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Devices For Doubt: Models and Reflexivity in Merger Arbitrage

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DEVICES FOR DOUBT: MODELS AND REFLEXIVITY IN MERGER ARBITRAGE

Financial models pose a cognitive paradox. As a powerful form of codified knowledge, models allow their users to interpret complex information in an uncertain world. But models can also blindside their users by locking them in the cognitive schema encoded in the models. Professional arbitrageurs, our ethnographic study reveals, overcome this paradox by introducing dissonance in their daily calculations. They compare the outputs of their models with the estimates made by their rivals, themselves obtained by using models in reverse. This form of reflexive modeling distributes calculation across rival arbitrage funds. Reflexive modeling differs from Granovetter's embedded action in that it entails a calculative activity centered on formulae and numbers. It differs as well from Callon's disentanglement in that it emphasizes how social relations make calculation possible.

We live in an age of modeling. Models of climate change are discussed on the front pages of our newspapers; architects and engineers use new visualization models to design and test our buildings, bridges, automobiles and aircraft; virtual avatars model our jeans; and molecular biologists model our genes. Not to be outdone by their colleagues in the natural sciences, social scientists have been prolific in disseminating their models to the worlds of public policy and business. Staffers in government agencies must be fluent in the modeling language of revenue, growth, taxation and poverty; and if MBA students learn nothing else, they want to be equipped to express discounted cash flow models into an Excel spreadsheet. National planning might have been discredited by the failure of communism, but modeling is everywhere a feature of the contemporary capitalist economy.

Nowhere is modeling more central than in finance. Starting in the 1970s, the combination of a new corpus of expert financial knowledge and new information technology sparked a veritable revolution in investment strategy, centered on the use of models, derivatives and electronic trading. In this brave new world of quantitative finance, two fields stand out. The first of these, structured finance – primarily, the packaging, recombination and circulation of mortgage risk into new securities such as collateralized debt obligations (CDOs) – would not have been possible without single-factor Gaussian cupola models (for a sociological account of how these figured in the credit crisis of Fall 2008, see MacKenzie, 2008). The second, arbitrage – the craft of valuing a security by means of another security – relies on models to determine similarity across securities (Beunza and Stark, 2004; Derman, 2004). During the past decade, arbitrage has contributed to legendary returns and a seven-fold increase in the number of hedge funds (Lo, 2008). But, like securitization, arbitrage has been associated with financial crisis. Arbitrage was a major contributing factor in recent shocks to global capitalism in 1987, 1998 and 2007 (see, respectively, Dunbar, 2000; MacKenzie and Millo, 2003; Lowenstein, 2000; Jorion, 2000; MacKenzie, 2006; Lo and Khandani, 2007).

Partly because of its association with financial crises, arbitrage has been an object of controversy among academic economists. But despite the importance of models for arbitrage, they have not been the point of contention in this controversy. As the leading proponents of arbitrage, orthodox finance scholars see the practice as the ultimate enforcement of market efficiency. Arbitrageurs in this view are the 'smart money' that understands the fundamental structure of the economy. Arbitrageurs exploit the disparities in prices created by 'noise traders,' less-informed investors who are driven by misinformation and momentum, eliminating mispricings as they profit from them. As long as arbitrageurs use the correct valuation model, orthodox scholars conclude, their activity will be rational, profitable and socially beneficial (Friedman, 1953; Fama, 1965; Ross, 1976). Against this optimism, behavioral scholars have pointed to the restrictions that impatient investors and misguided noise traders impose on arbitrage. Like drunken drivers on a crowded highway, noise traders pose financial threats to the more orderly arbitrageurs, thereby discouraging their activity (Shleifer and Vishny, 1997; DeLong et al., 1990; Abreu and Brunnermeier, 2003). By focusing on non-arbitrageurs, behavioral theorists have left unchallenged the purported epistemic superiority of the arbitrageurs' models.

Absent from this debate among academic economists is a crucial distinction. Whereas economic theorists build models for *representing* economic phenomena, Wall Street actors are ultimately interested in *valuing* securities (see Morgan and Morrison, 1999, for a related discussion). New research in the social studies of finance – a growing body of work commonly referred to as the 'performativity' approach – has addressed the role of models in finance, arguing that economic models are not representations but are interventions shaping markets (Callon, 1998, 2007; MacKenzie and Millo, 2003; MacKenzie, 2006; for reviews see Fligstein and Dauter, 2007; Fourcade and Healy, 2007; Ferraro et al., 2005). This new research, however, gives little attention to the practical difficulties in the actual ways in which models are used in the daily practices of the trading room. Nowhere is the gap between theory and practice more pronounced than in situations of Knightian uncertainty. In the realm of theory, academics circumvent their ignorance of the future with the abstract language of algebra. Practitioners, however, cannot afford such luxury. To take a position, a trader needs to move from Greek letters to plain numbers. And it is here that uncertainty raises its head. Because the inputs to financial models typically concern the future, they are often unknown, unavailable, or open to dispute. Motivating our research, then, is a fundamental question about the practical use of models in arbitrage: how do arbitrageurs calculate value in contexts of Knightian uncertainty?

To explore the calculative dilemma faced by the arbitrageur we adopt an ethnographic research design. This approach is particularly useful to understand the day-to-day social and material practices of calculation. Ethnography places the researcher in the same uncertain position as his or her subjects, thereby avoiding the danger of underestimating uncertainty (Agar, 1986; Spradley, 1979). Its emphasis on practice taps into the actual solutions developed by the users, as opposed to those intended by the designer of the system (Orlikowski, 1992; Barley, 1986). Our study spans three years of observations at the equity derivatives trading room of pseudonymous International Securities, a large global investment bank with American headquarters on Wall Street. From this period, we selected a single morning of trading at the merger arbitrage desk. The combination of two years of observation with one full morning of data provides a high-frequency, highly contextualized account, in line with the literature in cognitive science and distributed cognition (Hutchins, 1995; Hutchins and Klausen, 1992).

Empirically, our study centers on a particular arbitrage strategy, merger arbitrage. Partly because of its relative simplicity, merger arbitrage is a strategic setting to observe how traders confront uncertainty. Essentially, this arbitrage strategy involves placing bets on the likelihood that corporate mergers, once announced, will effectively take place. Like marriages between people, corporate mergers are subject to intense controversy from the moment they are announced. The debate is warranted, for a significant number of corporate mergers, once made public, are not subsequently completed (Officer, 2007). Merger arbitrageurs exploit the resulting uncertainty by making calculated bets on merger consummation (Reverre, 2001). In this, arbitrageurs exhibit a symbiotic relationship with corporate America: as mergers and acquisitions seized central stage in corporate strategies during the past three decades (Davis and Stout, 1992; Fligstein, 1990; Krippner, 2005), arbitrageurs found a way to profit from the resulting uncertainty. To be clear, in the trading strategy of the merger arbitrageurs we are studying, the trader is not simply monitoring the positions of others in order to anticipate 'where the crowd is moving.' That is, the specific form of specularity in our case differs from the problem of uncertainty posed by Keynes (1936) because traders are monitoring the actions of others for the purpose of deriving the implied probability of an event that will, in the end, happen or not happen. That event, by and large, is independent of the collective wagers of the arbitrage community.

Anticipating our argument in the broadest strokes: calculation has a material basis in market devices. It is a distributed calculation that is thoroughly social. But if models perform markets, they do so only with the skilled performances of actual traders. Among these skills is an ability to be reflexive about the role of models in shaping trades. And that skill, too, is socially distributed, as traders create and use devices for doubt. The resulting reflexivity is not exterior to (or above) the structures of socially distributed calculation but is an integral part of it.

Calculation in Economic Sociology

Our interest in calculation is motivated by a wide-ranging debate in economic sociology. That debate is of recent origin, for the problem of calculation was not addressed directly in the founding moments of the discipline. Within economic sociology, two schools stand out in shaping the field. The first, best represented by Mark Granovetter's (1985) path-breaking article, argues that economic transactions are embedded in social relations. The second, the new institutionalism, best represented in the work of DiMaggio and Powell (1983, 1991), argues that economic institutions operate through the 'unreflective activity' of scripts, routines, classifications and taken-for-grantedness. Whereas in the first perspective economic calculation is embedded in social relations, in the second perspective economic calculation is embedded in cognitive frames and cultural values. In both, calculative practices themselves are left unexamined.

