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RISK ARBITRAGE IN THE SWEDISH MARKET
EVALUATION WITH CONTINGENT CLAIMS

MASTER THESIS, DEPARTMENT OF ECONOMICS

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ABSTRACT

Title: Risk Arbitrage in the Swedish Market – Evaluation with Contingent Claims

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Keywords: arbitrage, Black-Scholes, CAPM, contingent claims, merger arbitrage, non-linear returns, risk arbitrage

Purpose: The purpose of this thesis is to investigate the ability of a risk arbitrage strategy to generate excess return, alpha, in the Swedish equity market

Theoretical Perspective(s): A deductive approach, using widely accepted theories on arbitrage and financial markets to examine the ability of the strategy to generate excess returns.

Empirical foundation: The sample portfolio includes a total of 111 deals, and the returns are computed for 2611 trading days, compounded into 132 monthly returns, from January 2000 to December 2010. All deal data was retrieved from BvD Zephyr and all price data retrieved using ThomsonReuters Datastream. In addition, data for the SSVX 90 day treasury bill was retrieved directly from the Swedish Central Bank.

Conclusion: The strategy is found capable of generating significant excess return over the period evaluated, using both linear and non-linear evaluation methods. The alpha is 120 basis points per month, in a linear framework and assuming CAPM holds, and 51 basis points per month using a non-linear framework and assuming Black-Scholes holds.

ACKNOWLEDGMENTS

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1. INTRODUCTION

In this first chapter I strive to introduce Risk Arbitrage as a concept and provide some relevant background information. I will also outline the purpose and limitations, as well as the problem formulation.

1.1. BACKGROUND

1.1.1. Risk Arbitrage – Definition and Introduction

Arbitrage, from the Latin word *'Arbitratus',* meaning free choice, is a centuries old practice for the secrecy-shrouded community of arbitrageurs. To engage in the practice of arbitrage in its most simple form, one undertakes the simultaneous purchase and sale of the same security in different markets and at different prices, yielding a risk-free profit. This is arbitrage as it was originally practiced by Venetian merchants in Medieval Europe. (Wyser-Pratte, 2009, p. 1) The definition as per the *Merriam-Webster's 11th College Dictionary* follows:

1. *The nearly simultaneous purchase and sale of securities or foreign exchange in different markets in order to profit from price discrepancies.*
2. *The purchase of the stock of a takeover target especially with a view to selling it profitably to the raider.*

The first definition is the one I referred to as the simple one, and while it may have been viable in the 13th century, it is rarely seen today, some nine hundred years later.

Merriam-Websters second definition, although it somewhat resembles what I refer to as risk arbitrage, fails to properly capture the full nature of the practice of true arbitrage, and hence we will move further on to the definition as it is used by academia. Arbitrage as a theoretical concept is widely practiced by academia within the field of economics, and the law of one price is a cornerstone in the pricing of assets and their derivatives. The formalised definition of arbitrage in the academic sense is that of a self financing trading strategy generating a positive return without risk, *i.e.* incurs no negative cash flow at any probabilistic or temporal state and a positive cash flow in at least one state. (Pennacchi, 2008, p. 66)

The particular form of arbitrage that will be covered in this thesis is commonly referred to as Risk Arbitrage (also referred to as Merger Arbitrage), and attempting to properly define it takes us back to definition 2. from the dictionary, *i.e.* "*The purchase of the stock of a takeover target*

especially with a view to selling it profitably to the raider." While being a trivialisation of the practice, it captures the broad strokes of the strategy. In essence, risk arbitrage is the practice of assuming positions in the companies involved in a deal in such a way that the arbitrageur is exposed only to the deal completion risk, and not to the market risk. (Wyser-Pratte, 2009, p. 21) In this context, the deal may refer to a merger, LBO, MBO, or any other type of deal in which – at deal completion – the securities issued by the target company will be consummated. Let us take a simple example, that of a cash offer in which XYZ will acquire 100% of ABC's outstanding shares, the arbitrageur takes a long position in the shares of ABC and holds them until the deal is completed, at which point the shares are sold to XYZ. We may also consider the case of a stock merger where XYZ offers a number of XYZ shares for every share of ABC, here the arbitrageur takes a long position in the shares of ABC and a short position in XYZ shares such that the ratio between them is equal to the amount of XYZ shares offered for each ABC share.

Both cases above does – in theory – only expose the arbitrageur to the very limited deal completion risk, by taking a position in the target when there is a formal offer made, the arbitrageur knows exactly which price the shares of the target company will fetch in a sale to the acquirer, provided the deal closes. The same is true for the second case, where the short position in the shares of the acquirer offset the long position the shares of the target, and ensures a locked-in profit, again provided the deal closes.

The expression Risk Arbitrage may by now seem to be a contradiction in terms, as I have outlined the concept of arbitrage as that of locking in a risk-free profit, and while the risk arbitrageur does not assume market risk, he does assume deal completion risk. As I have no intention to confuse the reader, I will return to a more elaborate explanation of arbitrage and risk arbitrage in Chapter 3.

1.1.2. Background Discussion

As should be clear from the brief introduction to the concept of arbitrage in general and risk arbitrage in particular, risk arbitrage is to many fund managers and investors something of a holy grail. It is widely regarded as an almost mystical concept, the ability to generate abnormal returns out of thin air with little or no risk-taking. Although for some it paints the pictures of the spectacular implosions, such as that of Long-Term Capital Management in the late 1990s, a

majority of academic studies conducted during the 1990s and 2000s suggest that risk arbitrage is capable of generating substantial excess returns over time. (Mitchell and Pulvino, 2001, p.2135)

Given the secretive nature of the arbitrage community, and the doubled-edged nature of the practice of risk arbitrage, it comes as no surprise that there have been quite a few academic studies over the years, of which a detailed review can be found in section 3.5. The common denominator for these studies is that they are usually performed in the US stock market, arguably the world's largest and most efficient equity marketplace. Nevertheless, risk arbitrage as a strategy can be practiced in any equity market, so long as the market liquidity satisfies the appetite of the arbitrageur. Sweden, being the largest economy in Scandinavia, has a very developed equity market, with an average daily volume of 285'451 trades corresponding to a daily turnover of EUR 2.5 billion (SEK 22.70 billion). (NASDAQ OMX, 2011) This market should hence pose no hindrance to the adoption of a risk arbitrage strategy. Despite this, there has been a virtual absence of academic studies on the subject, which in my opinion makes it ever more interesting to investigate.

1.3. PURPOSE

The purpose of this thesis is to evaluate the ability of a risk arbitrage strategy to generate excess returns, alpha, in the Swedish stock market, evaluating the returns using both linear and non-linear approaches. The purpose of the non-linear contingent claims evaluation is to capture any excess risk taking not captured by linear models, to the fullest extent possible

1.4. LIMITATIONS

The main involuntary limitation when attempting an empirical study of this nature is the availability of data. Each offer has to be examined, and even if one should read every newswire published for the period in the study, there is a risk of missing a deal. In addition to necessary data on the deal itself, there has to be data on the price and market value of the firms involved, otherwise computation of a portfolio would be impossible. Hence there is a practical limitation on both the scope and period available for study. As the M&A-database BvD Zephyr[1] provides complete data on deals announced in the Swedish acquisition market back to the year 2000, this

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[1] See section 2.3.1. for a detailed description of BvD Zephyr.

study will limit its scope to the period from January 2000 until December 2011, generating a portfolio for a total of 132 months, which should be adequate from a statistical perspective.

All target companies in the study were listed on the Stockholm Stock Exchange, now NASDAQ-OMX Stockholm, at the time of deal announcement, a study including companies on alternative 'venture' exchanges such as Nordic Growth Market and Aktietorget would be impractical given the scarce liquidity and generally low market capitalisation of companies listed there. These would most likely be excluded from the portfolio of any real-life arbitrageur and should hence be excluded from this study. Other than this, no limitation has been placed on liquidity, free-float or market value.

Any deals whose method of payment differs from cash or stock have been excluded, as well as those containing complicated terms such as derivative portions or similar. There has been no exclusion on foreign buyers, provided their payment method fulfilled the stated criteria. The purpose of these self-imposed limitations is to ascertain the accuracy of the portfolio, given the inherent complexity in retrieving the data necessary and computing the returns of specialised derivative and debt instruments.

2. METHOD

This chapter contains a description of the approach, general method as well as a thorough description of the data. Attention will be given to both sample selection and the selection of variables.

2.1. SCIENTIFIC APPROACH

When writing a thesis, it is important to ascertain the most viable strategy and approach to the subject at hand. There are two main scientific approaches which are the most commonly used, namely the qualitative and the quantitative. The qualitative method focuses on theory and understanding rather than numerical data and hence it cannot reach any significant conclusions. (Bryman and Bell, 2007, p. 28) The quantitative method on the other hand puts emphasis on systematic data collection, and the mathematical processing of that data. As the aim of this thesis is to evaluate the performance of a risk arbitrage portfolio, which includes the application of mathematical financial methods on a dataset, a quantitative approach has been deemed the most appropriate for the task at hand.

As the analysis undertaken constitutes the collection of empirical data from authentic and original sources, which is analysed using an already existing theoretical framework, a deductive approach would be the most fitting one. This as the deductive approach involves moving from theory to empiricism. (Bryman and Bell, 2007, pp. 11-15) According to Patel and Davidson (1991), a deductive approach is very common in academic theses, as it is common that the theoretical framework already exists. This is further reinforced by Bryman and Bell (2007, pp. 11-15), who outlines the deductive approach as the most common view on the relationship between theory and research.

2.2. GENERAL METHOD

Initially, I undertook extensive literature studies on the subject of risk arbitrage. The purpose of the studies were to identify theoretical frameworks on which to base the thesis, as well as identifying the practical problems that might arise from implementing a risk arbitrage strategy. The bulk of the literature reviewed consists of scientific articles in journals, as well as books on subjects such as arbitrage, asset pricing and derivatives theory.

