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A Sociology of Arbitrage: Market Instruments in a Trading Room

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Daniel Beunza and David Stark

I. Introduction

In this paper we develop a sociological approach to the market instruments that make up modern arbitrage. In contrast to value and momentum investing, arbitrage involves an art of association – the construction of equivalence (comparability) of properties across different assets. In place of essential or relational characteristics, the peculiar valuation that takes place in arbitrage is based on an operation that makes something the measure of something else – associating securities to each other. We examine how these associations come about by studying their material basis in the deployment of persons and things in the Wall Street trading room of a major international investment bank where we have been conducting ethnographic field research.

In the analysis that follows we argue that the cognitive work behind these market instruments involves a situated cognition. A trading room is an engine for generating equivalencies. Making associations among securities takes place *in situ*, that is, in a particular place where formulas are formed by associations among persons. Innovation – making novel and unanticipated associations – involves the organization of diversity (not fully ordered, but not random noise) among heterogeneous rationalities.

But the story we tell is not simply another example of social embeddedness (Granovetter 1985). That approach has rejuvenated economic sociology; yet social network analysis in its American application is limited by its obsessive sociologism that addresses only ties among persons (Stark 2001b). Drawing on the work of Michel Callon (ref.) and Bruno Latour (ref.), we examine socio-technical processes in which the work of making market instruments is distributed across a network of persons and artifacts. Because the social consists of humans and their non-humans (objects, things, artifacts), in place of studying "society" we must construct a science of associations – an analysis that examines not only links among persons but also among persons and things.[i] Interwoven among the mathematics are the machines.

Thus, in studying the contemporary practices of arbitrage, we examine the socio-cognitive and the socio-technical processes from which derivates are derived. In modern finance, the social meets the calculative, the cognitive meets the technical, and formulas meet judgment.

Our task is to analyze the organization of trading in the wake of a technological revolution that has taken place on Wall Street, the so-called quantitative revolution. Modern finance presents an analytically privileged setting for examining the co-evolution of organization and technology: as an industry, not only has it been an "early adopter" of the tools of information technology but also it has been a site where powerful

combinations of tools from different fields have been especially acute. With the creation of the NASDAQ in 1971,Wall Street had an electronic market long before any other industry. With the development of Bloomberg data terminals in 1980, traders in investment banks were connected to each other in an all-inclusive computer network long before other professionals. With the development of formulas for pricing derivatives such as the Black-Scholes formula in 1973, traders gained powerful mathematical tools. And with the dramatic growth in computing power and the declining costs of such, traders were able to combine these equations with powerful computational engines. This mix of formulas, data to plug into them, computers to calculate them, and electronic networks to connect them was explosive, leading to a mass shift to "quantitative finance."

To explore the socio-cognitive, socio-technical practices of arbitrage, we conducted ethnographic field research in the Wall Street trading room of a major international investment bank, following trades, observing interactions, and interviewing traders and managers throughout the room. Pseudonymous International Securities is a global bank with headquarters in Japan. It has a large office in New York, located in a financial complex in Lower Manhattan that includes the offices of Merrill Lynch and other major investment banks. If a retired trader of the bank were to visit these days the trading room of his old firm, he would find it changed beyond recognition. To appreciate the changes, consider the following description of a typical Wall Street trading room in the 1980s (Wolfe, 1987, p. 58):

> No sooner did you pass the fake fireplace that you heard an ungodly roar, like the roar of a mob... the bond trading room of Pierce & Pierce. It was a vast space, perhaps sixty by eighty feet, but with the same eight-foot ceiling bearing down on your head. It was an oppressive space with a ferocious glare, writhing silhouettes… the arms and torsos of young men… moving in an agitated manner and sweating early in the morning and shouting, which created the roar.

This boiler-room imagery is absent from the trading room of International Securities. Entering the trading room is like entering the lobby of a luxury hotel. Instead of a low ceiling, the observer finds high ceilings and a huge open space occupying almost the entire 22nd floor of a skyscraper in Lower Manhattan filled with rows of desks, computers and traders. Instead of a roar, the observer hears a hushed buzz among the traders in a background of numbers flickering in hundreds of flat-panel screens. Instead of an oppressive space, the observer finds generous corridors, elegant watercolors on the walls, and a dramatic view of Manhattan. Instead of agitated employees, the observer finds relaxed traders in business-casual wear standing up, walking around and even having coffee among themselves. Instead of a fake fireplace, the room is further populated by non-human "intelligent agents," the computer programs executing automated trades, referred to by the traders themselves as "robots."

Initially, we approached this research setting as providing an almost pure case of risk and calculation. Among these sophisticated derivatives traders, we thought, there would be a premium on information, a single metric of performance, and an emphasis on risk and

calculability. But after months of field work, we realized that as increasingly more information is almost instantaneously available to nearly every market actor, the more strategic advantage shifts from economies of information to socio-cognitive process of interpretation. This particular trading room makes profits (considerably higher than industry-average profits) not by access to better or more timely information but by producing a community of interpretation.

Similarly, the more we studied the actual dynamics, the more we became aware that, alongside the shared metric that a trader's value could be measured by the profitability of his "book," there were contending performance criteria for measuring the value of a model of the market. That is, your model (perhaps even one codified into an algorithm for automated trading) might be losing money in the short run but is, nonetheless, a valid representation capable of performing well in the long run. Although theories, models, and formulas are, indeed, performatives (representations that do not mirror social reality so much as constitute it by structuring expectations, see Callon 19xx and MacKenzie 2002), our attention here is on the performances (Hennion 19xx) and the multiple criteria and metrics of assessing their worth.

In analyzing the actual processes whereby traders construct these models, "test" them, and repair them, our attention turned to the importance of the spatial configuration of the trading room. That is, in trying to understand the modus operandi of the trading room, we came to see that its locus operandi was so important. These findings, elaborated below, are particularly salient in light of the work of Bruegger and Knorr Cetina (2002). That work is pathbreaking for the insight that the numbers on the screens of the electronic traders do not represent a market that is elsewhere; instead, the market is "appresented." Just as the eyes of traders in a commodities pit are glued to the gestures of other traders, so Bruegger and Knorr Cetina found that the eyes of their currency traders are glued to the screen – because in both cases that is where the market is. But whereas Bruegger and Knorr Cetina discovered "global microstructures" in cyberspace, we found that trading practices are intimately tied to the spatial deployment of traders and things in the room.[ii] If the "marketplace" is online, nonetheless, the work of making and using market instruments is situated in a material locale. While attentive to the screen, arbitrage traders are attentive to and interact with other traders in the room. As we shall see, the cognitive practices of creating models are situated, the interpretation or sense-making of information online occurs in situ, and even the "interactions" among robots are situated by their deployment in the room.

Arbitrage trading can be seen as an economy of information and speed. So is flying a fighter aircraft in warfare. Without the requisite information and the requisite speed neither trader nor pilot could do the job. But manuevering in the uncertain environment of markets, like manuevering in the fog of battle, requires situated awareness. As we shall see, the cognitive practices of the trading room entail pattern recognition (e.g., making associations, matching data to models); but they also involve practices of re-cognition (making unanticipated associations, breaking out of lock-in, reconceptualizing the situation). Arbitrage trade involves codification (sometimes quite literally as when a model is codified in software code) and de-codification (trading can be automated, but

knowing when to turn off the robot cannot). Expressed differently, arbitrage traders exploit knowledge, but they are continuously exploring. They engage in that most interesting kind of search – unlike the search where you call up "information" for a phone number – the search where you don't know what you're looking for but will recognize it when you find it. This process of locating occurs in a locale.

Place becomes a means of organizing diversity among heterogeneous communities of interpretation; and the trading room pulses with the tensions between risk versus uncertainty, information versus interpretation, and calculation versus judgment.

II. A sociological approach to arbitrage

Arbitrage hinges on the possibility to interpret stocks in multiple ways. By associating one security to another, the trader highlights different properties of the property he is dealing with. Hence, for example, associating the stock of Boeing with that of Microsoft, with Northrop, with Disney or with the S&P 500 index implies categorizing it respectively as (1) a technological stock; (2) an aviation stock; (3) a consumer-travel stock; or (4) an American stock. Derivatives play an important role when two firms cannot be directly compared. The point of arbitrage is finding two stocks with symmetrical exposure so that selling is a way to hedge buying the other. If the exposures of two stocks are not the same, a trader can modify them by, e.g., buying an option on the price of one of the two. Traders use derivatives such as swaps and options to slice and dice the exposure. These are like a surgeon's tools: scalpels, scissors, proteases, which give the patient (the stock) the desired resemblance.