It is into this vacuum that scholars with backgrounds in Science and Technology Studies enter economic sociology with an existing analytic toolkit. To understand economic transactions, argue Michel Callon and his colleagues (Callon, 1998, 2007; Callon and Muniesa, 2005), we must analyze the materiality of calculation. Among the artifacts, measuring instruments and other 'market devices' that populate this perspective, economic models have prominent place. Their effects, it is argued, are most decisively felt in contexts of uncertainty, for it is in these situations that models can frame decisions and quantify alternatives, thereby exerting a mediating role on the value of assets, goods and services. By privileging certain scenarios over others, by selecting a few variables to the detriment of others, and in short, by framing the situation in a given way, models and artifacts shape the final outcome of decision-making. This mediating effect, Callon concludes, is the fundamental way in which the economics discipline shapes the economy, for it is economists who create the models in the first place.

In making this argument, Callon (1998) proposed that social relations only shape calculation during the initial stages of a market, when models and their attendant artifacts are being constructed. Indeed, the argument went, it is precisely because a market device disentangles buyer from seller that it can remove social embeddedness and produce calculation (Garcia-Parpet, 2007; Callon, 1998).

Following Callon (1998), a burgeoning literature on market materiality has examined the mediating role of economic models and artifacts (MacKenzie and Millo, 2003; Beunza and Stark, 2004; Preda, 2006; Beunza and Garud, 2007). Most notably, MacKenzie and Millo (2003) studied the transformations induced by the Black-Scholes formula on the Chicago options market. By giving pit traders the ability to compute a sharp, numerical, unambiguous figure for option value, the Black-Scholes formula shifted the logic of transactions from business contacts and rules of thumb to data, formulae and numerical calculation (MacKenzie and Millo, 2003; MacKenzie, 2006, 2008). But the effect of Black-Scholes did not stop there: as more and more traders adopted the equation, options prices came to resemble the theoretical prices stipulated by their model (Rubinstein, 1985). Arbitrage, MacKenzie and Millo conclude, brings prices in line with the model used by the arbitrageur rather than with the fundamental value of the security, as orthodox arbitrage theorists would argue. In this view, performativity occurs when 'material artifacts incorporating economic models alter economic processes and/or their outcomes to make them more like their depiction by economics' (MacKenzie et al., 2007, p. 9). In our reading, a model is performative when its use improves its predictive ability.

The performativity literature, however, does not fully explain how models help actors cope with uncertainty. Consider again MacKenzie and Millo's (2003) study of options trading. By providing a precise point estimate of option value, the authors contend, Black-Scholes helped traders confront uncertainty. Equation in hand, all that an options trader needs to do is plug in the expected volatility of a stock into the formula, and the value of the option would automatically emerge as a result. Yet the process is far more complex, for expected volatility also needs to be estimated. And because this magnitude pertains to the future, the uncertainty involved in valuing an option is not addressed by Black-Scholes, but merely displaced to the problem of estimating volatility. The mere existence of a model, in other words, does not by itself account for how actors cope with uncertainty.

Our study points to a novel use of economic models that allows arbitrageurs to cope with uncertainty. In addition to using models to represent phenomena, arbitrageurs rely on them to find out what their rivals think. Specifically, merger arbitrageurs first create their own estimates of merger probability with the use of sophisticated but backward-looking devices: proprietary databases, detailed Excel spreadsheets, etc. Arbitrageurs then create a new collectively produced economic device, the 'spread plot.' With this object they find a way to extract or 'back out' from stock prices the probability estimates of other market actors. This magnitude is known as 'implied probability,' and used as a barometer of the social confidence that the merger will be completed. Not a price, it nonetheless functions as a communication tool in which information is produced by the buying and selling of the arbitrage traders.

Implied probability ties together the individual calculations of rival arbitrageurs. As a single arbitrageur changes his or her positions in response to movements in the spread, the action will have an impact on stock prices, alter the spread plot that rival arbitrageurs see and prompt them to reconsider their own probability estimates in the light of the new implied probability. In turn, changes in their financial positions will further impact the spread. Implied probability, in other words, is the collective outcome of multiple arbitrageurs reacting to a representation of the collective actions of others. The calculations of each individual arbitrageur, to the extent that are based on the comparison between internal estimates and implied probabilities, are co-produced. We denote this phenomenon as *distributed calculation*.

Distributed calculation, we further argue, involves a reflexive process. When we say that intelligence is distributed we do not imply that it is smooth and seamless. In the pages below we will examine how traders use the spread plot to break out of the traps of their prior experiences, relying on social cues to assess whether an apparent mispricing is a real opportunity or the result of their own misinformation or faulty interpretations. Reading the spread plot can trigger search processes along new dimensions in previously unexamined territories. Gaps, disparities, differences, mismatches can produce positive friction that stimulates re-search.

Finally, we argue that models are a double-edged sword. Because arbitrageurs forecast the risk of merger failure on the basis of the past, their individual estimates overlook unforeseeable contingencies. If *all* arbitrageurs simultaneously fail to see a problem ahead, implied probability will provide traders with a false reassurance, leading them to expand their positions and suffer widespread, potentially catastrophic losses. These pitfalls have been well documented in the finance literature, and are known as 'arbitrage disasters' (Officer, 2007).

We also derive methodological lesson from our findings for economic sociology. Far from *confining* itself to the intellectual space left by economics – to the emergent stages of markets, where relations ostensibly matter – sociology needs to *expand* and encompass the social element of calculation, as manifest in concepts such as liquidity, volatility or asset price bubbles (Zuckerman, 2004; Abolafia and Kilduff, 1985; Carruthers and Stinchcombe, 1999; Beunza and Millo, 2009).

Research Methods

Research site

The data reported below focuses on our observations from the merger desk at International Securities. The firm is a top-ten global investment bank in equity underwriting (Hoffman, 2006). Our observations center on its equity derivatives trading room, located in Lower Manhattan. Proprietary trading units of this kind function as internal hedge funds within bulge-bracket investment banks such as Goldman Sachs or Morgan Stanley. We conducted detailed observations at three of the bank's trading desks, sitting in the tight space between traders, following trades as they unfolded and sharing lunch and jokes with the traders. We complemented this direct observation with in-depth interviews of the traders at each desk. In the final year of our investigation we were more formally integrated into the trading room, provided with a desk, a computer and a telephone. Our involvement with the traders also included the time before and after the terrorist attack of September 11th, and our findings from their reaction to the tragedy are reported in Beunza and Stark (2003, 2005).

Period of observation

Our observations extend to more than sixty visits between December 1999 and March 2003. From these visits, the present study highlights a single morning of trading, March 27, 2003. This approach allows us to present an account that is both deep and broad. The need for deep, high-frequency observation stems from the speed of arbitrage: as we show below, two hours can make the difference between profit and loss. Only by limiting our presentation to a single morning can we convey the complexity of arbitrage in its requisite depth. At the same time, none of what we observed would have been intelligible without the breadth of our two prior years of field work in that same trading room, also examined in Beunza and Stark (2003, 2004 and 2005). This targeted approach combines the classic tradition of lengthy ethnographies of Van Maanen (1975) or Barley (1986) with that of a focused cognitive ethnography by Hutchins and Klausen (1996).

Moments of Modeling at the Merger Arbitrage Desk

Our focal visit to the merger desk quickly established the importance of tools and artifacts in the work of arbitrageurs. After two years of interviews and data gathering at the trading room of International Securities, we selected the merger arbitrage desk for a morning-long period of detailed observation. We arrived at the desk at 9.00 am on March 27, 2003, before the US markets opened. As we approached it, we found the arbitrageurs quietly at work on their computers. Oscar, the analyst among the three, was absorbed in a succession of PowerPoint slides on his screen, isolated from the others by a pair of headphones. Max and Andy, senior and junior traders respectively, were entering data from a sheet of paper into Excel spreadsheets. 'When we go down from here, we're gonna have negative gamma,' said Andy, without taking his eyes off his screen. 'Do you wanna revisit the volatility assumptions?' Max replied, staring at his computer.

This appearance of business as usual was somewhat surprising, for an important merger had just been announced. Career Education Corporation, a private provider of vocational training based in Illinois, had stated its intention to acquire Whitman Education Group, a Miami-based competitor. The news had landed on the Bloomberg terminals of the traders at 5.58 pm on the previous day, with the market already closed. The arbitrageurs confronted the news the following morning, minutes before our visit. Given the announcement, a visitor might have expected to see the traders engaged in energetic buying, selling or talking on the phone. Instead, all three traders appeared to be immersed in their typing.

