

Looking Out, Locking In: Financial Models and the Social Dynamics of Arbitrage Disasters

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Abstract This study analyzes the opportunities and dangers created by financial models. Through ethnographic observations in the derivatives trading room of a major investment bank, we found that traders use models in reverse to look out for possible errors in their financial estimates. We refer to this practice as reflexive modeling. The strength of reflexive modeling resides in leveraging the cognitive independence among dispersed, anonymous actors. But as our analysis demonstrates, it can also give rise to cognitive *interdependence*. When enough traders overlook a key issue, their positions send the wrong message to the rest of the market. The resulting lock-in leads to arbitrage disasters. Our analysis challenges behavioral finance by locating the root of systemic risk in the calculative tools used by the actors, rather than in their individual biases and limitations.

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On June 12th, 2001 the European Commission stated its firm opposition to the planned merger between two Fortune 500 companies. The Commission's ruling put an end to the proposed combination between General Electric and Honeywell International, initially announced in October 2000. As news of the cancellation arrived on Wall Street, Honeywell's stock price fell by more than ten percent. The drop caused losses of more than \$2.8 billion to the professional arbitrageurs, hedge funds and investment banks that expected the merger to succeed. Beyond their size, the losses are significant because they penalized arbitrageurs, the pioneering users of financial models. For three decades now, quantitative finance has brought to Wall Street complex tools once confined to the realm of science (MacKenzie 2006). The failed merger between GE and Honeywell is thus fertile ground to understand the possibilities and pitfalls posed by financial modeling. What role, if any, do models play in financial disasters?

We address this question with an ethnographic study of financial modeling. Our study focuses on the daily operations of a major international investment bank, pseudonymous "International Securities," located on Wall Street. Its proprietary trading unit lost \$6 million dollars in the GE-Honeywell deal. In examining this outcome, our analytic point of departure is the dilemma posed by models: they offer their users the possibility of extraordinary returns, but also create the risk of catastrophic losses. Our study investigates the ways in which traders grapple with their own fallibility, and how their efforts are mediated by models. Arbitrageurs, we found, not only use models to take positions but also to check their estimates

against those of their rivals. This form of reflexive modeling, however, can be dangerous because it creates cognitive interdependence among financial actors. A trader's position becomes the cautionary sign used by his or her rivals. When a sufficiently large number of arbitrageurs overlook a critical factor driving merger failure, the use of models can provide misplaced confidence, leading to widespread and oversized losses. The occurrence of such losses has been well documented in the finance literature, and is referred to as "arbitrage disasters" (Officer 2007).

Our analysis contributes to economic sociology by challenging the dominant accounts of systemic risk, rooted in behavioral finance. Behavioral accounts have attributed financial crises to individual biases: imitation, overconfidence, or lack of reflexiveness on the part of market actors. Our analysis questions this view by arguing that arbitrage disasters are not the outcome of these biases, but instead an unintended consequence of the material tools deployed by the actors – financial models-- to reduce risk and increase returns. In this sense, our study points to the double-edged nature of models. Along with greater precision and fewer losing trades, financial models also introduce the danger of oversized and widespread losses, that is, disasters.

In the following pages we examine the ways in which models lead to crises. Our context is modern arbitrage. The first element of our study is to use our ethnographic observations to reconstruct how the arbitrageurs at International Securities dealt with a particular merger. That is, from numerous hours of observations across many trades, we offer a detailed analysis of a particular arbitrage opportunity. Our presence in the trading room meant that we could

analyze a given merger from the moment the merger desk learned about its announcement. We analyze how the traders “set up the trade,” starting with the PowerPoint presentations and videos from the merger announcement, leading to the use of Excel spread sheets and proprietary databases. With these modeling tools the traders build a picture of the merger, anticipating the future by drawing analogies to the past.

Second, our ethnographic observations also demonstrate a counterintuitive aspect of financial modeling. Taking a position is only the first step in the trading process. Our research explores the next step, in which traders cast a sceptical eye on their own estimates. To do so they exploit the fact that other traders have also taken positions on the trade. Our arbitrageurs turn to a peculiar form of modeling, known as “backing out,” that yields the rivals’ estimate of merger probability. Knowledge of this implied probability can trigger search processes along new dimensions in previously unexamined territories. We refer to such a mechanism as *reflexive modeling*. Gaps, disparities, differences, and mismatches can produce positive friction that stimulates re-search. The lack of them gives traders greater confidence that their views are correct.

The final step of our analysis examines how this reflexive process can contribute to arbitrage disasters. If a sufficiently large number of arbitrageurs simultaneously fail to see a merger obstacle ahead, the use of implied probability will provide traders with misplaced reassurance, leading them to expand their positions and suffer widespread, potentially catastrophic losses if the merger is cancelled. The reflexive use of models, in other words, creates systemic risk.

UNDERSTANDING INTERDEPENDENCE IN MODERN FINANCE

Our study speaks to a growing interest in the interplay between models, systemic risk, and financial crises. Existing studies, mostly in behavioral finance, emphasize either the social or the model-related aspects of financial crises – but fail to present a comprehensive portrait that takes both into consideration.

Perspectives from behavioral finance

One major strand of the behavioral literature points to overconfidence and excessive risk taking. According to the “house money” effect (Thaler and Johnson 1990) individuals become more willing to take risks when their performance improves – even if the underlying probability distribution remains unchanged (see also Battalio et al. 1990; Keasey and Moon 1996). But this research does not take models into account. Its underlying assumption is that actors construct a sense of risk and opportunity by direct assessment of their past performance. Modern modeling techniques, however, provide the decision-maker with alternative tools to estimate the probability distribution that he or she confronts. Traditional accounts of excessive risk-taking, thus, need to be updated to reflect the quantitative nature of how investors size up uncertainty.

By contrast, financial models dominate “black swan” accounts of financial crises. Building on the Knightian distinction between risk and uncertainty, several authors have argued that crises occur when the unquestioned use of financial models leads banks to underestimate uncertainty (Taleb 2007; Derman 2004; Bookstaber 2007). The models used by these investors, the argument goes, assume a future that is excessively similar to the past. Investors assume, for instance, that

stock returns follow a Normal distribution. However, financial markets are social settings and therefore subject to unpredictable extreme events, or black swans. Instead of a Normal distribution, stock returns are more accurately described by fat-tailed distributions. To the extent that investors do not incorporate these exceptions into their models, their trading will be subject to the risk of disaster.

An important shortcoming of the black swan argument is that it presents financial actors as hopelessly irreflexive about the limitations of their models. According to the proponents of the black swan, traders either ignore what every finance academic already knows – namely, that extreme events happen – or lack the reflexive capacity to act on it. Confronted by this argument, we ask, why should we deny to financial actors the capacity for reflexivity that we prize and praise in our own profession?

Beyond overconfidence and modeling errors, behavioral studies have stressed the collective nature of financial disasters. This social dimension is captured by the economic concept of systemic risk: the danger posed by the failure of a single entity to other actors and possibly the entire financial system (Mishkin 1995; Bartholomew and Whalen 1995; Allen and Gale 1998). Systemic risk is predicated on the existence of linkages between market actors. These interdependencies, typically induced by liquidity constraints, can turn isolated losses into a cascading failure that bankrupts the entire system. In this sense, liquidity creates tight coupling. The classic example of this dynamic is a banking crisis: the default of an individual bank can prompt fears among depositors of other banks, leading to economy-wide withdrawals and further failures.

This view of systemic risk, however, is overly narrow. Because financial models are a form of distributed cognition, exploring the systemic dangers posed by models calls for the study of *cognitive* interdependence, as opposed to simply financial interdependence. In other words, it calls for a study of the ways in which models make a trader's beliefs dependent on the actions of others.

In this regard, behavioral studies have pointed to dynamics of imitation among financial actors. The mechanism, known in the literature as "herding," takes place when actors decide to disregard their own information and imitate instead the decisions taken by others before them (Scharfstein and Stein 1990; see also Banerjee 1992; Bikhchandani, Hirshleifer and Welch 1992 on information cascades). In the context of finance, herding adds to systemic risk by leading investors to artificially bid up the price of an asset, thereby contributing to financial bubbles (Shiller 1984 2000).