Our interest in arbitrage lies in that it constitutes the central trading strategy used in Wall Street to move from economics of information to socio-technical processes of interpretation. According Jon Corzine, then-CEO of Goldman Sachs: "information," Corzine said, "is transparent today. No one really generates a long-term competitive edge just because they know something that someone else doesn't."[iii] Yet, despite such lack of informational advantage, the returns from arbitrage strategies are impressive. While the average return from investing in a diversified index of stocks from 1987 to 2001 is 13.6%, returns of arbitrage-based strategies at hedge funds is 18%.[iv] In the case of International Securities, in the last five years -- when it has been engaged in arbitrage -- it has attained average returns of 15-20%.

Arbitrage is defined in finance textbooks as "locking in a profit by simultaneously entering into transactions in two or more markets" (Hull, 1996, p. 4). The archetypal example of classic arbitrage is connecting two markets that are geographically separate: if the prices of gold in New York and London differ by more than the transportation costs, a trader can realize a profit by buying where gold is cheap and shipping and selling it to city where it is expensive (Ross, Westerfeld and Jaffe, 1986). Profits are "locked in" because once the arbitrageur buys and sells gold simultaneously, no change in the price of gold can affect the profits: the trader has hedged his exposure. As such, however, classic arbitrage lacks sociological as well as economic interest-- it relates markets that

are the same in every dimension except for an obvious one such as the geographical, and as a result there are very few such obvious opportunities for profit (Soros, 2000).

It is modern arbitrage that sparked our interest. Instead of "locking in" a certain profit by connecting markets for the same security, modern arbitrage connects markets that are similar along some relevant dimension-- as opposed to the same thing. The securities involved have to be similar enough as to hedge exposure, but different enough so that other traders have not seen the resemblance before or cannot adequately gauge the extent of the similarity. Unlike simpler forms of association such as brokerage, arbitrage associates across, and benefits from the information-generating power of markets.[v]

To grasp the complexity of arbitrage, consider the trading strategies that it replaced, *value* and *momentum* investing. All three of them involve the identification of an opportunity, that is, a mismatch between the purported value of a security and the value that the stock market designates to it, its price. Value investing is the traditional "buy low, sell high" approach in which investors look for opportunities by identifying companies whose "intrinsic" value differs from its market value. Investors do so by studying companies' annual reports, financial results, products and comparing the intrinsic value that emerges from those with the market price (Graham and Dodd, 1934). Value investors are essentialists; they believe that value has some essential or intrinsic property independent from other investors, and that they can attain a superior grasp of that value through careful perusal of the information about a company. They proceed with the belief that the mispricing will be eventually corrected -- that is, that the rest of investors will eventually "catch up" with the intrinsic value and drive the price towards it, producing a profit for those who saw if first.

On the other hand momentum strategies, also called chartism, turn away from focussing on the company and towards the rest of investors (Malkiel, 1973). As with value investing, the goal is to find a trading opportunity. However, investors do not pretend to know the intrinsic value of a stock. Momentum investors focus instead on whether other market actors are bidding up or down the value of a security and assume that the trend will continue for some time, i.e., that there is "momentum," a self-sustaining social process amenable to be discovered by the study of patterns in the time series of the stock -- its chart. Momentum investors are relational. Like fashion victims or night-life socialites, they derive their strength from obsessively asking themselves, "what is everyone else doing?" in terms of choice of stocks, clothes, or cocktail bars -- and finding an better answer than most. They believe that opinions about value do not diffuse among investors instantly but slowly instead, producing an inertia that creates the visual patterns they look for in the charts. In contrast with value investing, a momentum strategy can involve buying when the price is extremely high, as long as the patters in the chart suggest that it is getting higher.

As with value and momentum investors, the arbitrageur also needs to find an opportunity -- an instance of disagreement with the market valuation of a stock. This opportunity is found by association. Instead of claiming superior abilities to process and aggregate information (as value investors do) or better knowledge of what other investors are doing

(as momentum traders do), the arbitrageur seeks some other security -- another stock, or group of stocks, or bond that is somehow related to it, and values one in terms of the other by establishing a value equivalency between the two.

Thus, whereas value trading is essentialist and momentum trading is relational, arbitrage is associational. Like a striking literary metaphor, a new arbitrage trade reaches out and associates the value of a stock to some other, previously unidentified security, or one that is tenuously related to it.

Modern arbitrage differs from classic arbitrage in that the equivalencies are new or uncertain. This reduces the scope of competing arbitrageurs, increasing the profitability. To see an uncertain equivalency at work, consider now an example of the most common case of modern arbitrage, so-called merger arbitrage. On August 13th 2001, Cendant Corporation and Cheap Tickets Inc. announced an agreement for Cendant to acquire all of the stock of Cheap Tickets, making them worth $17 per share if the deal went through. As the announcement came out, the price of Cheap Tickets shares jumped from $12.00 to $16.50. The merger offered traders an opportunity for arbitrage: if the merger was finalized, the traders would be able to obtain $17 for stocks that cost them only $16.50, realizing a profit of $0.50 per share. The purchase price that Cedant was willing to pay for Cheap Tickets became an alternative valuation mechanism. The merger created a possibility to establish equivalencies -- in this case, between the value of Cheap Tickets with and without merger with Cedant. Other types of arbitrage use other equivalencies. Convertible bond arbitrage, for example, is based on legal “convertibility provisions” of the stocks that stipulate the transformation of stocks into bonds at a fixed, non-market rate. In index arbitrage, the value equivalency is based on the premise that a stock will move in lock step with the rest of companies belonging to the index.

The tenuous or uncertain strength of the equivalency reduces the number of traders that can play a trade increasing its profitability. In the case of arbitrage, assessing the strength of the association amounts to finding out the probabilities of the merger taking place. In the example above, arbitrageurs had to take the acquisition price of Cheap Tickets and discount it to reflect the possibility that the merger might not take place at all. If it did not, the price of Cheap Tickets would presumably fall back to the original pre-merger price of $12.00, losing the arbitrageurs a ruinous $4.50 per share. Those traders that do not have competencies in assessing the likelihood of a merger taking place refrain from entering into the trade, or end up being selected out of the market anyway by force of their losses. Conversely, traders at International Securities possess a stock of historical information on various mergers, and are able to use data about the identity of the lead bankers, the degree of anti-trust risk, legal risk, or material adversity clauses risk to assess and refine the probability of the merger taking place.

Financial instruments such as options, swaps and futures play a crucial, surgical role in arbitrage. Arbitrage presents a challenge of dissociation similar to the requisites for constructing a neoclassical market identified by Callon (1998). Callon (1998) argues that creating a logic of abstract, anonymous calculability in markets requires “formatting” a framing process that extricates commodities from the social relationships that produced

them. But, he adds, this always finds the problem of overflow. Thus, while car companies attempt to circumscribe their relationship with car buyers to the moment of exchange, the car transfers with it to the buyer the company's know-how (who can cash it in by reverse engineering), potential tort liabilities, etc.

Arbitrageurs need to engage in this process of dissociation because they do not commit capital to a company but to a property of a company such as the merger it takes part on. In the Cedant-Cheap Tickets example above, arbitrageurs who buy Cheap Tickets to bet on the merger will be exposed not only to the possibility that the merger might be cancelled, but also to other changes in the price of Cheap Tickets stemming from its other properties such as, e.g., changes in the price of small capitalization stocks, of American companies, or of travel companies.

Arbitrageurs reject exposure to a whole company: they associate markets by disassociating the companies they long and short from those properties not involved in the equivalency principle. To eliminate from their exposure all the non-merger properties of Cheap Tickets, arbitrageurs "sell short" the acquirer, Cedant Corporation -- that is, they bet that its price will fall. This second leg of the trade is the hedge. Traders hedge by adopting opposite exposures between acquirer and target. They simultaneously bet that the economy will improve and that it will worsen, that low-capitalization companies will rise in value and will fall, or that air travel will be more profitable and also less profitable. Whatever happens in all these respects, the gains from one leg of the trade will offset the losses from the other, leaving traders "market-neutral," "industry-neutral," and neutral with respect to all the properties of the stocks but one -- the merger.