This impression proved to be misleading. Far from ignoring the merger announcement, the traders were reacting to it in their characteristic way: developing a model of it. The first step in this process was the elaboration of a memorandum, which Oscar had drafted earlier in the morning. The memo summarized the key details of the Whitman-Career combination. Oscar compiled the memo after listening to the presentation that the merging companies put out for analysts; hence his headphones. The output of his work was a document stating the legal details of the merger: the cash and stock that Career would pay for Whitman, the expected closing date, etc.

The second step in modeling involved translating the legal details of the merger into numbers. This began with a chart representing the legal provisions affecting the deal, its so-called 'collar structure.' (Collar provisions tie the conditions of the merger to the future stock prices of the companies, reducing or 'choking' the potential impact of a decrease in the stock price of the acquiring firm; hence the name.) When we arrived at the desk, Max and Andy were transposing the details of the collar into their respective Excel spreadsheets, working in parallel to prevent clerical mistakes. As they typed, their conversation turned to data about other ongoing trades. 'What's your price for Whitman?' asked one of them. 'I've got bad data on it.'

Modeling the merger entailed one final step. Having finished the spreadsheet, the traders proceeded by linking the document to yet another Excel spreadsheet, known as the 'Trading

Summary.' This second spreadsheet functioned as a brief of all the trades in which the desk was involved. On the morning of May 27 the traders were active in 31 deals, so the involvement in Career-Whitman meant the addition of a 32nd row to the document. Like the instrumentation panel of an aircraft, the Trading Summary made all financial action readily visible at a glance.

In sum, our first encounter underscored the importance of quantitative infrastructure in modern finance. A merger trade requires the assembly of electronic scaffolding to supplement the arbitrageurs' mental processes: a PowerPoint presentation, followed by a Word memorandum, followed by collar chart and an Excel spreadsheet, all of it condensed into a single live cell on a Trading Summary. Arbitrageurs are aware and understand this process, and refer to it as 'setting up' the trade. The implication is that calculation is socially distributed at the desk. Despite the inanimate nature of a spreadsheet, an Excel file allows traders to engage in a more collaborative approach at decision-making. The live cells, for instance, contain Andy's assumptions, Oscar's collar data, and Carl's routine verification. The arbitrageurs' tools make trading social by bringing the insights of different actors into the decisions. But, as we shall see below, setting up the trade is only the first step in a more elaborate social set-up.

From Uncertainty to Risk

The actions and utterances described above cannot be fully understood without an appreciation of arbitrage. As with other arbitrage strategies, the basic principle of merger arbitrage is to exploit situations where two different regimes of value coexist in ambiguity (Beunza and Stark, 2004).[1] In the case of mergers, the ambiguity arises from the fact that a company is being bought. The acquiring firm typically buys the target company at a price well above its market capitalization, leading to two possible valuations: if the merger is completed, the price of the company will rise up to its merger value; if it is not, the price will drop back to the level before the merger announcement. Arbitrageurs exploit the ambiguity as to which of the two will apply by speculating on the probability of merger completion. To the arbitrageurs, therefore, profiting from mergers boils down to successfully estimating a probability.

This approach to arbitrage is grounded on an established economic theory. The theory is known as the 'Law of One Price,' and it was developed in the nineteenth century by classical economist David Ricardo ([1817], 1951), later reformulated as the 'no-arbitrage' condition by Ross (1976). The theory argues that, because sustainable market prices cannot offer arbitrage opportunities, goods will not sell for different prices in different markets in equilibrium (allowing for transportation cost). The price of gold in London, for instance, cannot systematically differ from the price of gold in New York without inviting the actions of arbitrageurs. In the context of merger arbitrage, this law implies that as a merger becomes more probable, the spread between merging stocks will converge to zero.

Merger arbitrage can also be stated in algebraic terms. Formally, the merger value of the target company arises from the payment that the acquirer has to satisfy to the target firm's shareholders. In the simplest case, that is, when the payment takes the form of cash, the acquirer commits to pay an amount P_S for the shares in a target company (Larcker and Lys, 1987). Given this, the value V for the target firm involved in a merger can be expressed as:

$$V = (1-\Phi)P_{NS} + \Phi P_S \qquad (1)$$

Expression (1) simply states that the value of the merger target, V, equals a weighted average of the cash that the acquirer will pay for it, and the value it would have if the merger were unsuccessful. Of these magnitudes, P_{NS} and P_S are known when the original merger announcement is made. Only the probability of merger, Φ, is unknown. As we shall see below, this simple set-up can be considerably complicated. But regardless of the specific merger form, the essential point remains: the target firm can be valued as a probabilistic function of the value of the acquirer.

The problem of the merger arbitrageurs, therefore, is quintessentially a Knightian one. To profit from a merger, they need to know its probability of completion, but this information pertains to the future. Arbitrageurs make probabilistic bets about the future, but that future is unknown. They need numbers, but their raw materials are news, memos and corporate presentations. Their job is to transform this uncertainty into numbers and engage in probabilistic calculation: in the language of Knight (1921), to transform non-calculable uncertainty into calculable risk.

Estimating probabilities by association

The arbitrageurs developed their own probability estimates by linking the future to the past. We first observed this dynamic in an early-morning exchange between two traders. At 9.40 am, Max and Oscar engaged in a dialogue on Whitman and Career. 'Do they have regulatory approval?' asked Max, without taking his eyes off the screen. 'They do,' Oscar replied, looking at his spreadsheet. 'Do they have accreditation?' Max inquired. 'What schools are these, anyways?' he added emphatically, his eyes squinting at his screen. 'Technical, for adults,' Oscar responded. 'They teach you things such as how to be a dentist assistant,' he added.

The conversation, a seemingly casual exchange, was an effective first step in estimating merger probability. In their remarks, the two traders established that the merged company would belong to the 'for-profit post-secondary education sector.' The usefulness of this categorization soon became clear. At 9.45 am, Max turned to examine a chart of Whitman's sales. 'Is it true that there's a summer drop-off in this business?' he asked Oscar, faced with what appeared to be weak summer sales. This mattered, because a common source of merger failure is negative results at one of the merging companies. 'It's the summer recess,' Oscar replied. The weakness in sales, in other words, was the school holidays: a normal part of the education industry. Categorizing Career and Whitman, we observed, helped arbitrageurs interpret information that could have material implications for merger completion. Because the companies belonged to the education industry, the drop-offs in sales were not a relevant merger risk.

In addition to industry groupings, arbitrageurs categorized mergers according to many other criteria. As Max explains, 'we look for patterns, precedent, similar deals, either hostile or friendly, degree of product overlap, and earnings variability. We look at all the ways to slice the factors that weigh into the merger.' Indeed, Max's account is consistent with the drivers of merger success singled out in the applied finance literature (Walkling, 2005).

Arbitrageurs complement categorizations with analogies to past mergers. At 9.50 am, the conversation shifted to a discussion of the honesty of the management teams of Whitman and Career. 'This guy Edison,' Max explained, 'a few years ago wanted to manage the primary school system. But then went down in flames.' The entrepreneur mentioned by Max was Christopher Whittle, founder of Edison Schools. Edison began operations in 1995 with the promise to bring private-sector discipline to the bureaucratized education industry. But the company saw its stock price plummet in 2002 amidst accusations of corruption. A scandal of the type that Edison experienced would immediately ruin the merger at Career and Whitman, so the probability of a scandal had to be factored in.

The discussion of Edison in the context of Career Education illustrates how the traders use analogies. Like categories, analogies allow them to glean the future from the past. In the case of Career and Whitman, the analogy associated the merging firms with a for-profit primary education company, Edison Schools, which had previously been marked by corruption. The similarity between Edison Schools and the merging companies led arbitrageurs to focus on the honesty of the management team at Career and Whitman.

In addition to categories and analogies, arbitrageurs also rely on material artefacts. This became clear at 9.55 am, when Max called up a black-and-white window on his screen. The screen displayed a set of old fashioned, 1980s-style Microsoft DOS characters. Pressing a combination of commands keys, Max obtained information on Edison. The screen corresponded to a proprietary database that Max has manually assembled over the years, with information about all past mergers in which the desk has been involved, classified along several key dimensions.