Theories of herding, however, do not explore how financial models make cognitive interdependence more or less acute. In the classic model, herding actors simply disregard their own opinion for the sake of conforming to others (Scharfstein and Stein 1990). Beliefs, in other words, are replaced rather than combined, with the actors metaphorically disconnecting their brains to act according to the dictates of the mass. In our view, a theory of how models create interdependence should explain how actors combine their beliefs with those of rival traders. Lacking a theory of how actors use social cues to update their beliefs, theories of herding do not clarify how the financial models make imitation more or less likely.

Insights from economic sociology

Taken together, behavioral studies of systemic risk lack a framework for specifying the nuanced interdependencies that make risk social in modern, anonymous, model-centered markets. One form of this interdependence can be found in the competing literature in economic sociology. Here, the canonical study of systemic risk is offered by Merton's account of a run on a bank. As Merton (1968) observed, banking is a special form of economic activity in that it is subject to positive feedback between beliefs and behavior – that is, to self-fulfilling prophecies. Because a depositor's decision to draw out his or her funds reduces the liquidity available to other depositors, the collective perceptions of a bank's solvency among its depositors end up sealing the fate of the bank.

Self-fulfilling prophecies, however, are still an incomplete guide to modern systemic risk. In the standard account, these prophecies entail an over-abstracted, almost tautological portrait of how crises happen. *If* a sufficiently large number of depositors fear a crisis, the run on the bank will surely happen. But as Callon (2007) asks, *how* do these beliefs arise in the first place? One answer might be that these beliefs are a shared convention. But this poses the additional question of how depositors coordinate their views around a given convention in the first place. The answer, Callon suggests, points to the material basis of belief formation. For instance, a line forming outside a retail bank branch can be enough to prompt fears of a bank run. In more advanced forms of financial activity, financial models could be one such form of coordination. Theories of self-fulfilling prophecies, in other words, need to account for the ways in which material tools and techniques

coordinate the beliefs of market actors. Our interest is to explore how financial models might be one such source of coordination.

In sum, understanding modern systemic risk not only calls for understanding the existence of social dynamics among investors. It also calls for studying the ways in which financial models mediate these social dynamics.

In advancing towards that goal, four core sociological ideas orient our inquiry. First, the embeddedness perspective, developed by Granovetter (1985), Baker (1984) and others, provides a useful framework to conceptualize interdependence. The notion that market transactions are structured by personal ties in social networks can certainly explain some aspects of systemic risk. It has, for instance, direct bearing on phenomena such as Ponzi schemes, where clients are introduced to the scheme through friendship networks.¹ But the notion of embeddedness, developed before the full impact of the quantitative revolution on Wall Street, needs to be reconsidered in settings where personal networks have been augmented by the socio-technical networks that accompany financial models. Embeddedness presupposes the existence of personal acquaintance among social actors; by contrast, current markets are shaped by deliberate anonymity. To put it succinctly, embeddedness is excessively centered on people. What is the counterpart of embeddedness when the only actor that a trader sees is a screen?

In this respect, the application to markets of the analytic tools of Science and Technology Studies (STS) offers useful guidance. To understand anonymous

¹ The premier example of a Ponzi scheme is of course the recent fraud perpetrated by Bernard Madoff. The key question raised by the Madoff case concerns the ways in which the financier managed to elicit enough trust to obtain not simply thousands, but millions of dollars from investors, without any transparent account of the destiny of the funds.

transactions, argue Callon and his colleagues,² we must analyze the materiality of calculation (Callon 1998, 2007). Once a market has been designed to depersonalize transactions, actors turn to market devices such as financial models to perform calculations. These models frame decisions and quantify alternatives, thereby exerting a mediating role on the value of goods and securities. But Callon's theories, which eloquently account for the ways in which investors calculate smoothly, does not account for systemic risk. The notion that anonymous investors act in complete independence of each other is not attentive to the actual processes in which these investors make moves in relation to others. To capture systemic risk, researchers need to contemplate how interdependence exists among *anonymous* financiers.

In short, grappling with modern crises calls for an understanding of novel forms of engagement introduced by financial models. Models have given rise to a new mode of sociability, disembedded yet entangled; impersonal but nevertheless social. In attempting this redefinition of "the social," we draw on Knorr-Cetina's (2006) notion of *scopes*, or observational instruments. Knorr-Cetina draws a distinction between network-centered and scope-centered markets. In the former, personal relations carry the burden of coordination ("network architectures"). In the latter, objects are the central coordinating device. The actions of investors are projected onto a scope, creating a representation that investors can react to. Their reactions, in turn, become part of this representation. Investors, in other words, do not react to each other but to the aggregate traces of each other's actions, as seen on

² See also Callon 1998, 2007; MacKenzie and Millo 2003; Mackenzie 2006; for reviews, see Fligstein and Dauter 2007; Healy and Fourcade 2007; Ferraro, Sutton and Pfeffer 2005.

the scope. Such new rules of association – aggregation, anonymity, and mediation through shared representation – offer fertile grounds to theorize the ways in which systemic risk can originate in financial models.

While not explicitly referred to as such, the notion of scopic engagement underlies MacKenzie and Millo's (2003) work on performativity and the Black-Scholes formula for options pricing (see also MacKenzie 2006, and Millo and Mackenzie 2008). In our reading of their work, an economic model is performative when its use improves its predictive ability. According to these authors, performativity took hold as traders began to use the Black-Scholes model in reverse. Using the formula backwards allowed traders to translate option prices into a measure of "implied volatility." That is, it allowed them to see the estimates of future volatility of rival traders. This critical transformation of the formula into an observation instrument illustrates the mechanism of scopic engagement discussed by Knorr-Cetina.

However, MacKenzie and Millo (2003) do not take the extra step: exploring the implications of performativity for systemic risk. Thus, MacKenzie's (2006) analysis of Long Term Capital's debacle in 1998 turns to a traditional conceptualization of "the social," in the form of isomorphism. Specifically, he explains the systemic dimension of the financial crisis as the result of "consensus trades," that is, institutionalized trading strategies that arose from social interaction among investors. The dangers posed by financial models are not exhausted by MacKenzie's (2006) analysis. Financial models, we contend, create a distinct form of interdependence that needs to be understood. Once traders rely on anonymous

competitors for crucial insight, a novel mechanism of social influence exists. What potential pitfalls does it pose?

RESEARCH METHODS

Research site. The data reported below are taken from our observations of the merger arbitrage desk at International Securities. The firm is a top-ten global bank in equity underwriting (Hoffman 2006) with an active proprietary trading unit. 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 an investment bank. 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 study focuses on arbitrage, an ideal site to examine the role of models in systemic risk. Arbitrage exploits financial mispricing across markets by determining the similarity across differently-priced securities, partly by using financial models (Beunza and Stark 2004; Derman 2004). While this use of models has proved successful, leading to legendary returns and a seven-fold increase in the number of arbitrage firms in the past two decades (Lo 2008), arbitrage has also been associated with several recent financial crises. These include the market crash of 1987, the crisis of Long Term Capital in 1998 and the hedge fund "mini-crash" of August 2007 (see, respectively, Dunbar 2000; MacKenzie and Millo 2003;

Lowenstein 2000; Jorion 2004; MacKenzie 2006; Khandani and Lo 2007).

Our study centers on merger arbitrage. Unlike other arbitrage strategies, merger arbitrage allows us to identify financial failure. That is, it allows us to separate the perceptions of financial actors on Wall Street from the actual events that unfold outside it. Merger arbitrage is an “event-driven” strategy. It boils down to informed speculation about the likely completion of corporate mergers. Our traders, in other words are not simply monitoring the positions of others in order to anticipate “where the crowd is moving.” Rather, they do so to derive the expectations of other traders about the likelihood of an event – the merger – that will, in the end, happen or not happen. And that event, the merger, is by and large independent of the collective wagers of the arbitrage community. Thus, the specific form of specularity involved in merger arbitrage differs from Keynes (1936) view of financial markets as beauty pageants (see Dupuy 1989) in that arbitrageurs can collectively be wrong. This makes merger arbitrage ideal to understand financial crises.

We explore the role of models in merger arbitrage with an ethnographic research design. Ethnography is particularly useful to understand the day-to-day practices of calculation, for it places the researcher in the same uncertainty about the future as his or her subjects experience, thereby avoiding the danger of retrospectively underestimating uncertainty (Orlikowsky 1992; Barley 1986; Agar 1986; Spradley 1979). Partly for that reason, ethnography has been a method of choice in the social studies of finance literature (Abolafia 2001; Knorr-Cetina and Bruegger 2002; Zaloom 2003; Beunza and Stark 2004).