After research on past literature had been completed, the data was gathered, using BvD Zephyr to obtain the necessary data on deals subject to my criteria. Deal data retrieved from BvD Zephyr

was then mated to ThomsonReuters Datastream Advance in order to obtain the time-series data necessary to compute a portfolio. Data on the market index and the risk-free rate were retrieved from ThomsonReuters and the Central Bank of Sweden respectively, and all data was fed to an Excel database.

My portfolio, dubbed the MVWRA, Market Value Weighted Risk Arbitrage, was computed using the venerable MS Excel software. Linear econometric analysis was undertaken using the EViews, an econometrics package from Quantitative Micro Software. The more advanced nonlinear regression analysis was conducted using SegReg, which is a freely available econometrics package specifically designed for non-linear piecewise linear regression analysis.

After regression analysis, the resulting final output has then been dissected and discussed using the theoretical framework described in Chapter 3.

2.3. DATA METHODOLOGY

2.3.1. Sample Selection

The deliberate aim with this thesis is to include as many applicable deals as possible over the period from January 2000 to December 2011, *i.e.* over the course of 132 months.[2] For every deal, it is necessary to collect a number of different datasets, making the process tedious.

I based my deal data on the one available in Bureau van Dijk's Zephyr, a specialised M&A database claimed to be the world's most comprehensive database of deal information. (Bureau van Dijk, 2011) By taking a starting point in the data from Zephyr, I aimed to eliminate the risk of error that would be associated with manually searching 132 months of newswires. Furthermore, using a specialised deal database with well defined search criteria, it is very easy to align the sample with ones limitations by simply defining the criteria using a set of Boolean operators, a feature supported by Zephyr. This method of obtaining the data also had the distinct advantage of being much less time-consuming, giving me time to focus on the actual study at hand rather than the mechanical collection of data. A table describing the different data necessary to compute a portfolio can be found below in Table 2.1.

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[2] Once again deal may refer to a merger, LBO, MBO, or any other type of deal in which – at deal completion – the securities issued by the target company will be consummated.

Table 2.1. Deal data

Type	Rationale for inclusion	Source
Deal announcement date Deal completion date Deal withdrawal date	To know when to include the security of the target - and in stock deals also the acquirer - in the portfolio.	BvD Zephyr Complemented by: Dagens Industri The Financial Times
Price per share offered (alternatively the number of shares offered combined with the acquirer's share price)	In order to compute the arbitrage spread and ascertain if the bid premium is positive, *i.e.* if a trade should be made.	BvD Zephyr
Method of payment	In order to properly account for the different calculations necessary.	BvD Zephyr
Price, time series	Necessary in order to compute the daily returns.	ThomsonReuters Datastream
Market Value, time series	Necessary in order to compute the volume-weighted daily returns.	ThomsonReuters Datastream

After careful review of the Zephyr search results, Datastream was used to retrieve the necessary data. Out of 135 deals returned from Zephyr for the period lasting from January 2000 to December 2010, 111 matched all criteria set. Two were excluded on the basis of a negative bid premium, five contained complex deal terms, and for the remaining 17 there was a lack of time series data available in Datastream. The total sample contains 111 deals and the monthly returns span a total of 132 months, or 2611 trading days.

2.3.2. The MVWRA

The raw data mentioned in section 2.3.1. was used to construct a portfolio dubbed MVWRA, Market Value Weighted Risk Arbitrage. The portfolio contains all 111 deals, value weighted for when there were several parallel deals, and with the portfolio positioned in the risk-free rate for any period with an absence of ongoing deals.[3] The portfolio does not include transaction costs, and neither does it adjust for price impact or liquidity issues, the purpose of this is to avoid extensive assumptions, while also making the study easy to replicate.

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[3] The risk-free rate is derived from the SSVX90, the Swedish 90-day treasury bill, more information on this in section 2.3.4.

The MVWRA portfolio returns are computed on a daily basis and then compounded into monthly returns which are used in the study. Deals are included into the portfolio only on the day after they are announced and kept in the portfolio until the target stock is delisted, or the day after the deal failure is publicly announced. Use of the "day-after" approach is as to eliminate the possibility of inadvertently biasing the portfolio returns upward, as may otherwise be the case due to the wrongful inclusion of bid premiums. Furthermore, deals in which the terms are altered before consummation are considered multiple deals.

The MVWRA portfolio contains 111 deals on 82 unique targets, of which 28 deals were withdrawn and 5 unresolved as of portfolio close, December 31st 2010, while the remaining 78 deals were successful. Thus, on a unique target basis, the success rate for deals included in the portfolio was 95.12%. In 94 deals cash was offered as payment while 17 deals were stock deals, also referred to as stock swaps.

The return r on a cash deal i for a given day t is given in the following equation

$$r_{it} = r_{it}^T = \frac{P_{it}^T - P_{it-1}^T}{P_{it-1}^T}$$

(2.1)

where P_{it}^T denotes the price of the target company stock at market close and P_{it-1}^T denotes the stock price at market close t minus one day, this is how the daily return for the 94 cash deals was computed. For the remaining 17 stock deals the approach is slightly more complex as the portfolio has to assume a short position of Δ shares in the acquirer, where Δ is equal to the ratio of acquirer shares to target shares. The equation below gives the return for a stock deal

$$r_{it} = r_{it}^T - (r_{it}^A - r_f)\Delta \frac{P_{it-1}^A}{P_{it-1}^T}$$

(2.2)

where r_{it}^T and r_{it}^A are the returns on the target and acquirer stock respectively, r_f denotes the risk-free rate, and P_{it-1}^T and P_{it-1}^A are the t minus one closing prices of the target and acquirer stock respectively. In equation 2.2., the arbitrageur receives the kronor return $r_{it}^T P_{it-1}^T$ and has to pay the return in excess of the risk-free rate multiplied by his position in the acquirer, $(r_{it}^A - r_f)\Delta P_{it-1}^A$, the whole expression is the divided by the initial investment, P_{it-1}^T in order to yield the

return on day t. This is the same computational method, assuming no access to short sale proceeds for the arbitrageur, as used by Baker and Savasoglu (2002, p. 101) and hence, the up front investment required will be the same for both deal types, *i.e.* P_{it}^T.

When weighing the trades in the portfolio for parallel deals, there are two main methods, either equal weighting or value weighting. Equal weighting consists of weighting all open trades equally, regardless of the value of the deal, while value weighting takes into account the value of the deal at hand. While some studies such as Baker and Savasoglu (*Ibid.,* p. 102) evaluate both for robustness, others such as (Mitchell and Pulvino, 2001, p. 2147) use only the value weighted approach. Using an equal weighted portfolio is less complex, which is an argument for its usage. This argument is however void by the ease with which modern software can compute the weights of a portfolio, and given the market value weighted nature of my chosen reference index, the OMXS30, I have used the value weighted approach.[4]

The portfolio return r_{Pt} for a day t can be seen in equation 2.3 below, where w_{it} denotes the weight of each individual deal in the portfolio, as given by weighing the deals by the market capitalisation of their respective target shares.

$$r_{Pt} = \sum w_{it} r_{it}$$

(2.3)

While equation 2.3. gives the daily return of the portfolio, this can be compounded into the monthly return R_j as follows:

$$R_j = \prod \left(1 + \sum w_{it} r_{it}\right) - 1$$

(2.4)

Equation 2.4. above yields the monthly return for the MVWRA portfolio, which is calculated for $j = 1, \dots, 132$ to yield the 132 monthly MVWRA portfolio returns evaluated in this thesis.

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[4] Elaborate information on the OMXS30 can be found in section 2.3.3.

2.3.3. Market Benchmark Index

As this thesis aims to investigate the potential of a risk arbitrage strategy to generate a significant excess return, or alpha, the choice of benchmark index is an important one. For this thesis the OMX Stockholm 30, abbreviated OMXS30, was chosen as a benchmark index, and I intend to elaborate the rationale behind this.

OMXS30 is the leading Swedish index, and it is designed specifically for liquidity and to be a suitable underlying index for derivative products. (NASDAQ OMX, 2011) This makes the OMXS30 very suitable, as this is a study which will use a Black-Sholes model that involves index put options. Hence, there is an inherent value in a benchmark index on which derivative products are actively traded.

Furthermore, the index can claim a 99.9% correlation with the OMXS All-Share index since its inception, making it a good measure on the broader Swedish market. (NASDAQ OMX, 2011)

In the words of NASDAQ-OMX, the exchange provider:

> *"OMX Stockholm 30 is OMX Nordic Exchange Stockholm's leading share index. The index consists of the 30 most actively traded stocks on the OMX Nordic Exchange Stockholm. The limited number of constituents guarantees that all the underlying shares of the index have excellent liquidity, which results in an index that is highly suitable as underlying for derivatives products. In addition OMXS30 is also used for structured products, e.g. warrants, index bonds, exchange traded funds such as XACT OMX™ and other non-standardized derivatives products. The composition of the OMXS30 index is revised twice a year. The OMXS30 Index is a market weighted price index. The base date for the OMX Stockholm 30 Index is September 30, 1986, with a base value of 125."* (NASDAQ OMX, 2011)

All necessary data for the OMXS30 index was computed using daily price data retrieved using the Thomson Reuters Datastream Advance software.

2.3.4. Risk-Free Rate

The risk-free rate used in this study is that of the SSVX 90 (*Statsskuldväxel, 90 dagar*), which is the rate on the 90-day Treasury bill issued by the Swedish Central Bank, the Riksbank.

The rationale behind using the 90-day maturity is the absence of credit risk, as well as the short maturity giving rise to virtually no liquidity or market risk. Furthermore, the use of Federal Reserve 90-day T-bills is the standard in studies on the U.S. market, for example those by Glosten and Jagannathan (1994) and Mitchell and Pulvino (2001) covered herein. Adding a practitioners perspective, the 90-day T-bill is a very common risk-free rate used by hedge funds when determining performance fees.