The merger database played a significant function. It allowed traders to recombine historical data from previous mergers along with the categories and analogies of the current case. Its use in the Whitman-Career case is illustrative: according to the traders' database, the average probability that a merger will be completed once it has been announced is 95 percent. But that is a very broad baseline figure. The case of Whitman-Career presented some peculiarities that made the merger more likely. One key factor was the lack of shareholder opposition: 'it's good if the chairman owns a lot of stock,' said Max, because 'a problem might occur if shareholders are opposed,' he added. Another was the lack of financing difficulties, as the operation entailed the larger company taking over the smaller one. Combining these in the database, the arbitrageurs concluded that the probability of merger completion would be above the baseline 95 percent.

Profiting from uncertainty

Our conversations with the traders underscore the importance of uncertainty in arbitrage. Uncertainty is not only their central challenge but also their main source of profits. For instance, when asked about the reason for the disparity between their own assessment of merger probability and the merger spread, Max argued that it stemmed from their own original interpretation of the data. Max said,

> The reason why the spread is large is that other traders have their own proprietary models for it. And they can all be right. At this point, it's all about the future, and we don't know the future. So their assumptions on volatility, for example, could be different than ours. Or their assumptions about timing.

The opportunity that Max saw, then, was not the result of luck, privileged information or irrationality. To him, it resulted from their unique interpretation of publicly available information.

Max's observation points to the importance of interpretation in the capital markets. The orthodox-behavioral debate on the informational efficiency of the capital markets. Briefly put, the efficient market hypothesis relates competition to information diffusion, arguing that vigorous rivalry among actors in the capital market erodes any sustainable informational advantage (Samuelson, 1965; Fama, 1965; Malkiel, 1973). By contrast the case of the merger arbitrageurs suggests that above-normal returns do not accrue from asymmetric *information*, but from a superior *interpretation* of events (Zuckerman, 1999, 2004; Beunza and Stark, 2004; Beunza and Garud, 2007). As Max said, 'right now, the data is all on the

Internet, even the SEC filings.' That is, the information is widely available and therefore does not confer any advantage. (As we shall see below, however, arbitrageurs still retain small but crucial informational advantages, provided by their social networks and databases.)

The Social Dimension of Merger Arbitrage

Our account so far locates calculation in the tools of the arbitrageurs. Like a well-trained submarine crew, the traders come across as a team, maneuvering together in struggle against uncertainty. The limits of this metaphor, however, soon became clear. As we shall see, the elaborate instrumentation of the traders' cockpit was not enough to cope with uncertainty. The arbitrageurs addressed the calculative gap by opening up to the market and reaching out to the rest of the arbitrage community.

The first hint that the calculations of the arbitrageurs stretched beyond the merger desk was provided by the traders' decision to buy stock in Whitman. At 10.15 am, the market opened on Whitman Education with a price of $13.95. The arbitrageurs' spreadsheets showed the spread to be a generous ten percent. Given the estimates of merger probability that they obtained from the databases, this signaled a potential opportunity. 'I'd like to have a presence in the deal,' said Max. 'Let's bid $1360 for 10,000,' he added. Following the instruction, Andy lifted the headset from his phone turret and called the block trader to place an order.

The social construction of implied probability

The operation described above suggests that traders read merger spreads as a measure of merger probability. There is a logic to this interpretation: if a merger is completed and the two merging firms become a single entity, the difference in their stock prices (the spread) will narrow to zero. A narrow spread, therefore signals a greater likelihood of merger completion. Conversely, if the merger is canceled and the equivalence between the two firms disappears, the spread will widen to its pre-announcement level. A wider spread, then, signals a lower likelihood of completion. This magnitude is known as the 'implied probability.'

Quantifying the implied probability entails two crucial manipulations. In its standard formulation, the Law of One Price defines the value of the target as a function of merger probability. Arbitrageurs do not have data for that probability, but they have data about prices. Accordingly, they use the formula in reverse, solving equation (1) to express merger probability as a function of prices. The inputs to the original formula, in other words, are the outputs of the new one. Second, arbitrageurs plug the prices of the stocks into the reformulated Law of One Price to obtain the 'implied probability' of merger completion. This form of reverse engineering, known as 'backing out,' is used to glean unobservable magnitudes from stock prices. Backing out, or using formulae in reverse, unlocks the information content of prices. It allows arbitrageurs to leverage the Hayekian ability of prices to serve as communication devices... without need for a dedicated market. In this sense, it allows arbitrageurs to exploit the 'wisdom of the crowds' (Surowiecki, 2004) for their own private advantage, because only those investors with access to the model and tools can see this magnitude.

Backing out probabilities, however, is a delicate move. In accomplishing this translation, arbitrageurs make two key assumptions: first, they assume that movements in the spread are dominated by merger considerations. That is, if the spread changes for some reason unrelated to the merger, the interpretation of the move as a change in merger likelihood would be erroneous. Second, the translation assumes that markets equilibrate rapidly. Unless rival arbitrageurs have seen prices, compared them to their own information and acted upon it, the spread does not convey the private knowledge of these rivals. As we shall see, arbitrageurs are mindful of these two conditions, and come back to them repeatedly whenever prices do not behave in an understandable manner.

Visualizing merger likelihood

The social construction of implied probability does not take place in the abstract but is embodied in a visualization known as the 'spread plot.' We learned about this chart as the conversation at the desk turned to another merger. During the months of our study, Hong Kong and Shanghai Bank (HSBC) announced its intention to acquire Household International, an American bank based in Chicago specializing in mortgages. The traders at International Securities were 'playing' this deal. At 10.30 am on the day of our focal visit, the conversation between Max, Oscar and Andy shifted from Career and Whitman to HSBC and Household. At 10.40 am Max typed a command in his Bloomberg terminal, producing a large black and blue graph on his screen. The chart, reproduced in Figure 1 below, displays the difference in the prices of HSBC and Household over the five-month period in which the merger unfolded. This difference is adjusted by the terms of the merger in order to reflect the conversion ratio announced by the acquirer: 0.535 shares in HSBC for each share in Household International.

Figure 1: Charting the implicit probability of merger. Screen shot of a Bloomberg terminal showing the spread plot of Household International and HSBC Bank, November 2002 to May 2004. Source: International Securities.

Arbitrageurs use the spread plot for pattern recognition. Mergers have a strong temporal dimension to them: like marriages, they are scattered with milestones that signal engagement, intended to persuade observers (and each other) of the seriousness of their intent. Arbitrageurs exploit this by looking for a pattern of gradual decay in the spread. Visually, they look for an L-shaped curve as corporate bride and groom come together, not unlike the trajectory of a landing plane (see Figures 2 and 3). An upward-sloping spread, by contrast, signals difficulties in the merger. In this manner, the spread plot simplifies the discussion at the merger desk: instead of monitoring numbers, traders look for shapes and patterns on their screens.

For an example of these patterns, consider the spread plot of HSBC and Household International in Figure 1. The chart shows two clear spikes along a descending line. These correspond to instances in which market participants lost confidence in the merger. The first, on November 22, 2002, was inspired by funding concerns: was HSBC simply buying Household to get funding? In other words, was HSBC a sound company? This surge, along with the concerns, subsided after a general market rally in credit spreads. The second spike took place on March 20, 2003, following news that Household International was shredding documents. This reminded arbitrageurs of similar shredding at Enron years before. The spread then fell again after the company received its approval from the financial authorities, and once HSBC reassured investors. The two spikes illustrate how plotting the spread brings out the crisis points in a merger.

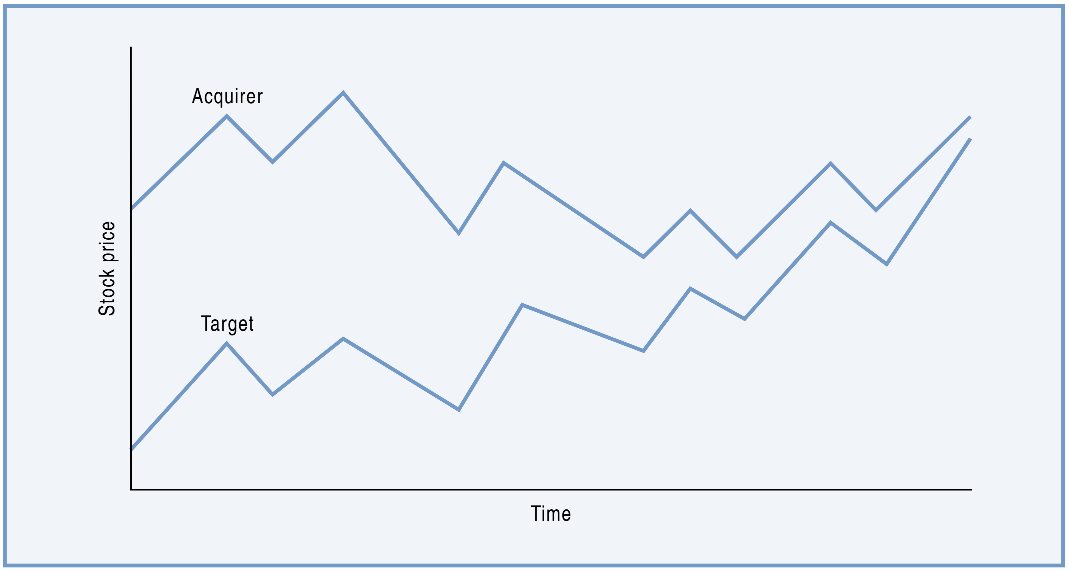

Figure 2: Mergers create price convergence. Two companies that merge successfully typically start from disparate values, but as the likelihood of their becoming one and the same economic entity increases, their stock market value becomes the same.

