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Hedge fund replication applied to the industry of Nordic hedge funds.

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Executive summary.

Hedge funds are aimed at providing their investors with absolute returns regardless of the market climate. This unique property comes at the cost of high fees according to the general 2+20 rule, i.e. 2% fixed management annual fee and 20% performance fee. Besides that, there are other drawbacks of investing in a hedge fund – those include a lack of transparency of investment schemes and a certain degree of illiquidity comparing to other types of investment.

The returns of a hedge fund can be decomposed into three main components. The first component is attributed to pure beta exposure and, as confirmed by academic research, constitutes the major part of the return. The beta part of the return is a result of direct investment in different equity and bond indices. The second component relates to different strategies which require professional skills and normally employ derivatives. It is called alternative beta source of the return. The final and most valuable part of the return is attributed to alpha and is based exceptionally on the skills and the competitive edge of the fund's managers. As in many situations the pure beta return can do well for the alpha which is extremely "hard to get" and taking into consideration the mentioned above cons of the hedge fund investment, the idea of hedge fund replication through relatively simple beta strategies was conceived.

The scope of this thesis is the replication of the Nordic Hegde Fund Index subdivided into 5 main strategies and of the single Swedish long/short equity fund Optimus by means of the factor analysis. In the first part of the analysis the fixed-weight clones based on multiple linear regressions are used for the replication. In the second part of the analysis a more sophisticated approach is applied to improve the quality of the clone – the rolling-window regression. The main purpose of this method is to get better replication results through capturing of the time-varying aspects of the historical hedge fund returns.

The results of the analysis are quite satisfying. The fixed-weight clones manage to outperform on a risk-adjusted basis the underlying indices in 4 out of 7 cases and the rolling-window clone is a clear winner in the replication – both considerably outperformed the underlying fund and delivered credible at the 5% confidence level results.

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1.Introduction.

Hegde funds are gaining more and more popularity as a type of investment funds which can apply different kind of strategies along with taking advantage of a more lax regulation. They can invest in different, at times illiquid financial instruments, are allowed to short-sell, to employ a significant degree of leverage and, moreover, locate in tax havens to escape harsh taxation. In recent years, they have been made more accessible for a private investor - the redemption periods are shorter now (once a month in most Scandinavian hedge funds), the entry threshold amount is smaller and there is a tendency to restrict the rules to mitigate the issue of non-transparency of their investment schemes.

The main desired property of hedge funds is the ability to achieve absolute returns regardless of the overall market conditions. Normally, the returns of a hedge fund are not pegged to a certain benchmark, they are aimed at achieving absolute positive returns, though there still exist some like high-watermark aimed at reducing the fees, when the fund performs badly.

The main focus of the analysis of this thesis is the Nordic hedge fund industry. The goal is to replicate the Nordic Hedge Fund Index subdivided into 5 main strategies by means of the fixed-weight clones and apply a more difficult method to the replication of a single Swedish equity fund Optimus returns – the rolling-window clone.

The hedge fund replication is a relatively new topic of the academic research. There is some work done on the North American hedge fund industry. All the main features of hedge fund investment like illiquidity, fees and lack of transparency are more pronounced among the US hedge funds. The new elements of this thesis are the target of replication, new replicating factors, since the Nordic funds operate in a different market environment and invest in different assets.

The return of a typical hedge fund can be decomposed according to its three main sources. The first source arises due to the pure beta exposure and has been confirmed as the one hedge funds mostly benefit from.The second source is the alternative beta – different strategies which require a certain level of professionalism and realized via derivatives.The third source is closely linked to the unique abilities of a hedge fund's manager which enable to achieve exceptional alpha return and distinguish the fund among its peers. The mentioned above properties of hedge fund returns led to the idea of hedge fund replication which is performed in this thesis by using two types of clones: the fixed-weight and the rolling-window clone.

1.2 Problem statement.

As the thesis starts off with the description of hedge funds as investment vehicles, their framework and informative chapters on the Nordic hedge fund industry, the main question addressed: ”Can Nordic hedge funds’ returns be replicated by means of factor analysis?” - is subdivided into two subquestions:

- the first part of the analysis, where the Nordic Hedge fund index is being replicated by means of the fixed-weight clone according to its 5 main substrategies, gives an answer to the first subquestion: Is it possible to achieve the same or a higher return than the Nordic hedge fund index using the fixed-weight clone?