All data for the SSVX 90 was retrieved directly from the Riksbank, using the online query system, freely available at their website. (Sveriges Riksbank, 2011)

2.4. STATISTICAL METHODS

This study will make use of the familiar and widely employed linear regression model (Ordinary Least Squares regression) in order to estimate the ability of the risk arbitrage portfolio to generate excess returns, this is given by equation 2.5 below.

$$y_i = \alpha + \beta x_i + \varepsilon_i$$

(2.5)

As can be seen, the $y = \alpha + \beta x$ part of equation 2.5. represents a general straight line equation, describing an exact linear relationship between y and x, which evidently would be unrealistic. Thus, in OLS one adds the residual term ε_i and then proceed to estimate the intercept, α, and coefficient β. These are estimated so that the sum of squared residuals $\sum_{i=1}^{n} \varepsilon_i^2$ is minimised, hence the name Ordinary Least Squares regression. (Brooks, 2008, pp. 29-32)

This method, while simple and crude, is extremely powerful within the context of the linear Sharpe-Lintner-Black Capital Asset Pricing Model, which I will return to in Chapter 3.

As it can be argued that risk-arbitrage does not have a linear relationship with the market, I will also utilise a non-linear regression model in order to capture this relationship, should it exist.[5] It is possible to estimate what is referred to as a non-linear piecewise linear regression model. This is a model which is overall non-linear, albeit consisting of linear segments or "pieces". The piecewise regression model is a sub-technique within the spline technique area. (Brooks, 2008, p. 462) If y_i varies with x_i so that their relationship differs should x_i assume a value larger or smaller than a threshold value, x^*, then their relationship can be described by a piecewise linear model, expressed as

$$y_i = \alpha_1 + \beta_1 x_i + \alpha_2 \delta_i + \beta_2 \delta_i x_i + \varepsilon_i$$

(2.6)

Equation 2.6. above includes a dummy variable, δ_i which assumes the value one if $x_i > x^*$ and zero otherwise. The evident problem from this is that it requires our threshold, x^* to be known, which it is not. To ensure consistency with the OLS-methodology, I will use the value of x^* that minimises the sum of squared residuals, $\sum_{i=1}^{n} \varepsilon_i^2$.[6] An introduction to piecewise regression models can be found in Brooks (2008, pp. 462-465)

While there are other models that will describe non-linear relationships, the nature of the piecewise linear model ensures compatibility with CAPM as well as non-linear frameworks, while also enabling a simple and elegant model to describe seemingly complex relationships.

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[5] Non-linearity is argued by several studies and present in a wide array of literature, including Branch and Yang (2005), Mitchell and Pulvino (2001), Kirchner (2009), Wyser-Pratte (2009). This topic is discussed in-depth in Chapter 3.

[6] An elaborative description on this course of action can be found in section 3.3.

3. THEORETICAL FRAMEWORK

In this chapter I will elaborate on the theoretical framework on which this study is built. The Black-Scholes model, CAPM as well as general theory on Arbitrage will be discussed. I will also present a number of previous studies on the subject, which will aid the analysis in Chapter 4.

3.1. RISK ARBITRAGE

3.1.1. Defining Risk Arbitrage

Continuing where I left the topic in my introduction, let us consider the definition of arbitrage as a self financing trading strategy generating a positive return without risk, *i.e.* the portfolio incurs no negative cash flow at any probabilistic or temporal state and a positive cash flow in at least one state. (Pennacchi, 2008, p. 66)

The assumption of arbitrage-free prices in academia can be made because of the presence of arbitrageurs in the marketplace. (Hull, 2008, pp. 14-15) Arbitrageurs exploit price discrepancies, for example by selling into the expensive market and buying into the cheap market, in doing so they force they prices to converge into an equilibrium price. It goes without argument that this makes markets more efficient, as there will be only one price for the asset or derivative, and hence other market participants are spared potential costs of information, overpaying and underselling. (Kirchner, 2009, p. 4) This has never been truer than today, in the second millennia, where the speed and ferocity with which arbitrageurs at hedge-funds and dealing desks strike down on price discrepancies is second to none.

The academic definition outlined above serves as "*the primary technique with which to value one asset in terms of another*". (Pennacchi, 2008, p.58) Being a prerequisite for general market equilibrium, the assumption of no-arbitrage is indeed a cornerstone in pricing frameworks such as the Black-Scholes (Black and Scholes, 1976, p. 637) and the Sharpe-Lintner-Black Capital Asset Pricing Model. (Black, 1972, p. 444; Sharpe, 1964, p. 436)

The definition above, that is the strict academic definition, does however differ from the definition as used generally in practice by traders. Not unexpectedly, arbitrageurs and traders have a less strict definition of arbitrage than does the academic scholar. The practitioners instead prefer the notion of arbitrage as a strategy with a positive expected value taking advantage of two securities being mispriced relative to each other. (Hull, 2008. p. 773) This strategy is most

commonly self-financing, but need not be. (Taleb, 1997, p. 80) As pointed out by Taleb (*Ibid.*), issues such as risk-neutrality and Martingale are at best irrelevant to most traders.

Table 3.1. below tranches the above "traders' definition" of arbitrage into three different orders, where only the first order can be said to be closely linked to the stricter, academic definition of arbitrage.

Table 3.1. Orders of arbitrage

Degree of Arbitrage	Definition	Practical Implementation
First order	A strong, locked-in mechanical relationship, same instrument	Cash-and-carry arbitrage Triangular arbitrage Location arbitrage Euro-option conversion arbitrage
Second order	Different instruments, same underlying security	Cash-future arbitrage Program trading arbitrage Delivery arbitrage Option spread trading
Second order	Different - albeit related - underlying securities, same instrument	Bond arbitrage Forward trading Volatility trading
Third order	Different securities, different instruments, deemed to behave in correlated/related manner	Asset spread trading Rates correlation trading Cross-currency yield curve arbitrage

Source: Nassim Taleb, *Dynamic Hedging : Managing Vanilla and Exotic Options* (1997, p. 81) Reproduced under the provisions laid forth in Section 108 of the United States Copyright Act.

As evident from Table 3.1. there is a wide range of practical implementations of arbitrage, of which those classified as second and third order are the most common. The second and third order strategies are also strategies where the arbitrageur assumes some sort of risk, the common denominator being that the arbitrageur avoids market risk, while still assuming a different form of risk. These quasi-arbitrage strategies are referred to by a number of names such as statistical arbitrage, or in our case risk arbitrage, which could be classified as second or third order arbitrage as per Table 3.1. (Kirchner, 2009, p. 5)

The risk assumed could theoretically be any kind of risk different from market risk, and in our case it will be the so-called deal completion risk. *i.e.* the risk that the deal is not completed due to

financial, legal, regulatory or other issues. It should also be noted that the author of Table 3.1., Dr. Taleb, does not consider risk arbitrage a form of arbitrage. Taleb (1997, p. 80) does however say about arbitrage in general that *"arbitrageurs believe in capturing mispricings between instruments or markets"*; which is exactly what the risk arbitrageur aims to achieve. That is, he (the arbitrageur) aims to capture the relative mispricing between the price offered, be it in stock or cash, and the price at which the target is trading.

Defining risk arbitrage as a quasi-arbitrage strategy, I would like to make a point analogous to that made by Kirchner (2009). That is, the recognition of arbitrage as its own practice, different from the practice of speculation. While the speculator assumes a position with the hope of making a profitable exit from said position, he does not know at which price he is able to execute the exit. The speculator may have a very well-defined strategy, but in the end he is open to uncertainty. This is in contrast to the arbitrageur who (in theory) knows at which price he buys, and at which price he sells.

In the case of the risk arbitrageur this is true in that the price offered is known, and the arbitrageur captures the spread between the known trading price of the target security and the known price offered by the acquirer. There is however a probability strictly greater than zero that the deal fails, the deal completion risk, and hence the word "risk" in risk arbitrage.

3.1.2. Characteristics of Risk Arbitrage

There is also a further *caveat* adjoined to the notion of arbitrage as a practice different from speculation, and that is the nature of the relationships one aims to arbitrage. While the very rare first order arbitrage opportunities offers a bet on an *a priori* known, mechanical relationships, the risk arbitrageur bets on the *a posteriori* knowledge that a significant part of deals are successfully consummated[7], yielding the arbitrageur a positive expected return.[8]

The risk arbitrageur then places a bet on behavioral stability, rather than mechanical, the former being inherently more risky than the latter, representing a weaker order of arbitrage. It could in fact be argued that where historical records suggest a behaviorally stable relationship, there are "booby traps" which could cause the arbitrage strategy to implode. (Taleb, 1997, p. 81)

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[7] My data records a 95.12% success rate, while that of Baker and Savasoglu records one of 86%, Jindra and Walking records 96.7% and Schwert one of 94%. Other studies show similar results.
[8] See table 3.2. below.

This would be consistent with the note by Mitchell and Pulvino (2001, p. 2135) that risk arbitrage has played a significant role in some very spectacular implosions, such as that of LTCM.[9] And we are yet to see the last scholar or trader to label the practice of risk arbitrage *"an act of picking up pennies if front of a steamroller"*[10] Despite these claims to the contrary, academic research into the ability of a risk arbitrage strategy to generate excess returns have returned very promising results, of which some are presented in Table 3.2 below.[11] The seemingly contradictory observations of large excess returns and "booby trap" or implosion-proneness are implying that the strategy is exhibiting non-linearity of returns.