Period of observation. Our study is based on a three-year engagement with the bank, extending to more than sixty visits between the Fall 1999 and the Spring of 2003. From this period we highlight an arbitrage disaster, the failed GE-Honeywell merger, and a subsequent morning of trading on March 27th, 2003. Understanding the mechanisms of disaster on the basis of one morning of regular business offers several advantages. First, by providing a symmetrical treatment of success and failure, our study avoids the trappings of the sociology of error (Bloor 1976), in which “the social” is only seen as the source of dysfunctional behavior. Thus, models of herding only consider the negative aspects of social interaction, our study explains disasters in the same way that it explains extraordinary success. A second advantage of focusing on a single morning is that it offers a disciplining device for the research. Rather than piecing together observations from different visits, our account shows that reflecting on what rival arbitrageurs think is a central activity for the traders, seamlessly integrated with taking positions and estimating merger likelihood through the day.

ANATOMY OF A MERGER ARBITRAGE TRADE

Distributed cognition

Our focal morning of observation at the merger arbitrage desk started at 9:00 am on March 27th, 2003, minutes before the US markets opened. We found the arbitrageurs quietly working at their computers. Oswald, the junior analyst among the three, was absorbed in a succession of PowerPoint slides displayed on his screen, isolated from the others by a pair of headphones. Max and Anthony, senior

and junior traders respectively, were entering data from a sheet of paper into Excel spreadsheets. They worked 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.”

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 of the previous day, with the market already closed. The arbitrageurs confronted the news on 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.

The impression of inactivity proved to be misleading. Far from ignoring the announcement, the traders were reacting to it in their characteristic way, preparing a trade. The first step in this process was the elaboration of a memorandum. The memo summarized the key details of the Whitman-Career combination. Oswald 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.

Preparing the trade entailed a further step. The traders proceeded by codifying the document into an Excel spreadsheet, known as the “Trading Summary.” This functioned as a brief of all the trades in which the desk was involved. On the morning of May 27th 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.

These early observations underscore 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 an Excel spreadsheet, all of it condensed into a single live cell on a Trading Summary. In short, cognition is distributed at the merger arbitrage desk. Like the pilots and ship crew studied by Hutchins and colleagues (Hutchins and Klausen 1996; Hutchins 1999), arbitrageurs can reduce their cognitive overload – the extent of their bounded rationality – by turning to the machines and instruments around them. Arbitrageurs are aware and understand this process, and refer to it as “setting up” the trade. As we shall see, however, even as arbitrageurs enroll machines in their calculations, taking up a position is far from mechanical, for it involves a good deal of judgment and interpretation.

Judgment

Amidst the hubbub of the data entry, the arbitrageurs sized up the nature of the newly announced merger. Categories, analogies, and other references to the past

allowed them to engage in pattern recognition that would lead them to take a position. At 9:40 am, for instance, Max and Oswald engaged in a dialogue about Whitman and Career. “Do they have regulatory approval?” asked Max, without taking his eyes off the screen. “They do,” Oswald replied, looking at his spreadsheet. “Do they have accreditation?” Max inquired. “What schools are these, anyways?” Max added emphatically, his eyes squinting at his screen. “Technical, for adults” Oswald responded. “They teach you things such as how to be dentist assistant,” he added.

The conversation, a seemingly casual exchange about Whitman, was an effective first step in estimating merger probability. This probability is the figure that arbitrageurs care about most. The basic principle of modern arbitrage is to exploit mispricings across markets. These situations arise when two different regimes of value coexist in ambiguity (Beunza and Stark 2004), and merger arbitrage is no exception. 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 or lower. 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.

In their exchange, Max and Oswald established a set of facts that subsequently proved relevant to establish this probability. For instance, they established that the merged company, if completed, would belong to the “for-profit post-secondary education sector.” The usefulness of this categorization became clear at 9:45 am, as 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 Oswald, 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,” Oswald replied. The weakness in sales, in other words, was the school holidays – a normal part of the education industry. Because the companies belonged to the education industry, the cyclical drop-offs in sales were not a relevant merger risk. Categorizing Career and Whitman, we concluded, helped arbitrageurs interpret information that could have material implications for merger completion.

Arbitrageurs complement categorizations with analogies to past mergers. At 9:50 am, the conversation shifted to a discussion of another company in the for-profit education sector. “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 (Denison 2002). 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.

Analogies, we conclude from our observations, help arbitrageurs anticipate possible merger obstacles. Like categories, analogies allow them to glean the future from the past. “We look for patterns,” Max explains, “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.” In the case of Career and Whitman, the analogy associated two merging secondary-education firms with a for-profit *primary* education company, Edison Schools, previously marked by corruption. The analogy associated the merging firms with another one from outside their industry. But the association between Edison Schools and the merging companies prompted a new concern: it led the arbitrageurs to focus on the honesty of the management teams at Career and Whitman. The flexible use of partly overlapping categories and analogies underscores that arbitrageurs do not just passively fit mergers into boxes.

The arbitrageurs also benefit from non-obvious parallels with other deals. Max recalls a merger between two junkyards that had incompatible databases. In the low-tech world of junkyards, one might not anticipate information technology to be a key factor in derailing a merger. But, Max added, “if the point of a junkyard is to find that door for the 1996 Volvo, you can imagine how important databases are. We had another deal with similar proprietary databases in a different industry [that] reminded me of that junkyard deal.” The arbitrageurs correctly predicted the failure of the merger between the junkyards and closed their positions early enough to avert any losses. As Max concludes, “drawing parallels and linkages and saying

‘this reminds me of that’ is at the heart of what we do.”

The traders, however, do not just rely on their own memory to draw those associations. At 9:55 am 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 to look for patterns that were similar to the Whitman-Career deal. The screen corresponded to a proprietary database that Max has meticulously assembled over the years, with information about all past mergers in which the desk has been involved, classified along numerous dimensions. This gives “thumbnail” information about each company that merged. “You think you would remember,” Max says about it, “but you don’t. Memory is very deceiving.” Like the other arbitrage artefacts presented above, the database contributes to distribute cognition at the trading desk. Specifically, by providing a costless system of storage and retrieval of past information, the database helped arbitrageurs mobilize past deals to make sense of current ones.

After two hours of establishing associations, the arbitrageurs were beginning to develop an overall impression of the Whitman-Career merger. Max explained,

There may be many issues with this company, but I can invest right away by knowing that they’re a \$5 million company and a \$2 million company. This means it’s not one company acquiring another that’s the same size, which right away means that there are not financing issues involved. If there were, it would be a whole different game.

In other words, even though the industry – for-profit education – was tainted by a past scandal, the traders were still encouraged by the lack of other obstacles.

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, signaling to the traders a potential opportunity. "I'd like to have a presence in the deal," said Max almost immediately. "Let's bid \$13.60 for 10,000" he added. Following the instruction, Anthony lifted the headset from his phone turret and called the block trader to place an order. Thus, barely two hours after starting to work on the deal, the merger traders at International Securities took a position in the Whitman-Career merger.

Why take a position within minutes of the opening? Arbitrage, we observed, is a game of speed. The longer arbitrageurs take to adopt a position, the more time their competitors have to seize the opportunity before they do. As in Occam's razor, arbitrageurs take into account as many factors as they need to take a position, but not more. Taking a position, then, involves a successive winnowing of the possible contingencies involved in the merger as the arbitrageurs think through the deal. The traders search through a form of mental decision tree in which each specific merger is considered in relation to similar deals that they encountered in the past. Max explains, "it's almost like you've been in this road before and [the past incidences] direct you." The advantage of this system, which Max describes as a "process-driven arbitrage," is that numerous issues need not be taken into account. Arbitrage, in other words, is fast, light, and deploys resources in a strategic manner.

The arbitrageurs, in other words, are not simply performing a routine task of recognition – classifying mergers into pre-existing categories – but a far more active task of *re-cognition*. That is, changing, expanding, and going beyond the

existing categorical structure to ascertain the key merger obstacles in a given deal. It is for these reasons that the arbitrageurs have not attempted to automate the process of sizing up a merger. According to Max, “it’s impossible to turn [the process] into a purely quantitative exercise. There’s judgment.”

