank's order flow (Beunza and Stark 2004).

The speed with which the physical entities that embody prices move is not dictated by physical and technological considerations alone. For instance, in the early days of connection by modem to the New York Stock Exchange, member firms tried to obtain an advantage by investing in faster modems. To prevent costly competition in ever-faster hardware, a 'speed limit' of 9.6 Kbaud was put in place. During the first author's observations, this limit became a problem for some of the banks affected by the terrorist

attack of September 11, 2001. Those banks' existing 9.6 Kbaud communication systems were inoperable, but sufficiently slow modems were no longer commercially available (Beunza and Stark 2003).

Also sometimes important to the conduct of arbitrage, and simultaneously both material and social, are the allowable forms that prices can take. In economic theory, prices are typically represented as real numbers – the equivalent of the points on a continuous line – while the physical embodiment of prices in market practice requires prices to be a subset of the rational numbers, the numbers expressible as a ratio of integers (see Mirowski 2002: 543). Furthermore, the allowable subset has often differed from that in the everyday usage of money.

For example, until recently securities prices in the United States were standardly not expressed as dollars and cents but as dollars and binary fractions of dollars, most commonly eighths. Thus until June 1997 prices on the New York Stock Exchange were denominated in eighths of a dollar. A stock could cost $\$15^{3}/_{8}$ ($15.375), but it was not allowed to have a price of, for instance, $15.37, $15.38, or $15.40. The issue sounds like a mere detail, but it has considerable consequences. One of the most significant scandals in U.S. financial markets in the 1990s resulted from accusations that NASDAQ broker-dealers had colluded to avoid odd-eighths price quotations, so boosting their earnings by increasing from $0.125 to $0.25 the minimum gap between the prices at which they would buy and sell a stock. A class-action law suit by NASDAQ investors led to the payment of damages reported to be $910 million, then 'the largest civil antitrust settlement in history' (Ingebretsen 2002: 153).

The size of the minimum unit of price affects the magnitude of the discrepancy at which arbitrage becomes feasible. After June 1997, when the New York Stock Exchange reduced the unit of price to a sixteenth of a dollar, the typical discrepancy that triggered index arbitrage decreased, and there were larger numbers of index arbitrage trades (Henker and Martens 2005). When in 2001 the Securities and Exchange Commission required the further shift from binary fractions to decimals (dollars and cents), the additional facilitation of arbitrage meant that index arbitrageurs faced enhanced competition – as one put it, 'We used to make our money by getting in between the sixteenth increments' – and some incurred losses.

Amongst the physical entities involved in the performance of arbitrage are arbitrageurs' bodies. For example, electronic trading on a futures exchange involves placing 'bids' (offers to buy) or 'asks' (offers to sell) for the asset in question. Normally, this done by using a computer mouse to click on a screen that shows, for each price level, the numbers of bids (often in blue) and of asks (often in red). At busy times, these numbers and levels change from second to second, with blue and red bars seeming to dance up and down. If an arbitrage opportunity persists only for seconds (as is often the case), constant attention and rapid physical execution are needed. The anthropologist Caitlin Zaloom reports to us that as trainee futures traders she and her colleagues were made repeatedly to practice with a computerized gold-price arbitrage simulation, so that the disciplined attention and fast, accurate action they would need became bodily habits. They were encouraged 'to play commercial video games on our own time to increase our reaction speeds and hand-eye coordination'. A particular danger they were trained to avoid was 'fat fingering', in which, for example, instead of left-clicking the mouse to 'join the bid' (putting in an offer to buy at a set price) they accidentally right-clicked, inadvertently buying the asset in question at its current market price. The managers' aim

was to 'train our bodies to operate as uninterrupted conduits between the dealing room and the on-line world, allowing our fingers to become seamless extensions of our economic intentions' (Zaloom, personal communication).