In the example above, hedging seems like a relatively trivial task. But hedging is a centerpiece of what arbitrage is also about: associating markets by isolating the stocks from all properties that are not the equivalency principle. Consider a more complex -- and more lucrative -- operation that the trade presented above. Imagine two firms have announced their intention to merge, but the acquirer belongs to an index, say the Dow Jones biotech index, while the target does not. As a consequence, the stock price of the acquirer stock moves up and down with wide movements of the DJ biotech index. This would not necessarily be a bad thing for the arbitrageurs, who, as we know, bet on the merger by simultaneously shorting the acquirer and longing the target. DJ biotech membership could benefit their short position on the acquirer if that index fell. But the biotech index could also rise and in any case, that is not the point; the point is that arbitrageurs tailor their exposure to what matters to them -- in this case, their bet that the merger will take place. To avoid exposure to those properties of the stock that are not the deal, traders hedge their exposure to them.

Arbitrageurs slice and dice their exposure with the help of derivatives such as options, futures or swaps, or other financial instruments such as indexes. In the simple example of Cedant and Cheap Tickets, the close similarity between the two merging stocks -- both were American, low-capitalization, airline stocks -- made hedging almost trivial. In the second case, for example, they offset their exposure to the DJ biotech index by engineering a separate long exposure to the index.

Arbitrage, then, is not about reducing or eliminating the trader's exposure -- it is not a trading strategy for cowards. Rather, arbitrage is about tailoring the traders' exposure to their position vis-à-vis the market, biting what they can chew, betting on what they know best and avoiding risking their money on what they don't. Traders expose themselves profusely, but precisely because their exposure is custom-tailored to the relevant deal. Their sharp focus and specialized instruments gives them a clearer picture on the deals they examine than the rest of the market. Thus, the more the traders hedge, the more solidly they can position themselves.

This points out to the irony of arbitrage. Arbitrage entails establishing multiple associations using several instruments and drawing from various formulas... but in the end it can boil down to a bet on a single event. Such events either happen or not such as, will these two companies merge or not? Their simplicity is increased because they carry with them a date in time that will resolve the uncertainties. We normally think of events as something different from companies, but arbitrageurs manage to equate the two by stripping the companies' stocks of all properties that are not the event itself. For all their sophisticated use of derivatives, arbitrageurs can end up engaging in bets about the outcome of a discrete event. Given the associational task of the arbitrageur it should be clear how existing network theory is not sufficient to account for it fully. Network theory is ideally suited for the study of ties between people and the identification of structural holes (Burt, 1992). But, as noted above, arbitrage requires financial instruments to slice and dice exposure, formulas, a degree in finance, and monitors, computers, robots, cables and other material tools to find new associations and execute them. A depiction of who talks to whom would miss the crucial information of what talks to what.

This last point is underscored by a comparison of market making and arbitrage. Market making, the process of matching buyers and sellers of securities, can be thought of a particular case of brokerage -- that is, the identification and exploitation of structural holes in a network of social ties (Burt, 1993). Before electronic markets, market-making was responsible for the cacophony of traditional Wall Street trading rooms as salesmen and traders matched deals internally in frenetic speed by shouting to each other. With the arrival of electronic markets, as Bruegger and Knorr Cetina (1999, p. 4) documented, the rooms became much more silent and the action moved to the screens. But both rooms and screens are doing the same function -- supporting conversations between people.

Arbitrageurs do not make markets -- they link markets. In doing so, they use prices and the wealth of information contained in them (Hayek, 1944) to profit from mispricings. This clever use of prices can be observed in the Cedant-Cheap Tickets. Merger arbitrageurs take the stock price of both companies, calculate the difference between them to come up with the "spread" between the value of the two securities being linked. Then they read the spread backward to gauge the probability that other market actors assign to the deal. For example, a price difference of $ 0.50 means total gain of $0.50. If the possible loss if $4.50 ($16.50 minus $12.00), this means that a in order to break even the probability of the merger would have to be at least 90%. To decide whether to play the deal, arbitrageurs then only need to determine whether they are more or less confident

than 90% that the merger will go through. This spread changes every day, and arbitrageurs follow its ups and downs to better determine what their positioning should be. By reading probabilities back from spreads, the arbitrageurs tap into the collective knowledge that two markets have aggregated (the markets for Cheap Tickets and Cedant) and use it in their favor. Arbitrageurs make value investors work for them.

How are these unprecedented and uncertain associations accomplished? What resources, organization, technology, would a bank need to establish them? Brokerage, filling structural holes, is about maintaining and expanding a social network of buyers and sellers. Modern arbitrage is also about networks, but networks that include not just people but also ideas, artifacts, material objects and securities -- all of them thrown in for generative recombination. In the next section we turn to a trading rooms to examine how it works in practice.

III. The trading room as an ecology of evaluative principles

To examine the organization of arbitrage we conducted field research in the trading room of pseudonymous International Securities, a global investment bank with offices on Wall Street. Over the past two years, we have been regularly observing interactions in the trading room, interviewing traders and managers on several desks, taking bus rides with clerical workers, and sharing lunch at the trading desk with traders.

Our traders face a conundrum presented to Wall Street by the quantitative revolution: the more pervasive and immediate information becomes, the more ideas diffuse as traders become connected; and the more technology facilitates the execution of derivatives trading, the lower the profits. Bruegger and Knorr Cetina (1999) have argued that the rise of electronic markets has brought the marketplace to the trader's screen, prompting the traders to shift from a "face-to-face" to "face-to-screen/ world," and bringing about a "diminishing relevance of the physical setting" (p. 23). Following a detailed examination of a market-making trading room of currency traders, the authors noted how the most relevant interaction takes place by means of email-like electronic conversations across trading rooms spanning organizations, continents, and time-zones. Participants, although physically located in the trading room "appear viscerally plugged into the screen reality of the global sphere" (p. 15).

Heath et al.'s (1995) account of traditional trading rooms (i.e., pre-electronic markets), by contrast, argues that co-location makes optimal use of traders' limited attention and bounded rationality at the local and global level. At the local level, grouping traders by desk lets them collaborate with each other with minimal intrusion into each other's activity. For example, the authors document how co-location allowed a trader to "time, with precision, an utterance which engenders collaboration, so that it coincides with a colleague… swallowing a mouthful of lunch" (1995, p. 6). At the global level of the room, the authors noted that clustering different desks together allows traders to monitor markets beyond the one in which they are trading. This is facilitated by the institutionalized practice of the "outcry," the habit of "when necessary, shouting names

and calling numbers without either waiting for, or apparently, expecting a reply" (1995, p. 10). These are, according to Heath et al., an economical way to reach everyone in the trading room, and to deliver information in an un-intrusive manner as the recipient is not asked to respond. However, because Heath et al remain within the economics of information (for them, the point of a trading room is to reduce the costs of transmitting information), their account would fail to explain the persistence of trading rooms in the age of electronic markets with its conditions of more comprehensive, nearly frictionless exchange of information.

We approach the tension between electronic markets and physical rooms as a particular case of what can perhaps be referred as the "Castells axiom." How, Castells (2000) asks, has the role of space changed in a network society structured by the Internet and information technology? Castells distinguishes between spaces of place, that is, locales "whose form, function and meaning are self-contained within the boundaries of physical contiguity," and spaces of flow, which he defines as "the organization of purposeful, repetitive, programmable sequences of exchange between physically disjointed positions." Contrast, for example, a street and an airport. According to Castells, as information technology creates spaces for repetitive, preprogrammed, machine-like interactions (spaces of flows), the original, spontaneous, unexpected interactions found in physical spaces (spaces of place) can provide an ever-increasing source of competitive advantage. Thus, for example, as the technology for remote surgery develops and surgeons gain the possibility to intervene from a remote location, they are clustering more and more in two or three neighborhoods of Manhattan. From the perspective of arbitrage as association, trading rooms can be seen as the "space of place" where novel associations emerge.