Representing the collective rival

Our analysis so far has established two related observations about merger arbitrage. First, it is clear that the arbitrageurs deploy sophisticated quantitative tools. Second, they also exercise their judgment. But, no matter how sophisticated their tools and judgment might be, their views are still fallible.

As we shall see, the traders confront their own fallibility by distancing themselves from the categories and procedures that guided them to an initial position. This, however, is easier said than done. Mental awareness of the limits of one’s view does not automatically provide a check against these limits. Traders, we found out, gain some cognitive distance from their categories by exploiting the fact that other arbitrageurs have also taken positions on this trade. It is to the second moment of a distributed cognition – across a socio-technical network outside the trading room – that we turn.

At 10:30 am, the conversation between Max, Oswald, and Anthony shifted from Career and Whitman to another ongoing merger. Five months before our morning visit, Hong Kong and Shanghai Bank (HSBC) had announced its intention to acquire Household International, an American bank specialized in subprime mortgages. The traders at the merger desk had been “playing” this deal.

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 evolution of the “spread” between HSBC and Household. The spread is defined as the difference in the prices of the merging companies, adjusted for the terms of the merger. In this case the spread corresponded to the difference in the prices of HSBC and Household over the five-month period in which the merger unfolded, weighted by the stock conversion ratio agreed by the merging partners: 0.535 shares in HSBC for each share in Household International.

[Figure 1 and Figure 2 about here.]

Visualizing merger likelihood. The graph, known as the “spread plot,” plays a key role in the work of the traders. Movements in the spread signal changes in the likelihood of merger completion. If a merger is completed and the two merging firms become a single entity, the difference in their stock prices – the spread – will disappear. Thus, arbitrageurs interpret a narrowing of the spread as a sign that other arbitrageurs collectively assign a greater likelihood of merger completion. Conversely, if the merger is canceled and the equivalence between the two firms disappears, the spread will revert to its wider level before the merger announcement. Thus, arbitrageurs interpret a widening spread as a sign that other arbitrageurs collectively assign a lower likelihood of merger completion.

Using the spread plot involves semiotic sophistication. In this complex system of signs, the spread plot provides each trader an indirect sign of the likelihood of the merger, achieved by signaling the aggregate of his or her rivals’ assessment of that likelihood. For the very reason that they are deeply proprietary,

the trader does not have access to the proprietary databases through which *particular* other rivals constructed their own independent probability estimates. And, indeed, to have such access would result in cognitive overload: how could one gain cognitive distance from one's own models if one had to engage in the time-consuming task of comparing them with those of dozens of other traders? The spread plot reduces that cognitive complexity by representing the *aggregate* of the expectations of other traders.

The arbitrage trader, however, is not interested in the spread plot as a sign of what others are doing in the market. They read the spread as a sign of an event that will or will not happen in the world – the merger. The promising aspect of *this* sign is that it is quasi-independent of a trader's own estimates of the probability of merger. That is, the arbitrage trader is not a technical trader who, like the fashionista who monitors others to anticipate the hottest clubs, seeks to profit by anticipating market trends. Instead, arbitrageurs use the movements of their rivals *as a check* on their own independent opinion.

The HSBC-Household merger illustrates how the spread plot helps traders (see chart on Figure 2). 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 22nd 2002, was inspired by funding concerns: was HSBC simply buying Household to get funding? In other words, was HSBC a sound company? This surge in the spread subsided after a general market rally. The second spike took place on March 20th 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. Even more interestingly, the obstacles underscored by the spread plot may not have been taken into account by the arbitrageurs in their initial decision process; that is, these concerns might have been unexplored as a abandoned branch as the traders advanced in their tree-like decision pattern. Checking the spread plot, then, is a way to avoid cognitive lock-in by the decision tree.

Translating prices into probabilities. A second key concept mobilized by the arbitrageurs is the “implied probability” of a merger. By implied, the arbitrageurs refer to the probability of completion that rival arbitrageurs assign to the merger. Quantifying this probability entails manipulating the basic regularity governing arbitrage, the Law of One Price, in a process known as “backing out.”

Backing out merger probabilities builds on the notion of risk-neutral pricing. The core idea behind this practice is to extract useful information from mispricings in markets where arbitrageurs are present (Cox and Rubenstein 1979; Harrison and Kreps 1979). As the Law of One price argues, the presence of arbitrageurs eliminates unjustifiable differences in prices across markets. (For instance, in the absence of transportation costs, the price of gold in London would not systematically differ from that of gold in New York without inviting the activity of arbitrageurs.) Given this, the difference in prices between New York and London can be interpreted as the cost of transportation. In other words, by assuming that the

Law of One Price, arbitrageurs are able to transform price differences into useful information.

Merger arbitrageurs apply this idea to a different setting -- corporate mergers. When a merger is certain and arbitrageurs are present, the uncertainty-adjusted value of a merger target and acquirer should be the same. The difference in prices between the two – the spread – can therefore be read as a measure of the uncertainty that arbitrageurs assign to the merger.

This operation is probabilistic in nature. Backing out the degree of uncertainty about a merger amounts to inferring a probability distribution on the basis of the payoffs. Consider, for instance, the toss of a coin. The decision-maker is not told the probabilities of heads or tails, but is told the payoffs involved in the bet. He or she is and is also told that they are *fair* – that is, that they are those that would make both players even after multiple rounds. With all that information, a decision-maker should be able to infer those probabilities from the payoffs. For example, if the payoffs are \$1 (heads) and minus \$1 (tails), a decision-maker can infer that the probabilities are 50-50. As Max says of merger arbitrage, “I would not need to describe the game to you at all, just the payoffs. And backing out from the payoffs, you would be able to infer the probability.” (See the Appendix for a mathematical expression of this idea.)

In this sense, backing out is an indirect form of observation. Just as office employees with a limited view of the sky can anticipate the likelihood of rain by checking for pedestrians carrying umbrellas, arbitrageurs check for merger obstacles by monitoring the aggregate actions of their rivals.

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 (in the coin example, that the prices are “fair”). For that reason, unless rival arbitrageurs have seen the relevant prices, compared them to their own information and acted upon it, the spread will not convey their private knowledge. 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.

This scheme gains additional complexity in the case of mergers that have “collar” provisions. A merger collar is a legal clause that alters the ratio at which the merging firms will exchange their shares if the price of the acquirer changes substantially. As a result, the deal's value fluctuates based on the price of the acquirer's stock. This structure is beneficial for the acquirer because it limits the overpayment risk, but it makes it more difficult to calculate the implied probability on the basis of prices.

Paradoxically, the difficulty posed by the collars benefited Max by creating arbitrage opportunities that only he was able to see. As he explains,

I was one of the first people to use pretty elementary probability theory combined with not-so-elementary log normal distribution and expected value to establish the right approach to collar deals. Initially, there were aberrations in the pricing. Over time, they disappeared.

Max, in other words, is acutely aware of the power of financial models. His pioneering efforts in this direction won him a reputation around Wall Street, leading to invitations to lecture in universities and routine appearance in the financial press as an authority on ongoing deals.

Gaining distance

“Are we missing something?” By 12:00 pm, the spread between Whitman and Career remained at the same wide margin it displayed two hours before, ten percent. Early on, a ten percent spread signaled an opportunity. But its persistence posed a puzzle for the traders, for it could now be interpreted very differently. It could mean, first, that other professional arbitrageurs were not “playing” the deal for some genuine reason: *“Are we missing something?”* Max asked. 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 faced 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, in other words, did not show anything they did not know in advance.

The database search is an instance of the way in which arbitrageurs respond to the discrepancy induced by the spread plot. Having observed the dissonance between their own probability estimates and the implied probability, the traders went back to search 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 need to be dug deeper.

The traders’ approach contrasts with early neo-institutionalist views of markets. In the classic account, the availability of social clues leads actors to economize on their search costs by imitating others (Meyer and Rowan 1976; DiMaggio and Powell 1983). 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.

A cultural artifact on Max's desk sums up this professional *habitus*. 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-deprecating 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, in 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.

This interpretation of the cartoon is consistent with the ways in which Max speaks about implied probability. To him,

It's a reality check. It's a number that's out there and it challenges everyday when you come in to have 85 percent confidence in this deal, whatever that is. You could have a little sign saying, are you challenging yourself in every day on every deal.