Table 3.2. Excess Return in Academic Studies

Study	Annualised excess return	Note
Baker and Savasoglu (2002)	12.5 %	Event study
Branch and Yang (2005)	22.42 %	
Dukes et al. (1992)	> 100%	Event study
Jindra and Walkling (2001)	26,97%	Event study
Karolyi and Shannon (1998)	25 %	
Mitchell and Pulvino (2001)	9.9 %	

An early study of the non-linear characteristics of risk arbitrage is that by Bhagat *et.al* (1987, pp. 975-976), where the conclusion is that linear asset pricing models such as CAPM fail to properly address the non-linearity of risk arbitrage. Mitchell and Pulvino's widely quoted study of 4750 mergers between 1963 to 1998 conclude that risk arbitrage is akin to writing uncovered index put options, generating an essentially zero beta in appreciating markets, and a non-zero, positive beta in depreciating markets. (Mitchell and Pulvino, 2001, p. 2137) This is further reinforced by Branch and Yang (2005, p. 55) who reach the same conclusion about non-linearity in cash deals. The same observation is made by Agarwal and Naik (2004, p. 66), referring to it as significant left-tail risk, or left-skewed non-linearity. On a more general basis, it is found by Merton (1981, p. 365) as well as Dybvig and Ross (1985, p. 397) in the course of their respective evaluation(s)

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[9] Long-Term Capital Management, arbitrage hedge fund founded by arbitrageur John W. Meriwether, with Myron Scholes and Robert C. Merton, quoted herein, serving as directors.

[10] This has in fact been used by several people, including by not limited to, Roger Lowenstein, Laurie Pinto and Nassim Nicholas Taleb, where the latter is most often credited with coining the phrase.

[11] A more in-depth review of some of the studies is presented in section 3.4.

of linear asset pricing models, that option-like non-linearities are present in portfolios managed with superior information.[12] They further conclude that the CAPM and other linear asset pricing models are generally insufficient in evaluating said portfolios due to their linear nature, something I shall return to later in this chapter.

The notion of non-linearity also makes sense from a practitioners view when considering two things, firstly the AVP, or asymmetric volatility phenomenon, and secondly, the use of leverage and lack of diversification with arbitrage hedge fund managers. Volatility feedback at the market level, exclusive of the firm leverage, is argued by Bekaert and Wu (2000, pp. 6-8) and forms the basis of the AVP. Given the widely observed tendency for markets to slowly gain ground only to crash rather spectacularly, this notion does not seem far-fetched. When this is coupled with the use of highly leveraged and/or non-diversified portfolios, as would likely be the case with risk arbitrage considering the rather small spread (median spread for successful deals with the MVWRA at $t = 0$ was 1.31%) and the high expected success rate (MVWRA unique target success rate 95.12%), it produces a rather lethal cocktail, or "booby trap"[13] While the MVWRA portfolio does not simulate leverage, it does simulate the absence of diversification by being willing to commit the whole portfolio to a few, or even a single, open deal(s).

To put it bluntly, it could be implied that picking up the pennies in front of the steamroller will generate alpha until a point in time, at which a shock sufficient enough to generate significant volatility is introduced to the system, at this point the steamroller runs over the arbitrageur. Nevertheless, over time, the expected excess return of risk arbitrage is consistently positive according to all studies I have researched.

3.1.2. Explanations for Excess Returns in Risk Arbitrage

From the significant excess returns reported by the studies outlined in Table 3.2., there is considerable evidence that the market is inefficient in pricing stocks involved in deals. The risk arbitrageur then simply acts as an arbitrageur in the classic sense of the word, and captures the pricing inefficiency. While this notion could be argued to partly explain risk arbitrage returns,

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[12] The fact that arbitrageurs typically resides with superior information is convincingly put forth by among others Shleifer and Vishnvy, 1997.

[13] This lethal cocktail (or "booby trap") being what Taleb (1997, p 81) refers to in his notion about implosion-proneness in quasi-arbitrage.

and likely is partly responsible, I argued in section 3.1.1. that pricing inefficiencies of this magnitude should, theoretically, not exist.

Enter the insurance explanation, as argued by Baker and Savasoglu (2000). The basic idea is that the arbitrageur acts as a *de facto* insurance provider to the marketplace, accepting the deal completion risk that other investors are unwilling to bear. In theory, the markets should immediately after announcement reflect the deal price. In reality, there could be a very large free-float held by a wide array of investors, most rather unwilling to assume the deal completion risk with a limited upside and unknown downside. This is coupled with a rather limited number of investors – the arbitrageurs – willing to buy these quantities of a stock with said limitations on returns. The result is a scenario of excess supply, arbitrageurs being virtually the only buyers in the market, which produces a selling pressure and dislocates the target share price from the actual deal price, hence producing a spread which can be arbitraged. (Shleifer and Vishny, 1997, pp. 36-37) By acting as an insurer in the marketplace the arbitrageur earns a known premium for assuming essentially unknown downside risk, another argument for risk arbitrage being analogous to writing uncovered put options.

3.2. THE CAPITAL ASSET PRICING MODEL

Despite their almost unanimous critique of the accuracy of the Sharp-Linter-Black Capital Asset Pricing Model (henceforth referred to as the CAPM) in evaluating risk arbitrage returns, the studies mentioned in section 3.1. have one thing in common, they all use the CAPM or one of its derivatives.

CAPM is the number one asset pricing model, as eloquently put by Fama and French (2004, p. 25) *"Although every asset pricing model is a capital asset pricing model, the finance profession reserves the acronym CAPM for the specific model of Sharpe(1964), Linter (1965) and Black (1972)..."* The model is so widely used, that even when attempting to correctly account for non-linearity, scholars use a linear CAPM in some respect, as will I. While it is not purposeful for this study to derive or fully elaborate the vast topic of the CAPM, a high-level overview is necessary in order to showcase its genius and its shortcomings.

As mentioned in section 3.1.1. the CAPM is an equilibrium pricing model, assuming general equilibrium as well as a few assumptions about investors and the opportunity set, these assumptions are as follows:[14]

a) Investors are risk averse individuals who maximise the expected utility of their wealth.
b) Investors are mean-variance optimisers.
c) Investors have homogenous expectations about asset returns.
d) The quantities of assets are fixed and all assets are marketable and infinitely divisible.
e) Perfect capital markets *i.e.*
   i. Investors are price-takers.
   ii. No taxes.
   iii. No transaction costs.
   iv. There is a risk-free asset and investors may lend of borrow unlimited amounts at the risk free rate.

Provided that general equilibrium as well as the above assumptions hold, the expected return on an asset, $E(R_i)$ can be expressed as follows:

$$E(R_i) = R_f + [E(R_m) - R_f]\frac{\sigma_{im}}{\sigma_m^2}$$

(3.1)

In equation 3.1. above, R_f denotes the risk-free rate, $E(R_m)$ the expected market return and σ_{im} the covariance between the market and the asset, while σ_m^2 is the market standard deviation of returns. Note that σ_{im} divided by σ_m^2 is equal to the beta-coefficient, β_i. Equation 3.1. is also referred to as the Security Market Line (SML), and perhaps the most important property of the CAPM is that in equilibrium all assets are priced so that their respective (risk-adjusted) rates of return fall exactly on the SML. A further implication is that investors will pay premium only to avoid covariance risk. (Copeland et al., 2005, p. 152)

Equation 3.1. represents an *ex ante* form of the CAPM, and while elegant, for the task at hand, that is the evaluation of portfolio returns, it serves no purpose. CAPM does however lend itself to an equally elegant transformation from a representation of expectations *ex ante* to observations

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[14] Assumptions as listed in Copeland et al., (2005, pp. 147-148), see also Sharpe (1964, pp. 430-434)

ex post. In making this transformation, it is assumed that capital markets represent a fair game, expressed in equation 3.2. below.[15] (*Ibid.,* p. 165) That is, equation 3.2. represents the "market model" as presented by Jensen (1968, p. 391), who showed that b_i is approximately equal to the beta coefficient, β_i. ϑ_m is a "market factor" equal to $\vartheta_m = R_m - E(R_m)$ and ε_i a random error term. (*Ibid.,* p. 392)

$$R_i = E(R_i) + b_i \vartheta_m + \varepsilon_i$$

(3.2)

In equation 3.2. the following holds: $\vartheta_m = R_m - E(R_m)$, $E(\vartheta_m) = 0$, $E(\varepsilon_i) = 0$, $\sigma_{\varepsilon_i,\vartheta_m} = 0$ and $\sigma_{\varepsilon_i,\varepsilon_j} = 0$. (*Ibid.,* p. 392) Substitution of $E(R_i)$ from equation 3.1. into equation 3.2. yields the following equation:

$$R_i - R_f = (R_m - R_f)\beta_i + \varepsilon_i$$

(3.3)

Equation 3.3. represents CAPM *ex post* and its usefulness is evident for anyone familiar with linear regression. By allowing for a non-zero intercept, α, in equation 3.3., we have the actual equation which will be used in conjunction with linear regression in order to estimate excess returns, equation 3.4.

$$R_i - R_f = \alpha_i + (R_m - R_f)\beta_i + \varepsilon_i$$

(3.4)

Equation 3.4 is commonly referred to as the Single-Index Model or the Security Characteristic Line. In the original CAPM context, the intercept term α_i should not be significantly different from zero for any asset, i. It is however argued by Jensen (1967) that allowing for a non-zero intercept in equation 3.3. will allow this intercept to represent the *"the average incremental rate of return of the portfolio per unit time which is due solely to the manager's ability to forecast future security prices"* (*Ibid.,* p. 394) This interpretation of the non-zero intercept, or alpha, has become the world standard in portfolio manager evaluation, and will be used in this thesis to measure the excess return of the MVWRA portfolio.

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[15] For a thorough explanation of CAPM as a fair game, see Copeland *et al.* Chapter 10, pp. 370-372 in particular.

3.3. PRICING NON-LINEARITY IN RISK ARBITRAGE

As mentioned in section 3.1, a wide array of academic studies have found hedge funds in general and risk arbitrage in particular to exhibit a non-linear, option-like relationship to market returns, *i.e.* similarities to writing uncovered index put options. This presents a peculiar problem as our widely used model, the CAPM, is linear in nature and would thus unable to properly account for such non-linearities, as shown by several studies presented in section 3.1.