- the second part of the analysis implements a more technically difficult type of a hedge fund clone- the rolling-window clone. The question remains unchanged in its core, but there is a new element of the comparison between the two types of the clones.

1.3 Delimitations.

There are certain limitations concerning mostly the data for the analysis of this thesis. Some factor variables time series were missing few observation points, those were filled with the first available value of the factor variable itself.

The second limitation relates to the second part of the analysis: most of the hedge funds daily NAVs from the data sample provided by Morningstar Denmark didn’t have sufficient variability, which made it impossible to complete rolling-window clones for all hedge fund substrategies.

The factor variables for the clones’ models were chosen based on the previous academic research, i.e. the Nordic indices similar to the US market’s indices were found along with the information about the investment assets of a hedge fund found on its official website. Afterwards, the best models were chosen by backward stepwise regression method in R(statistical software). There is a limitation in the sense that one can not include all possible factor variables in the backward stepwise regression in R.

Despite the fact that absolute priority was given to investible factor indices, some models included the first difference of the factor, since the original time series was non-stationary and had frequent outliers, and lagged values of the dependent variable to deal with autocorrelation in the residuals of the model. The explanation can be found in the previous

academic research on hedge fund clones.[1]According to that, the autocorrelation factor reflects the illiquidity in the returns of hedge funds.

There is an issue linked to different biases that could exist in the Nordic Hedge Fund index data. In this thesis the monthly NAVs of the index were taken not accounting for the possible negative effect from biases, since it is believed that the team behind the organization of the Hedgenordic website put sufficient effort into mitigating such.

The last delimitation concerns the statistical significance of some Sharpe ratios, even with the vast sample of observations of 1596, some of them didn't turn out significant even at the 10% confidence level. The author of the thesis finds this issue quite common in the financial analysis, since the same problem was encountered during the course "Financial models in Excel", where the explanation was the high sensitivity to the risk-free rate within the sample.

1.4 Structure of the thesis.

The thesis consists of six main parts.

The first part is the introduction.

The second part prepares the reader providing the general information about the hedge funds as investment vehicles, their theoretical framework and also the history and existing academic research on the hedge fund replication.

The third part describes the history and regulatory framework of Nordic hedge funds.

Thereafter follow informative chapters on Hedgenordic database and Optimus long/short equity fund.

The fourth part consists of the main chapters concerning the data and the methodology of the analysis which are backed up by the theoretical chapters on econometrics and statistical software used for the analysis.

The fifth part is the first part of the analysis of the thesis. The first part of the analysis is the replication of the Nordic Hegde Fund index subdivided into 5 main strategies by means of the fixed-weight clone.

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[1] Lars Jaeger, Christian Wagner "Factor modelling and benchmarking of hedge funds: Can passive investments in hedge fund startegies deliver?" , November 7th 2005

The sixth part is the second part of the analysis which is the replication of the single fund Optimus pursuing long/short equity strategy by two different types of clones: the fixed-weight and the rolling-window clone.
The seventh part draws a conclusion to the analysis carried out in the thesis.
Further follow the bibliography and the appendices with charts and the code script in R. The Excel files containing the models of the clones and all the calculations are included together with the electronic version of the thesis.

2. Theory.

2.1 Hedge funds.

Hedge funds are the private pools of capital[2] which differ considerably from the traditional investment funds.This applies to different aspects of their regulation, strategical asset allocation and also the different risk –return relationship which is fundamental when investing in a hedge fund.

The contemporary hedge fund industry is characterized by its significant size and has both evolved qualitatively and increased in number despite the downturn of the 2008-09, when many hedge funds incurred drastic losses and were destined to close down. According to Hedge Fund Research data provider the relative industry grew from about 39$ billion in the 90-s to 2,375$ in the first quarter of 2013[3].

Hedge funds are quite a heterogenous industry. They have a wide range of different investment strategies, risk-return combinations, differ in sizes and a certain degree of discretion which is maintained over how they operate. They are often seen as a financial alternative as they invest heavily in distressed debt, in equities of underperforming companies.This can be considered both good and bad at the same time. Creating liquidity for the unpopular equities, allowing underperforming companies to raise capital at a lower cost they act as the so-called "lendor of the last resort" helping companies to stay afloat and providing them with a needed cash. At the same time there is a risk that they arouse an excessive trust and investing overconfidence in highly risky assets, which, in its turn, threatens the market stability.