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, Anthony 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. No other arbitrageur, the floor broker implied, was 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 Anthony, 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 decided to inquire about the identities of the shareholders, partially lifting the veil of anonymity that protects securities trading. In doing so, the arbitrageurs were seeking to clarify whether backing out made sense in this context: that is, was the spread reflecting the information in the hands of rival arbitrageurs? The traders concluded it was not.

The traders, however, were emphatically not mimicking their rivals. Theirs was not a case of classic isomorphism or herding. Instead, they were attempting to disentangle overall market movements 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 desk cuts both ways: whereas an hour or so earlier, the spread plot had led 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 light of the above, consider now why Max told Anthony “pick your spots.” The expression reminded Anthony to cover his tracks as he increased the desks’ position on Whitman, with the aim of avoiding an increase in its stock price. The traders’ efforts suggest that Max and colleagues felt they were being observed by other arbitrageurs through the lens of the spread. 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.

Reflexivity as a socio-technical process. The developments described above suggest that the traders’ caution unfolds as the confrontation between two related magnitudes. A trader’s ability to mobilize prices for greater precaution hinges on the encounter between the probability of the merger, estimated at the desk -- and implied probability, obtained from the market. This comparison provides an

invaluable advantage: it signals to traders the extent of their deviation from the market, warns against missing information, motivates additional search, prompts them to activate their business contacts, and provides the necessary confidence to expand their positions.

This distinct combination of internal and external estimates points to a novel use of economic models, which we refer to as reflexive modeling. The expression denotes the process whereby dispersed market actors employ economic models to confront their own estimates. This confrontation pits a trader's estimates against those of his or her rivals, thereby introducing dissonance in his or her calculations. This dissonance is attained through the construction of implied probability. This variable is a representation of an economic object that does not have a price,³ is otherwise not observable, and is co-produced by the positioning of actors who use it to confront their interpretations and re-evaluate their positions. Collectively produced, the implied probability is a device for dissonance. Reflexive modeling thus denotes a heightened awareness on the part of the arbitrageurs about the limits of their own representations of the economy.

³ The peculiar nature of implied probability is best understood in comparison to market prices. Hayek (1945) famously described markets as a self-organizing system of coordination in which prices were 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. Implied probability, however, differs from Hayek's prices on three counts. First, unlike coordination for the purpose of resource allocation, arbitrageurs do not seek to coordinate with other arbitrageurs but to deviate from them in pursuit of speculation. Second, the problem of the arbitrageurs is not only dispersed information but, most acutely, heterogeneous, disparate interpretations. Third, there is no market for mergers: that is, there is no market in which the event, a given merger, has a price.

From personal networks to financial models. The use of the spread is a telling sign of the calculative orientation of the arbitrageurs. Up until the late 1980s, merger arbitrageurs focused on anticipating the merger *announcement* by pursuing rumors from the networks of the traders. Currently, however, arbitrageurs center their bets on merger *completion*, which can be anticipated with the modeling tools described above, that is, the spread plot and implied probability. Thus, whereas the typical strategies of investors traditionally entailed accessing information ahead of their competitors (Abolafia 1996), merger arbitrageurs base their advantage on financial models. These models have given arbitrageurs enough precision to access profit opportunities that did not exist before.

Max emphasized this important shift with an example. “Look at this jump,” he said, in reference to the brusque price movement of Household International on the day its merger with HSBC was announced (see Figure 3 below). He added,

This is the value that the [mutual] 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.

Thus, in other words, the arbitrageurs eschew the fat margins that can be found by correctly anticipating the merger announcement, and only come into the trade once the deal is officially announced. The narrow margins to be obtained once the announcement is made are open to them, thanks to the precision of their quantitative techniques. Indeed, this shift in strategy was not only motivated by the availability of tools but also by the dangers involved in relying on rumors and privileged information. The indictment of merger arbitrageur Ivan Boesky in 1986

on charges of insider trading discouraged the rest of the arbitrage community from exploiting privileged information about unannounced mergers.

[Insert Figure 3 about here]

In line with this long-running shift from rumors to models, the traders have come to see nuanced interpretation, rather than raw information, as the source of their advantage. 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 a differential 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 privileged information. As Max said, "right now, the data is all on the Internet, even the SEC filings." That is, most of the information is widely available and therefore does not confer any advantage. To him, it resulted from his desks' distinct interpretation of publicly available data.

Our account so far presents the bright side of financial models. Thanks to reflexive modeling, arbitrageurs have increased the accuracy of their estimates, gaining access to new opportunities while reducing their risk. As we shall see, however, there is also a dark side to financial modeling. Because arbitrageurs use models to check their positions against the rest of the market, the diffusion of reflexive modeling creates cognitive interdependence between otherwise independent rivals.

Arbitrage disasters

The preceding analysis of the morning in the trading room sets the stage to return to the events of June 2001 presented in the introduction. The cancellation of the merger between General Electric and Honeywell International imposed collective losses on arbitrageurs of \$2.8 billion. An *arbitrage disaster* is a concept developed in the literature in financial economics, and is defined as “deal failures that cause merger arbitrageurs worst-loss day exceeding \$500 million” (Officer 1997: 12). Officer (2007) characterizes GE-Honeywell as an arbitrage disaster, and indeed, the most serious one. Our analysis suggests that the GE-Honeywell disaster was the unintended consequence of reflexive modeling.

The history of the GE-Honeywell disaster is in many ways the history of a fatal neglect. Arbitrageurs overlooked the danger that the European Commission might oppose the merger. Indeed, the traders had reason to do so: in the past, the anti-trust authorities of the United States and Europe had consistently coordinated their rulings. Never before, in other words, had a merger authorized in Washington been blocked in Brussels (Bary 2001: 43). This time, however, the precedent was broken by Mario Monti, the famously rigorous European commissioner, on the grounds that the merger would give the combined entity an ability to engage in anti-competitive “bundling.” The ruling caught arbitrageurs by surprise, inflicting disastrous losses upon them.

[Table 1 and Figure 4 about here.]

Our examination of the episode points to cognitive interdependence as the cause of the arbitrageurs’ neglect. We make this claim on the basis of three observations: the

fact that losses at International Securities resulted from a form of overconfidence; that this overconfidence was shared by rival arbitrage funds; and that it was diffused by the spread plot and reflexive modeling.

First, our conversations with the head of the trading room at International Securities – which was active in the deal – make clear that their losses were a result of misplaced confidence in the deal. According to Bob,

Max traded it ... everyone's database lacked a field, and the field was "European regulatory denial." ... I encouraged him [Max] 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, the desk lost six million because it increased its exposure to the trade, and the increased exposure was the result of high confidence in the deal.

Second, the traders' confidence was not a psychological disposition, but a calculated response to the narrowing spread. As the narrow GE-Honeywell spread on Figure 5 shows, arbitrageurs assigned a very large implied probability to the merger in the months before May 2001.

[Figure 5 about here.]

Third, the narrow spread was itself a consequence of the fact that numerous arbitrageurs had missed the danger of European regulatory opposition. This can be deduced from a comparison between the merger spread plot and the media response to the news of concerns at the European Commission. The bar chart in Figure 5 shows the number of weekly articles in the business press that included in their text the words "Honeywell" and "Monti." These include publications such as *The Wall Street Journal*, *The Financial Times*, *The Economist*, etc. The spike in the number of articles on February 27th 2001 shows that the media had genuine concern about

European opposition.⁴ But even as it voiced these concerns (leading to a surge of the bar in February 2001), the spread between the merging companies barely inched. The implication is that the arbitrage community was not sharing the concern.

In sum, our examination of the failed GE-Honeywell merger points to cognitive interdependence as the cause of the arbitrage disaster. Specifically, our analysis suggests that the losses at International Securities stemmed from an underestimation of the merger's key derailing factor; that this underestimation was made worse by the narrow spread; and that the spread was narrow because most other arbitrage funds had also overlooked the risk of European opposition. In other words, the individual overconfidence of independent arbitrage funds reinforced each other via the spread plot. The spread plot thus acted as a source of cognitive interdependence. Were it not for this device and the practice of reflexive modeling, trading losses would have been less profound and widespread.

How serious are arbitrage disasters? The consequences of the GE-Honeywell fallout were substantial. The total dollar loss across all merger arbitrageurs in this deal was \$2.8 billion, according to Officer (2007); see Table 1. Industry-wide, the merger arbitrage community has experienced several arbitrage disasters in the past three decades. Furthermore, these disasters have not abated over time, and their size appears to be growing larger.