The bodily aspects of arbitrage are most prominent when it is performed in open-outcry trading 'pits': stepped amphitheatres, traditionally octagonal. Dozens or hundreds of traders stand on the rungs of a pit, making deals by voice or by eye contact and an elaborate system of hand signals. In Chicago (the prime site of open-outcry trading), the hand-signal language that is used is called 'arb' because its speed was essential to arbitrage. For example, when a trading firm spotted an arbitrage opportunity, canonically between the prices of gold futures traded in Chicago and in New York, it was quicker to 'arb' (hand-signal) instructions from the firm's booth to the trading pit than to send a clerk running to the pit with a written order (Lynn 2004: 57-59; see also Zaloom 2003 and 2004).

Where bodies are positioned with respect to each other can be of considerable significance to arbitrage in open-outcry trading. For example, the two main forms of option are calls (options to buy at a set 'exercise price') and puts (options to sell at a set price), and discrepancies between call and put prices can be exploited by arbitrages such as 'conversion'. (In conversion, a trader sells a call option and simultaneously buys a put option with the same exercise price and expiration plus the stock or other underlying asset in question.) Options arbitrageurs on the American Stock Exchange found it advantageous to stand in between the 'specialist' (designated main trader) responsible for calls and the specialist responsible for puts on the same stock. That was the optimum bodily position for detecting and exploiting opportunities for conversion and similar arbitrages.

Because the physical location of bodies is of such importance to open-outcry trading, pits and trading floors are bodily places in an especially strong sense. In Chicago, there is lots of jostling and occasional fist fights (often over the right to occupy a particular spatial location in a pit); height and a loud voice are advantages; and, unsurprisingly, male bodies predominate. Even mundane artefacts such as shoes are consequential: Chicago traders often wear platform heels to increase their height, while traders on the more sedate New York Stock Exchange keep special shoes in the locker room because of the amount of walking between trading floors and trading booths their job entails.

Over the last ten years, however, open-outcry trading has declined rapidly, and it may soon become extinct. Nevertheless, bodily location still matters in the screen-based trading that has replaced it. Because arbitrage involves trading pairs (or larger sets) of securities, the expertise it demands is often distributed across more than one person. The physical placement of traders and other members of staff in the investment-bank trading room studied by the first author was designed quite consciously to facilitate the necessary interaction, and also to inhibit interactions that might be detrimental (Beunza and Stark 2004).

For example, the bank's customer desk executes orders for clients while the 'special situations' desk trades complex, hybrid strategies for the bank and is not in direct contact with clients. The two sets of traders sit facing each other, separated only by their keyboards and computer monitors. One way in which the customer desk generates ideas is by considering why customers might be doing what they are doing: for example, as the head of the customer desk put it, if someone pays a lot for a stock,

it can be interpreted as 'what does he know that I don't?' The physical proximity of the situations desk meant that possible interpretations of puzzling client orders could quickly and informally be discussed between desks:

> I [the head of the customer desk] looked at it and said, 'why does he do that?' I talked to Josh [a proprietary trader] and it didn't make any sense. 'That guy's crazy,' we thought. That was the tip-off. We structured what we thought was a better trade …

'It is like brainstorming', the head of the desk said: 'we really don't know what we're gonna think in the end. I could have told "buy" to those guys, and conclude five minutes later that it was "sell"'.

In contrast, the four 'statistical arbitrageurs' in the bank's trading room were deliberately kept at some distance from each other. 'Statistical arbitrage' involves the detection of patterns in the ever-changing flux of security prices. (It is of theoretical significance because by detecting, exploiting and eliminating predictable statistical structure in price movements it may leave behind only unpredictable randomness, making markets, in the terminology of financial economics, 'weak form' efficient. Statistical arbitrageurs, however, deny that structure is entirely eliminated in this way.) The structure exploited by statistical arbitrageurs is seldom or never deterministic: they hope only to do better than pure chance. In consequence, the risks of the activity are minimized if different statistical arbitrageurs are exploiting different patterns, and increased if – perhaps because they have shared ideas – their trading becomes too similar. As a senior trader put it: 'We don't encourage [statistical arbitrageurs] to talk to each other. They sit apart' (see Beunza and Stark 2004).