One exemplary passage from our fieldnotes finds Bob, the manager of the trading room, restating the Castells' paradox:

> It is hard to say what percentage of time people spend on the phone vs. talking to others on the room. But I can tell you the more electronic the market goes, the more time people spend communicating with others inside the room.

The response of International Securities to the challenge posed by information abundance has been to step up the level of complexity of its arbitrage trades. To be sure, traders must have access to the most timely and complete array of information; but this is not enough. In addition to being a nexus of data flows the trading room also constitutes a community of interpretation. In this section, we examine the room first as a kind of "primate society" of 160 traders and anciliary personnel, exploring some features of their interaction; second, we examine how these traders are grouped into desks, exploring the specialized functions by which each recognizes patterns through distinctive financial instruments; next, we examine the trading room as an ensemble of desks, exploring how this ecology of evaluative principles facilitates practices of re-cognition; and finally, we examine the room as an assemblage of material tools, exploring how the socio-cognitive and the socio-technical are intertwined.

Facilitating sociability

The architecture of the trading room at International Securities is designed to create an atmosphere conducive to association. Consider, for example, Gladwell's description of the layout and distribution of "a classic big-city office tower,"

> The center part of every floor is given over to the guts of the building: elevators, bathrooms, electrical and plumbing systems. Around the core are cubicles and interior offices, for support staff and lower management. And around the edges of the floor, against the windows, are rows of offices for senior staff… The executive in one corner office will seldom bump into any other executive in a corner office. Indeed, stringing the exterior offices out along the windows guarantees that there will be very few people within the critical sixty-foot radius of those offices (Gladwell, 2000, p. 64).

The contrast between the classic corporate offices and International Securities is striking. Turn right from the reception area on the 22nd floor of the skyscraper where the bank is located, and the trading room opens up in all its magnificence: almost an entire floor filled with multi-colored Bloomberg screens, moving images in the CNBC monitors and relaxed traders clad in elegant business casual wear. No cubicles. No partitions to block the view. There is even a strict "low-monitor" policy enforced by Bob, the manager of the room, since, as he notes, "people are insecure on the floor and build themselves a nest," that is, they stack their Bloomberg monitors two- or three-high, to produce a sense of privacy. Bob prevents that. "We try," he says, " to keep the PCs at a low level so that they can see the rest of the room."

Moreover, the composition of the room promotes association among disparate communities of practice: the room not only accommodates traders and their assistants, but also salesmen, analysts, operation officers, and computer programmers. Flouting an industry-wide trend of relegating these latter employees to a back-office, International Securities has kept programmers and operations officers in its money-making core. They not only stay in the trading room but are given desks as large as the traders', and their area of the room has the same privileged feel as the rest. The objective, Bob states, is to prevent differences in professional status from undermining communication among these groups. If placed in a different building, says Bob, "they might as well be in a different planet."

The size of the trading room is designed to maximize communication. At 160 people, it has a small size by current Wall Street standards. But its dimension was purposely chosen by Bob to create a space where communication could be facilitated. Bob says, "managers, they'll tell you, 'communication, communication,' but you wonder." For example, he pointed us to a trading room of another international bank located in Connecticut:

> It is the size of three aircraft carriers. And the reason for it is that it is a source of pride to the manager. It is difficult to see how can traders communicate shouting at each other across two aircraft carriers. At [name of bank], what you'll find is chaos that looks grand.

Instead, at the trading room of International Securities,

> The key is [to avoid] social awkwardness. Two traders are talking to each other. A third needs a piece of information. He has to interrupt. 'Can I interrupt? Can I interrupt?' The key there is the social cost of the interruption [emphasis by Bob].

Promoting sociability among traders is not an easy task. In the age of mathematical finance, arbitrageurs, unlike Tom Wolfe's image of traders as Master of the Universe, are all very qualified, very competitive, and fiercely individualistic. They are intellectually over-confident, but socially inept:

> A trader is like an engineer type. Difficult when they think they're right. Abrasive. And not very social. Not socially adept. I can easily find you ten traders in the room who would be miserable at a cocktail party.

This results in territoriality in the trading room. For example, back in the early 80s, Bob recalls, in the bank where he began his career,

> There were areas of the trading floor I would never venture onto in years. People I never, absolutely never, talked to. There was no reason why I should go there, since we traded completely different things. Being there felt strange. There were these cold looks.

International Securities has avoided this territoriality in the trading room by moving traders around. "I rotate people as much as I can." Bob says, "because sitting near each other is the best rule of thumb to predict that they will talk to each other." However, Bob is careful not to displace them excessively. He describes his approach as "not really shifting, more like drifting," as with those puzzles that have only one hole and in which only one piece can be moved at a time.

> Once two traders have been sitting together, even if they don't like each other they'll cooperate, like roommates. Everyone gets moved every six months on average. But not everyone at a time.

This emphasis on communication underscores that the cognitive tasks of the arbitrage trader are not those of some isolated contemplative, pondering mathematical equations and connected only to a screen-world. Cognition at International Securities is a distributed cognition. The formulas of new trading patterns are formulated in association with other traders. Truly innovative ideas, as one senior trader observed, are slowly developed through successions of discreet one-to-one conversations within the desks,

> First you talk to others. You tell someone else, 'I've got this great idea,' and if he tells you 'I read it yesterday in Barron's,' you say, 'Oh, I did too.'

An idea is given form by trying it out, testing it on others, talking about it with the "math guys," who, significantly are not kept apart (as in some other trading rooms), and discussing its technical intricacies with the programmers (also immediately present). Because they have been stirred up by the subtle churning of the room, they can test the ideas on those with whom they were once "like roommates" but who might now be sitting in different parts of the room. Appropriately, the end of this process of formulation (and the beginning of the next stage of material instrumentation, see below) is known as a "victory lap" – a movement around the room in and through which the idea was generated.

And where is Bob, the trading room manager? He sits in the middle of the room despite the fact that he has a very well-appointed office in one corner, complete with designer furniture, a small conference table and a home cinema-sized Bloomberg screen to watch the markets that can be controlled from a wireless mouse and keyboard. But he prefers to sit in a regular trader's desk in the middle of the room.

> I have that office over there – you just saw it. But I like this place better [referring to his desk]. Here, I am more connected. No one would come to tell me stories if they had to come into my office. Also, here I get a feel for how the market is doing. I have to know this, because the atmosphere definitely influences the way these guys trade.

"The phone and on-line communication are inefficient," said Bob. "It takes longer for people to tell each other what they want. Also, you miss body language." As he emphasizes,

> Body language and facial expressions are really important. You're not conscious of body language and so it's another channel of communication, and it's one that's not deliberate. So it's a good source for what's happening. I don't try to get too conscious of how I'm reading body language and facial expressions. I just let it work its way to where its useful.

Bob's observations (and those of many other traders with whom we spoke) highlight that cognition in the trading room is not simply distributed. It is also a <u>situated cognition</u>. A trader needs tools – the financial instruments of derivatives and the material instruments to execute a trade. But in addition to these calculative instruments, the trader also needs a "sense of the market." Knowing how to use the tools combines with knowing how to read the situation. This situated awareness is provided, in large part, by the room. As the passage quoted above about deliberately not being too conscious of how one reads body

language nicely illustrates (points emphasized in different terms by other traders), the activities of the trading room involve pre-calculative components.

Pattern Recognition at the Desk

We now move from the individuals that compose the trading room as a "baboon society" to the teams that compose the trading room as a more complex organization of diversity. This organization of diversity begins by demarcating specialized functions. The basic organizational unit, "team," has a specific equipment, "desk." The term "desk" not only denotes the actual piece of furniture where traders sit, but also the actual team of traders – as in "Tim from the equity loan desk." Such identification of the animate with the inanimate is due to the fact that a team is never scattered across different desks. In this localization, the different traders in the room are divided into teams according to the financial instrument they use to create equivalencies in arbitrage: the merger arbitrage team, options arbitrage team, futures arbitrage team, convertible bond arbitrage team, etc. (see fig. 1 below). The desk is an intensely social place. The extreme proximity of the work setting enables traders to talk to each other without lifting their eyes from the screen or interrupting their work. Lunch is at the desk, even if the sandwich comes from a high-end specialty deli. Jokes are at the desk, a never-ending undercurrent of camaraderie that resurfaces as soon as the market gives a respite.

