Risk Arbitrage: Analysis and Trading Systems

by

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Abstract

In this thesis we quantify the risk arbitrage investment process and create trading strategies that generate positive risk-adjusted returns. We use a sample of 895 stock swap mergers, cash mergers, and cash tender offers during 1998 – 2004Q2. We test the market efficiency hypothesis, and after accounting for transaction costs, we find that our risk arbitrage strategies generate annual risk-adjusted returns in excess of 4.5%. The research also obtains various other merger statistics, and relates them to a variety of economic indicators and merger timing models, as described in past work. We also estimate conditional probabilities of a merger's success, using a deal characteristic-driven prediction model, and combine it with market-implied probabilities. Our analysis suggests that the probability of success of a merger depends on a deal's characteristics. Further, it implies that one can improve on the market-implied estimates thereby creating trading opportunities. The analytical results achieved in this thesis can be used as the foundation for building an effective risk arbitrage trading platform.

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Finally, special thanks to my family for their unwavering love and support. My aunt and uncle in Boston, Upma and Manish, have also both been very caring.

This thesis is dedicated to all the people who have enriched my life, from childhood to present.

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Chapter 1

Introduction

"Give a man a fish and you feed him for a day. Teach him how to arbitrage and you feed him forever."
— Warren Buffet [4]

Arbitrage, in its classic form, involves the identification and capture of value resulting from price differences between two or more identical or related assets. However, risk arbitrage is an event-driven investment process which involves the purchase and/or sale of securities affected by announced transactions, including mergers, acquisitions, spin-offs, and corporate reorganizations. The arbitrageur invests with the intent of profiting from changes in the value of the securities on the consummation of the transaction.

Although a small community of professionals had practiced risk arbitrage in the United States for several decades, the strategy was popularized during the corporate takeover frenzy of the 1980s. Today, investment managers employ risk arbitrage strategies at an extensive number of firms (see Figure 1-1), where they have realized its potential to generate significant returns with low correlation to systemic stock market risk. These characteristics have made risk arbitrage an attractive investment management diversification tool.

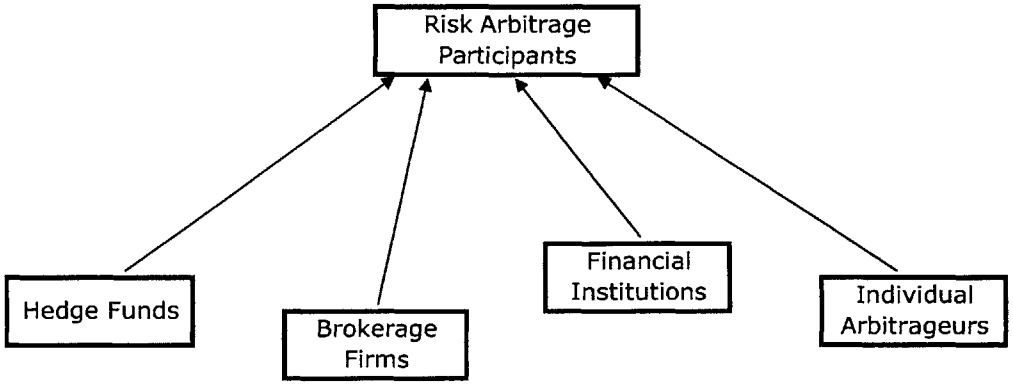

Figure 1-1: Risk arbitrage industry participants

1.1 Background and Previous Work

The risk arbitrage position essentially constitutes a "bet" on whether the proposed transaction event of deal is consummated. The spread between the market values of consideration received in the deal (i.e., acquirer's stock, cash, etc.) relative to the market values of securities to be given up (i.e., target's stock) reflects the bet's payoff. Between the time of announcement and that of its closure, two factors primarily dictate the magnitude of the spread: the time value of money and the risk premium.

Risk arbitrage invokes images of extraordinary profits and implosions. Numerous articles in the popular press detail large profits generated by famous arbitrageurs such as Ivan Boesky [2] and even larger losses by hedge funds such as Long Term Capital Management [11]. The existing academic studies demonstrate that risk arbitrage strategies generate substantial excess returns. For example, Mitchell and Pulvino [8], using a sample of 4,750 merger offers from 1963 – 1998, find that risk arbitrage creates excess returns of 4% per year. Jindra and Walking [7] and Dukes *et. al.* [6] focus on cash tender offers between 1971 – 1985 and document annual

excess returns far exceeding 100%. In a study using a diversified portfolio of risk arbitrage positions in the U.S. cash and stock mergers between 1981 – 1996, Baker and Savaşoglu [1] conclude that risk arbitrage generates excess returns of 12.5%.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YTD
1997	3.02	1.28	-0.01	0.33	3.46	2.59	3.1	0.33	4.09	0.93	1.63	1.54	24.6%
1998	0.7	4	3.21	1.31	-1.32	-0.6	-0.22	-9.94	-0.59	1.47	3.37	2.3	3.0%
1999	2.66	-0.35	3.4	6.17	2.13	3.06	1.45	-0.33	0.25	-0.32	2.86	3.65	27.3%
2000	1.49	4.11	1.36	-0.45	-0.63	2.15	1.11	2.35	-0.03	-0.3	-1.27	1.7	12.1%
2001	2.96	0.29	-0.7	0.93	1.91	0.93	0.25	0.21	-2.65	1.36	1.06	1.6	8.4%
2002	0.65	-0.88	1.61	0.59	0.21	-3.55	-3.32	0.27	-1.55	0.45	2.56	0.26	-2.8%
2003	1.21	0.07	0.76	3.1	3.67	1.78	1.01	1.52	1.23	2.22	1.36	2.21	22.0%
2004	2.69	1.63	0.43	-0.35	-0.7	1.28							3.9%

Figure 1-2: Monthly/Annual returns for event-driven hedge funds, Source: Barclays Risk-Arb Index

The practitioner community has long included dedicated risk arbitrage partnerships and individual arbitrageurs. Today, several hedge funds operate focused event-driven groups and opportunistically pursue risk arbitrage strategies, thereby generating substantial returns for their investors, see Figure 1-2.

We also revisit the issue of merger timing models with respect to economic factors and capital market conditions [14, 16]. In particular, we explore the relationship between merger activity and valuation levels in the capital markets, Figure 1-3 and find several characteristics of the data speaking to the questions of when mergers occur and how they are funded.

1.2 Mergers and Acquisitions

A merger or acquisition represents a defining moment for the acquiring company. No other single corporate action has such a marked effect on the future performance of an acquiring company. Motivations for conducting mergers and acquisitions vary,

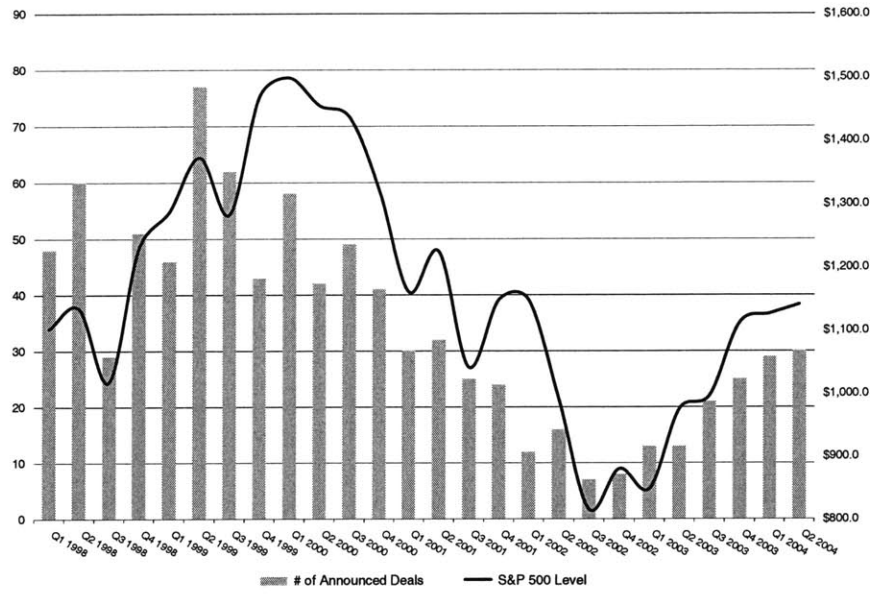

Figure 1-3: Announced merger deals since 1998 and S&P 500 level

but many focus both on realizing potential cost synergies and other benefits from economies of scale as well as fueling growth by acquiring a company with an attractively valued set of services and/or products. Strategic considerations for conducting a merger or an acquisition often include a geographic extension of current products and/or services. The desire to combine complementary products or services which enhances the acquirer's overall business mix may also be included. However, conducting a merger or acquisition creates unique execution risks for the acquiring company, and as history proves, integration difficulties can erode the potential value of a transaction.

The announcement of a merger or acquisition conventionally accompanies investor inquiry regarding the general strategic merits of the combination. If skepticism follows the transaction, shareholders tend to first sell and then later determine the value of the combination. General shareholder skepticism stems from the myriad of execution risks that accompany any proposed merger or acquisition. Typically,

closing conditions become numerous and may include U.S. and foreign regulatory approval, shareholder approval, state and local approvals, as well as the satisfaction of disclosure conditions contained within the merger agreement. At times, shareholders believe the efforts required to satisfy these closing conditions distract management from focusing on the day-to-day operations of the acquiring company. These doubts create opportunities for arbitrageurs to take on calculated "bets" based on such deals.