There is however remedy for this problem in the form of a method shown by Glosten and Jagannathan (1994), built on Merton's (1981) and Merton and Henriksson's (1981) research on fund managers and market timing. The paper by Glosten and Jagannathan (1994) is very general in nature and shows that, using a contingent claims approach, one can more accurately approximate the performance of active managers than with linear approaches. Glosten and Jagannathan (1994) show that the value of performance is the equivalent to valuing a specific contingent claim on an index, *i.e.* by constructing a replicating portfolio using options on an index, and comparing this to an investment in the portfolio being evaluated, one can value the performance of the portfolio. The contingent claim can be valued using any options-pricing model, and I will make us of the widely used Black-Scholes model, which is covered in section 3.4.

The form of the payoff (return) projection is not given in the general method and must hence be estimated, it is however suggested to use a "one-knot spline", an approach similar to the one suggested by Henriksson and Merton (1981). (Glosten and Jagannathan, 1994, p. 145, p. 158) The most significant difference here is that while the Henriksson-Merton-approach suggests placing the knot spline exactly at the risk-free return (rate), Glosten and Jagannathan (1994, p. 143, p. 148) suggest choosing the knot spline placement, or threshold, based on minimisation of the sum of squared errors (residuals).

The basic concept is to utilise a linear model, such as CAPM, in conjunction with a linear estimation method, such as linear OLS regression, albeit with a threshold point (the one-knot spline) which will generate an overall non-linear function. Agarwal and Naik (2004, p. 64) suggest specifying a non-linear piecewise linear regression model, which is an approach used by Mitchell and Pulvino (2001, p. 2142). Now recall equations 2.6., my piecewise linear regression

model, and 3.4., the CAPM *ex-post*. Combining them to estimate a piecewise linear CAPM-derived model yields the following equation to be estimated for a portfolio p

$$R_p - R_f = (1 - \delta)[\alpha_{pMktL} + \beta_{pMktL}(R_m - R_f)] + \delta[\alpha_{pMktH} + \beta_{pMktH}(R_m - R_f)] + \varepsilon$$

(3.5)

Equation 3.5 makes use of one alpha for appreciating markets, α_{pMktH}, and one for depreciating markets α_{pMktL} while the same is applied to beta, β_{pMktH} and β_{pMktL} respectively. Appreciating markets are those where $(R_m - R_f) > (R_m - R_f)_T$ and depreciating markets are where $(R_m - R_f) < (R_m - R_f)_T$, similarly, δ is a dummy variable whose value is one for $(R_m - R_f) > (R_m - R_f)_T$ and zero if $(R_m - R_f) < (R_m - R_f)_T$ $(R_m - R_f)_T$ denotes the treshold level, or knot spline, as denoted by x^* in equation 2.6.

In keeping with Glosten and Jagannathan's (1994, p. 143, p. 158) method the model is composed as portfolio return as a function of a market return, as well as a residual term, ε, with an expected value of zero, $E(\varepsilon) = 0$. This is, as evident from sections 2.4. and 3.2., perfectly in line with the assumptions of both the CAPM and the OLS regression model. Equation 3.5 is also estimated subject to a continuity-ensuring restriction, as used by Mitchell and Pulvino (2001, p.2142) $\alpha_{pMktL} + \beta_{pMktL}(R_m - R_f)_T = \alpha_{pMktH} + \beta_{pMktH}(R_m - R_f)_T$ to ensure that the estimation yields a continuous non-linear piecewise linear function. This estimation is necessary to keep the piecewise linear regression estimation in line with Glosten and Jagannathan's (1994) method, advocating a spline on a non-linear piecewise linear, continuous line.

While equation 3.5. will yield information about the characteristics of the series, it is not the purpose of this thesis to evaluate the characteristics of risk arbitrage in the Swedish market, but rather to evaluate its ability to generate alpha in both linear and non-linear models. In order to generate a meaningful, non-linearity-adjusted alpha from equation 3.5., an option-pricing framework has to be put to use, I intend to utilise the Black-Scholes model, as presented below in section 3.4.

In evaluating excess returns, I will assume that risk arbitrage *is* akin to writing uncovered index put options, as there is significant academic research pointing towards this, research which is further underlined by observations of scholars and fund managers as presented in sections 3.1.

and 3.5. Hence, a risk arbitrage portfolio could be replicated by writing (issuing, shorting) uncovered index put options and purchasing a risk-free bond.

To replicate the one-month return on an investment in risk arbitrage, I construct a replicating portfolio by acquiring a bond with face value $(V_{RiskArb}) \cdot (1 + R_f + \alpha_{pMktH})$ and write β_{pMktL} number of put options with strike $(V_{RiskArb}) \cdot (1 + (R_m - R_f)_T + R_f)$. The value of this portfolio, V_{pR} equals:

$$V_{pR} = PV\big[(V_{RiskArb}) \cdot \big(1 + R_f + \alpha_{pMktH}\big)\big] - (\beta_{pMktL}) \cdot P\big(X, S, R_f, \sigma, T - t\big)$$

(3.6)

where PV denotes present value, $P(X, S, R_f, \sigma, T - t)$ denotes the Black-Scholes price of a put option with strike, X as above, underlying value, $S = V_{RiskArb}$, risk-free rate, R_f equal to the actual sample average, standard deviation of returns, σ also equal to the sample average, and time until expiry, $T - t$ of one month. The value of this portfolio, V_{pR}, is subsequently compared to the value of the investment in risk arbitrage $V_{RiskArb}$ and should $V_{RiskArb} < V_{pR}$ then risk arbitrage generates a monthly excess return, alpha, equal to $\alpha = (V_{pR} - V_{RiskArb})/V_{RiskArb}$

The above constitutes a generalisation of the approach presented by Mitchell and Pulvino (2001, pp. 2161-2164), built on the framework by Glosten and Jagannathan (1994), Merton (1981) and Henriksson and Merton (1981) as presented herein.

3.4. THE BLACK-SCHOLES MODEL

In order to properly account the non-linearity in risk arbitrage using Glosten and Jagannathan's (1994) framework, I will value a portfolio consisting of a bond and a contingent claim. While the contingent claim, or option, can theoretically be valued using any option pricing model, I will employ the Black-Scholes model (sometimes referred to as the Black-Scholes-Merton model). Originally conceived in the early 1970s, the model and its spin-offs has become the standard in option pricing in academia as well as with practitioners. (Hull, 2008, p. 277) Despite the numerous, rather ambitious attempts to dethrone the Black-Scholes model with improved models, almost all of these models have died trying. *"No experienced trader would willingly trade Black-Scholes-Merton for another pricing tool."* (Taleb, 1997, p. 109)

As with the CAPM, I will refrain from a full derivation as it would not serve any purpose for the thesis, and I will briefly outline the assumptions and basic mechanics of the model. Black and Scholes (1973) present a few assumptions under which the model is derived. These are referred to as the "ideal conditions". (*Ibid.*, p. 640):

a) The short-term interest rate is known and remains constant as time passes.

b) The stock price follows a random walk in continuous time, having a variance rate proportional to the square of the stock price.[16] The variance rate of return is constant.

c) The stock pays no dividends or other coupons.

d) The option can only be exercised at maturity. (it is European)

e) There are no transaction costs.

f) It is possible to borrow any fraction of the price of a security to buy or hold it at the short-term interest rate.

g) There are no penalties for short selling, *i.e.* the short sale is the exact opposite of a buy and the short seller is not penalised by fees.

The above assumptions are shown by Merton (1973, p. 160) as being equivalent to:

1) The standard form of the CAPM holds for intertemporal trading, and that trading takes place in continuous time.

2) The short-term interest rate remains constant as time passes.

3) There are no dividends or exercise price changes during the life of the contract.

Thus, the Black-Scholes model invokes the very same assumptions as the CAPM, with the addition of two. Under the presence of these assumptions, Black and Scholes (1973 p. 641) showed that: *"it is possible to create a hedged position consisting of only a long position in the stock and a short position in the option, whose value will not depend on the price of the stock."* The basic concept behind their derivation is that of perfect hedging. That is, the "position" or portfolio above is adjusted as the stock price changes, by the selling of further options, or repurchase of already sold ones, this in order to maintain the perfect hedge. Provided this hedge is maintained continuously the return on the position becomes certain, and equal to the risk-free

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[16] This makes the distribution of the stock price, at the end of a finite interval, lognormal. See Hull (2008, p. 277-280) for an elaboration on lognormal distributions within the context of option pricing.

rate of return. (Merton, 1973, p. 160) Then, the price of a European call option can be derived using stochastic calculus to reach the Black-Scholes option pricing formula:[17]

$$C = S \cdot N(d_1) - Xe^{-R_f(T-t)}N(d_2)$$

(3.7)

Where $d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}}$ and $d_2 = d_1 - \sqrt{T-t}$, S denotes the stock price, $N(d)$ represents the cumulative distribution function of the standard normal distribution, X the exercise price, R_f is the risk-free rate, σ is the standard deviation (volatility) of returns, and $T - t$ denotes time to maturity.

By using put-call parity, *i.e.* the notion that $C + Xe^{-R_f(T-t)} = P + S$, it is possible to show that the price of a European put option will be given by the following formula:

$$P = Xe^{-R_f(T-t)}N(-d_2) - S \cdot N(-d_1)$$

(3.8)

Equation 3.8. above, yielding the Black-Scholes price of a European put option, is the pricing formula which will be used in this thesis in order to assign a value, V_{pR}, to the replicating portfolio from section 3.3.

While extensive in assumptions, the Black-Scholes formula is a very attractive as all of its variables are clearly observable, and that it is independent of the expected return on the underlying stock. (*Ibid.*, p. 160)[18] Furthermore, while it is known from empirical tests that prices paid by option buyers are systematically higher than the prices given by the formula, Black and Scholes (1973, p. 653) have shown through empirical test that the prices received by writers of options are approximately equal to the equivalent Black-Scholes price. This is a favourable observation for the evaluation undertaken in this thesis, as the valuation of V_{pR} involves the theoretical writing of a put option.