Each desk has developed its own way to look at the market, based on the principle of equivalence that it to uses to calculate value and the financial instrument that it enacts in its particular style of arbitrage trade. For example, traders at the merger arbitrage desk value companies that are being acquired in terms of the price of the acquiring firm and specialize in asking themselves, "how solid is company X's commitment to merge?" Analytical and calculating, for them the companies in the S&P 500 index are little more than a set of potential acquirers and acquisition targets. In contrast, traders at the convertible bond arbitrage desk look at stocks as bonds, and specialize in information about stocks that would typically interest bondholders such as their liquidity and likelihood of default. Traders at the index arbitrage desk value market indexes according to the weighted average of the prices of the companies that constitute them, and specialize in executing high-volume high-speed trades that exchange indexes for their baskets and in finding companies that upset the accuracy of indexes when they split into two or disappear. The traders at the customer sales desk, meanwhile, take and propose orders to customers outside the confines of the room. Although not specialized in a distinct financial instrument, this most sociable bunch in the room provide a window on the anxiety level of their customers and thus of the market at large by the sound of their voices on the phone and the bangs of the headsets against the desks in frustration.

Each of these desks organizes a specific form of pattern recognition. For example, merger arbitrage traders, keen on finding out the degree of commitment of two merging companies, look for patterns of progressive approximation in stock prices. As noted in the previous section, they probe into commitment to a merger by plotting the "spread" (difference in price) between acquiring and target company over time. As with marriages between humans, mergers between companies are scattered with regular rituals of

engagement intended to persuade others of the seriousness of their intent. As time passes, arbitrage traders look for a pattern gradual decay in the spread as corporate bride and groom come together.

Such joint focus on visual and economic patterns creates, at each desk, a distinctive community of practice within a principle of equivalence with its own tacit knowledge and its own denunciations of the others. Traders on a desk develop a common sense of purpose, a real need to know what each other knows, a highly specialized language, and idiosyncratic ways of signaling to each other. This sense of joint membership translates into denunciations of others. A senior arbitrage trader, for example, confided in us that, to him, statistical arbitrage is "like playing video games. If you figure out what the other guy's program is you can destroy him. That's why we don't program trades," he added, referring to his own desk. Tod, one of the statistical arbitrage traders, told us that the more he looked at his data (as opposed to letting his robot trade), the more biased he becomes.

These functional teams are thus markedly different from the cross-functional teams that make up "projects" in fields such as film, new media, construction, etc., where heterogeneous evaluative principles combine in a single team (Girard and Stark, 2001). Within a new media team, different members may find the value of a web site in metrics as varied as its speed, ease of use, profit-making abilities, or beauty and elegance. Within an arbitrage desk, in contrast, all traders find value along the same equivalency principal. Nonetheless, the complex trades that are characteristic of our trading room seldom involve a single desk/team in isolation from others.

Connecting for cutting, co-location for disassociating

The desk, in our view, is a unit organized around a dominant evaluative principle and its arrayed financial instruments (devices for measuring, testing, probing, cutting). This principle is its coin; if you like, its specie. But the trading room is composed of multiple species. It is an ecology of evaluative principles. Complex trades take advantage of the interaction among these species. To be able to commit to what counts, to be true to your principle of evaluation, each desk must take into account the principles and tools of other desks. Recall that shaping a trade involves disassociating some properties in order to give salience to the ones to which your desk is attached. Recall also that cutting and slicing (dis-associating) requires making associations (identifying the relevant categories along which exposure will be limited). It follows that shaping a trade involves associations among desks. Co-location, the proximity of desks, facilitates the connections to do the cutting.

While in most textbook examples of arbitrage the equivalence-creating property is easy to isolate, in practice this isolation is difficult to accomplish completely. For example, merger arbitrage traders lend and borrow stock as if they were going to be able to reverse the operation at any moment of time. However, "if the company is small and not traded often, it may be difficult to borrow," and traders may find themselves unable to hedge, notes Carl. Similarly, some companies have "A-" and "K-class" stocks, depending on the

voting rights they carry. “Arbs hedge with the As, because they are easier to borrow,” according to Carl, “but actually get the Ks,” creating the subsequent challenge to get transform the K into A stocks. In other cases, “one of the parties may have a convert provision [that is, its bonds can be converted into stocks if there is a merger] to protect the bondholder. Then, the question is how does that affect the deal.” Finally, traders will occasionally resort to financial engineering to create synthetic arbitrage products. As a result traders end up exposed to properties of the companies different from that which constitute the equivalency.

In the case of arbitrage – linking, as opposed to creating markets – traders face a similar problem. Hedging their exposure to overall market movements may leave them with exposure to something else through convertibility provisions. Interestingly, traders reintroduce the overflow exposure in their calculations in the same way as they achieve association: through co-location. Physical proximity in the room allows traders to survey the financial instruments around them and assess what additional variables they should take into account in their calculations. The stock loan desk, according to Carl, “help[s] us by telling us how difficult it is to borrow a certain stock.” The index arbitrage desk helps with regard to A and K stocks; since it profits from the fact that A stocks are included in indexes while K stocks are not -- and therefore sometimes the two classes of stocks move out of lockstep. The convertible bond arbitrage desk helps merger arbitrage traders clarify the ways in which a convertibility provision can affect the deal. “The market in converts is not organized,” says Carl. There is no single screen representation of the prices of the converts. For this reason, says Carl,

> So we don’t know how the prices are fluctuating, but it would be useful to know it because the price movements in converts impacts mergers. Being near the converts desk gives us useful information.

In any case, according to Carl, “even if you don’t learn anything, you learn there’s nothing major to know about.” It’s important because, as he says, “what matters is having a degree of confidence.” Or, as one senior trader puts it, a hedge entails multiple components, and as time passes “the component pieces of the hedge are moving.”

In the previous section we noted that the teams/desks of a trading room are very different from the teams that make up “projects” in other industries. But if a given desk is organized around a relatively homogeneous principle of evaluation, a given trade is not. Because it involves hedging exposure across different properties along different principles of evaluation, any given trade can involve heterogeneous principles and heterogeneous actors across desks. If a desk involves simple teamwork, a (complex) trade involves something more like collaboration. This collaboration might be as primitive as an un-directed expletive from the stock loan desk which, overheard, is read as a signal by the merger arbitrage desk that there might be problems with a given deal. Or it can be as formalized as a meeting (extraordinarily rare at International Securities) that brings together actors from the different desks. And much in between. A trade is a project.

Re-cognition in an ecology of equivalences

By putting close the teams that trade in the different financial instruments involved in a deal, the bank is able to associate different markets into a single trade. As a senior trader observed,

> While the routine work is done within teams, most of the value we add comes from the exchange of information between teams. This is necessary in events that are unique and non-routine, transactions that cross markets, and when information is time-sensitive.

How to use the creativity, vitality and serendipity stemming from the trading room to make new interpretations? By interpretation we mean processes of categorization, as when traders answer the question, "what is this a case of?" but also processes of re-categorization such as making a case for. Both work by association -- of people to people, but also of people to things, things to things, things to ideas, etc.

The following instance illustrates a case of re-cognition across two desks, the customer trading and the special situations desk. Jay L., senior trader at the customer trading desk, takes orders from clients and suggests new trades to them. Across the table sits Josh P., head of the special situations desk, close enough to overhear Jay's conversations with his clients at any given point in time. On one occasion, a client phoned Jay L. with an order to buy company X, sell company Y and short Z. Jay recollects:

> I looked at it and it didn't make any sense. Why does he do that? I talked to Josh [gestures over there at the nearby desk]. 'That guy's crazy,' Josh said. That was the tipoff.

This fleeting exchange was the tipoff that set Jay to work on the customer's trade to find an opportunity for a genuinely good trade. Following a quick give-and-take between the two of them about what was wrong and what was right with the trade, Jay says,

> We structured what we thought was a better trade. Then I phoned my client. 'This is the trade you should be doing. And this is why.' I operate in this way. And he might say, 'You're an idiot, that's never going to happen.' Then I'll say, 'Great. Do you want to take the other side?'"

In doing so, Jay and Josh use the client's trades as the starting point for their own brainstorming. It is also a useful way for the traders to put fresh thinking into their strategies – even if it's wrong.