1.3 Thesis Contributions

In this thesis we quantify the risk arbitrage investment process and create trading strategies that generate positive risk-adjusted returns. We use a sample of 895 stock swap mergers, cash mergers, and cash tender offers during 1998 – 2004Q2, see Figure 1-4.

Initial shareholder reaction is critical to any successful merger deal, as a declining acquirer share price may spark opposition to the transaction and attract hostile bidders towards the target company. To analyze this reaction, we conduct an event study to scrutinize and determine which market and merger-related attributes lead to an adverse initial reaction in the acquirers share price in the event of the announcement of a merger or acquisition.

Deal Status	# of Deals	%	Aggregate Value ($mil)
Completed	792	88.5	$3,560,541
Terminated/Withdrawn	103	11.5	$811,028
Total	895	100	$4,371,569

Figure 1-4: 1998–2004 merger data set used for analysis, Source: Bloomberg

We then perform a probit analysis on the data to obtain a merger prediction model and implement the Mitchell and Pulvino [8] risk arbitrage portfolio policies on this data. We test the market efficiency hypothesis, and after accounting for transaction costs, we find that our risk arbitrage strategies generate annual risk-adjusted returns in excess of 4.5% with variations across deals. We also estimate conditional probabilities of a merger's success, using our prediction model, and combine with market-implied probabilities. Our analysis suggest that the probability of success of a merger depends on a deal's characteristics. Further, it implies that one can improve on the market-implied estimates thereby creating trading opportunities.

We also quantify the risk and return process within risk arbitrage strategies in a novel and effective manner. The analytical results achieved in this thesis can be used as the foundation for constructing an effective risk arbitrage investment management process.

Chapter 2

Acquirer Share Price Reaction

We conduct an analysis of acquirers' share price reactions to announced transactions. We compile data on all mergers and acquisitions involving public targets and public acquirers from January 1, 1998 through June 30, 2004. In order to best interpret the share price reaction of acquirers, we first provide a brief statistical review of the 895 announced mergers and acquisitions during the past five years. We then use these results as a motivation to build models for aiding in the risk arbitrage investment process.

In aggregate, 895 transactions over $400 million in value involving public U.S. or Canadian targets were announced. The aggregate value of these announced transactions is roughly $4.4 trillion[1]. Of these 895 transactions, 103 prevail as either withdrawn or terminated (88.5% completion rate), as shown in 1-4.

[1]For some perspective, the aggregate market cap of all the companies in the S&P 500 at the end of 2003 was about $10.3 trillion.

2.1 Price Reaction

An acquirer's share price trades down 3% on the day of an announced merger or acquisition, as shown in Figure 2-1. This result matches our intuition, as investors generally react cautiously to the announcement of a merger or acquisition and may decide to sell the acquirer's stock due to a perceived elevation in execution risks. From a technical standpoint, this result is not surprising, as typically risk arbitrageurs initially short sell the acquirer and buy the target company to set up a hedged arbitrage position.

However, based on our data set, acquirer share prices generally do not rebound in the days following the announcement of a merger of acquisition. On average, we ascertain that acquirer share prices are still down 3.2% in the subsequent 15 trading days after announcement. Contributing to this result is the continued pressure arbitrageurs place on acquirer shares as they build positions in the deal. Interestingly, this short pressure is not mitigated by fundamental buying, as it appears that investor apprehension toward the announcement is not temporary.

Years	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
1998 -- 2004 Q2	895	-3.0%	-3.2%	-3.1%	-3.2%	-3.1%	-3.1%	-3.1%	-3.2%

Figure 2-1: Acquirer share price reaction post merger/acquistion announcement

2.1.1 Yearly

To determine the yearly variability of acquirer share price reactions, we break our data set by calendar year, as shown in Figure 2-2. The range of acquirer returns (excluding S&P 500 performance) on announcement date is negative 1.5% to negative 5%, which suggests a significant calendar year difference: Importantly, no yearly

average proves positive. The two years of largest negative initial reactions are 2000 and 2002, when acquirer share prices trade down 5.0% and 3.9%, respectively. The two years of the least negative initial reactions are 1998 and 1999, when acquirer share prices trade down 1.5% and 2.5%, respectively. These acquirer share price reactions appear generally tied to overall market conditions and investor sentiment. In 2000 and 2002, the S&P 500 posted negative returns, and in 1998 and 1999, the S&P 500 posted positive returns.

Years	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
1998	187	-1.5%	-2.1%	-2.2%	-2.1%	-2.4%	-2.4%	-3.0%	-3.6%
1999	229	-2.5%	-2.5%	-2.5%	-2.9%	-2.8%	-2.7%	-2.6%	-2.7%
2000	191	-5.0%	-5.6%	-5.7%	-5.7%	-5.5%	-5.2%	-4.8%	-5.0%
2001	112	-0.3%	-2.2%	-1.8%	-1.8%	-1.8%	-1.7%	-1.8%	-1.2%
2002	43	-3.9%	-2.9%	-2.7%	-2.5%	-1.9%	-2.7%	-2.7%	-2.5%
2003	74	-3.1%	-3.4%	-3.2%	-3.4%	-3.1%	-2.6%	-2.9%	-2.6%
2004 YTD	59	-2.5%	-2.9%	-2.9%	-3.3%	-3.1%	-3.2%	-3.5%	-2.9%

Figure 2-2: Acquirer share price reaction post merger/acquistion announcement computed annually

2.1.2 Quarterly

As expected, the variability of average acquirer share price reactions increases when analyzing quarterly data. Figure 2-3 highlights the quarterly breakdown of average acquirer share price reactions from 1Q98 through 2Q04. In the 26 quarters we analyzed, 25 induce negative average acquirer share price reactions on the day of the announcement of a merger or acquisition. Overall variance remains high as quarterly acquirer share price performance ranges from negative 6.9% (1Q03) to positive 0.3% (3Q98).

The quarterly S&P 500 performance partially explains the high variance of quarterly average acquirer share price reactions. Generally speaking, negative quarterly

Quarter	S&P Return	Avg VIX Level	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
98 Q1	13.5%	21.4%	47	-0.5%	-0.8%	0.0%	0.4%	0.4%	0.3%	-0.7%	-1.1%
98 Q2	2.9%	21.5%	60	-2.1%	-2.4%	-2.9%	-2.9%	-3.2%	-3.1%	-4.4%	-4.4%
98 Q3	-10.3%	29.8%	29	0.3%	-0.7%	-1.4%	-0.9%	-1.2%	-2.3%	-2.0%	-3.1%
98 Q4	20.9%	29.5%	51	-2.8%	-3.7%	-3.9%	-4.0%	-4.6%	-4.1%	-4.2%	-5.3%
99 Q1	4.6%	27.3%	46	-3.0%	-3.2%	-3.6%	-3.2%	-3.2%	-3.3%	-4.3%	-5.8%
99 Q2	6.7%	24.4%	77	-3.2%	-3.4%	-3.2%	-3.7%	-3.3%	-3.1%	-2.9%	-2.8%
99 Q3	-6.6%	23.3%	62	-1.4%	-0.9%	-0.6%	-0.9%	-1.2%	-1.0%	-0.3%	-0.4%
99 Q4	14.5%	22.6%	44	-2.1%	-2.6%	-3.0%	-3.8%	-3.9%	-3.7%	-3.4%	-2.7%
00 Q1	2.0%	23.1%	58	-4.6%	-5.4%	-6.2%	-6.0%	-5.5%	-5.8%	-6.0%	-8.2%
00 Q2	-2.9%	24.3%	43	-6.1%	-6.6%	-6.8%	-6.3%	-6.3%	-6.4%	-3.8%	-5.1%
00 Q3	-1.2%	19.2%	49	-4.4%	-4.1%	-4.4%	-4.3%	-3.7%	-3.3%	-4.0%	-3.1%
00 Q4	-8.1%	26.0%	41	-5.2%	-6.4%	-5.2%	-5.6%	-5.3%	-5.6%	-5.1%	-2.9%
01 Q1	-12.1%	25.7%	30	-4.0%	-2.7%	-1.8%	-2.3%	-1.5%	-1.5%	-1.5%	0.2%
01 Q2	5.5%	24.0%	33	-2.8%	-2.7%	-2.4%	-2.8%	-2.3%	-3.1%	-3.8%	-2.0%
01 Q3	15.0%	25.4%	25	-1.9%	-2.0%	-2.6%	-1.3%	-1.4%	-0.8%	-0.9%	-0.9%
01 Q4	10.3%	27.9%	24	-1.4%	-0.9%	-0.4%	-0.4%	-1.4%	-0.9%	-0.4%	-2.4%
02 Q1	-0.1%	21.4%	12	-3.1%	-2.0%	-2.9%	-2.0%	-1.5%	-1.7%	-1.1%	-0.1%
02 Q2	-13.7%	21.6%	16	-4.1%	-3.4%	-3.3%	-3.2%	-2.2%	-3.6%	-3.8%	-3.8%
02 Q3	-17.6%	35.1%	7	-5.6%	-4.3%	-2.6%	-2.8%	-2.4%	-3.1%	-2.0%	-3.1%
02 Q4	7.9%	30.7%	8	-3.4%	-1.9%	-1.5%	-1.5%	-1.5%	-2.2%	-3.6%	-2.7%
03 Q1	-3.6%	30.0%	14	-6.9%	-6.8%	-6.6%	-7.2%	-6.3%	-5.5%	-5.6%	-7.1%
03 Q2	14.9%	21.5%	14	-0.6%	-0.9%	-0.7%	-0.7%	0.6%	1.2% 1	.8% 3.	6.0%
03 Q3	2.2%	19.3%	21	-2.2%	-3.3%	-2.7%	-3.2%	-3.5%	-2.7%	-3.2%	-2.8%
03 Q4	11.6%	17.4%	25	-3.0%	-2.9%	-3.1%	-2.8%	-3.0%	-2.9%	-3.9%	-3.6%
04 Q1	1.3%	16.7%	29	-2.6%	-3.1%	-3.1%	-3.2%	-2.9%	-2.8%	-3.2%	-1.8%
04 Q2	1.3%	16.2%	30	-2.5%	-2.8%	-2.7%	-3.3%	-3.4%	-3.4%	-3.8%	-3.8%