The Sociality of Arbitrage

A price is a thing, but it is also social. All forms of arbitrage depend for their success on what others will do. Even in the classic forms of arbitrage that exploit differences in the prices of the 'same' asset between different places, others must be depended upon to fulfil their obligations: for example, to deliver gold if the arbitrageur has struck a deal to buy it, or to deliver money if the arbitrageur has sold gold. Procedures carried out by others must also be relied upon to ensure that gold in Riyadh is 'the same' as gold in Manhattan.

Many – probably most – current forms of arbitrage exploit discrepancies in the prices not of the 'same' asset but of 'similar' assets: Brazil 14s and 40s; stocks and stock-index futures; stocks and options on those stocks; Italian and German government bonds; newly-issued ('on-the-run') government bonds and previously-issued ('off-the-run') bonds; government bonds and bonds carrying implicit government guarantees but backed by pools of mortgages; the stocks of the two legally distinct but economically integrated corporations that until 2005 made up the Royal Dutch-Shell group; and so on. The 'sameness' of gold is established by assay procedures 'external' to the market that can be treated by market practitioners as a 'black box'. However, the similarity of assets such as the Brazil 14s and 40s, or of shares in Royal Dutch and in Shell, depends, at least over the short and medium term, on others within the market treating them as similar, and the arbitrageur can seldom afford to treat this as a black box.

The 'similarity' of financial assets is always in a sense theory-dependent. Sometimes, the theory in question is a sophisticated mathematical model, such as Black-

Scholes-Merton option pricing. At other times, the theory is vernacular and down-to-earth: for example, that the government of Brazil *will* call the 40s in 2015, thus making them similar to the 14s, or that the intended Eurozone would converge, making Italian bonds similar to German bonds.

To embark upon arbitrage, traders thus have to convince themselves that the theory on which the arbitrage rests is correct, or at least plausible enough to be the basis of practical action. They will often also want to or need to convince others. In our observations both of the investment bank and the hedge fund there was much discussion of possible trades and of the theories underlying them, both inside the organization and in the form of analyses coming in from outside (and occasionally flowing in the opposite direction). Critical roles in these discussions are often played by material representations of value, such as the chart showing the recent history of the difference in prices between the 40s and the 14s, or the 'spread plot', showing the relative prices of Hewlett Packard and Compaq, that the first author observed being closely followed in 2001-2 by 'risk arbitrageurs' hoping to exploit the probable – but not certain – merger between the two corporations (Beunza and Muniesa 2005). But material representations are often not on their own conclusive: information about what other traders are doing – for instance, about the behaviour of 'real money' in the Brazilian bond market – can also be important in allowing the plausibility of theories to be judged.

The need to convince others does not necessarily cease once a trader takes on an arbitrage position. Often, the price discrepancy that is being exploited will increase further before it decreases, which means that the arbitrageur will incur apparent losses. (For example, in September 1998, the Harvard endowment, whose arbitrage activities were caught up in the crisis surrounding LTCM, had racked up temporary losses that the *Wall*

Street Journal [Sandler 1998] reported to be in excess of $1 billion.) Sometimes, apparent losses are actual outflows of money or securities (or, at least, the electronic traces thereof), for example as a result of the daily process in which exchange clearing houses adjust the 'margin' deposits that participants must maintain in order to be allowed to continue to hold their positions. At other times, there are no actual outflows, but as banks and hedge funds 'mark to market' (revalue their trading positions, which is now also normally done at least daily), a position shows a loss. In either case, the losses will be temporary (the outflow will be replaced by an inflow, a 'paper' loss will turn into a realizable profit) *if* the theory underpinning the arbitrage is correct, but others may need to be convinced of this to allow the arbitrageur to continue holding the position.