Re-cognition can be more dramatic as in the following example in which the proximity of desks lead to a new kind of trade, a hybrid that resulted from recombination across equivalences. The case involved an announced merger between two financial firms. On January 25th, 2001, Investors Group announced its intention to acquire MacKenzie

Financial. The announcement of the merger immediately set off a rush of deals from merger arbitrage desks in trading rooms all over Wall Street. Close contact with the merger arbitrage desk and the equity loan desk allowed the special situations desk at International Securities to conceive a new arbitrage trade, which they called "election trade," that recombines in an innovative way two previously existing strategies, merger arbitrage and equity loan strategies.

The facts of the merger were as follows: following established practice, the acquiring company, Investors Group offered the stockholders of the target company to buy their shares and offered them an alternative of cash or stock in Investors Group. The offer favored the cash option. Despite this, Josh and his traders reasoned that a few investors would never be able to take the cash. For example, board members and upper management of the target company are paid stocks in order to have an incentive, so it would look wrong if they sold them -- they had "symbolic" or "hierarchical" rationalities, as opposed to a purely financial profit-maximizing approach.

The presence of such symbolic investors in effect created two markets of sorts -- one made up of profit maximizers, and one made up of captive investors in MacKenzie. As with any other situation of disconnected markets with diverging local valuations, this could open up an opportunity for arbitrage. But, how to connect them? The genesis of the idea lied precisely in co-location in the room. The "special situations" desk (its name denotes a purposive attempt to cut through the existing categories of financial instruments in the room) is located in between stock loan and merger arbitrage. Stock loan makes its margin by a lending and borrowing operation. Just as the merger arbitrage desk uses mergers to create equivalencies, the possibility to lend and borrow stocks for election day became the equivalency principle that tied together two disparate options, cash and stock, faced by investors in MacKenzie. According to Josh P., head of the desk,

> [The idea was generated by] looking at the existing business out there and looking at them [the trades] in a new way. Are there different ways of looking at merger arb?

The traders used physical proximity to the other desks and the strong acquaintance that it creates to envision opportunities for arbitrage:

> We imagined ourselves sitting in the stock loan desk, and then in the merger arbitrage desk. We asked, is there a way to arbitrage the two choices, to put one choice in terms of another?

The traders found one. What if International Securities were to borrow from "symbolic investors" their shares in the target company at the market price, exchange them on election in the more favorable terms (i.e., taking the cash instead), then return the stock to symbolic investors? That way these investors would be able to bridge the divide that separated them from the most favorable option on election day. The special situations desk was linking these investors to the cash by engineering a financial bridge between the two, not unlike the classic operation of shipping gold from London to New York.

Physical proximity and social similarity helped further in assessing the risk-rewards of the trade. As with merger arbitrage, the possibilities for a new equivalency imagined by Josh and his traders were not cast in stone, but tenuous and uncertain (and that was what made them so profitable -- the fact that no one had done them before). Depending on how many investors chose cash over stocks, International Securities might find itself with large losses. The reason was as follows: IG, the acquiring company, intended to devote a limited amount of cash to the operation; if, as planned, on election day most investors elected cash, the acquiring company would prorate its available cash (i.e., distribute it equally) and use some of its shares to pay even those stockholders that elected "cash." This was the preferred scenario for International Securities, for then it could use these shares to return the stock it owed to those symbolic investors it borrowed from. But if, in an alternative scenario, most investors were to opt for stock, then the acquirer would not run out of cash on election day, investors who elected cash such as International Securities would not get stocks back, and Josh and his traders would find themselves without stock in IG to return that which they had borrowed. They would then be forced to buy the stock of IG on the market, perhaps at prices high enough to turn the profits from the deal into losses.

The profitability of the trade, then, hinged on a question: would investors elect cash over stock? Uncertainty about what investors would do on election day posed a problem for the traders. Finding out about their plans, note, is not a trivial challenge in a capitalistic economy that is based on the notion of dispersed stock ownership across various people in different places and approaches to investment. The traders overcame this infinite-search problem with the help of co-location and technology. As a first step, Josh pulled up a list with the names of the twenty majority holders in the target company in the screen of their Bloomberg terminal. Then he went down the list with his team. According to his own account,

> What we did is, we [would] meet together and try to determine what they're going to do. Are they rational, in the sense that they maximize the money the get?

But knowing the identity of the owner of stock was only half of the equation. What would this company or that individual do? Josh and his crowd resorted to social similarity.

> See... the major owner is Fidelity, with 13%. They will take cash, since they have a fiduciary obligation to maximize the returns to their shareholders. [Some others are] hedge funds doing merger arbitrage... so I shouted across the question to the merger arbitrage team here at International Securities... who were doing the same and work right across me.

To summarize, co-location helped develop an opportunity for arbitrage that took advantage of the existence of multiple rationalities among investors. Traders were then

able to gauge the prevailing rationality in the market from their close knowledge of the rationality of one of the desks. This process of going from the local to the global the trading room was transformed into a tool for probing the uncertainties left in electronic markets.

IV. The trading room as an assemblage of market instruments

To this point, we have emphasized the role of abstract market instruments. But there is another, equally important set of instruments that includes cables, phone lines, computers, modems, electrical power, algorithms, TVs and buildings -- the material tools of trading. The formers are considered worthy of study in The Journal of Finance, while the latter supposedly belong to the province of handymen, contractors or electricians. But overlooking this last group would mean missing another important way in which the room makes up for more than the sum of the parts. We refer to both financial instruments and the material tools as market instruments. Paradoxically, while the former have a reputation for being more interesting, we would argue that the latter are the least understood of the two. While derivatives have a clear purposive nature, the tangible tools have a diffuse, complex use, and their effect on socio-technical networks is multifaceted.

We know from the previous section that traders use financial instruments to associate and dissociate and reshape the trader's exposure from a stock into the desired form. Similarly, material market instruments associate data, models and ideas. Instruments, according to Latour (1986), are actively inscribed to translate other people's interests into those of the instrument designer. The key weight that is customarily found in traditional hotels is inscribed to persuade the guests to leave their keys in reception as they go on the street. In the context of science, Latour (1987) defines an instrument as an inscription device that shapes the reader's view, that is "any setup that provides a visual display of any sort," as long as it "is used as the final layer in a scientific text." Examples of instruments include radio telescopes, Geiger counters, or petri dishes.

Perhaps the most visible of all instrument are the Bloomberg terminals that traders use, three extra-wide high-contrast flat panel screens that make a manifest difference between a trading room now and twenty years ago. The screens are not mere transporters of data. They are heavily inscribed. They select, modify and present data in ways that shape what the trader sees. As we show below, some of the data is arranged to be a "magnifying glass," other data constitutes trading "baskets," and yet other data is tied among itself in the form of "active links."

Steve P. at the customer trading desk devotes a lot of care to the conscious inscription of his screens. He arrives to the trading room at 8:30, but the markets do not open until 9:30. An important part of the preparation for the day is preparing the screen set-up. One by one, Steve opens each of his windows and places it in its customary place. Steve's screens are divided into several areas that reflect the many types of data he faces. On the extreme left, a series of windows give him general information on the market: a Bloomberg window, charts for the Dow Industrials and NASDAQ. The indexes provide a general view. A more personalized perspective is provided by another window further

to the right, that Steve calls his "magnifying glass." These are 60 additional stocks that he considers representative of what happens in different sectors such as chips, oil, or broadband. They give more information than just the general direction of the market indexes. Visually, the numbers of this window momentarily increase in size when an order is received, resembling a pulsating meter of live market activity.

Steve complements the magnifying glass with the "footprints" of competitors. These carry information about the stocks that he is trading each day, contained in about six individual windows that vary in appearance depending on whether the stock trades in the NYSE or the NASDAQ. In addition to magnifying sectors and tracing his rivals' footprints, Steve's screens double as workbench for his operations. These are displayed on several windows that show the trades that Steve undertakes, called "trading baskets." An additional workbench window shows pending work. This is contained in a spreadsheet in which Steve introduces entries with "active links" to stock prices, so that they are automatically updated. That allows him to program in the cells next to the links the conditions that the clients give them (e.g., if the order is "set the spread at 80,") and an additional cell that changes color depending on whether the conditions are met for him trade or not (cyan equals good, dark green not good). The window is a traffic light for operations.