Figure 2-3: Acquirer share price reaction post merger/acquistion announcement, by quarter

returns loosely associated with lower-than-average[2] acquirer share price reactions. The four quarters of poorest average acquirer share price reactions (00Q2, 00Q4, 02Q3, and 03Q1) each feature negative quarterly S&P 500 returns. Significantly, these four quarters also associate with high absolute levels of the CBOE SPX Volatility Index (VIX), see Figure 2-4. This suggests that during times of high market-implied volatility, indicating high perceived market risk levels, investors are more acutely aware of merger-related execution risks. However, the converse does not generally occur. Periods of historically low levels of the VIX do not generally associate with above-average acquirer share price reactions.

[2] A negative reaction implies a drop in price for a stock.

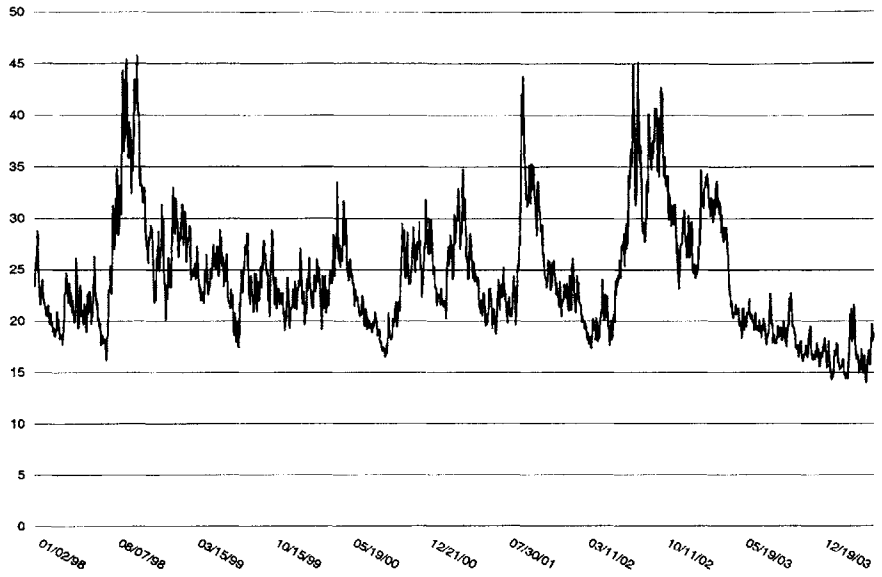

Figure 2-4: The Chicago Board of Exchange S&P 500 Volatility Index, 1998–2004Q2

The overall performance of the market can influence average acquirer share price reactions. The four quarters that feature the highest S&P 500 returns (98Q1, 98Q4, 99Q4, and 03Q2) all exhibit better-than-average acquirer share price reactions. From our analysis, we conclude that high levels of the VIX and negative S&P 500 returns are associated with below-average acquirer share price reactions and that high S&P 500 quarterly returns are associated with above-average acquirer share price reactions.

2.1.3 Consideration Type

To test whether the consideration offered by the acquirer affects share price reaction, we divide our data set into four categories: all stock, all cash, cash and stock, and cash or stock mergers and acquisitions, see Figure 2-5. The results were surprising, especially 15 trading days after the announcement of the transaction. The announcement of an all-cash acquisition, on average, had no impact on the share

price of the acquirer. Initially, the acquirer share price traded down half a percent, but after 15 trading days, it trades back to preannouncement levels.

Type of Transaction	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
Cash	229	-0.5%	-0.3%	-0.3%	-0.6%	-0.7%	-0.5%	-0.2%	0.0%
Cash & Stock	129	-3.0%	-2.0%	-2.1%	-2.2%	-2.0%	-1.8%	-2.4%	-2.2%
Cash or Stock	48	-3.2%	-3.7%	-3.2%	-2.7%	-2.2%	-1.7%	-1.9%	-2.2%
Stock	489	-4.0%	-4.7%	-4.7%	-4.6%	-4.5%	-4.6%	-4.8%	-5.0%

Figure 2-5: Acquirer share price reaction post merger/acquistion announcement by consideration type

The announcement of an all-stock merger or acquisition experiences a significantly deteriorating reception, and the acquirer's share price on average trades down 4% on the day of the announcement. Furthermore, its performance does not improve even after 15 trading days, thereby trading down 5% on average. The divergence in performance may be attributed to a number of factors. All-cash deals generally are smaller than all-stock deals, and investors can react more adversely to larger mergers and acquisitions that carry greater execution risks and potential financial impact. All-cash acquisitions do not require risk arbitrageurs to short sell the shares of the acquirer, and the lack of selling pressure can also help performance. Mergers and acquisitions that combine cash and stock lie between all-cash and all-stock transactions as acquirer share prices trade down about 3% on the day of announcement.

2.1.4 Premium Range

The average announced premium across our entire data set is 25%. Anecdotally, we observe that the larger the premium, the greater the negative acquirer share price reaction. To test this observation, we examine the relationship between acquirer

share price reaction and premium paid for the target company. We divide our data set into quintiles representing premium ranges, as shown in Figure 2-6. Acquirer share price performance habitually appears inversely related to the premium paid, and the under-performance of high-premium-paying acquirers persists from the day of deal announcement through the 15-day post-announcement trading period.

Premium	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
Less than 20%	431	-1.5%	-1.4%	-1.5%	-1.6%	-1.5%	-1.6%	-1.5%	-1.9%
20% to 39%	281	-3.9%	-4.3%	-4.1%	-4.2%	-4.2%	-4.0%	-4.3%	-4.1%
40% t0 59%	118	-4.7%	-4.9%	-4.8%	-5.0%	-4.6%	-4.3%	-4.4%	-3.7%
60% to 79%	36	-4.9%	-5.1%	-4.5%	-4.3%	-4.1%	-4.5%	-4.6%	-5.6%
80% and Up	29	-5.4%	-8.3%	-8.4%	-8.3%	-8.7%	-9.3%	-9.1%	-8.8%

Figure 2-6: Acquirer share price reaction post merger/acquistion announcement, by premium range

The results of our analysis match our general intuition, as high-premium deals predominantly attract higher levels of investor scrutiny for various reasons. High-premium mergers and acquisitions generally are associated with strategic rationales focused on future growth potential and are usually dilutive in the near term. Realizing the future growth potential of a dilutive transaction can be perceived as having a high degree of execution risks. However, moderate-premium deals that seek to realize operational synergies and are immediately accretive principally are viewed as having lower execution risks. Speaking to this conclusion, mergers and acquisitions with premiums below 20% exhibit an average acquirer price reaction of only negative 1.5%. Transactions that feature a premium of 40% or more, exhibit an above-average acquirer price reaction of negative 5%.

2.1.5 Relative Acquirer Size

We observe that investors perceive a greater degree of execution risk in mergers and acquisitions in which the deal size represents a large portion of the acquirer's market cap. To test this, we segregate our data set of acquirer share price reaction into quintiles of deal equity value divided by acquirer market capitalization, see Figure 2-7. Reflecting our intuition, the larger size of the merger or acquisition vis-à-vis the size of the acquirer, corresponds to a more negative acquirer share price reaction. Mergers and acquisitions that are of larger relative size pre-eminently have greater financial impact on the acquirer and carry greater execution risks. Transactions that represent a low value relative to the size of the acquirer (less than 20%) correspond to a negative 1.6% average return on the day of announcement. Importantly, this initial reaction is effaced in the 15 trading days following the announcement.

Deal Equity Value / Acq Mkt Cap	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
Less than 20%	391	-1.6%	-1.2%	-0.8%	-0.9%	-0.9%	-0.9%	-0.5%	-0.2%
20% to 39%	139	-3.2%	-4.3%	-4.6%	-4.6%	-3.8%	-3.8%	-4.2%	-4.5%
40% t0 59%	89	-3.7%	-4.4%	-4.4%	-4.5%	-4.6%	-4.9%	-5.6%	-6.6%
60% to 79%	68	-4.4%	-4.5%	-5.2%	-4.6%	-5.0%	-4.7%	-4.9%	-5.4%
80% and Up	195	-4.7%	-5.2%	-5.6%	-5.8%	-5.6%	-5.5%	-6.0%	-6.0%

Figure 2-7: Acquirer share price reaction post merger/acquistion announcement, by relative acquirer size

Conversely, in transactions that represent a substantial portion of the acquirer's size (80% and more), average acquirer share prices trade down 4.7% on the day of announcement and continue to depreciate to negative 6.0% in the 15 trading days after announcement. Overall, the relationship remains fairly uniform, and as the quintile augments, the acquirer share price reaction exacerbates.