In a large institution such as a bank, the immediately important audience for arbitrage is an arbitrageur's manager or managers, who will normally be closely attentive to the 'P&L' (profit and loss) figures of those they supervise. 'There's a saying in trading circles', one trader and manager told us: 'the white sheet [P&L sheet] doesn't lie' – losses are real, and should be acted upon as if they are real. The arbitrageur's problem, however, is that from his or her viewpoint the white sheet does sometimes lie, at least temporarily. A common complaint amongst arbitrageurs is of being instructed by managers to liquidate loss-bearing positions that they were certain would become profitable. Even 'textbook' arbitrages can be subject to this risk: the traders in the Japanese securities firm studied by Miyazaki (2003) reported being forced to abandon index-arbitrage positions because of the apparent losses incurred when they had to deposit additional futures margin.

In hedge funds, the manager/arbitrageur divide seems typically to be much less marked: even in large funds such as LTCM the two roles are not distinct. Investors, however, form a more immediate audience than they do in the case of banks. Hedge funds

report changes in net asset values to their investors monthly, while banks report quarterly or less frequently (depending on the jurisdiction in which they are incorporated), and losses in a hedge fund's trading are not masked by the profitability of other lines of business as they often are in banks. The increasingly important 'funds of funds', which allocate their investors' capital to hedge funds that they select (and also frequently withdraw it), are able to demand reports more often than monthly: sometimes even daily. So a large loss by a hedge fund conducting arbitrage – even a 'paper' loss – quickly becomes visible. One hedge fund manager (and former investment banker) told us that in a bank 'you can justify why you want to hold on to those positions', while hedge fund investors 'don't care. They just look at the number [changes in net asset value]'. The threat of investors withdrawing their capital from the fund is thus almost continuous: 'there is very small tolerance to losing money. … [W]e cannot have a losing month'.

The risk of arbitrageurs in a bank having to abandon their positions because of temporary losses is reduced if managers understand and accept the theory underpinning a trade, and thus believe that losses will indeed be temporary. One advantage of investment banks with long experience of arbitrage over newcomers such as the firm studied by Miyazaki is that this understanding is much more likely. Often, though, the technical details of arbitrage trading are daunting even to those with extensive market experience. Arbitrage between government bonds and mortgage-banked bonds, for example, involves (a) adjusting the spread between their yields to take account of the consequences of the fact that most mortgage contracts allow borrowers to take advantage of falls in interest rates by repaying a mortgage with funds borrowed more cheaply from another lender, and (b) offsetting those consequences, for example by appropriate purchases of interest-rate options. Neither the adjustment nor the offsetting is an elementary matter.

In such cases, trust in arbitrage often in practice has to be trust in the arbitrageur or arbitrageurs *as particular people*, just as in many cases trust in science comes down to trust in the scientist (see Shapin 1992). A hedge fund, a university endowment manager, or an individual trader or trading desk at a bank who or which has built up a good reputation is more likely to be trusted. LTCM's founder John W. Meriwether had led Wall Street's premier arbitrage desk (at Salomon Brothers), and his colleagues included other traders with high personal reputations. They were able to have LTCM's investors accept a three-year 'lock-in' in which they were not allowed to withdraw capital, and after the 1998 crisis they successfully recruited investors to a successor fund, JWM Partners. During the1998 crisis, the overseers of the Harvard endowment appear to have trusted its management, and rather than insisting that loss-bearing positions be liquidated, they tolerated the apparent huge loss – thus making it possible for it to be temporary (as indeed it was).

Losses, even temporary, can in addition be avoided if other arbitrageurs and professional traders also come to view the price difference that an arbitrageur is exploiting as a discrepancy. In our observations and interviews, we were struck by the extent of the circulation amongst traders in different funds and banks, mainly by electronic mail, of ideas for trading and by the attention most professional traders pay to what others seem to be doing. If that discussion and attention leads others also to seek to exploit a discrepancy, then their purchases and sales will narrow the discrepancy, or at least reduce the risk of it widening. That, for example, was why the trader discussed in this paper's second section wanted the chart displaying the 14s/40s anomaly circulated to others. 'All I want is people even to talk about it', the trader told us. If others also took action on the pricing anomaly, they would prevent it widening. Should it widen, the trader explained, he might even come to doubt his belief (the 'theory' behind the trade) that the anomaly was a

discrepancy that would close. 'There might be a reason [for the anomaly] I don't understand. I might have to reconsider the decision [to construct a trading position predicated on it narrowing]'.