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[17] See Black-Scholes (1973, pp. 642-644) for the full, formal derivation.
[18] Let it be noted that the volatility, unlike the risk-free rate, the time to maturity, the stock price and the exercise price, cannot be directly observed, but rather has to be estimated from historical stock price data.

Mitchell and Pulvino (2001, p. 2164) tested the validity of their contingent claims approach using Black-Scholes, by also assigning a value, V_{pR} to their replicating portfolio using actual put prices. It was found that the use of Black-Scholes only slightly overestimated the alpha, when compared to actual put option prices, and that this stemmed from the difference between actual and implied volatilites. This slight difference was found to have no significant implications on their result or conclusions. (*Ibid.*, p. 2164) Thus, there is no empirical evidence against using the Black-Scholes formula to price the contingent claim in the replicating portfolio.

3.5. PREVIOUS STUDIES OF RISK ARBITRAGE RETURNS

Although sections 3.1 and 3.3. contains an glimpse of some previous studies of risk arbitrage returns by default, I will herein attempt to summarise previous findings with the intention that this will aid the reader in interpreting my results as well as putting my conclusions into context. The studies are presented in alphabetical order by author surname, and emphasis is put on studies aiming to evaluate the ability of risk arbitrage to generate excess returns.

3.5.1. Baker and Savasoglu (2001)

Title: *Limited Arbitrage in Mergers and Acquisitions*. The authors aim to evaluate risk arbitrage returns, in doing so they also aim to evaluate the origin of the excess returns generated by risk arbitrage strategies. It is shown, that for the period from 1981 to 1996, risk arbitrage produces an excess return of $0.6 - 0.9\%$ per month. The dataset used is one of 4135 announced deals retrieved from the CSRP database. Rather than constructing a calendar time portfolio, such as my MVWRA, Baker and Savasoglu (2001) calculate the returns for the first 30 days after deal announcement. While this has the benefit that it eliminates benchmarking over longer horizons, which can be challenging, it also has the disadvantage that it is very unlikely that these event-time returns would be sustainable. Nevertheless, Baker and Savasoglu (2001, p. 112) reach some interesting conclusions not only regarding the excess returns, but also regarding the characteristics of said returns. They find that the average, often undiversified investor, is keen to sell stock holdings to arbitrageurs to avoid completion risk. The limited capital of arbitrageurs ensure that investors will have to sell at a discount, essentially earning the arbitrageur a premium for insuring deal completion risk. This point is convincingly argued and parallels are made to empirical studies of the insurance market.

3.5.2. Branch and Yang (2005)

Title: *A Test of Risk Arbitrage Profitability.* The title says it all, a thorough test of the profitability of risk arbitrage and its ability to generate excess returns. Using a sample of mergers between 1990 and 2000 for a total of 1309 U.S. deals, it is found that risk arbitrage generates a significant monthly alpha of 1.7% (22.42% annualised)

The sample does not exhibit the same option-like characteristics as argued by other studies, rather than producing a significant and higher beta in down markets, it produces a negative beta in said markets. It is however found that this is due to the high percentage (79%) of stock offers in the sample, implying that sample bias may influence whether a sample exhibits option-like non-linearities.[19] This is logical from the fact that stock offers are hedged by shorting the acquirer stock, thus ensuring some degree of hedge against negative market returns.

3.5.3. Jindra and Walkling (2001)

Title: *Speculation Spreads and the Market Pricing of Proposed Acquisitions.* Jindra and Walkling's (2001) working paper has the primary aim to study the behaviour of post-announcement spreads, *i.e.* the differences between the market price of the target stock and the actual price offered by the acquirer. The sample used is a total of 362 cash deals spanning the 1981-1995 period. The average annualised excess return found from investing in their sample is 33% for the event study, however this drops to 26.97% using a Fama-French three-factor model on monthly portfolio returns. Additionally, the paper finds that spreads in mergers and acquisition deals are significantly related to bid premiums, pre-offer run-up of the stock price, managerial attitude to the offer, as well as the presence of rumours. The findings about arbitrage spreads and their determinants – while interesting – does not represent findings of significane for this study, and hence the interested reader is referred to the paper itself.

3.5.4. Mitchell and Pulvino (2001)

Title: *Characteristics of Risk and Return in Risk Arbitrage.* Mitchell and Pulvino's (2001) paper was one of the main inspirations for myself when researching this thesis, it has also turned out to be the most widely quoted of the studies presented here in section 3.5. Using a sample of 4750 deals in the years from 1963 and 1998, by far the most comprehensive in both calendar-time and

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[19] When evaluating the cash offers separately, they are found to exhibit the same kind of non-linearities as shown by Mitchell and Pulvino (2001).

number of deals, it is found that risk arbitrage generates a significant monthly alpha of 0.74% (9.25% annualised) using a linear approach, and 0.33% (4% annualised) using a contingent claims approach based on the findings by Glosten and Jagannathan (1994).[20] The approach used is a calendar-time portfolio approach with monthly returns, similar to that used by myself and Baker and Savasoglu (2001).

The characteristics of risk arbitrage are evaluated using the CAPM, the Fama and French three-factor model as well as a non-linear contingent claims model, using Black-Scholes. Regressions are also done on a sub-sample basis to ensure robustness, and their RAIM (Risk Arbitrage Index Manager) portfolio is designed so that transaction costs, including the cost of entering a (relatively) illiquid stock, are accounted for to the extent possible under some assumptions. These rather ambitious attempts to "cover it all", sets the paper apart from other previous studies as well as this thesis. In addition to the excess return figures produced, the single most significant finding is that risk arbitrage is found to exhibit significant option-like non-linearities, and it is concluded that practicing risk arbitrage is akin to writing uncovered index put options. (Mitchell and Pulvino, 2001, p. 2137, 2171) While other studies touch the subject of option-like non-linearities and also show that risk arbitrage does exhibit them, the large nature of the sample and the approach using a monthly return series does lend this study some quite unparallel academic credibility.

It should be duly noted that the resulting excess returns are lower than in most other studies, which could imply that the efforts to fully capture the characteristics of risk arbitrage may have resulted in return figures that are in fact too low. However, given the encompassing nature of the sample, and the rather spectacular results produced by some other studies, it is my personal opinion that Mitchell and Pulvino (2001) have produced the most accurate and rigorous study of risk arbitrage returns to date.

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[20] As stated in section 3.3., my approach is analogous to the one used by Mitchell and Pulvino (2001), the difference being that I present it in a more general manner for ease of replication.

4. RESULTS AND ANALYSIS

Herein the data output is presented together with descriptive statistics in section 4.1. In section 4.2. I aim to discuss the output of the regression analysis using the theories and research presented in Chapter 3.

4.1. DESCRIPTIVE STATISTICS AND DATA

The MVWRA portfolio constructed using the assumptions and methods in section 2.3. contains a total of 132 monthly returns, covering 2611 trading days, a full summary of the monthly returns is located in Appendix I. In Table 4.1. below you will find a brief summary of the yearly returns, yearly standard deviations and yearly Sharpe ratios.

Table 4.1. MVWRA yearly data

Year	Return	Std. Dev	Sharpe Ratio
2000	9,49%	3,54%	2,68
2001	12,78%	8,35%	1,53
2002	7,72%	6,68%	1,16
2003	16,81%	14,58%	1,15
2004	28,54%	13,94%	2,05
2005	21,24%	17,32%	1,23
2006	17,51%	16,19%	1,08
2007	3,72%	20,50%	0,18
2008	-4,42%	8,18%	-0,54
2009	66,73%	36,68%	1,82
2010	15,74%	19,12%	0,82

Investing in the MVWRA over the total 132-month period would have yielded a return of 444.57% (16.66% annualised) while an investment in the OMXS30 index would have yielded −6.75% and an investment in the SSVX90 risk-free rate, reinvested on a monthly basis, would have returned 34.35%, the series are plotted in Figure 4.1. The average yearly standard deviation of returns for the MVWRA portfolio was equal to 15.01% for the full 11-year period. (OMXS30 averaged a yearly standard deviation of 19.83%), while the sample average annual risk-free rate (SSVX90) was 2.68%.[21]

The MVWRA returns are not deemed to be extraordinary within the context of risk arbitrage (see sections 3.1. and 3.5.), and are in fact lower than even the excess returns of four out of six studies in Table 3.2. This despite the fact that the only year with negative performance was 2008, when the MVWRA suffered a loss of 4.42% while the market index lost 38.75%. Sharpe ratios are

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[21] Volatility per annum given by: daily volatility multiplied by the square root of 252, the number of trading days. Method as described by Hull (2008, p. 284)

calculated for reference, being a popular measure among hedge funds, on a yearly basis, and could be deemed satisfactory for all years, less 2007 and 2008, where they are exceptionally low. The average monthly return for the MVWRA portfolio was 1.41%, the three best months were July 2009 (28.05%), December 2009 (21.06%) and March 2010 (14.40%), while the worst were September 2003 (−6.78%) February 2007 (−7.99%) and February 2010 (−6.37%).

In terms of deals, as stated in section 2.3.1., there were 111 deals included covering 82 unique target companies, of which 78 acquisitions were successful. This implies that there were 29 offer amendments or competing bids launched, which are most likely responsible for the more extreme monthly returns, such as the three shown above. The unique target success rate of 95.12% is in-line with those of previous studies, where success rates in the high nineties are common.