2.1.6 Deal Consummation Time

We observe that deals featuring longer estimated times to completion correlate to greater risks. Frequently, transaction time lines are dictated by the expected duration of the regulatory review process, and a lengthy review by regulators generally indicates an increased likelihood of an in-depth investigation and possible structural remedies which are required to receive necessary approvals. To test whether a relationship exists between time and initial acquirer share price reaction, we divide our data set into three-month increments of time to completion, as shown in Figure 2-8.

Time to Completion	Total # of deals	Acq % on ann dt	Acq % on day+1	Acq % on day+2	Acq % on day+3	Acq % on day+4	Acq % on day+5	Acq % on day+10	Acq % on day+15
Less than 3 Months	313	-3.1%	-3.3%	-3.3%	-3.5%	-3.3%	-3.1%	-3.0%	-3.3%
3-6 Months	358	-3.1%	-3.4%	-3.3%	-3.2%	-3.1%	-3.1%	-3.0%	-3.1%
6-9 Months	149	-2.1%	-2.4%	-2.3%	-2.4%	-2.6%	-2.9%	-3.4%	-3.5%
9-12 Months	41	-2.5%	-2.9%	-2.5%	-2.7%	-2.7%	-2.6%	-4.1%	-1.7%
1 Year and Up	34	-4.3%	-3.9%	-4.2%	-4.2%	-3.6%	-3.8%	-3.7%	-4.5%

Figure 2-8: Acquirer share price reaction post merger/acquistion announcement, by time to completion

The results of our analysis remain generally inconclusive. As the time to completion advances, we would expect the negative average acquirer share price reaction to increase. However, transactions that took less than three months to complete and those that took three to six months to complete exhibit average acquirer share price reactions. Surprisingly, transactions that take six to nine months to consummate and nine to twelve months to complete exhibit above-average acquirer share price reactions. Transactions that take one year or more to complete match our pre-supposition, as they exhibit worse-than-average acquirer share price reactions. Based on these weak results, we cannot conclude that a longer time to completion leads to below-average acquirer share price reaction.

2.2 Merger Analysis Summary

Based on our analysis of 895 mergers and acquisitions exceeding $400 million in value that were announced from January 1, 1998 through June 30, 2004, we arrive at the following conclusions:

- On average, acquirers trade down 3% on the day of an announcement of a merger or acquisition. Regardless of whether or not the dataset is divided by quarter, year, consideration, or relative size, the average acquirer share price reaction remains negative on the day of announcement.

- From our analysis of the quarterly average acquirer share price reactions, we generally conclude that high levels of the CBOE SPX Volatility Index (VIX) and negative S&P 500 returns are associated with below-average acquirer share price reactions while high S&P 500 quarterly returns are associated with above-average acquirer share price reactions.

- The announcement of an all-stock merger or acquisition experienced a materially worse reception, with the acquirer share price, on average, trading down 4% on the day of the announcement, and its performance does not improve even after 15 trading days and on average down 5%. As expected, the announcement of an all-cash acquisition, on average, had no impact on the share price of the acquirer.

- Mergers and acquisitions with premiums below 20% exhibit an average acquirer price reaction of only negative 1.5% on the day of announcement. Transactions that feature a premium of 40% or more exhibit an above-average acquirer price reaction of negative 5%.

- The larger relative size of the merger or acquisition vis-à-vis the size of the acquirer corresponds to a more negative acquirer share price reaction.

Our findings in this chapter are consistent with those described from a macroeconomic perspective by Shleifer and Vishny [14] and Verter [16], with respect to merger timing models.

Chapter 3

Risk Arbitrage Investment Process

Risk arbitrage is an exciting and challenging process. Stocks involved in such transactions may become volatile, and if the deal works out, the arbitrageur involved in the transaction may realize a large gain. On the other hand, if the transaction is terminated, the share price may drop precipitously, thereby leading to large losses for the arbitrageur.

In order to minimize the variance in investment returns and to maximize the success of a transaction, the arbitrageur tries to determine the probability of a deal's occurrence. The flow chart in Figure 3-1 shows the process that the arbitrageur uses in analyzing information and estimating returns and risks for a particular investment. This chapter focuses on the boxed part shown in Figure 3-1, and we effectively quantify and characterize the risk and return for risk arbitrage investments. We also discuss certain qualitative factors which emerge as essential to the quantification process and the success of investments in risk arbitrage. The results of this chapter can be used as the foundations for an electronic trading platform for these types of investments.

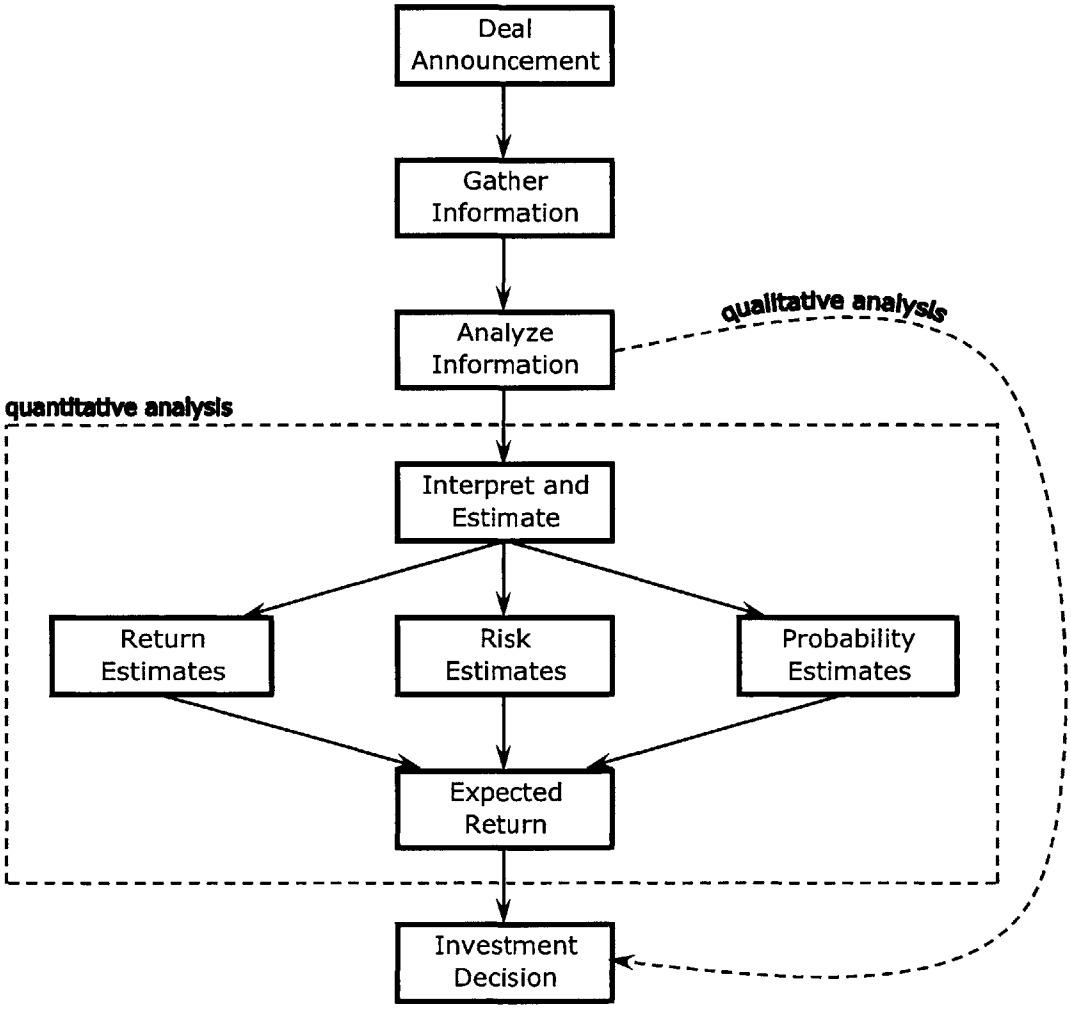

Figure 3-1: Analyzing and estimating returns for a risk arbitrage investment

3.1 Typical Investments

Two primary types of mergers embody typical investments: cash mergers and stock mergers. In a cash merger, the acquiring company offers to exchange cash for the target company's equity or assets. In a stock merger, the acquirer offers its common stock to the target's shareholders in lieu of cash. The arbitrageur's investment depends on the form of payment to the target shareholders. In a cash merger, the arbitrageur simply buys the target company's stock. Because the target's stock typically sells at a discount to the payment promised by the acquirer, profits can be made by buying the target's stock and holding it until merger consummation. At that time, the arbitrageur sells the target's common stock to the acquiring firm for the offer price. There are two sources for the return from this investment. The primary source of profit is the difference between the purchase price of the targets stock and the ultimate offer price. The secondary source of profit is the dividend paid by the target company.