Instead of reducing the nature and importance of social interaction in the room, the screens give a new rationale for it. As a trader said, "thanks to technology, you don't need to hear from your neighbor on price action. All that information, we can find in Bloomberg". But there is a sense in which a screen reproduces the rigid categorical structure created by bureaus and bureau-based organizations, bureaucracies. Screens can be "bureau-tronic." According to the trader referred above, "Bloomberg shows the prices of normal stocks. But sometimes, normal stocks morph into new ones." Whenever stocks morph, that is, change their properties and defy the categorization system, electronic information is not enough. Furthermore, Steve comments, "no two screens are the same." "We all have different information, so I sometimes check with them," he adds, referring to other traders. How often does this happen? "All the time."

Just as Latour (1987) defined a laboratory as "a place that gathers one or several instruments together," trading rooms can be understood as places that gather market instruments together. Seen in this light, the move from traditional to modern finance can be contemplated as an enlargement in the number of instruments in the room, from one to several. The best scientific laboratories maximize cross-pollination across instruments. For example, the Radar Lab of MIT in the 1940s made breakthroughs by merging the epistemologies of physicists and engineers (Galison, 1996). Similarly, the best trading rooms encourage different desks to relate to each other.

Monitoring the price mechanism

Another example of inscripted instrument are the "robots," computer programs used by statistical arbitrage traders that automate the process of buying and selling stocks. Robots are inscribed in the sense that they execute only one possible trading strategy -- the one

they were programmed to perform. For example, the mean reversion robot will only buy and sell stocks based on whether their prices are close or distant from their historic average price. The earnings robot will only buy and sell based on companies' earnings. In this sense, robots contain in them a complex set of assumptions about the market and undertake an active selection of the available data that is consistent with it. Robots are models and representations.

The room plays a crucial part in the robots from the moment of their inception, the process of codifying, literally turning tacit knowledge into algorithms and code to make it usable by robots. This takes place at the whiteboard, in meetings that include for example, a trader specialized in indexes, and a programmer from the computer department. At the whiteboard, an idea for arbitrage trade mutates in medium from a trader's utterances, to graphs, to models, to equations, and finally to computer code. The robot is quite literally codified knowledge.

Once codified into a computer program, the robot goes to traders specialized in implementing computer programs such as the statistical arbitrage desk. End of the story? Not really. Piloting a robot requires inputs from a kind of emergent traffic control – cues and signals from other parts of the room.

Consider the case of Tom, a trader at the statistical arbitrage desk. Instead of trading directly, Tom uses, programs and maintains a robot. Automated trading poses the same challenge as driving a car at a high speed: any mistake can lead to disaster. "I have," Tom says, "a coin that comes heads 55% of the time." With margins as low as 0.05, the only route to high returns is trading a very high volume or, as Tom says of the coin, "the point is to flip it a lot." As with formula 1 car or speed-boat racing, traders need a very good instrumentation Indeed, they have navigation instruments as complex as an airplane cockpit -- a price mechanism. Yet, as it turns out, these are not enough. The price mechanism has to be monitored, and calibrated, and for that purpose Tom obtains crucial cues from the social interaction in the desks around him.

To illustrate how bad things can go when instrumentation fails, Tom recounts an instance in 1997. Price movements were large, the index was going up very quickly, and other banks were getting delayed information because of problems in the Reuters server. The result of delay, in a rising market, was that these competitors consistently saw the index below its real level. But while the index data were delayed, they were getting timely price feed on the futures index, so what seemed to them cheap was in fact expensive. Tom and others at International Securities, on the other hand, were getting timely information on both (see fig. 2). Tom explained to us,

> 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.

More generally, the episode not only illustrates the challenges of execution but also the dangers of representation. Given the advanced automation of the market, what traders see

– the numbers on their screen – is a representation of the market. If they take this to be reality but it turns out not to be accurate, there can be huge problems. The key to good execution, then, is an accurate representation. How does Tom know that the robot's representation of the market is accurate?

The most immediate solution to the challenge of execution is more technology. Tom's robot provides him with as many dials as a cockpit in an airplane. He trades with three screens in front of him. Two of them correspond to two powerful Unix workstations and the third one is a Bloomberg terminal. The first of the two Unix terminals has real-time information about his trades. Across the top of one of them there is a slash sign that rotates and moves from side to side. It is a "pulse meter" to gauge the speed with which information on prices is arriving to him, or "price feed". The character stops moving when prices stop arriving. It is very important to realize when this happens, because then the "price robot" gets confused: it thinks that prices don't change and imagines false opportunities, while in reality prices are moving but not arriving to his terminal.

On the right hand-side corner of his second Unix station Tom has five squares; each of them is a kind of traffic light that indicates how quickly the orders are getting through the servers of the specialists or electronic communication networks. If they are green, everything is fine. If they are yellow, the network is congested and deals will get through slowly. If they are red, their servers are clogged. The clocks in the Unix workstations are synchronized everyday to the Atomic Clock. In addition to a large display of an analog clock in his computer, Tom has two "CPU-meters" which measure how busy is the database that deals with the order flow of International Securities. When it is busy for long periods of time, orders take longer to execute. Thus, to monitor prices in the market, traders must monitor the price mechanism – literally, they must monitor the machines that bring and make prices.

However, technology is not the only answer to the problem of execution, for the dials that measure the accuracy of the technology are a representation themselves. Technology, in other words, answers one question, "is the robot getting the data?" but raises another one, "is the robot right in what it says?" We call this infinite-regress problem the "calibration" problem.

The calibration problem became notable following the nuclear accident at Chernobyl. An unfortunate circumstance that reportedly made the damage much worse is that radiation was so high that the dials of the Geiger counters of the control room of the Soviet nuclear power station did not register any abnormal level of radiation even at the peak of the escape. The dials had been calibrated for registering nuances, so the sharp increase went unnoticed. Technology, then, helps in execution of automated tasks, but needs calibration.

How to solve the calibration problem? Tom solves it by the use of space and sociability in the trading room. He sits in between the merger arbitrage desk and the systems desk. There he hears what the system people tell others through their microphones, getting a sense of how well the systems are running. According to Tom,

> When you hear screams of agony around you, it indicates that perhaps it is not a good time to trade. If I hear more screams, maybe I should not use the system even if it's green.

Similarly, price feed in stocks and futures has to come at the same speed. Hence sitting near the futures arbitrage desk is helpful in answering the question of whether there is something anomalous in the data feed. Tom's solution to the calibration problem suggests that when technology and the existing representations come under doubt, traders resort to the social relations that spawned them. Thus, the calibration problems is relevant to our discussion so far because it takes from the screen and its economics of information back to the room

The final challenge that Tom can encounter is that the assumptions underlying his arbitrage robot may not apply, or, as he puts it, that "the world may change in a way that is not envisioned in the system." In these cases, he will take a stock out of the robot. How does Tom know when to do so? Listening to the media is only partly helpful:

> Rumors in CNBC--should I listen to them? I need to find out when a stock is going to go through exceptional circumstances, takeover or restructuring. In principle, it would be useful to anticipate what is going to happen. But there are ten rumors for every takeover. So I just turn off the volume [As he said this, he turned off the volume of CNBC and ignored it.]

According to Tom, there is an additional problem with rumors.

> You never know how they're going to be interpreted. Take Motorola, the big news today. They have done worse than expected. But the stock went up. Why? Because all tech stocks went up, apparently because some trader at Salomon decided that tech's so low that we should buy anyway.

But free interpretation is dangerous, according to Tom.

> I find that the more that I can articulate simple rules for myself, the more I can be consistent in my own interpretation of events. Otherwise, if I start to interpret events freely, I'm using a 50% coin... to go against a 55% one. The algorithm in computer trades gives you the necessary discipline to stick to strategies.

For that reason, Tom limits himself to reading the second column in the cover of the Wall Street Journal and avoids media that is closer to the rumors. He finds it very useful to listen to activity in the merger arbitrage desk.

While promoting association through proximity, the trading room also uses distance to preserve the requiste measure of variety amongst traders -- a form of organized diversity.