The common feature of all hedge funds is a great flexibility in the investment choices. They also benefit from the lower minimum capital requirements from the authorities. They are allowed to use different instruments like derivatives, short selling is allowed, let alone the risky leverage. All good things come at cost. By leveraging hedge funds magnify eventual returns, but simultaneously take on a huge risk in case the markets drop even by a little amont.

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[2] "Investing in hedge funds: a guide to measuring risk and return characteristics." Turan G. Bali, Yigit Atilgan, K. Ozgur Demirtas, Elsevier inc., 2013

[3] www.hedgefundresearch.com

The great flexibility leads to the next drawback of the hedge funds which is an obvious lack of transparency. Trying to beat the markets and compete for the "hard-to-get" alpha they are less prone to disclose the exact positions they take and provide the public with the detailed description of their strategies. In addition to that, the quite lax tax legislation and regulation of the hedge funds allows them to locate their premises in tax havens and thus gain considerable tax benefits.

Although, for the sake of the argument, it is fair to mention that a lot has been done so far to make them more transparent and the relative rules more stringent. In 2006 the requirement for certain types of hedge funds to register with SEC (Security Exchange Committee) in the U.S. was passed. The same thing applies to Nordic hedge funds which have to register with the local financial supervisory instuitutions. Finally, the additional disclosure requirements have been introduced in the U.S. in 2010.

Despite some issues, hedge funds are still very popular with the investors. The main reason for this popularity is that they aim at achieving absolute return regardless of the market movements. For this purpose hedge funds try to take advantage of all kind of price discrepancies. The ability to earn profit regardless of the general market situation lies in the core of the hedge fund investment and distinguishes them among other traditional capital funds like mutual funds.

Part of the hedge fund return is related to a pure beta-return which is the overall performance of traditional assets' markets like equities and bonds, another part is an alternative beta-return which is a result of strategies using derivatives and flexibility due to the special regulation, the third and the most valuable part is considered an abnormal return, alpha, and represents the result of the manager's effort and skills digging through the financial instruments trying to identify the mispriced ones which represent arbitrage opportunities. Thus, for most investors delegating their fortune to hedge funds' managers means that they strongly believe in the talent of the hedge fund investment team.

2.2 Illiquidity and fees.

Hedge funds set up strict rules for redeeming the invested capital, so investors can't subscribe to funds or withdraw their capital on an ongoing basis. In most funds there are certain time

windows allowing this kind of operations, normally quarterly or once a month (on a monthly basis - in most Scandinavian funds).

Bringing up the issue of illiquidity, it is worth noticing, that it is there for a reason. Hedge funds managers invest capital into illiquid financial instruments that provide much higher return, than if they had to keep a certain amount of cash in a deposit earning just the normal risk-free rate. Another argument for keeping a low level of liquidity is the fact that longer capital subscription periods reduce transaction costs which are inevitable while disposing of (selling) the assets, hence improving the overall performance of a fund.

The fees charged by the funds are exceptionally high. The fixed annual management fee is about 2% of assets under management and there is a certain incentive fee based on the performance of a fund which can account for up to 20-50% percent of hedge fund returns. Fund of funds tops the list of the hedge funds with the highest fees, since the fact of investing in other hedge funds more than doubles their amount.

The common agency problem arises, when the level of the manager's risk aversion drops, as a consequence of the corresponding fees soaring to record high. Making a manager put his own money at stake could be a solution to the problem. The other way hedge funds governance mechanism deals with this problem is by imposing certain benchmarks for hedge fund performance, one of them is the so-called high watermark. The high watermark presumes that the performance fee is charged only if the returns have exceeded their historical peak. The high watermark makes sure the manager makes up for past losses before being rewarded for the current performance. The benchmark is normally an investable market index, like MSCI world and etc. The peer effect also plays a significant role incentivizing manager performance.

2.3 Hedge fund strategies.

Hedge funds employ a wide range of different investment strategies which differ by the level of complexity, by the types of instruments used and by their geographical allocation. Hedge fund strategies are classified by major financial data providers like Credit Suisse, Barclay, Hedge fund research and etc. Despite the fact that one may find minor differences in the devised strategy classifications, there exist a few commonly used hedge fund strategy types. These types will be described in this thesis.