In a stock merger, the arbitrageur sells short the acquiring firm's stock in addition to buying the target's stock. In such cases, there are three sources of the arbitrageur's profit. Like cash deals, the primary source of profit is the difference between the price obtained from the short sale of the acquirer's stock and the price paid for the target's stock. The second source of profit is the dividend paid on the investment in the target's stock. However, this is offset by dividends that must be paid on the acquirer's stock, as it was borrowed and sold short. The third source of profits in a stock deal comes from interest paid by the arbitrageur's broker on the proceeds from the short sale of the acquirer's stock. For individual investors, the interest rate typically equals zero. However, for institutions and hedge funds, short proceeds earn interest at a rate close to the risk-free rate.

3.2 Risk

The risk estimation process begins with the initial announcement of the merger. The key for the arbitrageur, is to calculate the worst-case absolute dollar loss exposure he may have in entering the deal. In addition to the total dollar risk, the arbitrageur would also want to calculate the market-implied probability and various other qualitative risks that the deal may involve.

The initial step in analyzing a deal's risk involves the examination of the trading history of the target company's securities. The arbitrageur wants to ensure that there is no evidence of an information leak that generated insider-trading prior to the merger announcement. In verification: if the target company's stock significantly progresses upward in the days prior to the announcement, and no fundamental explanation or reason can be sought to explain this activity, the total risk that we quantify will not be a good guide for determining the actual risk exposure. In this type of a situation, the arbitrageur should use the price level that the stock traded at before any significant move.

3.2.1 Total Dollar Risk

The dollar risk can be broken down in to two parts: 1) that of the target's stock and 2) that of the acquirer's stock. We characterize TOTAL RISK as:

$$\text{TOTAL RISK} = R_D + R_U \ .$$

R_D is defined as the downside risk which stems from the long position in the

target's stock:

$$\begin{aligned} R_D &= S_T - \widehat{D}_T \\ &= -0.01 S_T \ , \end{aligned}$$

where, S_T is the stock price of the target on the date of the announcement and $\widehat{D}_T$ is the historical[1] estimate of the target stock (for the long position in the portfolio) if the deal is terminated and is equal to $1.01 S_T$.

R_U is defined as the upside risk which derives from the short position in the acquirer's stock:

$$\begin{aligned} R_U &= (\widehat{U}_A - S_A) \left(\frac{N_A}{N_T} \right) \\ &= 0.02 S_A \left(\frac{N_A}{N_T} \right) \ , \end{aligned}$$

where, S_A is the the stock price of the acquirer on the date of the announcement, $\widehat{U}_A$ is the historical[1] estimate of the acquirer's stock (for the short position in the portfolio) if the deal is terminated and is equal to $1.02 S_A$, N_A is the number of acquirer shares sold short, and N_T is the number of target shares owned.

Hence, total risk can be defined as:

$$\text{TOTAL RISK} = -0.01 S_T + 0.02 S_A \left(\frac{N_A}{N_T} \right) \ .$$

We can consider TOTAL RISK (per share of target's stock) to be our estimate of the absolute dollar loss ($\widehat{L}$) one could experience if an announced deal went sour.

3.2.2 Market-Implied Probability

The absolute dollar loss estimate $\widehat{L}$ is a key for correctly identifying individual arbitrage risks and in estimating the market-implied probability. Allocating a precise

[1]The historical estimates, for the target and acquirer share price, after a deal is terminated are calculated by averaging through all historical deals in our data set, Figure 1-4.

probability estimate for a deal's outcome proves to be a difficult task. Most arbitrageurs rely on their experience instead of quantifying the probabilities to obtain estimates for expected return.

The arbitrageur uses his estimates of return and risk, along with the market value of securities to obtain the expected loss $\widehat{L}$ and expected profit, which equals the net spread between the merger terms and that of the current stock prices, $\widehat{P}$. The optimal way then to identify the outcome probability is to work backward from the market inputs and to obtain the probability that would make the expected rate of return $\mathbf{E}(R)$ equal to zero. Given the horizon and the risk characteristics of such deals, zero expected return appears to be a good approximation. In actuality, the expected return is normally positive due to the embedded time-value of money in a risk arbitrage strategy.

Thus, the market-implied probability π_m is calculated as:

$$\begin{aligned} & (\pi_m \times \widehat{P}) + ((1 - \pi_m) \times \widehat{L}) = 0 \\ \text{So,} \quad & \pi_m = -\frac{\widehat{L}}{\widehat{P} - \widehat{L}} \,. \end{aligned} \tag{3.1}$$

3.2.3 Other Risks and Measures

A critical part of the work performed by the arbitrageur is continuously monitoring the deal, see Figures 3-3 and 3-2, as it progresses through the approval process and assessing at each stage the probability of the deal's actual completion at the anticipated spreads, see Figures 3-4 and 3-5. In short, an arbitrageur must perpetually quantify the *risk* initially taken on in the arbitrage.

Unfortunately, a lot of other risks surrounding a merger transaction are not concretely quantifiable and are very qualitative in nature. The arbitrageur's experience then stands as an important asset and becomes very useful. However, as we show