Another way of minimizing the risk of premature capital withdrawal is diversification. If a fund, trading desk, or bank holds a wide variety of arbitrage positions – for example, in different parts of the world and in different asset classes – then, on the face of it, there is little likelihood of enough of those positions losing money simultaneously to create a serious overall loss. (The matched 'long' and 'short' positions characteristic of arbitrage mean that common factors such as global economic conditions, the levels of interest rates and the buoyancy of stock markets should have little or no effect.) Diversification of this kind was, for instance, a core aspect of LTCM's strategy.

However, the constant attention of many professional traders to what others are doing may undercut the benefits of diversification. If large numbers of traders are led all to take similar positions, then arbitrages that 'ought' to be uncorrelated can suddenly become linked. This, for example, was what caused LTCM's diversification to fail. LTCM tried hard to keep its positions private: as a very large market participant with a largely locked-in capital base, it was concerned less with the benefits of others preventing discrepancies widening than with their trading causing the opportunities it was exploiting to diminish or vanish. However, others did frequently take on similar positions, either because they were following the same general strategy (in part in emulation of LTCM's success) or because they learned specifics of LTCM's trading directly or indirectly from those who took the other side of those trades. 'I can't believe how many times I was told to do a trade because the boys at Long-Term deemed it a winner', says one hedge-fund manager (Cramer 2002: 179).

The resultant overlapping set of arbitrage positions made it possible for an event to which LTCM itself had only a limited exposure – the Russian government's default on its rouble-denominated bonds on August 17, 1998 – suddenly to cause highly correlated adverse price movements across the globe and in apparently unrelated asset classes. Arbitrageurs who incurred losses in Russia had to liquidate positions (even in apparently unrelated assets) to meet margin calls, withdrawals by investors, and other demands on their capital. In aggregate, the positions they sought to liquidate overlapped considerably with each other and with LTCM's portfolio. These liquidations in turn caused more losses, leading to further liquidations, and so on in a disastrous, market-paralysing spiral.

The sociality of arbitrage goes beyond relations to particular others such as managers, hedge fund investors, and other arbitrageurs: the conduct of arbitrage is affected deeply by the forms of action in financial markets that are seen as permissible and to be encouraged or as impermissible and to be discouraged. One persistent issue is the difference in this respect between the two standard 'legs' of an arbitrage trade. Typically, a price discrepancy is exploited by buying (or in other ways taking a 'long' position) in an undervalued asset, and short selling a similar overvalued counterpart.

Long positions are almost always regarded as unproblematic, but short positions have historically often been the object of suspicion. Short sellers are frequently blamed for falls in price, and the activity is seen as morally reprehensible for other reasons: for instance, in current interpretations, the securities borrowing involved in short selling is contrary to *Sharia*, creating a problem for those who wish to set up 'Islamic' hedge funds. In some markets (for example, Mexican government bonds), only specific, trusted market

participants are allowed by regulators to sell short. In other markets short selling by a wide range of participants is permitted but is constrained in other ways. Short sales of stock in the U.S. and in Japan, for example, are subject to the 'uptick rule'(see Robotti n.d.) – they are legal only after a rise in prices – which can cause substantial delays in short selling if prices are falling consistently. Not all the problems of short selling are the result of deliberate policy (other constraints include the availability of securities to borrow, the cost of such borrowing, and sometimes the vulnerability of short sellers to predatory trading by those who hope to profit by forcing them to unwind their short positions), but the resultant difficulties can be crucial. Accordingly, for example, the 'stock loan' desk (which arranges stock borrowing) occupies a pivotal position on the bank trading floor studied by the first author.

Because the extent of the problems of short selling varies from asset to asset, systematic effects of these problems can be detected. Thus Dow Jones futures and other stock-index futures seem to tend more often to be below the value implied by the level of underlying index than above it (Shalen n.d.). The trading required to exploit 'overpricing' of futures is straightforward: the arbitrageur has to establish a short position in futures (which means simply selling futures, and involves no particular difficulties), while buying the stocks that make up the index (also straightforward). Exploiting 'underpricing' of futures requires the arbitrageur to buy futures (again straightforward), but it also involves short selling the underlying stocks, which is, as noted, often more problematic.