Equity long/short –the strategy is realized by establishing long and short positions in equities.The success of the applied strategies is dependent on the strategy's active component

which is the stock-picking ability of the managers. The strategy's passive component is the exposure to the equity market. The bigger is the spread between short and long positions taken, the higher is the return from the strategy. The focus is mainly on absolute returns. That's why the overall performance is not supposed to track a particular benchmark. One of the subtypes of the general strategy is **equity market neutral.** It is based on taking long and short positions in a way that the overall beta-exposure of the portfolio is zero. Despite the fact that market exposure is almost eliminated, there are other risks which may endanger the outcome. Among those are investing major part of the portfolio in a specific vulnerable industry sector.

Dedicated short bias subtype is the bet on the decreasing value of the company. The bottom up financial analysis of companies which are investment targets is a crucial part of the strategy**.** It is characterized by relatively high risk comparing to other hedge fund strategies. The risk is explained by the nature of short selling, i.e. the potential losses can be enormous.

Event-driven- the strategies' underlying sources of profit are upcoming or ongoing events in the companies' life, corporate changes which will inevitably result in the equity price shift. The challenging part is to forecast the direction of the price changes right and take the appropriate positions using the equities itself, corporate bonds or derivatives on the both. The main goal is to take advantage of the price descrepancies in the financial markets which accompany different corporate events as mergers, acquisitions, spin-offs, corporate restructuring, financial distress , bankruptcies and liquidations.

Building a strategy which involves **distressed securities** offers many high profit opportunities. The securities might be greatly undervalued due to illiquidity risk, negative outlook on the future of the company from the part of the investors, lack of good financial analysis of the company and liquidation risk.

Exploiting mispricing which accompanies mergers is called **merger arbitrage** and is the bet on the rising value of the equity of the target company.When the rumors about the deal spread on the market the shares of the target company, initially undervalued, start appreciating and offer great profit opportunities. The strategy is carried out by taking long positions in the stocks. The risk comprises the situations, when the merger fails or there is no visible effect from the synergies.

Credit arbitrage is a strategy which involves trading corporate bonds and taking positions in its derivatives, like credit default swaps or interest-rate swaps. The main advantage of these

strategies is that they provide a considerable return, but at the same time have a limited exposure to the broad fixed-income securities' market, hence keeping a relatively low risk profile.

Managed futures and CTA(commodity trading advisors) strategy is based on investment in futures contracts which are well known contracts to deliver the underlying asset on a specific date**.** It is common to use "commodity trading advisors" title referring to the same strategy.This title has deep historical roots, since in the past futures were written mostly on commodities. The strategy can be trend-following, looking for the best timing on the market or contrarian which is obviously the opposite of the latter. It is characterized by a significantly high leverage.

Relative arbitrage aims at earning relative return on mispricing of different securities during the periods, when markets are unusually highly volatile. **Convertible arbitrage** is one of the most popular subtypes of the relative arbitrage strategy.The main financial instrument of this strategy is a convertible bond. This hybrid security allows the company to get relatively cheap financing. In return for the provided financing an investor can get a share in the company converting the bond into a stock.That will normally occur if the company is on its upturn and starts prospering. The same security is issued, when managers believe their equity is undervalued and want to sell it forward at a premium.

Selling the convertibles to the hedge funds will be an act of a low-cost equity distribution.

Convertible bond comprises different characteristics typical for three other types of securities: straight bond, stock and a call/put option on a company's stock.That's why the pricing method of this type of security is quite difficult. The complexity of the convertible bond can be explained by different types of its risk which lie within: credit risk, equity and interest rate risk. The position in this security is hedged via interest rate swaps, going short/long in the underlying stock; the credit risk is hedged by taking positions in credit default swaps and going short in the straight bond. These measures are necessary as the firms which issue convertibles are normally prone to high leverage and high volaitlity in the cash flows. Moreover, the convertible bond is of a subordinated character and is closer to the end of the priority list than the regular one, when it is time to settle with the company's creditors in case of bankruptcy.

The relative strategies can be built using a great variety of different instruments within the asset classes of equities, fixed-income securities and derivatives, but the principles of the

positions are similar.They are normally long and short positions aiming to earn profit on the changes of the valuing spread between different financial instruments.