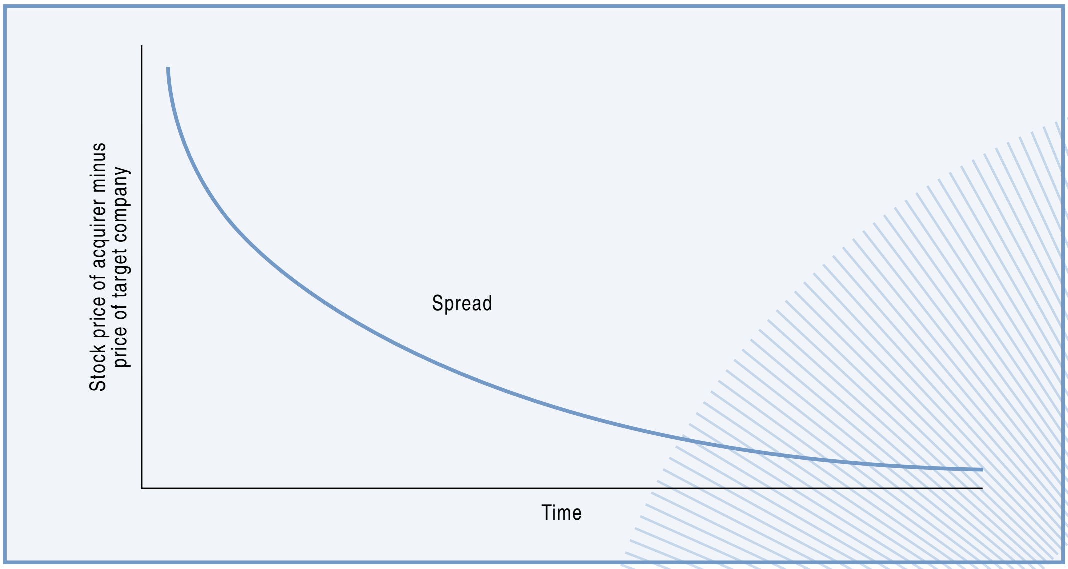

Figure 3: The spread plot of a smooth merger. The difference in prices or 'spread' between two companies that merge successfully decreases over time in an L-shaped pattern of gradual decay. Arbitrageurs look for this pattern to identify whether market investors believe that the merger will be completed.

Devices for dissonance

Aided by the spread plot, the construction of implied probability offers arbitrageurs an unparalleled tool to confront their own probability estimates with those of others. We observed its advantages in connection with the merger between Whitman and Career. As noted above, at 10.00 am on the day of our visit, the traders had purchased stock in Whitman. By 12.00 pm, however, the spread between the two companies remained at the same wide margin, ten percent. This persistence posed a puzzle for the traders, as it could be interpreted very differently. It could mean, first, that other arbitrageurs were not 'playing' the deal for some genuine reason: 'are we missing something?' Max asked himself. Second, it could also mean that there were incorrect assumptions in the traders' model. 'After all, the spread is only wide if my assumptions are right,' Max said. These assumptions were 'based on the 20-day moving average of the prices before closing date, but if the deal closes on a different date the price would be different.' Finally, the wide spread could also mean the reverse of a threat: a better-than-expected opportunity. 'Can it be,' Max asked, 'that the deal has gone under the radar screen of other traders?' The persistently wide spread, in other words, could be signaling missing information, incorrect modeling or a profit opportunity. Establishing which of these applied was crucial to the traders. The spread, in other words, was a wake-up call that prompted arbitrageurs to think twice.

The conundrum experienced by the traders is symptomatic of the disruptive role of the spread plot. Arbitrageurs, the chart reminded them, should not blindly trust their probability estimates, because they hinge on a representation of the merger (implicit in their databases) that may be incorrect. Given this, the spread plot provides traders with a much-needed device for doubt: by displaying their degree of deviation from the consensus, the spread plot provides arbitrageurs with timely red flags.

Responding to dissonance

Max and his colleagues responded to the discordant spread by plunging into a search for possible merger obstacles that they might not have anticipated. They first turned to databases: at 12.10 pm, one of them typed the names 'Whitman' and 'Career' on an online proprietary database. Like a Google keyword search, the database presented them with several hits ranked by relevance. Skimming through the sources of each result, the trader was reassured to see familiar newspapers. The search did not show anything they did not know in advance.

The database search illustrates how arbitrageurs respond to discrepancy. The traders went back for missing information. In doing this, the database helped even though the traders hardly knew what they were looking for: by including news from local media that the national media might have overlooked, it provided leads for issues that needed to be dug deeper.

The traders' approach contrasts with an institutionalist view of markets. In the classic institutionalist account, the availability of social clues leads actors to economize on their search costs by imitating others. In contrast, knowledge of the spread stimulated the arbitrageurs to search *more*. The discrepancy illustrates an important point about arbitrage: the material tools allow traders to come up with more sophisticated answers than traditional investors precisely by inducing skepticism about the tools. (We expand on this below.) Arbitrageurs, in this sense, are persistent but skeptical users of calculative devices.

This dynamic is aptly illustrated by a cultural artifact at the desk. Taped to Max's Bloomberg screen, a cartoon drawing showed Snoopy in full pilot gear, goggles, helmet, and scarf flapping in the wind. Sitting atop his doghouse, Snoopy extends his arms to hold an imaginary plane yoke. The fictional dog is seemingly piloting a plane. On a basic level, the cartoon illustrates the sophisticated, self-depreciating humor of the trader – if you think I am a Master of the Universe steering the world financial markets, think again: I am a plain dog in trader gear. On a different level, it illustrates the nature of Max's job: like flying, trading requires maneuvering through uncertainty. But the artifact goes far beyond that: it can also be seen as Max's reminder that the opportunities he sees on screen depend on a constructed magnitude, implied probability. And if this probability is not applicable to the case at hand, the opportunity is fictitious. Bob, the manager of the trading room, confirmed this interpretation by remarking on Max's ability to sustain self-doubt. 'Max,' said the manager, 'calculates the most sophisticated Bayesian formulas to get at a probability number, and then he'll say, "it's all guessing."'

Confronting uncertainty with recourse to the network

Following the inconclusive search on Whitman, the arbitrageurs got on the telephone. At 12:20 pm, Andy lifted the headset of his phone turret and called the floor broker who handled orders for Whitman at the exchange. 'John says buy this WIX [for Whitman], no one's really hedging it,' he said to Max as he finished the conversation. In other words, the broker implied, no other arbitrageurs were active in the Whitman trade. From this, Max concluded that the merger had passed 'under the radar screen' of other arbitrageurs. He reacted by increasing the desks' exposure to the merger. 'Let's work another ten [thousand], but pick your spots,' he said to Andy, asking the junior trader to purchase additional shares in Whitman, but to do so carefully to avoid inflating the stock price.

Why did the arbitrageurs call up their contacts? Until 12.00 pm, the traders had interpreted the spread as the implied probability of the merger. The persistent discrepancy between the wide spread and the traders' estimates, however, created a dissonance that led them to question their own interpretation. Having re-checked the database, they then decided to inquire about the identities of the shareholders, partially lifting the veil of anonymity entailed in securities trading. In doing so, the arbitrageurs can be seen as seeking to clarify whether the second of the boundary conditions of the Law of One Price actually held: that is, was the spread reflecting the information in the hands of rival arbitrageurs? In so doing, the traders were emphatically not 'reading the market.' They were attempting to disentangle the market from the actions of the players who, in their view, were the only ones who really counted: their rivals, namely, other professional arbitrageurs. On learning that no other real player was hedging the stock, they concluded that the spread could *not* be interpreted as a measure of implied probability. Thus, reflexivity at the merger arbitrage desks cuts both ways: whereas an hour or so earlier, the spread plot had stimulated Max and his team to raise doubts about their database, here their phone conversation stimulated doubts about the meaning of the spread plot, the device for doubt itself.