Arbitrage can sometimes also raise more specific questions of proper conduct in markets. The most prominent recent case in which this is clear were huge trades in

Eurozone government bonds and bond futures undertaken by Citigroup Global Markets Ltd. on the morning of August 2, 2004. Like conventional arbitrage between futures and the underlying asset, Citigroup's trading intended to exploit a discrepancy, but in this case it was not a pre-existing price discrepancy but one resulting from differences in the liquidity of the bond and bond futures markets.

In the words of a Citigroup internal memo (quoted in Skorecki and Munter 2005), Citigroup's traders had noticed that 'the liquidity being offered in the bonds is far greater than that offered in the bund future': futures on *bunds*, German government bonds, are the benchmark European government bond future. In consequence, a standard 'market neutral' position of the kind often constructed by arbitrageurs (in this case, short futures and long bonds) could be unwound profitably, even in the absence of a pre-existing price discrepancy, if the position was very large. Buying futures on a large scale to unwind the short futures position would lead to losses through 'slippage' (the price of futures would rise as the purchases were being made), but the arbitrage-imposed link between futures and bond prices would then cause the latter also to rise correspondingly. At that point, the greater liquidity of the bond market meant that the long position in bonds could be unwound by selling bonds at these favourable prices, and crucially the sales would not lead to slippage: they could be completed before prices were forced down. The asymmetry in liquidity would mean that the profit from being able to sell bonds at these elevated prices, without slippage, would more than compensate for the losses caused by slippage in the futures purchases.

The bond-market liquidity on which the profitability of Citigroup's trade depended had not arisen spontaneously, but was the result of a conscious 'liquidity pact' between the banks and Continental European governments using the MTS bond-trading system (which has now expanded far beyond Italy). On most price-dissemination systems, prices are indicative: one can conclude a deal only by directly contacting the participant that has posted a price, and it is not obliged to trade at that price. On MTS, in contrast, the banks using the system have to commit themselves to trade up to a set quantity of bonds at posted prices. This exposes them to trading losses, but it makes the Eurozone government bond market more liquid and thus more attractive to investors. The *Financial Times* claims that 'banks were prepared to subsidise their MTS business' because governments often select banks at the 'top of the list in terms of MTS trading volumes' when awarding 'lucrative business such as derivatives transactions or syndicated bond sales' (van Duyn and Munter 2004).

Critical to Citigroup's trade was its materiality: it required 'hitting' all the bids (offers to buy bonds) on the MTS system nearly simultaneously, a task that was impossible manually. So Citigroup's traders developed software – which they referred to as the 'spreadsheet' – to do this. From 9.12 to 10.29 am on August 2, they made the planned bond futures purchases, and the price of these futures and of European government bonds rose as anticipated. At 10.28 am, they launched the 'spreadsheet', with the intention of selling bonds to the value of €8 to €9 billion (Financial Services Authority 2005).

Although the 'spreadsheet' had been tested in simulated trading, and had been operated on a small scale in the actual market, it had been impossible to try it out on

anything like the scale required on 2 August, so how it would operate in material reality was not known with full certainty. Some 20 seconds after launching the 'spreadsheet', the traders became concerned that it had not functioned properly, so they activated it a second time. In fact, it had worked even better than anticipated. In consequence of the second activation and of the unanticipated success of the first activation, instead of the bond sales cancelling out earlier purchases, Citigroup was left with a net short position in European government bonds of €3.8 billion. The 'spreadsheet' (designed to sell bonds) was hurriedly reconfigured to buy them, and reactivated at 11.25 am (Financial Services Authority 2005).