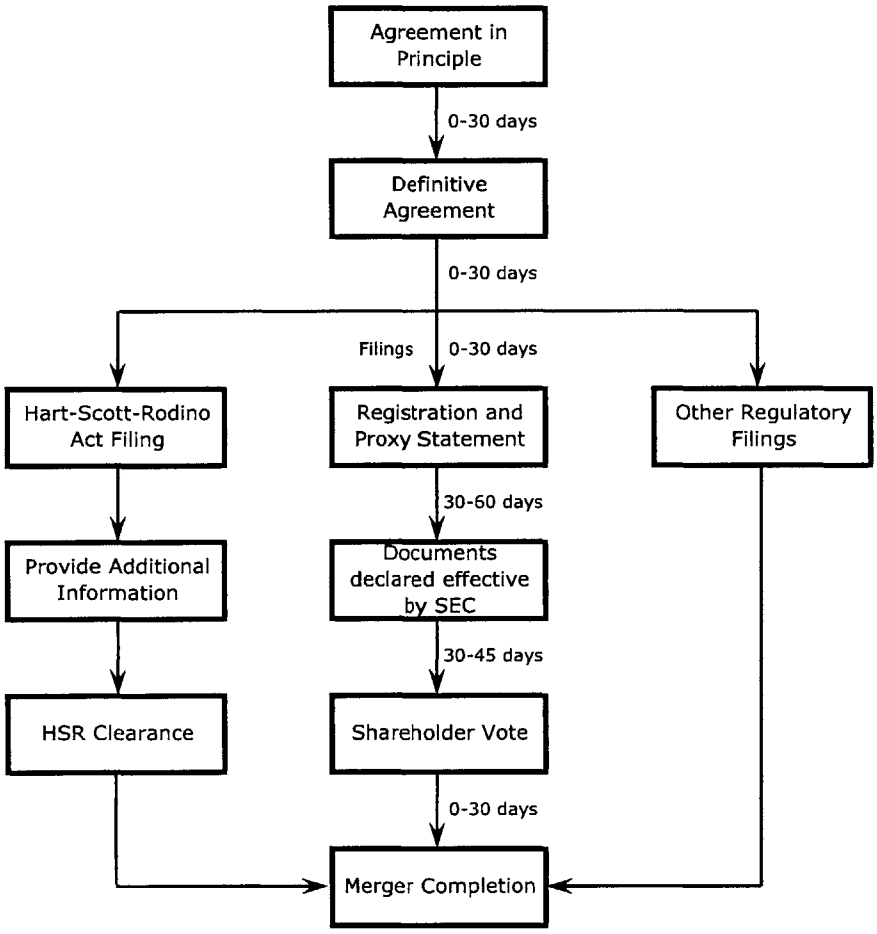

Figure 3-2: Conventional merger offer timing and procedure

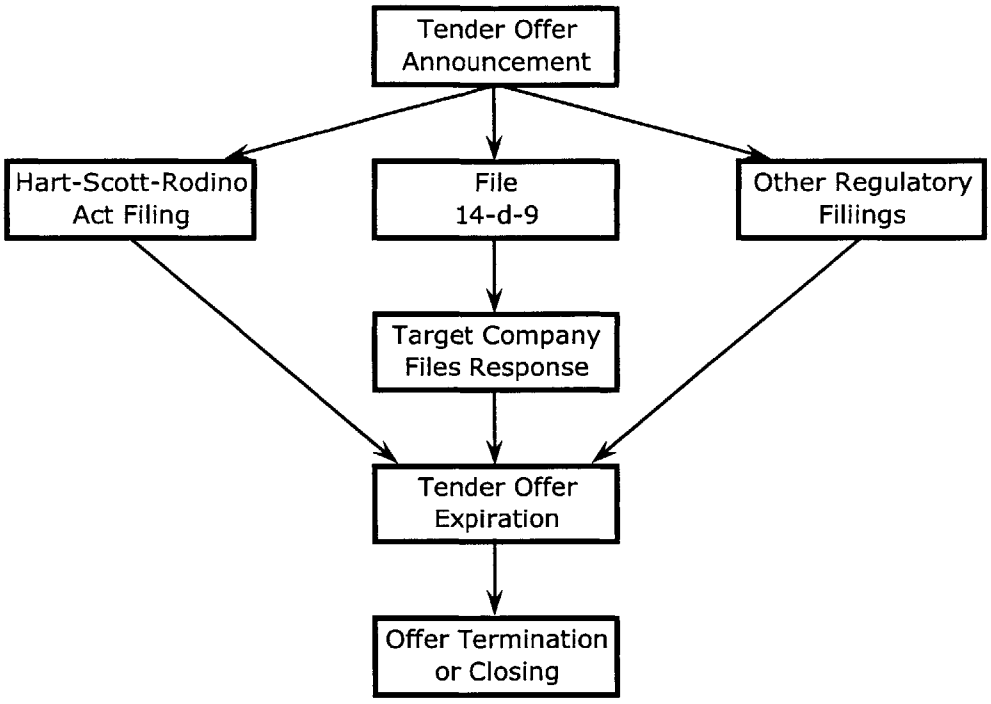

Figure 3-3: Tender offer timing and procedure

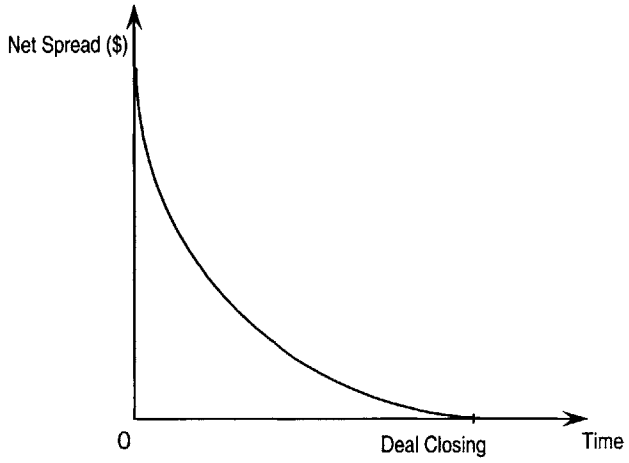

Figure 3-4: Net $-spreads over time in a simple transaction with no unexpected developments

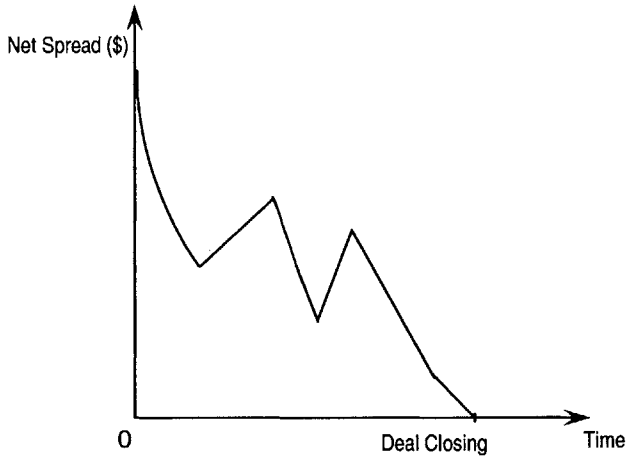

Figure 3-5: Net $-spreads over time in a complex transaction, e.g. antitrust or financing risks

in the portfolio construction part of this chapter, Section 3.4, an understanding of these factors is certainly not a prerequisite to good returns, but we feel that limiting one's investments through an understanding of these factors would further enhance the reported returns.

Some common deal risks include the following:

Shareholder dissent Shareholders who disagree with the merger plans could pursue various legal measures to block the deal. The amount of institutional holding in the company then becomes a part of the investment decision process as well.

Tax Approval IRS approval for attempted tax-free reorganizations is not guaranteed. An adverse ruling by the IRS could dramatically change the economics of the contemplated transaction and force it to be called off.

Antitrust Issues The antitrust analysis process is usually a difficult phenomenon to predict. The most common procedure remains to identify similar transac-

tions and compare and contrast their characteristics.

Management Management teams leading the target and acquirer corporations may find themselves clashing throughout the process and thus may threaten the successful completion of the deal. The only way of pacifying oneself to this risk, is talking to the management and understanding their philosophy and motive behind the transaction.

3.3 Returns and Portfolios

The analysis reported in this section are based on monthly risk-arbitrage returns and closely follow the analysis reported by Mitchell and Pulvino [8] for comparison of results. Monthly returns are obtained by compounding daily returns using two approaches, each of which is described below. In both approaches, we begin by calculating daily returns at the close of the market on the day after the merger announcement. Daily returns are calculated for every transaction-day up to and including the "resolution day." For successful deals, the resolution day is defined by the day on which the target's stock is delisted from the index. For failed deals, the resolution day is the day after deal failure is publicly announced. Using the day after the announcement as the beginning date ensures that arbitrage returns are not inadvertently biased upward by the takeover premium. Similarly, using the day after deal failure is announced as the resolution date for failed transactions insures that the arbitrage returns are not biased upward by inadvertently exiting failed deals before the failure is announced.

Transactions in which the terms of the deal are revised before deal consummation are treated as multiple transactions. An investment in the transaction under the original terms is made at the close of market on the day following the announcement.

This position is closed at the close of market on the day following the announcement of the bid revision. At the same time, an investment is made in the revised transaction and is held until the transaction resolution date. Transactions in which there are multiple bidders are handled in a similar manner. That is, one target can generate multiple transactions. Positions in a given transaction are held until the bidder announces that it is terminating its pursuit of the target, or when the target is delisted from the index, whichever occurs earlier.

We now describe the different portfolios that we will simulate, and we then evaluate and compare them.

3.3.1 Value-Weighted Returns (VWRA)

For every active transaction-month in the sample period, monthly returns are calculated by compounding daily returns. An active transaction-month is defined for every transaction to be any month that contains a trading day between the transaction's beginning date and its resolution date. If a transaction is active for only part of a month, the partial-month return is used. This effectively assumes that capital is invested in a zero-return account for that portion of the month that the transaction is not active. Portfolio monthly returns are obtained by calculating a weighted average of transaction-month returns for each month, where the total market equity value of the target company is used as the weighting factor. This approach mitigates the bias that is induced by calculating monthly returns by compounding equal-weighted daily returns [5]. The equation below specifies the monthly return calculation procedure:

$$R_{month,j} = \sum_{i=1}^{N_j} \frac{V_i \left[\prod_{t=m}^{M} (1 + R_{it}) - 1 \right]}{\sum_{i=1}^{N_j} V_i} \tag{3.2}$$

where j indexes months between 1998 and 2004Q2, i indexes active deals in a month (there are N_j active deals in month j), t indexes trading days in a transaction month, R_j is the monthly return, R_{it} is the return on deal i on day t, and V_i is the market value of deal i's equity. Because the targets market equity is used as the weighting factor, a greater proportion of the portfolio is invested in larger, and presumably more liquid targets. However, this approach in no way controls illiquidity in the acquirer's stock. Thus, returns calculated using the weighted averaging procedure may be deemed unrealistic in that they assume that there is an ample supply of the acquirer's stock available to be shorted. Of course, this is only a problem with stock-for-stock mergers where the acquirer's stock is difficult to borrow. In cash tenders and mergers, the typical risk arbitrage investment does not involve trading in the acquiring firm's equity, and therefore, the liquidity of the acquirer's stock is considered inconsequential.

There are two other features of the VWRA approach that are worth noting. First, this method effectively assumes that the arbitrage portfolio is invested in every transaction. Because of the fixed costs associated with investing in a transaction, this is a feature that large risk arbitrage hedge funds are unable to implement. Second, it assumes that there are no transactions costs associated with investing in a transaction. Both of these assumptions are clearly unrealistic. However, the time series of returns generated from this approach provide a benchmark that is useful for comparing results from this study to those documented in other papers.

VWRA Portfolio

This portfolio is constructed using the VWRA series described in Section 3.3.1 and we invest money in all merger transactions that take place between 1998 and 2004Q2.

The portfolio generates a compound annual return[2] of 5.48% with a standard deviation of 14.47%, without any transaction costs. The portfolio generates an annual α of 81 basis points[3].

3.3.2 Risk Arbitrage Index Manager (RAIM)

The risk arbitrage index manager [8], attempts to compensate for the unrealistic assumptions embedded in the VWRA method by simulating a risk arbitrage portfolio. Note that in this portfolio, the hypothetical arbitrageur does not attempt to discriminate between anticipated successful and unsuccessful deals. To generate this time series of returns, the portfolio is seeded with $1 million of capital at the beginning of 1998. As mergers are announced, the $1 million is invested subject to two constraints. The first constraint is that no investment can represent more than 10% of the total portfolio's value at the time the investment is made. This is a standard rule of thumb followed by most risk arbitrage hedge funds and is intended to insulate the fund from a catastrophic loss caused by failure of a single deal. The second constraint limits the fund's investments in illiquid securities. It does this by restricting the amount invested in any single deal so that the price impact on both the target and acquirer's stock is less than 5%. To implement this constraint, the following price impact model developed by Breen et. al. [3] Equation 1) is used:

$$\frac{\Delta P}{P} = \beta(NTO) \tag{3.3}$$

where price impact, $\frac{\Delta P}{P}$, is set equal to 5% and β is the illiquidity coefficient and equals to the predicted value from the Breen et. al. model [3] (detailed description

[2]The use of emphreturns in this thesis, implies *raw returns*.

[3]α is as determined by the CAPM, and is described as the absolute return on a particular investment that is uncorrelated with the market, see Section 3.5 for details.

is provided in A). To determine the size of an investment, the most restrictive stock (e.g. target or acquirer) is used as long as the resulting position is less than 10% of the simulated funds total capital. If both the target's stock and the acquirer's stock are extremely liquid, the 10% diversification constraint binds our investment. In this case, as long as the simulated fund has sufficient cash, it invests 10% of total capital in the deal.