In this light, consider again why Max told Andy to 'pick your spots.' The expression reminded Andy to cover his tracks as he increased the desks' position on Whitman, with the aim of avoiding an increase in the stock price. The traders' efforts suggest that Max and colleagues felt they were being observed by other arbitrageurs through the lens of the spread. In other words: just as Max and his team engaged in a calculated game of guessing, so were rival arbitrageurs at other firms. Preserving an opportunity that had gone 'under the radar screen' of rival traders required avoiding warning competitors.

Distributed Calculation

The events described so far boil down to a simple point: arbitrage is social. Arbitrage, we found, hinges on the encounter between the probability of merger estimated by the traders and the implied probability backed out from stock prices. Note, however, that this implied magnitude is entirely constructed: it simply captures how different traders think about the merger. There is, in other words, no inherent correspondence between the implied and the 'real' probability of merger completion. And yet, implied probability was invaluable to the arbitrageurs: it signaled the extent of their deviation from the market, warned them against missing information, motivated search and prompted them to activate business contacts. Finally, it provided arbitrageurs with the necessary confidence to expand their own positions.

These practices point to a novel calculative mechanism, which we refer to as *distributed calculation*. The expression denotes the process whereby dispersed market actors co-produce their positions through successive acts of estimation, modeling and confrontation. Distributed calculation builds on the related anthropological concept of distributed cognition (Hutchins, 1990, 1995; Hutchins and Klausen, 1996), which contends that material artifacts play a key role in allowing actors to develop shared interpretations. For instance, the yokes used by the captain of an airplane are often mechanically linked to the yokes of the first officer, allowing the captain to monitor the officer's actions effortlessly (Hutchins and Klausen, 1996). Our proposed concept, distributed calculation, extends Hutchins' insights to markets and models. It contends that calculation, traditionally conceived of as an individual process, is made social by the economic models used by the arbitrageurs. Just as the intention of a pilot is rendered visible by the linked yokes, an arbitrageur's estimates are made visible to his or her rivals via the implied probability.

Distributed calculation differs from the conventional sense in which markets have distributed intelligence. Hayek (1945), most famously, described markets as a self-organizing system of coordination in which prices are the key means and mode of communication. Because an increase in the quantity demanded of a good typically leads to an upward movement in its price (and vice versa), market actors coordinate their plans by simply buying and selling, without any other explicit communication. The problem that Hayek was addressing, however, was resource allocation in a context where information is dispersed. Merger arbitrage differs from Hayek's context on three counts. First, unlike coordination among consumers and producers facing a problem of resource allocation, arbitrageurs do not seek to coordinate with other arbitrageurs but to deviate from them in pursuit of speculation. Second, although the context similarly involves dispersed information, under conditions of uncertainty the situation differs because it also involves heterogeneous, disparate, dispersed interpretation. Third, there is no market for mergers. That is, there is no market in which the event, a given merger, has a price.

Finally, distributed calculation allows participants in the arbitrage community to engage in economic controversies over value. That market participants would confront a situation of uncertainty by engaging in debate is hardly surprising; the dynamic has been amply documented in science and technology studies (Bloor, 1976; Latour, 1987; Galison, 1997). Scientists, according to this body of literature, transform their claims into widely accepted facts by engaging in controversies over the meaning of experimental data. What is new and different about the activities of arbitrageurs is that the controversy takes place without journals, articles, citations and… indeed, without words. (In many ways, it is also a controversy without people, as the identity of position-holders was only revealed when the ambiguities of the data reach their peak.) The communication device that traders employ is the price of stocks. Arbitrage, in other words, could be seen as a controversy without babble. In this process, prices are a highly coded, ambiguous signal that arbitrageurs collectively generate and interpret. The price mechanism, seen through the lens of the spread plot, functions as a giant platform for independent, yet coordinated calculation and interpretation.

Coordinated Attention in the Trading Room

The emergent coordination between the arbitrageurs and their rivals has a counterpart within the trading room. Arbitrageurs, as we shall see, rely on social cues from colleagues in other desks inside the trading room to question and reformulate their own calculations. We observed an instance of this in the morning of March 27. At 11.20 am, a growing hum interrupted the conversation between Max and Andy. The sound came from the television speakers that each trader had in his or her station, prompting Max and Andy to look up. On the oversize televisions that hug on the walls of the room, Tony Blair and George Bush stood against a background of American and British flags. The dignitaries were staging a joint US-Britain international press conference. Curious, Max turned up the volume of his speaker. As more and more traders did the same, the sound of the conference enveloped the entire room. On the TVs, the British Prime Minister replied to journalists' questions about the estimated duration of the war in Iraq. Blair admonished the audience that,

> It does not make sense to speculate about the length of the war. We are in it just under a week, but because there is 24-hour media coverage of it, it seems as if we've been there forever…

In other words, Tony Blair was asking for patience. At the time, spring of 2003, the Iraq war had barely started. Nobody, Blair insisted, could reasonably commit on a date for its end. Such was the message that was broadcast to the traders through a chorus of a hundred small speakers on the traders' desks.

After ten minutes of listening, the traders began to tune out of the conference. As they turned down the knobs of their individual speakers, the chorus died down. Turning back to his computer, Max called up a scatter plot on his Bloomberg screen. This showed the price movements of Household International plotted against the movements of the S&P 500 index. 'The stock has a point eight correlation with the S&P,' he said to Andy. 'It's going to be affected by macro events.' Max's reflection concerned the possible implications of the war for the merger: HSBC and Household International was a cross-border deal and, as such, it was particularly subject to political upheaval. Uncertainty about the war in Iraq could imply a lower probability of merger completion.

The episode illustrates the complex manner in which social interaction supports calculation. We note, first, that the arbitrageurs rely on each other to orient their attention. Second, the abrupt rise in the volume signaled to Max the importance of the television program. The outcome of this shift in attention was a recalculation of probabilities. In other words, Max's response to the news conference was not to panic and sell stock, but to check the probabilistic impact of the war on the Household-HSBC trade. At the end of the televised intervention by Bush and Blair, the merger desk had enriched their calculations about the Household-HSBC merger by adding one extra variable, the military dimension, in their estimations of completion date.

Taken together, the traders' response to the Blair-Bush press conference adds to the previous discussion of distributed calculation. Clustered in the same room, the arbitrageurs in different desks benefitted from each other's eyes and ears. In that sense, co-location in the same premises is akin to the construction of implied probability: just as Max and his colleagues relied on the opinions of their rivals in the virtual space of the market (prices, models and implied probability), they also relied on the actions of their colleagues in the shared space of the trading room. Just as implied probability turns a buyer's footprints into a seller's roadmap, the trading room turns one trader's noises into another trader's cues to recalculate probabilities.

Distributed Calculation and the Abnormal Profitability of Merger Arbitrage

In the past decade, the finance literature has identified the existence of 'above-normal' returns in merger arbitrage, that is, returns that cannot be explained by recourse to the risk they incur.[2] Distributed calculation helps explain the remarkable returns enjoyed by the merger arbitrageurs.

Our observations attest to the legendary profitability of merger arbitrage. For instance, in one conversation towards the end of the year 2001, Bob explained:

> We made around one billion in this past five years, which in terms of return on capital puts us in the upper 25 percent of comparable firms, multi-strategy hedge funds. We made very little money on our first year, a lot in the following three, and have not done so well on this last year [...]. Still, right in the pack of multi-strategy hedge funds – upper third.

Thus, in other words, the trading room as a whole was realizing a level of excess returns comparable, if not superior, to figures offered by the literature, which refers to average levels. In the specific case of merger arbitrage, the returns were even more generous. Bob, the manager of the room, often remarked on the economic success of Max and his desk, especially in the light of their unassuming personalities: 'if you see him [Max] in the subway, you would think he's a postal inspector. But he makes millions.'