Figure 4.1. MVRWA, OMXS30, SSVX90, indexed to one
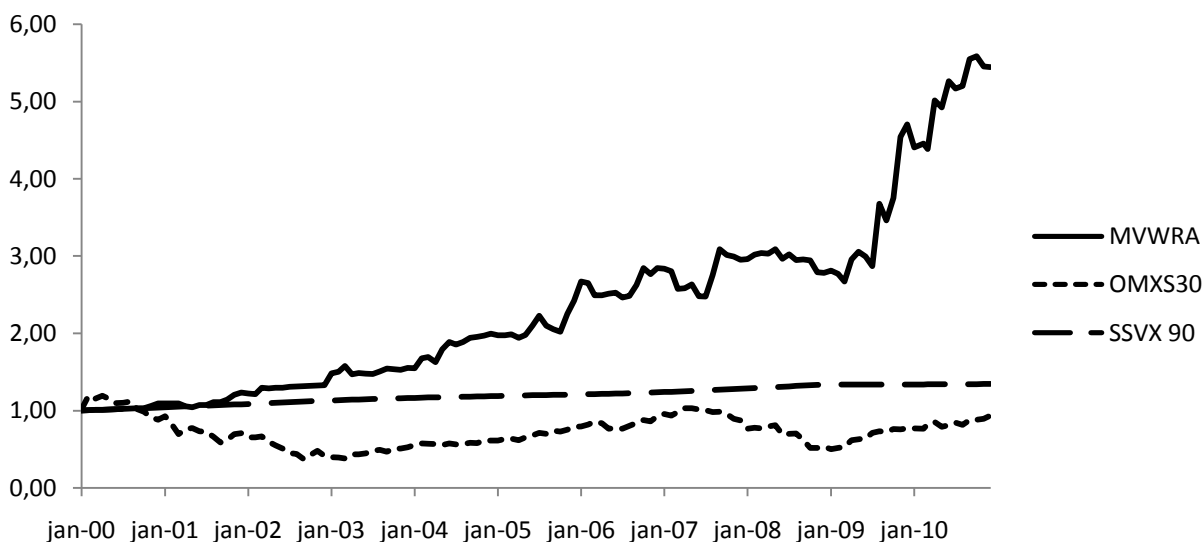
It can also be observed that the median arbitrage spread in successful deals decays to zero as time passes, in line with the notion that risk arbitrage is akin to write uncovered index put options, (the prices of all non-linear derivatives are time-dependent, and options are non-linear derivatives [Taleb, 1997, p. 9]) See Figure 4.2. for a plot of the median arbitrage spread, which is identical in form to the graph of successful deal spreads presented by Mitchell and Pulvino (2001, p. 2139) While an interesting note, this does not carry significant implications for the conclusions of the study.

Figure 4.2. Median Arbitrage Spread - Successful Deals

Note: median spread = 0 for all t = 50,...,T
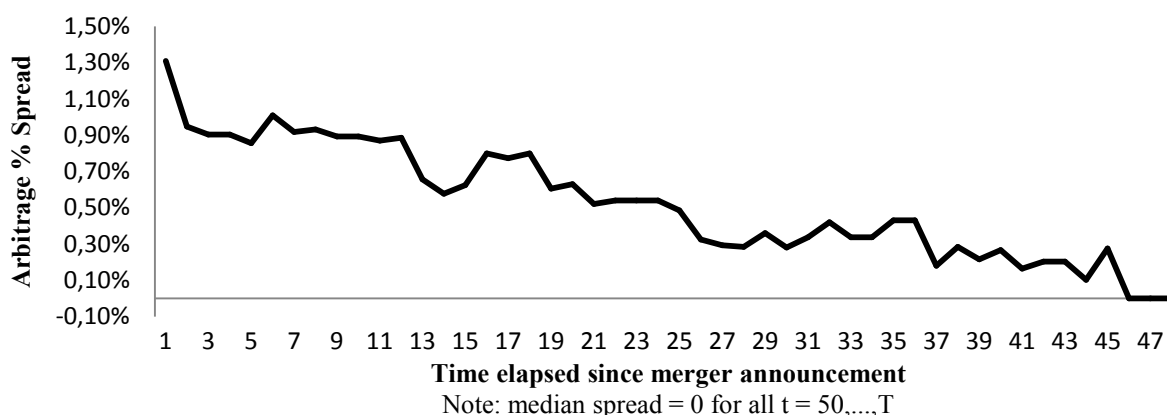
4.2. RESULTS AND ANALYSIS

4.2.1. Linear Regression

CAPM ex-post, equation 3.4., was estimated for the 132 monthly returns using the general OLS regression framework as described in section 2.4., the resulting output follows in Table 4.2.

Table 4.2. MVWRA returns CAPM estimation

Dependent var.	Regressor var.	α	β	R^2
MVWRA less SSVX90	OMXS30 less SSVX90	0.0120 (∗)	0.2976 (∗)	0.1454

* denotes significance at the 5%-level

The output in Table 4.2. indicates a statistically significant alpha of 120 basis points per month, or 15.39% annualised, while the beta is 0.30 for the sample. All estimations are significantly different from zero at the 5% level of confidence, albeit with a low coefficient of explanation, R^2. One should not be alarmed by the latter, as it is fairly common in evaluating portfolio performance, for comparison, Mitchell and Pulvino's (2001) linear estimation produced an R^2 of 0.057. Comparing Table 4.2. to the studies presented in Chapter 3, the estimated coefficients are not in any way exceptional, but rather in line with the findings of previous studies. The estimated beta is low, indicating a low dependence of MVWRA returns to market returns, as is the case in previous studies presented in Chapter 3, such as Branch and Yang (2005) and Mitchell and Pulvino (2001).

4.2.2. Piecewise Linear Regression

Herein I have estimated the non-linear, piecewise linear model as given by equation 3.5., once again using the framework presented in section 2.4., the results from this regression are presented in Table 4.3. below, the threshold minimising the sum of squared residuals, $(R_m - Rf)T$, was found at a *(Rm−Rf)*-value of *−0.01394.*

Table 4.3. MVWRA returns piecewise CAPM estimation $((R_m - R_f)_T = -0.01394)$

Dependent var.	Regressor var.	α_{MktL}	$\alpha_{MktH}{}^I$	β_{MktL}	β_{MktH}	R^2
MVWRA less SSVX90	MVWRA less SSVX90	0.0071 (∗)	0.0093 (∗)	0.2510 (∗)	0.4060 (∗)	0.1570

* denotes significance at the 5%-level, **I** denotes intercept

Once again the regression parameters are all significantly different from zero at the 5% −level, this time with a higher, albeit still rather low, coefficient of explanation, R^2. When compared to the linear model estimations, the results indicate a slightly lower alpha. The alpha for the whole estimation is α_{MktH}, as this is the intercept of the continuous non-linear, piecewise linear regression line. This amounts to 93 basis points per month or 11.75% annually.

The betas come in lower in depreciating and higher appreciating markets respectively, when compared to the linear model. This indicates that the MVWRA returns have a higher non-diversifiable statistical variance in appreciating markets. *i.e.* the market risk is greater above the market return threshold than below it. This observation of the beta-coefficients is especially noteworthy as the previously presented theory concurrently leads one to expect it to be the other way around, *i.e.* a beta closer to zero in appreciating markets and a higher positive beta in depreciating markets. A higher, non-zero beta in appreciating markets is, for example, seemingly contradictory to the results presented by Mitchell and Pulvino (2001) and others in sections 3.1. and 3.5. There could be a number of explanations for this behaviour of the sample, one being a right-tail bias due to the number of deals where the first bid was outbid by a competing bid, in favour of the arbitrageur. Other factors such as the mix of cash and stock offers in the sample could also be influential in this, as shown by Branch and Yang (2005). Naturally, excessively excluding criteria in deal selection or period selection for portfolio generation could also be influential factors in causing the sample to exhibit this behaviour.

Nevertheless, given the overwhelming support from academia in favour of left-skewed non-linearity in risk arbitrage, I personally deem the possible explanation that risk arbitrage in Sweden is right-skewed non-linear to be implausible at best.

4.2.3. Contingent Claims Evaluation using Black-Scholes

Although the MVWRA-portfolio have not shown the same non-linear relationship with the market as have been indicated in previous studies, this analysis is implemented on the basis of assumptions. One of the central assumptions being that risk arbitrage in general is non-linearly related to market returns, in such a way that the strategy is akin to writing uncovered index put options. (as stated in section 3.3.)

In order to capture the risks of characteristic when estimating excess return, the contingent claims approach using the Black-Scholes pricing framework presented in 3.3. and 3.4., is applied to the results in Table 4.3. Now consider equation 3.6. from earlier which is reprinted below:

$$V_{pR} = PV\big[(V_{RiskArb}) \cdot \big(1 + R_{fM} + \alpha_{pMktH}\big)\big] - (\beta_{pMktL}) \cdot P\big(X, S, R_f, \sigma, T - t\big)$$

(3.6)

also consider that $X = (V_{RiskArb}) \cdot (1 + (R_m - R_f)_T + R_{fM})$ and $V_{RiskArb} = 100$ is an invested amount of cash. The Black.Scholes price for the put option, $P\big(X, S, R_f, \sigma, T - t\big)$, as given by equation 3.8., was calculated using Wolfram Alpha and for $X = 100 \cdot (1 + (-0.01394) + 0.0022) = 98.83$, $S = 100$, $R_f = 2.68\%$ (SSVX90 sample average), $\sigma = 19.83\%$ (OMXS30 sample average), $T - t = 1$ month, P is equal to SEK 1.66. Inserting this value together with the values known from Table 4.3. into equation 3.6. yields:

$$V_{pR} = \frac{[100 \cdot (1 + 0.0022 + 0.0093)]}{1.0022} - (0.2510) \cdot 1.66 = 100.51$$

This means that V_{pR} is SEK 0.51 more expensive than $V_{RiskArb}$, equating to a monthly alpha of 51 basis points, or an annual excess return of 6.29%. Comparatively, Mitchell and Pulvino (2001) estimated the monthly alpha to 33 basis points using the same method.

The resulting annual alpha of 6.29% is markedly lower than the linear alpha of 15.39% per annum presented in section 4.2.1., and also lower than the non-linear, piecewise linear alpha estimated in section 4.2.2. This is expected as the purpose of this contingent claims approach

using Black-Scholes is to price the correct excess return, which takes into account the extra risks the risk arbitrageur is exposed to through the assumed non-linear left-skewed nature of the strategy. In addition to being an intuitive result from the specification of Glosten and Jagannathan's (1994) framework, the markedly lower non-linear alpha result is consistent with the results presented by Branch and Yang (2005) as well as Mitchell and Pulvino (2001).