RAIM Portfolio

This portfolio is constructed using the VWRA series described in Section 3.3.2 and we invest money in all merger transactions that take place between 1998 and 2004Q2. The portfolio generates an average annual return of 1.42% with a standard deviation of 5.39%, with transaction costs of $0.04 per share traded. The portfolio also generates an annual α of 57 basis points.

3.3.3 Probit Model

A probit model is an econometric model and is defined as:

$$\mathcal{P}(\mathbf{y} = 1|\mathbf{x}) = \Phi(\boldsymbol{\beta}\mathbf{x})$$

where Φ is the standard cumulative normal probability distribution, $\mathbf{x}$ is a vector of independent variables, and $\boldsymbol{\beta}$ is a row vector of coefficients. $\boldsymbol{\beta}\mathbf{x}$ is called the probit index.

Motivation

We make an attempt to quantify the probability of a successful merger transaction for a particular deal. We believe that the success of such transactions depends on

the characteristics of a deal and the companies involved in the deal, and test the awareness of the market about such information by creating a probit model.

We use the quantitative and qualitative analysis of different metrics from Chapter 2 and isolate certain key statistics that emerge as imperatively linked to the success of a merger deal. We then use these measures as the conditional variables for our merger prediction model and develop a trading strategy based on this model.

Data Description

Unlike many previous studies that focus on specific types of transactions such as cash tenders, we study arbitrage returns to cash tenders, cash mergers, and stock swap mergers. There are two advantages to including multiple types of mergers in the sample. First, it allows us to simulate a realistic investment strategy more similar to strategies pursued by risk arbitrage hedge funds. In order to keep investors' money employed, these hedge funds typically invest in a broad range of merger situations, not just cash deals. Second, it provides a sample that is large enough to study the time series characteristics of risk arbitrage returns, especially returns realized during severe market downturns. This stays necessary to accurately measure the systematic risk inherent in risk arbitrage. The data set for this study includes all publicly traded firms that were listed during 1998 - 2004Q2 and were involved in a merger or acquisition, see Figure 1-4.

Variable	Estimate	Standard Error
α	-0.4386**	0.1457
β_1	0.2437*	0.0902
β_2	0.1760**	0.0302
β_3	-0.0812**	0.0179
β_4	0.1932**	0.0789
β_5	0.0613*	0.0318
Significance levels: $* = 0.05$, $** = 0.01$		

Table 3.1: Our Probit Model. Standard errors are calculated assuming independence across years. Assumptions are made regarding the independence of transactions that terminate in the same year.

Our Model

We developed the following probit model:

$$\mathcal{P}(\texttt{Fail} = 1) = \Phi\Big(\alpha + \beta_1\texttt{Cash} + \beta_2\texttt{RelSize} + \beta_3 \ln\frac{\texttt{Size}}{\texttt{S\&P500}} + \beta_4\texttt{Tender} + \beta_5\texttt{NoMergers}\Big) \tag{3.4}$$

where `Fail` is a dummy variable which is equal to one if the deal fails and zero otherwise; `Cash` is a dummy variable if the acquirer offered to pay 100% cash for the target; `RelSize` is the fraction of the target's market cap to that of acquirer's market cap; $\ln\frac{\texttt{Size}}{\texttt{S\&P500}}$ is the log of the target's market value to that of the annual average of the S&P 500 index; `Tender` is a dummy variable equal to one if the offer was a cash tender; `NoMergers` is equal to the number of mergers that took place in the past six month window. The results of the model are depicted in Table 3.1.

The average success probability for our probit model is 0.57 and the model has a variation of 0.058.

Probit Probability v/s Market-Implied Probability

One way to visualize the fact that deal characteristics matter, is to construct a scatter plot for the market-implied probability (π_m) and probit model probability (π_{pm}) on a deal-by-deal basis, as shown in Figure 3-6. We can see that the implied probabilities and our model probabilities match most of the time. We also compute a metric $\widehat{\Xi}$,

$$\widehat{\Xi} = \frac{1}{N}\sum_{n=1}^{N}\left(\pi_{pm}^{n} - \pi_{m}^{n}\right)^{2} \tag{3.5}$$

which we refer to as market-error. The market-error is equal to 0.0410. This confirms that our estimates of conditional probabilities of a merger's success combined with market-implied probabilities suggest that the probability of success depends on a deal's characteristics and that one can improve on the market estimates, thereby creating trading opportunities.

PM Portfolio

This portfolio is constructed using the probit model and has RAIM constraints. In particular, we invest in all deals that have a greater probability (as computed by our model) than the average probability of success of the probit model. The portfolio generates a compound annual return of 4.15% with a standard deviation of 4.50%, with transaction costs of \$0.04 per share traded. The portfolio also generates an annual α of 97 basis points.

3.3.4 Expected Returns

The expected return $\mathbf{E}(R)$, on a particular investment is defined as:

$$\mathbf{E}(R) = \frac{(\pi_S \times \widehat{P}) + (\pi_F \times \widehat{L})}{\mathcal{I}} \times \frac{365}{\widehat{T}} \tag{3.6}$$

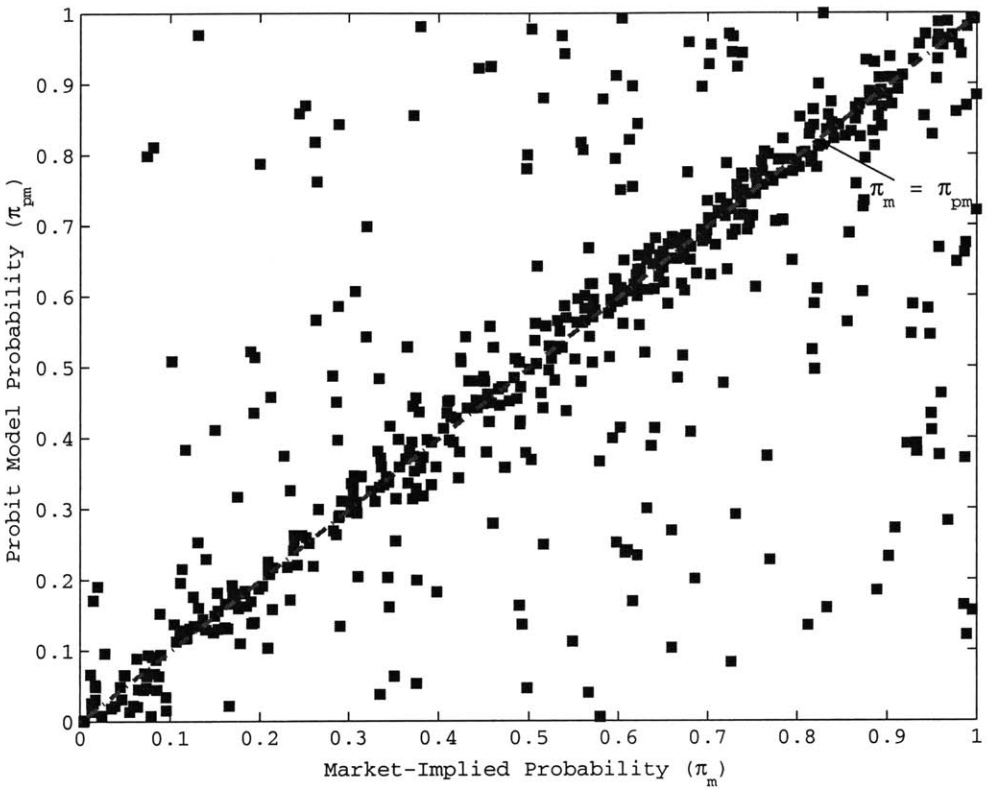

Figure 3-6: Variation between the conditional probabilities generated by our probit model (π_{pm}) with that of the market-implied probabilities (π_{m})

where, π_S is equal to the probability of success, $\widehat{P}$ is the estimated profit, π_F (= $1 - \pi_S$) is equal to the probability of failure, $\widehat{L}$ is the estimated loss, $\mathcal{I}$ is the total investment in a particular deal, and $\widehat{T}$ is the estimated time to completion.

ER Portfolio

This portfolio is constructed using the probit model generated probabilities and the computation of the expected return on each deal. In particular, we invest in a deal if the expected return[4] is greater than two times that of the `T-Bills` rate: $\mathbf{E}(R) > 2 * \texttt{T-Bills}$. The portfolio also incorporates the RAIM constraints for diversification purposes. The portfolio generated a compound annual return of 5.77% with a standard deviation of 5.18%, with transaction costs of $0.04 per share traded. The portfolio also generates an annual α of 115 basis points.

3.3.5 Cross-Validation Portfolios

Cross-validation [15] is often used to estimate the ability of a statistical classifier. Under cross-validation, the available data is divided into 2 disjoint sets; we then estimate a probit model, based on the variables described in Section 3.3.3, on one partition and test it on the other. The cross-validation estimate of a given performance statistic is simply the mean of the statistic evaluated for each random test partitions of the data. Cross-validation thus makes good use of the available data as each pattern is used both as training and test data. Cross-validation is therefore especially useful where the amount of available data is insufficient to form strong conclusions about results.

[4]We use the historical estimate of the expected time, as computed by our data set. $\widehat{T}$ = 90days. The probabilities of success and failure are obtained from our probit model, described in Section 3.3.3.