⁴ "Brussels," the *Financial Times* wrote on February 28th, "tells GE to re-do merger homework" (Hargreaves and Hill 2001: 10). "For Mr. Monti," *The Economist* added, "the danger is that GE-Honeywell will be able to use the muscle it gets from a range of related products to squeeze rivals out of the market" (*The Economist*, 2001:43).

Reflexive modeling and arbitrage disasters. Arbitrage disasters point to the dark side of reflexive modeling. Disasters start when active arbitrage funds overlook a potential cause of merger failure. Or as Max puts it, “when there is a first impression and people don’t have a basis for handicapping it properly.” This initial oversight is then compounded by the fact that each individual arbitrage fund erroneously takes the other funds’ lack of visible concern (the absence of spikes in implied probability) as reassurance that the merger will be completed. The added confidence leads each fund to increase its position, compounding its losses when the merger is canceled. Reflexive modeling, in other words, amplifies individual errors when all arbitrage funds think alike.⁵ Whereas the *dissonance* induced by implied probability typically improves trading, reflexive modeling can also lead to a disastrous form of *resonance*.

COGNITIVE INTERDEPENDENCE AND SYSTEMIC RISK

The starting point of our study is the challenges and paradoxes introduced by quantitative revolution on Wall Street. How are markets social when the dominant tools of work are impersonal? How do markets collapse when careful reflexivity is the norm? Understanding the modern roots of systemic risk calls for an understanding of financial interdependence even in situations of anonymity and reflexivity.

Beyond individual biases

Our analysis of arbitrage disasters challenges the behavioral account of systemic risk. Instead of ascribing crises to excessive risk-taking, misuse of the

⁵ Khandani and Lo (2007) explain the crisis of August 2007 in the similarity in strategy across hedge funds.

models, or irreflexive imitation, our notion of reflexive modeling offers an account of crises in which problems unfold in spite of repeated reassurances, early warnings, and an appreciation for independent thinking. Specifically, our findings challenge behavioral views of crises as the outcome of excessive risk taking such as the house money effect (Thaler and Johnson 1990). The arbitrageurs we studied deploy detailed proprietary databases and model-driven mechanisms of reflexiveness that combat overconfidence. As noted, it is precisely this reflexiveness that can lead to disasters, not the absence of it.

Arbitrage disasters also question the black-swan approach to financial crises. This approach contends that models cause problems by inducing an underestimation of extreme events. Our observations, however, show that traders at the merger desk were keenly aware of the fallibility of their own assessments; hence their reliance on reflexive modeling.

Finally, the notion of reflexive modeling challenges the applicability of the behavioral notion of herding to contemporary finance. Models of herding, cascades, and rational imitation explain how a dysfunctional form of mimesis can purposefully set into a market, brewing trouble in the future. The merger arbitrageurs that we observed, however, used the spread plot in a far more reflexive manner. As we noted in the case of the Whitman-Career merger, these arbitrageurs retained their views in the face of divergence with the market. Indeed, they mobilized discrepancy to widen their search and gain greater confidence in their position. Furthermore, the *quant* culture at the bank celebrates individual inquiry and looks down on aping competitors.

These considerations point to the benefits of incorporating the tools of trading into the study of quantitative finance. Implicit in the behavioral accounts of systemic risk is an emphasis on the individual biases and limitations of the investors. At the extreme, investors are portrayed as reckless gamblers, mindless lemmings, or foolish users of models they do not understand. By contrast, our detailed examination of the tools of arbitrage offers a theory of crisis that does not call for any such bias. The reflexive risks that we identified befall on arbitrageurs that are smart, creative, and reflexive about their own limitations. In its emphasis on market devices, our study adds to the literature in the social studies of finance (Knorr Cetina and Bruegger 2002; MacKenzie and Millo 2003; Beunza and Stark 2004; Preda 2006; Zaloom 2003; Lepinay 2005; Muniesa 2000; Beunza and Garud 2007).

Scopic engagement

Our study adds to economic sociology by offering a new way to conceptualize sociability in markets shaped by models. Traditional sociological accounts prove to be limited. The embeddedness perspective is a useful point of departure, but personal ties are often absent in arbitrage.

In that sense, our arbitrageurs can be said to realize the grand vision of the strawberry market analyzed by Callon (1998). As with French strawberry traders, the introduction of anonymity and calculating tools disentangled arbitrageurs from the rest of their profession. Mathematical sophistication, in other words, liberated our arbitrageurs from the obligations of constant reciprocity and the penury of the networking event. Nonetheless, our traders were too sophisticated to place all their

trust on their own views.

The skepticism of the arbitrageurs, however, requires considerable creativity, for the classic solution to the problem of uncertainty – herding and isomorphism – is unavailable to them. Candidates for imitation are nowhere to be seen, thanks to the anonymity induced by quantitative tools. Instead, arbitrageurs turn to models for reflexivity. Using models in reverse, traders find out what their rivals are collectively thinking. As they react to this knowledge, their actions introduce a degree of interdependence that is absent in Callon (1998).

Quantitative tools and models thus give back with one hand the interdependence that they took away with the other. They hide individual identities, but let traders know what the consensus is. Arbitrageurs are thus not embedded in personal ties, but neither are they disentangled from each other. Decoding the intellectual challenges posed by modern finance calls for an understanding of this elusive interdependence. Building on Knorr-Cetina (2007), we adopt the term scopic engagement. Scopic markets are fundamentally different from traditional social settings in that the tool, not the network, is the central coordinating device.

Reflexivity as material practice

Calculative tools are crucial to merger arbitrage. In its simplest form, merger arbitrage rests on the contraposition of two screens. In one, traders develop their own assessment of the likely success of corporate marriages. But they know that their assessment is fallible. As a result, they turn to a second representation of the deal and exploit the dissonance between the two. Arbitrage disasters happen when the two representations march in misleading lockstep.

These two screens capture the thought-worlds of the arbitrageurs and their external environment. The first, an Excel spreadsheet, summarizes how the traders think about the merger. This so-called Trading Summary builds on a web of associations, including categories and analogies, leading up to the key issue facing the deal. Every company has one such spreadsheet, built from its own proprietary data. Because they are proprietary, companies cannot see the spreadsheets of their rivals. The second screen, the spread plot, is shared by all arbitrage funds. The spread plot captures how competitors think about the merger by showing the difference in the prices between the merging companies.

Reflexivity is possible because the friction between the two representations clue arbitrageurs that they might be missing a material obstacle to the merger. The premise of the system is that whenever an arbitrageur misses a relevant merger obstacle, rival arbitrageurs with a different view will prompt a dissonant chord (a spike in the spread plot), leading to additional search and correction. Thus, the dual screen system lets arbitrageurs confront their own associations against those of their rivals. Arbitrageurs compare the two representations and exploit the difference for reflexive purposes. Instead of substituting search with imitation, as in the classic form of mimetic isomorphism, arbitrageurs use social cues to complement their search.

Reflexive modeling, in other words, can be seen as a form of stereoscopic vision, as in the two-eyed form of vision that characterizes human sight. Just as the human brain gains a third dimension – a sense of depth, indeed distance – by the comparison of two flat images (left, right eye), arbitrageurs gain a sense of

opportunity and risk.

As a practice of using a model to gain cognitive distance, reflexive modeling is a cognitive process. But it is not taking place in the heads of the traders, as if cognition could be turned back onto itself. Just as the cognitive process of deriving their own probability estimates is socially distributed across the tools and instruments at the arbitrage desk, so reflexive cognition (Stark 2009) is a socio-technical process of distributed cognition triggered by the spread plot – a device for dissonance that is itself a socio-technically constructed object. Thus, the reflexivity of the traders is not a mental process or a solipsistic practice. The traders we observed were not engaging in some heroic mental feat, 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-granted of their models were cognitively disrupted by devices for dissonance.

Cognitive interdependence and systemic risk

There is a dark side to the process described above. The strength of reflexive modeling resides in leveraging the cognitive *independence* among dispersed, anonymous actors. But as we saw in the case of arbitrage disasters, it can also give rise to cognitive *interdependence*. Just as reflexive modeling can be a source of correction, it can also lead to the amplification of error.