Although Citigroup's trading had not gone as planned, it made a profit of almost £10 million, much more than the trade was expected to yield, because after Citigroup's huge bond sales other participants in MTS sharply reduced the prices they were quoting, and the 'spreadsheet' was thus able to buy bonds back at prices significantly lower than those at which it had sold them. What is of interest, however, is the reaction to the trade. Citigroup had not traded on inside information, nor had it spread false rumours. Yet '[m]any traders on the day Citigroup did its deal thought the bank was breaking a "gentleman's agreement"' by taking advantage on such a huge scale of the 'forced liquidity' required of participants in MTS. A leading banker said that: 'By some European government treasuries, this trade was perceived as open warfare'. The sentiment was not universal – another senior banker said 'Citigroup spotted a way to make a quick buck. I guess we just have to say well done to them' (van Duyn and Munter 2004) – but Citigroup was widely condemned, and the UK Financial Services Authority (FSA) forced it to relinquish the profits from the trade and to pay a further penalty of £4 million.

The FSA did not accuse Citigroup of having broken the law, but nevertheless held that its trading had violated two of the authority's 'Principles for Business'. In particular, the FSA ruled that Citigroup Global Markets Ltd. 'did not have due regard to … the likely consequences the execution of the trading strategy could have for the efficient and orderly operation of the MTS platform' (Financial Services Authority 2005: 2). Precisely as Abolafia (1996) posits in his classic ethnography of financial markets, behaviour in such markets is in practice governed by more than the pursuit of self-interest and the constraints of the law: less explicit norms matter too.

Conclusion

In sketching a material sociology of arbitrage, we hope we have exemplified a number of characteristics of the social studies of finance. First is the emphasis on the material. Financial markets are assemblages not of abstract economic agents but of embodied human beings, artefacts, and technological systems. What circulates in them is not disembodied information, but physical representations of prices, processes, events, opinions and rumours.

Second, the actors in financial markets are not isolated human individuals. Their relations to each other – trader and manager, trader and other traders, hedge fund and investor, and so on – are enormously important, and considerable effort is devoted to cultivating those relations. All successful traders need to anticipate the behaviour of

others at the aggregate level of 'the market', and frequently they need also to understand it, to anticipate it, and even to influence it in more specific ways as well.

Third, the human actors in financial markets are not 'naked': their equipment goes beyond their bodies, consequential as the latter sometimes are. This equipment is part-technological, part-conceptual. The 14s/40s trade, for instance, was not just an idea thought up by partners A and B. It was prompted by the physical traces of prices on a computer screen, checked by constructing a material representation (the assistant's price chart), and circulated in the form of the bits encoding an Excel file. Central to it was the belief that the 40s are, and would continue to be, the benchmark Brazilian-government dollar-denominated bond, a belief that at the collective level is self-reinforcing: a particular bond is a benchmark to the extent that regulators, investors, traders and others make it a benchmark.

Fourth, actors' equipment matters. That is plainly the case for technological systems – why else would participants in financial markets spend the not-inconsiderable sums they do on acquiring and gaining access to these systems? – but true for conceptual equipment as well. An economic actor equipped with the Black-Scholes-Merton option-pricing model, for example, is different from an actor without the model. The effects of the model's adoption by participants in the U.S. options market in the mid and late 1970s can be traced in changing patterns of prices in those markets (MacKenzie 2006).

Fifth, the social studies of finance does not set out to debunk conventional financial economics. Orthodox finance theory, for example, gives an account of markets that is in many respects perfectly successful – more successful, for instance, than any systematic rival. Where the social studies of finance departs from conventional understandings, however, is in conjecturing that at least some of finance theory's success is performative (Callon 1998): that finance theory succeeds because it is *used* by traders, regulators and others.

Black-Scholes-Merton option-pricing theory, for instance, was not originally a close empirical description of patterns of option pricing. The fit between 'theory' and 'reality' improved rapidly after the theory's practical adoption. Indeed, one of the main ways in which the theory was drawn upon – an arbitrage called 'spreading' – seems to have helped move prices towards the particular patterns tested for in econometric investigations of the theory's validity. In 'spreading', the traders used material implementations of the theory (in particular, paper sheets of theoretical option prices, sold by, amongst others, Fischer Black himself) to identify relatively cheap and relatively expensive options on the same underlying asset, buying the former and selling the latter, and so reducing discrepancies between empirical price patterns and the model's postulates (MacKenzie 2006).