As mentioned in section 4.2.2. the beta coefficient in depreciating markets is unexpectedly low given the results presented by other studies. That is, there is reason to believe that estimation with my MVWRA portfolio sample yields a too low beta in depreciating markets, and this should in fact be higher, which would have implications for the price of V_{pR}.[22] While mentioning this, it is also important to stress the fact that the above observation does not render the contingent claims model incapable of functioning properly. As laid forth in Chapter 3 in general and section 3.3. in particular, my non-linear evaluation was undertaken on the basis of the assumption that risk arbitrage in general does exhibit a left-skewed non-linearity to market returns, an assumption based on previous research. The contingent claims Black-Scholes model is then constructed from that , and it will essentially work with any input-values, so long as they are fetched from a continuous non-linear piecewise linear regression. That being said, what still stands is – as with all empirical finance – that should the assumption(s) be false, the model would not be accurate.

As a final remark in this analysis, I find the monthly alpha of 51 basis points produced by the contingent claims model a far more realistic estimate of excess return for the MVWRA portfolio, than the linear monthly alpha of 120 basis points. This especially when considering the overwhelming academic research in favour of risk arbitrage as a strategy exhibiting option-like, left-skewed non-linearities.

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[22] Increasing β_{pMktL} in equation 3.6. will, *ceteris paribus*, make V_{pR} cheaper, decreasing the alpha.

5. CONCLUSION

Here room is given to the conclusions drawn from the analysis of the results in the previous chapter. I will also suggest further studies that might be undertaken on the subject.

5.1. DISCUSSION OF FINDINGS

The purpose of this thesis has been to evaluate the ability of a risk arbitrage strategy to generate excess return in the Swedish market, and the objective has been to perform this evaluation using both linear and non-linear approaches.

For the sample studied, 132 months starting with January 2000, the strategy have generated a monthly alpha of 120 basis points when evaluated in a linear CAPM ex-post regression, and 51 basis points per month when evaluated using a non-linear, contingent claims approach. The results are all significant at a level of significance of 5%.

Hence, it can be concluded that risk arbitrage is clearly capable of generating significant excess returns in the Swedish market. My findings in linear evaluation are consistent with those of Branch and Yang (2005), Karolyi and Shannon (1998) and Mitchell and Pulvino (2001), who all conclude that risk arbitrage is capable of generating significant excess returns over extended periods of time. Furthermore, the non-linear evaluation exhibited a lower, albeit still significant, alpha, consistent with the findings of Branch and Yang (2005) and Mitchell and Pulvino (2001).

There is one *caveat* important to stress here, and that is the fact that my MVWRA-portfolio did not exhibit the same non-linear characteristics in terms of beta coefficients as found by for example Mitchell and Pulvino (2001). Rather than being non-linearily skewed to the left, *i.e.* a higher beta in depreciating than appreciating markets, the sample exhibited a higher beta in appreciating markets. This would be very positive for the arbitrageur, who essentially gets a free lunch, risk arbitrage without the left-skewed non-linearity observed in other markets. However, as shown by Branch and Yang (2005), the nature of non-linearity can be highly dependent on the nature of the sample, and the prevalence in my sample of acquirers outbidding each other for target companies is most likely an influential factor.

Conclusively, the MVWAR portfolio sample produces a significant excess return of 51 basis points per month in contingent claims evaluation, assuming Black-Scholes holds. Using a linear framework and assuming CAPM holds, it is concluded that the MVWRA portfolio generates a

significant excess return of 120 basis points per month. These two results are deemed to be overall consistent with previous studies as laid forth in Chapter 3.

5.2. FURTHER STUDIES

This thesis has shown that risk arbitrage have been capable of generating a significant alpha in the Swedish market over the last eleven years. This evaluation has however been undertaken under assumptions based on previous research.

My primary suggestion for future research would be to perform a study into the actual characteristic of risk arbitrage in the Swedish market. Should one want to draw relevant conclusions on the full characteristics of risk arbitrage in said market, one would have to undertake a more rigorous study along the lines of that undertaken by Mitchell and Pulvino (2001). Such a study would likely require painstaking efforts to retrieve relevant merger data, for a sample period that should be longer, perhaps as long as 25 to 30 years.

Another suggestion for any further studies would be to attempt an incorporation of true transaction costs, such as how one moves the market when taking positions in illiquid assets, expenditures for shorting acquirer stocks, commission costs and other relevant costs incurred by the trading performed. Any further study should also consider relaxing the deal selection criteria, with the *caveat* that this would likely render the portfolio more technical to compute on several orders of magnitude. In fact, even in the technically advanced, peer-reviewed, studies presented herein, it is common to have a rather restrictive deal selection criteria similar to the one used by myself. For example, Mitchell and Pulvino's (2001) study does attempt to incorporate costs incurred when trading, including commissions, premium for lack of liquidity etc., they do however not relax deal selection criteria beyond that used by myself.

Given the rather small number of deals over my 132 month sample when compared to some of studies covering the U.S. market, it is my suggestion that further research also consider including the whole Nordic market, even as this likely would present with currency conversion issues. This would present the researcher with both a larger market and a more likely theater of operations for a real life arbitrageur.

Risk arbitrage represents a niche field, which undoubtedly requires a savvy practitioner in order to survive in the long run. The MVWRA portfolio suffered eight days with losses exceeding five

percent for the full 132 month period. In a strategy where many practitioners are leveraged many times over, this could potentially have cataclysmic real-life implications, as argued for in section 3.1. As such, the simulation of leverage in a portfolio should also be considered, although this would likely require both lengthy assumptions and rather complex simulations in order to generate any useful results.

With this being said, there are evidently rewards to reap for the successful arbitrageur, and the field does warrant more academic research, especially in the Nordic market(s).

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APPENDIX

Contains data that I felt would have disrupted readability if included in the text.

APPENDIX I: MONTHLY MVWRA RETURNS

Below you will find each of the monthly MVWRA returns

jan-00	0,30%	**okt-02**	0,34%	**jul-05**	6,00%	**apr-08**	-0,24%
feb-00	0,32%	**nov-02**	0,33%	**aug-05**	-5,66%	**maj-08**	1,94%
mar-00	0,34%	**dec-02**	0,30%	**sep-05**	-2,13%	**jun-08**	-4,01%
apr-00	0,33%	**jan-03**	2,32%	**okt-05**	-1,70%	**jul-08**	2,00%
maj-00	0,33%	**feb-03**	1,49%	**nov-05**	11,58%	**aug-08**	0,20%
jun-00	0,33%	**mar-03**	4,73%	**dec-05**	7,42%	**sep-08**	-2,46%
jul-00	0,34%	**apr-03**	11,48%	**jan-06**	10,26%	**okt-08**	-5,23%
aug-00	0,33%	**maj-03**	1,20%	**feb-06**	-0,71%	**nov-08**	-0,37%
sep-00	0,33%	**jun-03**	-0,51%	**mar-06**	0,81%	**dec-08**	1,07%
okt-00	0,33%	**jul-03**	-0,30%	**apr-06**	0,03%	**jan-09**	-0,36%
nov-00	2,65%	**aug-03**	2,29%	**maj-06**	-5,92%	**feb-09**	-1,45%
dec-00	3,23%	**sep-03**	-6,78%	**jun-06**	0,43%	**mar-09**	-3,58%
jan-01	0,33%	**okt-03**	-0,50%	**jul-06**	-2,52%	**apr-09**	10,77%
feb-01	0,34%	**nov-03**	-0,46%	**aug-06**	0,86%	**maj-09**	3,27%
mar-01	0,33%	**dec-03**	1,63%	**sep-06**	5,77%	**jun-09**	-1,95%
apr-01	2,64%	**jan-04**	-0,31%	**okt-06**	8,24%	**jul-09**	28,05%
maj-01	-1,05%	**feb-04**	8,41%	**nov-06**	-2,72%	**aug-09**	-4,14%
jun-01	-3,53%	**mar-04**	0,91%	**dec-06**	2,88%	**sep-09**	-5,89%
jul-01	0,00%	**apr-04**	-3,89%	**jan-07**	-0,26%	**okt-09**	8,38%
aug-01	3,63%	**maj-04**	1,70%	**feb-07**	-7,99%	**nov-09**	3,60%
sep-01	0,00%	**jun-04**	5,40%	**mar-07**	-1,29%	**dec-09**	21,06%
okt-01	3,04%	**jul-04**	-1,80%	**apr-07**	2,05%	**jan-10**	1,15%
nov-01	5,30%	**aug-04**	10,13%	**maj-07**	0,18%	**feb-10**	-6,37%
dec-01	2,39%	**sep-04**	2,82%	**jun-07**	-5,80%	**mar-10**	14,40%
jan-02	-1,03%	**okt-04**	0,68%	**jul-07**	-0,29%	**apr-10**	-1,62%
feb-02	-0,52%	**nov-04**	0,94%	**aug-07**	11,28%	**maj-10**	-1,81%
mar-02	6,54%	**dec-04**	1,23%	**sep-07**	12,19%	**jun-10**	6,89%
apr-02	-0,36%	**jan-05**	-0,99%	**okt-07**	-2,40%	**jul-10**	0,66%
maj-02	0,55%	**feb-05**	0,54%	**nov-07**	-0,69%	**aug-10**	-1,85%
jun-02	-0,01%	**mar-05**	0,00%	**dec-07**	-1,46%	**sep-10**	6,69%
jul-02	0,82%	**apr-05**	-2,23%	**jan-08**	0,38%	**okt-10**	0,66%
aug-02	0,35%	**maj-05**	1,91%	**feb-08**	1,91%	**nov-10**	-2,36%
sep-02	0,35%	**jun-05**	6,03%	**mar-08**	0,61%	**dec-10**	-0,14%