Multi-strategy is a kind of "all-in one" strategy which chooses different investment approaches under different circumstances. The main goal is an absolute return regardless of the market movement with a lower risk profile than that of the market.

Global macro strategy is a kind of multi-strategy, when hedge funds invest in different kinds of financial instruments , in different markets around the globe without any geographical restrictions. The common feature of the markets they invest in is a sufficient level of liquidity. Whenever and wherever the profit opporunity is encountered, hedge funds make sure they have a tight grip on it, in this sense, they are dependent on the quality of the global financial forecast.

This strategy differs from the relative arbitrage, since it is directional, i.e. the return is obtained due to the general price movements of the financial instruments, not some mispricings. The strategy is applied on a global scale and, unlike equity strategy, is not concentrated around some particular companies on the market and their fundamental analysis. Pursuing global macro strategy hedge funds invest in currency indices, commodities and etc.

Fund of funds is a more diversified strategy, thus less risky, now, thanks to the recent changes of regulation, accessible to a small investor strategy. It is also relatively liquid concerning the general illiquidity issue of the hedge funds, but at the same time it is the most expensive in terms of the performance fees. They are surely more than double the original amount, since the fund of funds' main investment asset is other hedge funds.

2.4 Hedge fund replication and theory underpinning the relative research.

The idea of the hedge fund replication arised as a consequence of certain insights revealed about the nature of the hedge fund returns. Three major components of returns above the risk-free rate are:

Market beta – the return achieved through the exposure to market equity, bonds, commodity indices

Carry-trade returns (or alternative beta) – returns achieved through the construction of a more sophisticated than an ordinary buy-and-hold investment strategy, for example using derivatives, which requires skills to access

Alpha – the extra, idiosyncratic to each hedge fund component of its return, not explained by the exposure to market indices, but based on the competitive edge of a certain hedge fund. The existing academic research has proved that the first component constitutes a bigger part in the returns of most hedge funds. That led to the idea that the major part of a hedge fund return can be replicated escaping from the three major disadvantages of a hedge fund investment, i.e. high fees, limited liquidity and a lack of transparency. There exist three dominant approaches in international practice to hedge fund replication: the **factor approach** which will be described in detail in this thesis, since this approach is used in the analytical part, the **distributional approach** and the **rule-based approach**. The **factor approach** to hedge fund replication consists in projecting hedge fund returns on to a set of investable factor indices, the beta loadings are estimated by linear regression (Maximum likelihood or Ordinary Least Squares approaches) or non-linear optimizations (like including option factors and similar).The approach can capture most of the return of the hedge fund indice in-sample, but often fails in an out-of-sample period.The **distributional approach** aims at replicating the unconditional distribution of hedge fund return using an equivalent investment in a set of assets.[4]It finds clone that match higher moments of hedge fund return time series (skewness, kurtosis), but fails to achieve relatively high correlation between original hedge fund returns' time series and those of a clone. It is advocated by Kat and Palaro in their study in 2005 and 2007. The **rule-based approach** consists in finding appropriate liquid assets which can provide the return similar to that of a hedge fund indice. It is very often combined with the factor –based approach.

The first attempts to explain the variance of equity funds' returns by its exposure to the systematic factor was undertaken by Jensen in 1968. Two decades later, the research was continued by William Sharpe who developed an approach in 1992 on the basis of Jensen's research. This approach established the foundation of the hedge fund replication. It is known in international practice as **style analysis.** In his work he tried to estimate traditional equity fund returns' exposure to different market indices representing all investment classes:

Bills

Cash-equivalents with less than 3 months to maturity

[4] Richard D. F. Harris, Murat Mazibas "Factor-based hedge fund replication with risk constraints"p.31 from G.Gregoriou, M. Kooli "Hedge fund replication", Palgrave Macmillan, 2012

Index: Salomon Brothers' 90-day Treasury bill index

Intermediate-term Government Bonds

Government bonds with less than 10 years to maturity

Index: Lehman Brothers' Intermediate-term Government Bond Index Long-term Government Bonds

Government bonds with more than 10 years to maturity

Index: Lehman Brothers' Long-term Government Bond Index

Corporate Bonds

Corporate bonds with ratings of at least BAA by Moody's or BBB by Standard & Poor's