The issue of performativity is one of the reasons arbitrage is a pivotal topic for social studies of finance. Only very rarely does financial economics suggest that a particular asset or asset class is too cheap or too expensive in absolute terms. The relationships that finance theory posits are typically patterns of *relative* prices, and trading

that exploits discrepancies in relative prices is arbitrage, in this article's usage of the term. If financial economics is performed by traders, therefore, it will normally be when they undertake arbitrage.

The relationship between social studies of finance and the 'behavioural finance' (see, e.g., Shiller 2002) that is the most prominent challenge to orthodoxy is a subtle one. Both note that the human actors in financial markets have limited powers of calculation and memory capacity. However, while behavioural finance focuses on those limitations and on actors' judgemental biases, the social studies of finance is concerned at least equally with the way in which cognition stretches beyond the individual human being and is distributed across humans and material artefacts. Distributed cognition (Hutchins 1995a &b) of this sort, and the action such as arbitrage with which it is interwoven, may be quite different in their dynamics from the thought processes and acts of an unaided human individual.

Our argument in this paper has been that arbitrage – how it is practised, its risks, its uncertainties, its limits, and its capacities to weld markets together into a financial system – can properly be understood only if it is grasped in its full materiality and sociality. That kind of rich, qualitative understanding is of course different from the more abstract but quantitatively more precise understanding typically sought by economists, even 'behavioural finance' specialists. Nevertheless, there are areas of overlap between a 'social studies of finance' perspective and financial economists' recent investigation of the consequences of relaxing their discipline's traditional purist definition of arbitrage.

For example, Shleifer and Vishny (1997) model the risk that those who provide arbitrageurs with capital will withdraw it prematurely in the face of temporarily adverse price movements. Brav and Heaton (2002) address what we have discussed in this paper as the difficulty that arbitrageurs can have convincing themselves and their audiences that a price pattern is indeed a discrepancy that can be the object of arbitrage. In circulating the chart of the price history of the Brazil 14s and 40s, the trader we observed was seeking to solve in practice the problem modelled by Abreu and Brunnermeier: the limit to arbitrage that can arise when 'rational traders face uncertainty about when their peers will exploit a common arbitrage opportunity' (2002: 341). Attari, Mello and Ruckes (2005) model a risk that became very pertinent for LTCM after the fund's difficulties became known to others at the start of September 1998, but of which all large arbitrageurs need to be wary: that the combination of capital constraints and positions known to other traders can make arbitrageurs' actions predictable and exploitable.

Shleifer and Vishny, Brav and Heaton, Abreu and Brunnermeier, and Attari, Mello and Ruckes put forward four separate models, each capturing one of the aspects that we posit as intrinsic to arbitrage as market practice. No integrated model has yet emerged from the literature in economics on the limits of arbitrage, but our fieldwork suggests that it is in the *interaction* of arbitrage's aspects that its crucial limits may reside. Thus the crisis surrounding LTCM arose from the way in which the process of capital withdrawal modelled by Shleifer and Vishny interacted with the consequences of others imitating a single prominent arbitrageur, and LTCM's crisis was worsened (to a degree that is hard to

determine) by other traders 'arbitraging the arbitrageur' in the manner modelled by Attari, Mello and Ruckes.

We would therefore be hopeful that the study of arbitrage could be a productive area of collaboration between financial economists and those in the wider social sciences prepared to tackle financial markets in their materiality, their sociality, and their full technicality. We are in addition certain that arbitrage is a pivotal topic for social studies of finance. The powers and limits of arbitrage are critical to global financial markets. The details of arbitrage may seem to be little things, but they are little things connected to big issues: as, for instance, the materiality of Citigroup's 'spreadsheet' connects to the 'forced liquidity' of MTS and thus to government budgets, Economic and Monetary Union, and even the overall project of European unification. A price is indeed a social thing.

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