Given the above, do financial models add or reduce risk to market participants? In escaping that false dichotomy, we draw on the sociology of risk developed by Luhmann (1993) and others (Beck 1992; Giddens 1999). The

distinction drawn by Luhmann between first-order risks and second-order dangers argues that risk is rarely eliminated in modern societies. Efforts to mitigate risk, whether through technology or organizational means, often give rise to unintended consequences in the form of second-order dangers. In this sense, arbitrage disasters can be seen as an unintended consequence: as the second-order danger that results from risk mitigation through reflexive modeling. Our study thus extends the work of Holzer and Millo (2005) on market crises such as the implosion of Long Term Capital in 1998 or the role of program trading during the 1987 market crash. In both cases, as in ours, the unintended consequences of risk mitigation arise from feedback effects that come into play once a financial innovation is widely adopted.

The problem of cognitive interdependence also adds to the performativity literature by highlighting the possible dangers posed by performative processes. A model is performed when its adoption increases the accuracy of its predictions (Callon 1998; MacKenzie and Millo 2003). The proponents of performativity, however, have not considered how performative mechanisms can threaten the actors that make performativity possible. Our analysis of merger arbitrage suggests how. Reflexive modeling is a performative mechanism: it has narrowed merger spreads, that is, made the prices of stocks undergoing merger processes closer to the predictions stemming from the Law of One Price. But as we saw, the adoption of reflexive modeling has also increased the interdependence between merger arbitrageurs, giving rise to arbitrage disasters. In this sense, arbitrage disasters can be seen as a form of *performativity trap*, in that the same mechanism that made the model more accurate also gave rise to disasters.

The traps and dangers of reflexive modeling also speak to the academic debate on the credit crisis. Existing accounts pit the relative role of incentives versus that of the tools used by market actors (MacKenzie 2008; Salmon 2008; Tett 2009a, 2009b). Our analysis of cognitive interdependence adds to the tool-based view by suggesting how such devices can add to cognitive interdependence and therefore to systemic risk. Indeed, Tett's (2009b) analysis of the crisis suggests that credit derivatives traders might have engaged in a form of reflexive modeling. According to Tett, the worst excesses of the bubble were associated with creation of new indexes such as iTraxx, CDX or ABX in 2006. These indexes allowed mortgage traders to back out implied correlations in credit default swaps on the basis of the indexes. The company that designed these indexes, Tett (2009b) writes, turned "from a camera into an engine," creating a feedback mechanism that "allowed the market to explode."

CONCLUSION

Following three decades of rapid expansion in a low-regulation environment, quantitative finance now faces the likely prospects of regulatory reform. Our analysis informs the academic debate about the regulation of finance. Since the late 1980s, financial institutions have replaced administrative controls with model-based risk management techniques, leading to a situation of self-regulation by modeling. The persistence of arbitrage disasters points to the limits of this setup. The arbitrageurs at International Securities, for instance, were not able to avoid arbitrage disasters by simply trading off less risk for higher returns. As the GE-Honeywell merger shows, disasters strike precisely when arbitrageurs mistakenly believe they are playing it safe.

Notably, the some entrepreneurial actors seem to have found a way to exploit arbitrage disasters. According to the Clow (2001), the New York hedge fund Atticus Global has developed a strategy to exploit arbitrage disasters such as the GE-Honeywell deal. Atticus bets against mergers when other arbitrageurs are most confident in them.⁶

Beyond self-regulation, our analysis suggests a theoretical framework for thinking about the regulation of financial modeling. First and foremost, our findings should not be read as a denunciation of financial models. Certainly, the models used to back out implied probabilities are necessary to produce reflexive disasters. But by allowing arbitrageurs to be reflexive, these models are averting other difficulties.

Recognizing the fallibility of financial models underscores the importance of diversity of perspectives. Reflexive modeling requires a requisite variety of views among the arbitrage community. Policies that favor participation in arbitrage trading add to this diversity, while policies that restrict participation will reduce this diversity.

Our analysis also provides a way to think about the relative advantages of regulatory disclosure and oversight of arbitrage. As with other innovations, reflexive modeling poses dangers because of its success. In the presence of widespread diffusion, reflexive modeling gives rise to positive feedback, leading to aggregate consequences that are different from its more obvious individual effects. Recognizing this wedge calls for the creation of a government agency that, as the Food and Drug Administration does with new compounds, examines possible unintended

⁶ According to Clow (2001: 25), “Most risk arbitrage managers followed their usual strategy of going long the target, Honeywell, and short the buyer, GE. Atticus shorted Honeywell and bought GE, making a 10 per cent return on its investment.”

consequences of new financial innovations (See Lo 2008 for a related proposal). By obtaining access to the positions of all arbitrageurs, such agency could conceivably see disasters as they brew up.

At the same time, our framework makes clear that such a move would not be without costs. By entangling banks and their regulators, government intervention can eliminate the possibility of calculative action. It could alter market engagement from scopio back to embedded: a return to lobbying, dinners with government officials, and guessing games about future public policy. Indeed, an embedded regime could mark a return to the 1970s, when the Federal Reserve Bank of New York regularly met with the “money center” –the ten largest New York banks—and exerted monetary policy through informal suasion.

Paradoxically, the regulatory solution to the risks posed by models necessarily involves a greater use of models. Given the breadth and complexity of the current financial system, it is inconceivable that regulators could reform the system and prevent future systemic failures without the help of modeling techniques such as stress testing and network analysis. As this reform takes place, further research in economic sociology will be required to understand the interplay between models used for the purpose of profit-seeking, risk management, and regulatory objectives.

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Appendix A: Backing out implied merger probability from stock prices. A formal approach.

The implied probability of a merger can be derived from the merger spread. The method is based on the classical results of the Arrow-Debreu theory of contingent claims, and the probabilities that are derived are known as risk neutral probabilities. Here we follow the notation of (Vidyamurthy 2004: 177). See Jarrow and Turnbull (2000) for an expanded treatment.

According to Arrow-Debreu, any two bets with the same expected payoff have the same current value. Denote by S_0 the merger spread at time zero. Upon the successful completion of the deal, the spread will converge to zero. The position is reversed at no additional cost at time T , and the reward earned by the investor will be $e^{rT}S_0$, with r being the interest rate. If there is cash paid out as well, the payoff will be $e^{rT}S_0 + \text{cash}$. If, on the other hand, the deal ends up in failure, the spread will not converge to zero, but will rise to a value of S_T . The net payoff will then be $e^{rT}S_0 - S_T$.

By the no arbitrage condition, the expected payoff is zero. Writing out the equations, we have:

$$\pi_{\text{success}} (e^{rT}S_0 + \text{cash}) + \pi_{\text{failure}}(e^{rT}S_0 - S_T) = 0 \quad [1]$$

$$\pi_{\text{success}} + \pi_{\text{failure}} = 1 \quad [2]$$

Solving the two equations, we have:

$$\pi_{\text{failure}} = \frac{e^{rT}(S_0 + e^{-rT} \text{cash})}{S_T + \text{cash}} \quad [3]$$

Table 1. Arbitrage disasters, 1990-2003.

Acquirer	Target	Cancelation date	Percentage holding by arbitrageurs	Implied total losses, \$000s
General Electric Co	Honeywell International Inc	10/2/2001	53	2,798,376
American Home Products Co	Monsanto Co	10/13/1998	45	2,335,367
British Telecommunications PLC	MCI Communications	11/10/1997	40	1,908,240
Tellabs Inc	CIENA Co	9/14/1998	34	1,179,412
Investor Group	AMR Co	10/16/1989	36	712,042
Staples Inc Inc	Office Depot	7/2/1997	44	558,804
Investor Group	UAL Co	10/18/1989	29	542,058
Abbott Laboratories	ALZA Co	12/16/1999	46	525,194
Tracinda Corp	Chrysler Co	5/31/1995	42	458,918
Revlon Group	Gillette Co	11/24/1986	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	5/18/1989	29	165,816
Investor Group	Goodyear Tire & Rubber	11/20/1986	25	145,344