Max himself attributes the difference between arbitrage and speculation to the reliance on tools and models. 'Look at this jump,' he said, pointing to the price of Household International on the day its merger was announced (see Figure 2). He added,

> This is the value that fund managers and the guys on the Street are after. Once the jump has taken place, it's a matter of pennies. The value investors don't have the fine-tuned tools to position themselves in this spread, to determine if it's too wide or too narrow for them. We do.

The arbitrageurs' ability to read the spread, in other words, lends them a key financial advantage over non-arbitrageurs. Simply put, thanks to their tools, arbitrageurs can see what plain speculators cannot.

The Dangers of Financial Models

In addition to opportunities, the use of models poses important financial perils for arbitrageurs. Indeed, in truly exceptional events, the use of models can inflict wide-ranging and oversized losses on arbitrageurs, phenomena known in the finance literature as 'arbitrage disasters' (Officer, 2007). Perhaps the best-known disaster is the aborted combination between General Electric and Honeywell International in 2001. The cancellation imposed collective losses of $2.7 billion on arbitrageurs, large enough to offset the cumulative quarterly profits of most arbitrage desks (Bary, 2001). According to the financial press, 'the GE/Honeywell blowup surprised Wall Street because [...] no merger that passed muster with U.S. antitrust regulators has ever been blocked in Europe' (Bary, 2001, p. 43). Like the war in Iraq, the GE-Honeywell disaster suggests that distributed calculation fails in the presence of so-called 'black swans,'

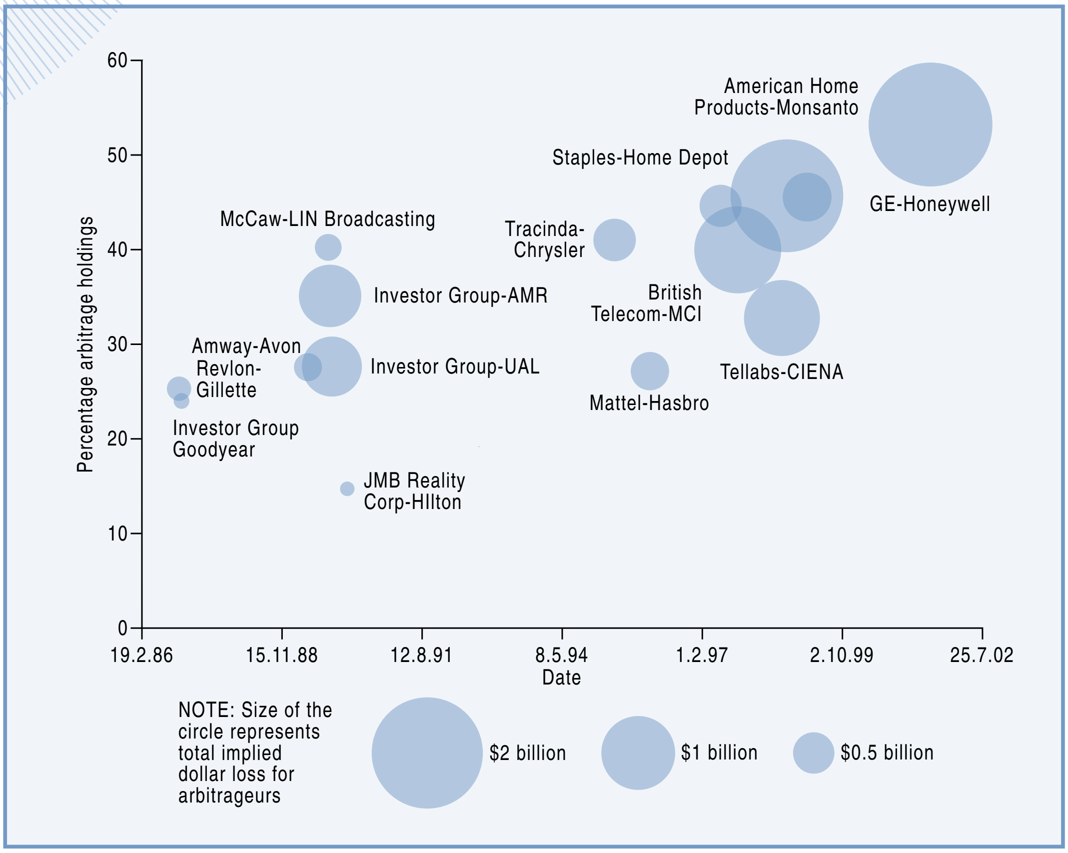

Figure 4: Merger arbitrage disasters. Failed arbitrage deals, with total losses incurred by arbitrageurs (circle size) and relative participation of arbitrageurs (y-axis). Source: Officer, 2007, p. 27.

Acquirer	Target	Cancellation date	Percentage holding by arbitrageurs	Implied total losses, $000s
General Electric Co.	Honeywell International Inc	2.10.2001	53	2,798,376
American Home Products Co.	Monsanto Co.	13.10.1998	45	2,335,367
British Telecommunications PLC	MCI Communications Co.	10.11.1997	40	1,908,240
Tellabs Inc	CIENA Co.	14.9.1998	34	1,179,412
Investor Group	AMR Co.	16.10.1989	36	712,042
Staples Inc	Office Depot Inc	2.7.1997	44	558,804
Investor Group	UAL Co.	18.10.1989	29	542,058
Abbott Laboratories	ALZA Co.	16.12.1999	46	525,194
Tracinda Corp	Chrysler Co.	31.5.1995	42	458,918
Revlon Group	Gillette Co.	24.11.1986	25	286,371
Mattel Inc	Hasbro Inc	2.2.1996	228	228,557
McCaw Cellular Communications	LIN Broadcasting	10.10.1989	50	219,937
Amway Co.	Avon Products Inc	18.5.1989	29	165,816
Investor Group	Goodyear Tire & Rubber	20.11.1986	25	145,344

Table 1: Arbitrage disasters, 1990-2003. This table contains details of the fourteen largest merger arbitrage disasters from 1985 to 2004. All dollar arbitrage losses are in 2004 dollars. Arbitrageurs' percentage holding is the percent of target shares outstanding reported as owned by arbitrageurs at the first quarterly 13F reporting date after the bid announcement date. Implied dollar arbitrage loss is the total arbitrage loss multiplied by arbitrageurs' percentage. Source: Officer, 2007.

that is, entirely unexpected circumstances (Taleb, 2007).

Our conversations with the head of the trading room corroborate the above. According to Bob, the merger desk was also active in the GE/Honeywell deal:

> Max traded it [...] everyone's database lacked a field, and the field was 'European regulatory denial.' [...] I encouraged him to increase his size [...] you have confidence, all of your fields are fine [...] so instead of four million, I said six million.

In other words, Max and his desk were not an exception to the losses experienced by the rest of arbitrageurs. Each of these events, Bob said, is 'sharp and traumatic.' The loss of six million dollars was not a problem for the fund, but it illustrates the size of the potential losses.

There have been several arbitrage disasters in the past decade (see Figure 4). The total dollar loss of all merger arbitrageurs in this deal was $2.8 billion, according to Officer (2007); see Table 1. These disasters underscore the dangers of relying on cues that provide misplaced reassurance. In the literature of social psychology, the concept of groupthink (Janis, 1972) argues that flawed decisions arise when group members avoid testing, analyzing and evaluating ideas in order to minimize conflict. As with groupthink, arbitrage disasters ensue because each individual arbitrage fund mistakenly takes the lack of visible concern on the part of others – that is, the lack of spikes in implied probability – as reassurance.

The existence of arbitrage disasters points to the ultimate paradox of financial models. Arbitrage disasters befall traders in the very process of pursuing an extraordinary performance. Unless arbitrageurs enlarge their exposure whenever implied probability confirms their views, their returns will not be able to surpass the average returns of traditional investors. Thus, it is *because* arbitrageurs insist in improving their own estimates – thereby turning to models – that they receive false confirmation of their views. The dangers of models, in other words, go hand in hand with the benefits.

Conclusion

Our ethnographic study of merger arbitrage has examined the use of economic models in modern finance. How, we asked, do models help merger arbitrageurs calculate value in contexts of uncertainty? Our research findings have strong implications for the ongoing debate on the role of social relations in markets dominated by numbers and formulae. In particular, they offer a critical counterpoint to two approaches that were foundational moments in economic sociology. The first, the embeddedness approach, argues that calculations are replaced by social relations (Granovetter, 1985). The second, the new institutionalist approach, argues that calculations are embedded in cultural and cognitive routines, scripts and 'unreflective action' (DiMaggio and Powell, 1983, 1991). These perspectives have been enormously generative and continue to influence much of the field.