Instead of the work of cleansing differences that produces "one right way" to calculate, the trading room actively promotes diversity in itself. Thus, for example, in the case of statistical arbitrage traders, the notion of the desk has been abandoned. For example, of the four statistical arbitrage robots, a trader said,

> We don't encourage the four traders in statistical arb to talk to each other. They sit apart in the room. The reason is we want some diversity." The diversity of these stat arb units is ensured by making sure that they have different P & L [profit and loss] patterns, and different risk profile.

The stat arbs are organized according to the push-pull mechanism. What pushes them apart is the the need to avoid the danger that they become similar to each other. They might evolve closer because robots are partly "alive" -- they change as they are re-tooled and re-fitted to changes in the market.[vi] They are kept separated to reduce the possibility that their evolution will converge (thereby resulting in a loss of diversity in the room). On the other hand, robots are pushed closer (or at least kept inside the room) because a given stat arb unit cannot be too far from the other types of arbitrage desks – proximity to which provides the cues about when to turn off the robots.

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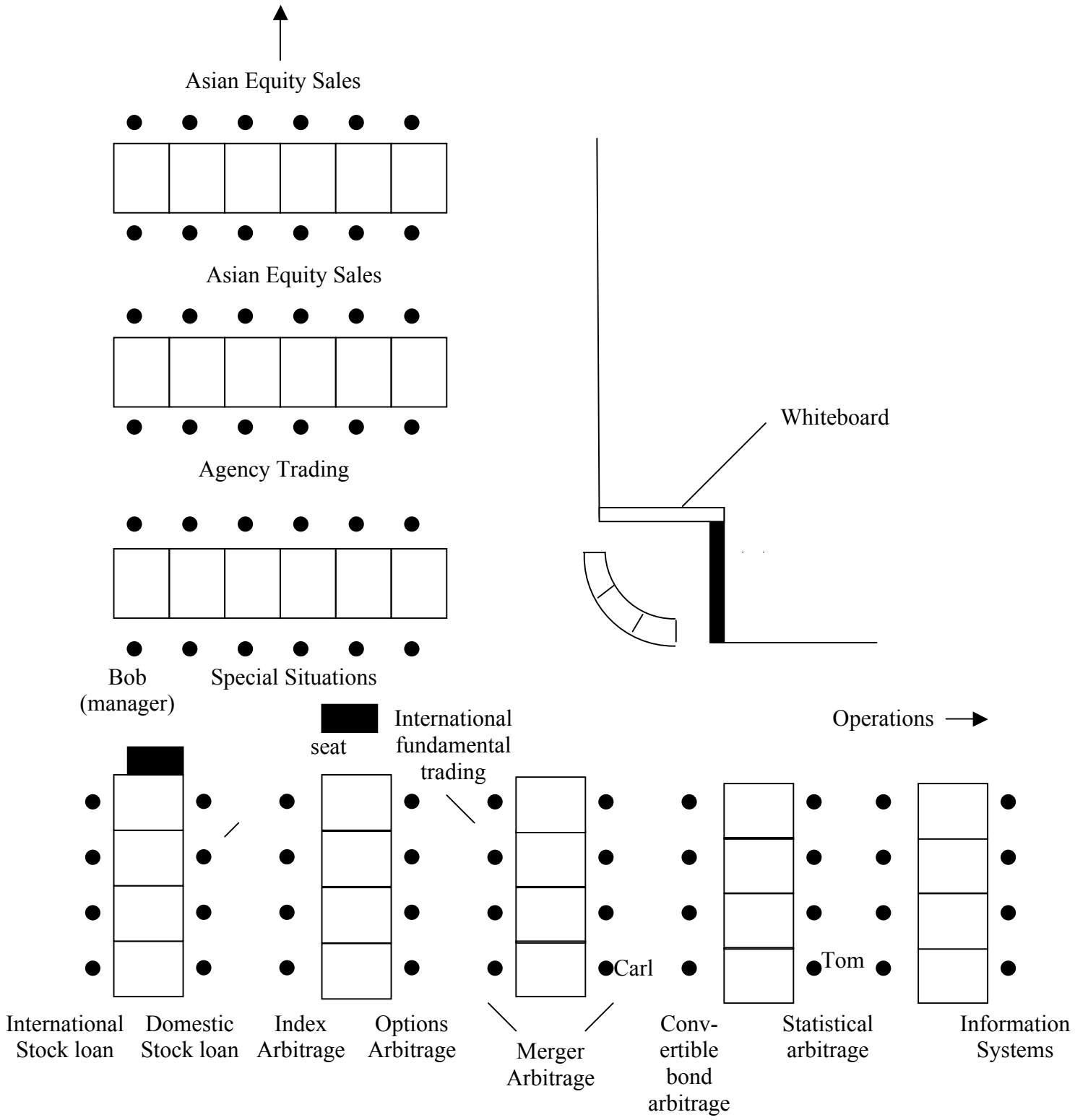

Figure 1: The trading room at International Securities

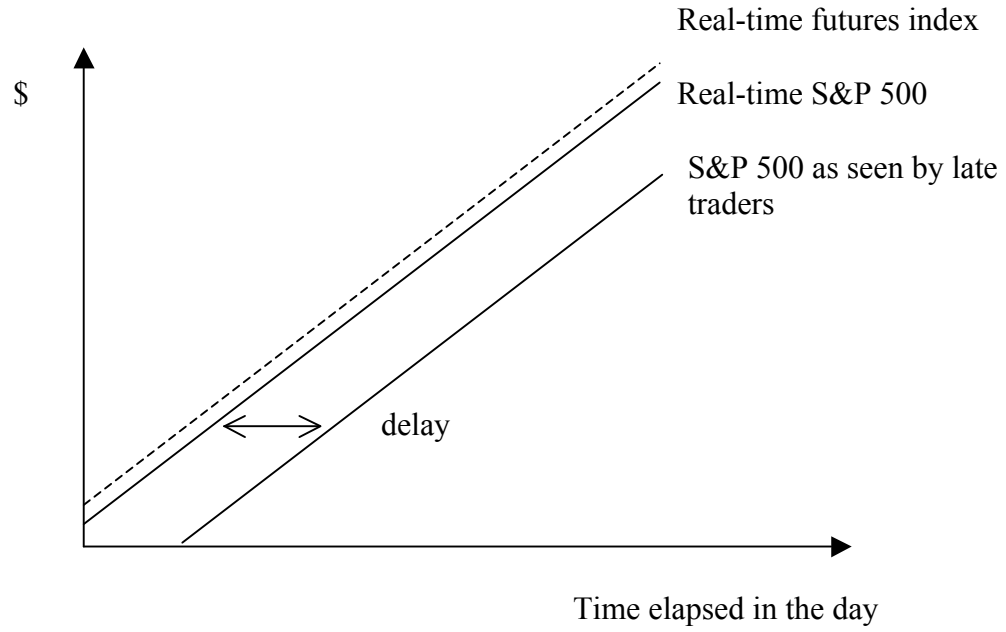

Fig. 2: Note distance between futures and spot-market indexes: a slight time delay can make it look as if there is an opportunity for arbitrage.

[i] Although American sociologists have not yet incorporated the insight that network analysis should include artifacts as well as persons, other social scientists in this country have been working with similar concepts. Hutchins (1994), for example, argues that cognition is distributed across a network of persons and instruments, and documents this dramatically and painstakingly in the case of a US Navy cruiser that is navigated into port after a power system failure. Suchman's (1987) pathbreaking work on human-machine interaction similarly resonates with the work of Callon and Latour and provides the basis for further studies on distributed design.

[ii] Note that Bruegger and Knorr Cetina studied currency traders. As we shall see, the practices of arbitrage traders are less conducive to localization online.

[iii] Joshua Cooper Ramo, "Welcome to the Wired World," *Time Magazine* (February 3rd, 1997).

[iv] Anonymous, "Hennessee Releases 8th Annual Hennessee Hedge Fund Manager Survey(R) Findings; 2001 Marks Record Capital Inflows and Record Number of Survey Respondents," Yahoo Finance, Thursday March 7, 8:32 am.

[v] For example, in the case of market making, association and disassociation predate the market, and calculation follows disentanglement. In the case of arbitrage, local calculation feeds into global association.

[vi] For example, according to one trader, if one of the stat arb traders left the bank, "it is unlikely that we would retain the profitability in the medium term... they [the robots] would loose fit with the market, and who would adjust them?"