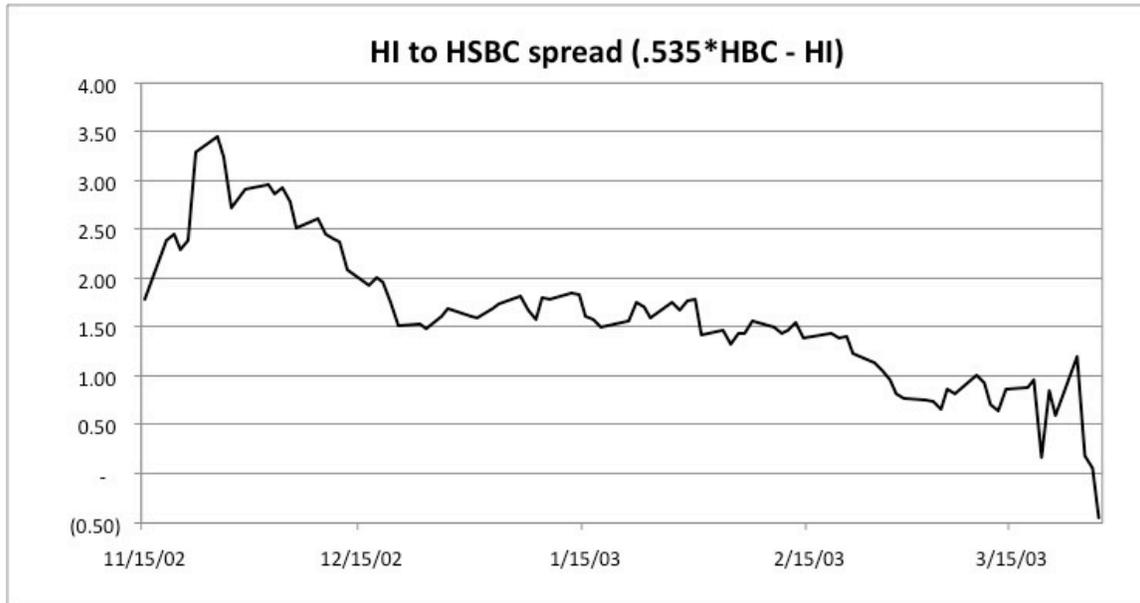
This table contains details of the fifteen largest merger arbitrage disasters from 1985 to 2004. All dollar arbitrage losses are in 2004 dollars. Arbitrageurs' percentage holding is the percent of target shares outstanding reported as owned by arbitrageurs at the first quarterly 13F reporting date after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

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.

Figure 2. Charting the implicit probability of merger.



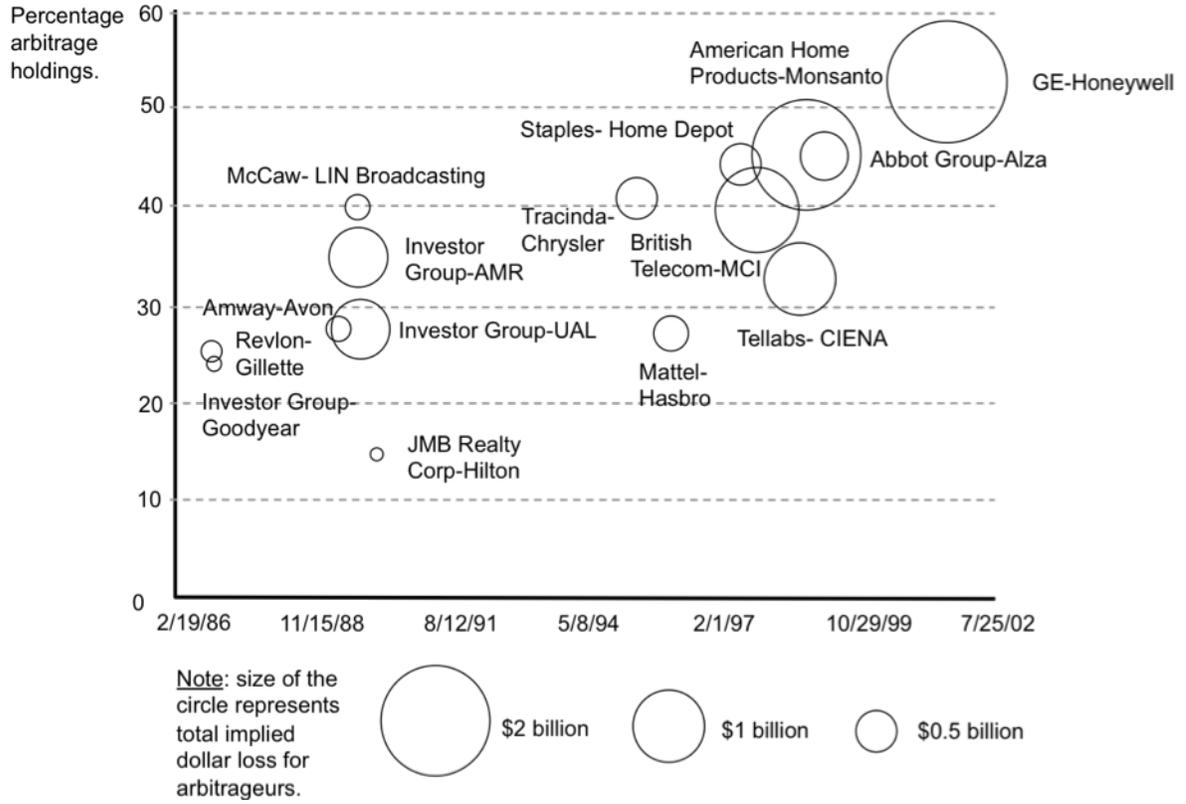
Spread plot of Household International and HSBC Bank. The two spikes in the figure, November 22nd and March 20th, correspond to events that called the merger into question. 2002 to May 2004. Source: Bloomberg.

Figure 3. The jump in the spread on merger announcement date.



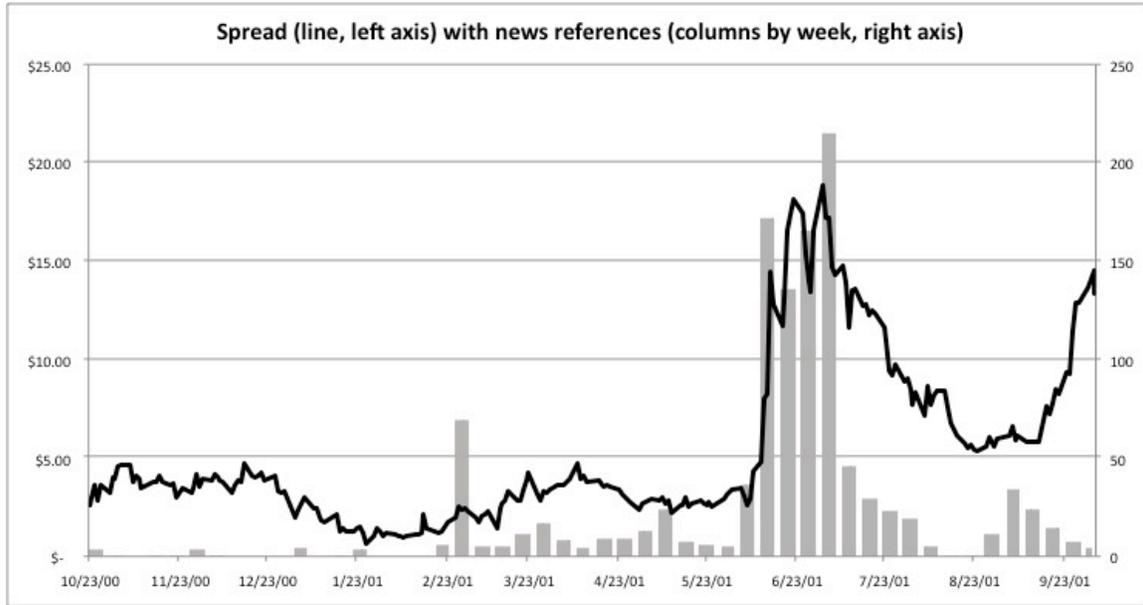
Spread plot of Household International and HSBC Bank, before and after the merger announcement. The jump in the spread on November 2002, corresponds to the merger announcement. Contemporary arbitrageurs, however, focus their trading on the post-announcement period. Source: Bloomberg.

Figure 4. Merger arbitrage disasters



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

Fig. 5: Arbitrageurs overlooked the danger of European opposition.



Spread between GE and Honeywell (line) and media concern over EC opposition to the merger (bar). The graph shows that the surge in media concern in late February was not matched by a corresponding increase in the merger spread. Source: Bloomberg and ABI/In.