Central to the embeddedness perspective was the dichotomy of calculation versus trust. Contracts and other types of economic transactions rest on networks of social relationships that generate trust. Such embedding does play a role in the world of capital markets. Baker (1984), for example, showed that variation in networks of cohesiveness explained aspects of trading behavior (notably volatility) in the open outcry pits of an options exchange. The mathematical formulae, databases and visualizations that we saw on the merger desk present a different side of Wall Street – one that has little to do with personal relationships. From this standpoint, quantitative finance would appear to be far less social. Instead of privileging personal traits – demeanor, tone of the voice, even physical size – the interactions among arbitrageurs appear to be centered on numbers, hypotheses and data.

This would not be surprising to Michel Callon, who argues – in keeping with the dichotomy of calculation versus embedded social relations – that calculation in fact requires the severing of social ties (Callon, 1998). Because one might think about the risk arbitrageurs of quantitative finance as the calculative agents par excellence, then, of course, these are the least of all social economic actors. Our findings, however, suggest a very different interpretation.

Our argument differs from both Callon and from Granovetter, while simultaneously reconciling the two. We argue that the calculative practices of merger arbitrage are not embedded in social relations. Instead, calculation itself is social. Its social character occurs in two aspects – the (material) relation between traders and their artifacts (instrumentation, databases and formulae), and the (model-based) relation between traders and their rivals. The arbitrageurs we studied used the second for critical input to realize the first.

When we say that calculation is 'socially distributed' we do not refer only to knowledge that is distributed among human agents. Our notion of 'the social' includes not only such human agents but also the *relationships* between these human agents and their instrumentation, formulae, algorithms and other artifacts that populate socio-technical networks. Without databases, spreadsheets, 'collar charts,' customized screens, trading engines and various graphic representations, the trader could not be a player in the game of arbitrage. In addition to the human capital of the traders themselves, such instrumentation is a core resource of the firm and is therefore deeply proprietary. No tools, no trades. Highly specialized instrumentation provides the traders with 'scopes,' distinctive views on the markets (Knorr Cetina and Preda, 2007).

But, although scopes can reveal patterns, they can also conceal. In the process of focusing on and highlighting some patterns, they necessarily obscure other patterns. As we have seen, in order to recognize opportunities, the trader needs tools, models and frames that allow him to see what others cannot. But the fact that the tool has been shaped by his theories means that his sharpened perceptions can sometimes be highly magnified misperceptions, perhaps disastrously so. The danger is that by distributing calculation across the instruments at their desk the traders are inscribing their sensors with their models.

The findings from our research in the trading room at International Securities indicate that the merger arbitrage traders are reflexively aware of this cognitive challenge. That finding has direct relevance for the new institutionalism in economic sociology. Within that approach, cognition occupies a central place; but cognition within the institutionalist paradigm is encapsulated in 'scripts, routines, taken-for-granteds, and unreflective activity' (DiMaggio and Powell, 1991, p. 63). To this we reply: why should we deny to traders the capacity for reflexivity that we prize and praise in our own profession?

Whereas the new institutionalists emphasize unreflective activity and the taken-for-granted, in our case we have documented actors who are acutely aware that if they take their knowledge for granted, they can lose their shirts. The method through which arbitrage traders achieve this reflexivity marks the second dimension along which we argue that calculation is social. Restating the epistemic challenge for emphasis: our arbitrage traders confront the problem that their models, tools and instrumentation are theory-laden. Traders view markets through the 'scopes' of their instrumentation – scopes that are inscribed with their beliefs. Because arbitrageurs can only see the market *through* their models, they cannot simultaneously look *at* how applicable their models are. So as not to remain the captive of this epistemic trap, sophisticated calculation, therefore, entails a second-order cognition – reflexivity about the very process of using and enacting market models.

The reflexivity of the traders, however, is not a mental process or a solipsistic practice. The traders we observed were not engaging in some heroic mental feats, splitting and twisting their minds back on themselves like some intellectual variant of a flexible contortionist. Instead, as we saw numerous times in a single morning at a single trading desk, the 'taken-for-granteds' of their models were cognitively disrupted by devices for doubt. Such devices, we further observed, were profoundly social. Most illustrative of this process of a socially induced reflexivity were the practices of how our merger arbitrage traders used the implied probability – a representation of an economic object that does not have a price and is otherwise not observable, co-produced by the positioning of actors who use it to confront their interpretations and re-evaluate their positions. As we saw, the implied probability involves the collective insights of dispersed participants *outside the trading room*.

In contrast to Callon, who regards calculation as instantiated after the social has been disentangled, here not only calculation but also reflexivity about it are thoroughly social. In contrast to Granovetter, the social here is not comprised of the personal ties that generate relations of trust but is built out of the positioning of anonymous others.

The relationship between the arbitrageurs and his other models is a social relationship. Precisely as a relationship, the trader can be a captive of his models. At once and the same time, to disrupt this relationship and thereby to fulfill the relationship with the necessary inputs needed to enact the model, the trader deploys another set of social relations. This second set is established through the trader's interactions with devices that instantiate the results of the interactions of other (distant and anonymous) traders and their own models. The social relation trader-model is mediated by another social relation, trader-rival. Calculation is the result.[3]

Distributed calculation, in short, constitutes a novel mode of engagement with markets. A much-remarked characteristic of markets, first identified by Hayek (1945) and the Austrian School in economics, is the ability of the price mechanism to mobilize the local knowledge of dispersed actors for the purpose of resource allocation. Merger arbitrageurs extend this self-organized calculation beyond the price mechanism to include non-price magnitudes such as merger likelihood. This collaborative mode of inquiry brings the collective insights and information-gathering capabilities of other market actors to bear on their own estimates. Indeed, distributed calculation allows arbitrageurs to mobilize the dispersed diversity of interpretations. This unprecedented marshalling of distributed cognitive resources in their own advantage is perhaps the reason for their much-publicized profitability. However, as the existence of 'arbitrage disasters' makes clear, the construction of implied probability does not eliminate Knightian uncertainty, nor does it confer a fundamental glimpse of the 'true' probability of merger success. It simply offers a more refined, albeit fallible, way to cope with uncertainty.

Our observations in the trading room led us to argue that reflexivity is the outcome of materially induced dissonance. Reflective cognition is not acquired by superior mental powers or a reflexive self-awareness. It is not an intellectualist rising above or conceptual transcendence. Instead, the arbitrage traders whom we studied used the dissonance provoked by devices of doubt to help break out of the possible traps of their analytic models and categorical frames. It is precisely the social character of arbitrage that offers opportunities for cognitive disruption.

That is, against the powerful private resources for generating categories and frames at the desk, the traders confront a public resource that reminds them, almost minute-by-minute, that their frames and models should not be taken for granted. That public resource, the spread plot, is a social object co-produced by dispersed actors who need have no knowledge of each other and, indeed, no other social relation than the fact that they too are constructing an object that they monitor.

These observations have their counterpart in parallel debates within art and science during the past century. Recalling René Magritte's 1929 painting, *The Treachery of Images* ('Ceci n'est pas une pipe'), biochemist Mike Hann produced an image showing the model of a protein molecule with the inscription 'Ceci n'est pas une molecule.' Traders do likewise, populating their workspace with devices that say, in so many words, 'this model is not a market.'

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Notes

[1]Here, our definition of arbitrage departs from the orthodox economic. In the economics literature, arbitrage is defined as exploiting perceived mispricings across markets; as Hull (1997, p. 4) put it, 'locking in a profit by simultaneously entering into transactions in two or more markets.' This definition, in our view, says nothing about the source of the mispricings nor about the role of Knightian uncertainty in arbitrage.

[2]Thus, for instance, Dukes et al. (1992) and Jindra and Walkling (2004) document annualized returns to arbitrageurs of 117 percent and 46.5 percent, respectively. Baker and Savasoglu (2002) report an average annualized risk-adjusted return of 9.6 percent for a sample of cash and stock deals, and Karolyi and Shannon (1999) document a 26 percent annualized return. More modestly, Mitchell and Pulvino (2001) report a four percent annualized excess return after taking into account transaction costs.

[3]Distributed calculation, we contend, is not limited to merger arbitrage. Beyond mergers, our findings within have clear parallels in options arbitrage. Our reading of MacKenzie and Millo (2003, p. 125) suggests that options traders use models in a way that very closely resembles distributed calculation.

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