CV Portfolio

We use the cross-validation procedure on our data set, and using the merger characteristic variables described in Section 3.3.3, we compute returns by investing in all deals that have a probability of success greater than that of the average success probability for the other set. The portfolio also incorporates the RAIM constraints for diversification purposes. The portfolio generates a compound annual return of 5.76%, incorporating transaction costs of $0.04 per share traded, with a standard deviation of 2.79%, compounded across all the simulations, and has a Sharpe Ratio of 1.35. The portfolio also generates an annual α of 68 basis points.

3.4 Portfolios

We summarize the performance of all the portfolios, with and without trading costs, in Figures 3-7 and 3-8. We can conclude that our probit prediction model is effective and generates returns that are partly uncorrelated with the market. Also an arbitrageur could potentially use this model to create even more sophisticated trading strategies, e.g. strategies based on the market-error $\widehat{\Xi}$. Further, our transaction cost of $0.04 seem to be reasonable once we factor the various costs: brokerage commissions, surcharges, and price impact. The approximate hit on earnings due to these costs vary between 2% and 2.5%.

It must be noted that even the most conservative risk arbitrage fund managers use a leverage of 2-3 times. Once we incorporate this leverage into our portfolio our reported risk-adjusted returns are substantial even by industry standards.

Year	VWRA	RAIM	PM	ER
1998	12.64%	4.88%	7.48%	7.96%
1999	27.95%	11.29%	15.03%	18.41%
2000	7.69%	3.73%	4.98%	5.13%
2001	-20.62%	-8.07%	-1.01%	-0.92%
2002	1.83%	3.25%	4.55%	6.72%
2003	5.43%	3.86%	6.03%	8.17%
2004 YTD	6.97%	3.84%	5.77%	7.58%
Compounded Returns	5.48%	3.73%	6.51%	8.05%
α	0.0081 (0.0010)	0.0061 (0.0011)	0.00101 (0.0011)	0.0118 (0.0011)
β_{mkt}	0.161 (0.0289)	0.166 (0.0289)	0.16 (0.0289)	0.147 (0.0289)
Std. Dev.	14.47%	5.72%	4.76%	5.73%
Sharpe Ratio	0.31	0.39	0.98	1.09

Figure 3-7: Portfolio returns for the different portfolios constructed in Section 3.3 without trading costs.

Year	RAIM	PM	ER
1998	3.78%	5.36%	5.67%
1999	8.79%	12.10%	14.93%
2000	1.30%	3.05%	2.68%
2001	-9.12%	-3.18%	-2.31%
2002	0.45%	2.76%	4.57%
2003	2.73%	3.97%	6.89%
2004 YTD	2.18%	3.43%	5.76%
Compounded Returns	1.42%	4.15%	5.77%
α	0.0057	0.0097	0.0115
	(0.0011)	(0.0011)	(0.0011)
β_{mkt}	0.163	0.158	0.142
	(0.0289)	(0.0289)	(0.0289)
Std. Dev.	5.39%	4.50%	5.18%
Sharpe Ratio	0.08	0.70	0.92

Figure 3-8: Portfolio returns for the different portfolios constructed in Section 3.3. All portfolios have a direct trading cost of \$0.04 per share traded.

3.5 Possible Explanations for Risk Arbitrage Returns

Most of the previous studies that attempt to assess the profitability of risk arbitrage conclude that it generates substantial risk-adjusted returns. Excess returns are greatest in those studies that focus on cash tender offers.

In this thesis, we use a long time series of risk arbitrage portfolio returns to attempt to distinguish between market inefficiency and two alternative explanations of returns to risk arbitrage investments. The first alternative explanation is that transaction costs and other practical limitations prevent the average investor from realizing the extraordinary gains documented in previous studies. Of the practical limitations, one of the most important stems from the use of event time, rather than calendar time, to calculate risk arbitrage returns. The event-time approach involves calculating the rate of return obtained from investing after the merger announcement and selling after deal resolution. Returns from individual deals are first "annualized" and then averaged across deals. The problem with this approach is that it assumes that the risk arbitrage portfolio can earn event-time returns continuously. Particularly for transactions that are consummated quickly, this assumption can lead to large annualized returns.

The second possible explanation for the extraordinarily large documented returns to risk arbitrage is that they represent compensation to investors for bearing extraordinary amounts of systematic risk. Because most announced mergers are successfully consummated, risk arbitrage investments usually generate small positive returns. Conditional on successful consummation, these returns depend on the initial arbitrage spread and not on overall stock market returns. Therefore, returns to risk arbitrage should contain very little systematic risk. However, risk arbitrage

returns may be positively correlated with market returns during severe market downturns. This will be true if the probability of deal failure increases in depreciating markets. Shleifer and Vishny [14] argue that although the hedge fund managers who typically invest in merger situations may comprehend the risk/return profile associated with risk arbitrage, their investors may not. Consequently, investors may redeem their capital at precisely the wrong time, forcing risk arbitrage hedge fund managers to "bail out of the market when their participation is most needed."

To distinguish between the market inefficiency story and the risk story, we estimate the Capital Asset Pricing Model (CAPM),

$$(R_{riskarb} - r_f) = \alpha + \beta_{mkt}(R_{mkt} - r_f) \ .$$

Here $R_{riskarb}$ is the monthly return to a portfolio of risk arbitrage investments, r_f is the risk-free rate, and R_{mkt} is the return to the S&P 500 index. The intercept α measures the average monthly abnormal return to the risk arbitrage portfolio, which is zero under the null of market efficiency, given the model. If the estimated α is significantly positive, this suggests that the risk arbitrageur earns excess returns, assuming that the model is correct.

As seen from our portfolio results, in Section 3.4, there is some evidence of market efficiency, in that one can construct a strategy with positive risk-adjusted returns even after adjusting for trading costs. We can also see that market implied probabilities do seem to capture

Chapter 4

Summary and Future Work

4.1 Summary

The central motif of this thesis is the quantification of the risk arbitrage investment process. We compute different merger deal statistics and then through the intuition obtained by those statistics we build a deal consummation prediction model to formulate trading strategies. The model is based upon deal characteristics and we construct and analyze portfolios based on our prediction model. Our portfolio construction is concentrated on simple strategies and we obtain annual risk-adjusted returns in excess of 4.5%. The described investment process and characterization of the risk and return in risk arbitrage can be used as a stepping stone in building an electronic trading platform.

4.2 Future Directions

This thesis represents one corner of a problem which not only requires a multifaceted approach but has also traditionally been treated from a qualitative perspective. We

briefly discuss some key open issues on which further study is necessary and provide ideas on how they could be approached.

We mention a number of qualitative factors that are associated with the risk arbitrage investment process (Section 3.2.3). Quantifying these factors in a meaningful way is a difficult task. However one way of approaching the problem would be by identifying the characteristics of deals which terminated due to one of the specific risks (e.g. antitrust issues).

Given the dynamism of financial markets, the long term agenda of any electronic trading program has to adhere to continuous review, calibration, and improvement. On a more practical note, we suggest that a unifying theory of merger timing models and the quantitative analysis presented in this thesis would form the cutting edge of a risk arbitrage trading platform, and is much needed.

Appendix A

Price Impact Model

Breen, Hodrick, and Korajczyk [3] estimate the price impact of a trade of specified size based on liquidity characteristics of the underlying security. The price impact equation is given as:

$$\frac{\Delta P}{P} = \beta(NTO) \tag{A.1}$$

where price impact, $\frac{\Delta P}{P}$, is equal to the percentage change in price resulting from a trade with net turnover equal to NTO. Net turnover is defined as one-tenth of the buyer initiated volume minus seller-initiated volume divided by shares outstanding. Using the above equation, Breen et. al. estimate β from price changes and net turnover over 5 minute and 30 minute intervals. βs are then used in a cross-sectional regression to obtain the following price impact model:

$$\begin{aligned}\beta = 8.77 + 2.52X_1 - 1.84X_2 - 1.39X_3 - 1.92X_4 - 27.5X_5 - 8.29X_6 \\ - 0.02X_7 - 0.38X_8 + 0.63X_9 - 0.08X_{10} - 0.39X_{11}\end{aligned} \tag{A.2}$$

where,

X_1 = log of market capitalization,

X_2 = log of previous quarter's trading volume,

X_3 = price at the end of the previous month divided by price 6 months prior,

X_4 = dummy variable equal to 1 if the equity is included in the S&P 500,

X_5 = dividend yield,

X_6 = R^2 of returns v/s NYSE obtained from regressing monthly returns over the prior 36 months,

X_7 = NYSE inclusion dummy,

X_8 = NASDAQ inclusion dummy,

X_9 = dummy variable equal to 1 if last earnings release was more than two months ago,

X_{10} = percentage institutional ownership, X_{11} = dummy variable equal to 1 if there are options traded on the security.

We use equation (A2) to estimate β for both the acquirer and the target. For any arbitrary price impact level, we then use the estimate of β to calculate the maximum allowable number of shares that can be traded, assuming this maximum does not result in a position that exceeds 10% of the portfolio's total value. Equations (A1) and (A2) are also used to compute the indirect cost of trading. For every transaction in our index portfolio, we subtract transaction costs equal to the price impact implied by equations (A1) and (A2), divided by 10. The factor of 10 is used to account for the fact that traders attempt to limit the price impact of their trades by placing many small orders to accumulate a large position.

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