Index: Lehman Brothers' Corporate Bond Index

Mortgage-Related Securities

Mortgage-backed and related securities

Index: Lehman Brothers' Mortgage-Backed Securities Index

Large-Capitalization Value Stocks

Stocks in Standard and Poor's 500-stock index with high book-to-price ratios

Index: Sharpe/BARRA Value Stock Index

Large-Capitalization Growth Stocks

Stocks in Standard and Poor's 500-stock index with low book-to-price ratios

Index: Sharpe/BARRA Growth Stock Index

Medium-Capitalization Stocks

Stocks in the top 80% of capitalization in the U.S. equity universe after the exclusion of stocks in Standard and Poor's 500 stock index

Index: Sharpe/BARRA Medium Capitalization Stock Index

Small-Capitalization Stocks

Stocks in the bottom 20% of capitalization in the U.S. equity universe after the exclusion of stocks in Standard and Poor's 500 stock index

Index: Sharpe/BARRA Small Capitalization Stock Index

Non-U.S. Bonds

Bonds outside the U.S. and Canada

Index: Salomon Brothers' Non-U.S. Government Bond Index

European Stocks

European and non-Japanese Pacific Basin stocks

Index: FTA Euro-Pacific Ex Japan Index

Japanese Stocks

Japanese Stocks

Index: FTA Japan Index[5]

The factors represent market-capitalization weighted indices on a large number of securities.The factors are chosen based on the following properties:

- they are mutually exclusive, none of the securities is included more than in one asset class
- they are exhaustive, represent possibly all securities on the market
- they have returns that differ

The exposure was estimated running a multiple regression according to the equation:

$R_i = [b_{i1} * F_1 + b_{i2} * F_2 + \cdots + b_{in} * F_n] + e_i$ (1)

where

R_i is a return on asset *i* (the return on an open-end mutual equity fund)

F_k is a value of different factors

e_i is a non factor return uncorrelated with that of every other

b_{ik} are sensitivities of the return of an asset to factor F_k

The sum of sensitivities b_{ik} (parameter estimates) is assumed to be equal to "1" to represent them as portfolio weights. As the policy of the mutual funds doesn't allow short selling, the factor sensitivities are bound to be of positive sign. The most parsimonious model is preferred, i.e. the model with the least number of statistically significant factors. The R-squared described in the econometric part of the thesis is used as a tool of comparison between the models along with the variance of e_i, the difference between the return of the fund itself R_i and the passive portfolio constructed from the indices of different investment classes $[b_{i1} * F_1 + b_{i2} * F_2 + \cdots + b_{in} * F_n]$, which is supposed to be as small as possible. It is important to point out that the R-squared measures only the in-sample fit of the model. That's why it is important to make the out-of-sample forecasts and compare them to the actual values of the fund's returns to make sure the model is worthy. The R-squared value, the

[5] William F.Sharpe "Asset allocation:management style and erformance measurement"from "The journal of portfolio management"1992, pp.7-19

explained variance in the fund's returns, is attributed to the investment style of the fund and the (1- R-squared), the unexplained variance, is attributed to its stock selection abilities.
The style analysis was initially performed by William Sharpe for 395 funds with different strategies, the averages of their R-squared and styles (sensitivities) values were taken to build an overall effective asset mix portfolio which can be used as a benchmark evaluating the performances of individual funds. The overall effective asset mix portfolio was built according to the mentioned above formula (1), where b_{ik} is a value-weighted average of the exposures of the component funds to the asset class in question. Using these average exposures' values as weights the relative amounts were invested in the funds. The difference between the return of the mix of asset classes with the same estimated style and the relative asset style fund's return is defined as a fund's selection return. One must note, it is different from the value of variance e_i in individual regressions, since the latter is estimated for the in-sample period. Obviously, if the fund's selection return is of positive sign it means that the fund has outperformed its benchmark and vice versa.
It is crucial to underscore the role of **the styles analysis** in hedge fund replication - it sparked the impulse to the development of the whole idea and provided a theoretical basis for further research.

The evolution of hedge fund replication continued with **William Fung and David Hsieh** who in 1997 building on the existing research applied factor analysis for the purpose of replicating the return of hedge funds instead of mutual funds:

$R_i^F = \sum_{k=1}^{n} \beta^k * R_i^k + \alpha + e_i$,

where

R_i^F-return of the hedge fund in month i

β^k- the beta loadings of the fund to factor k

R_i^k- the return of the factor k

α- the return non explained by the factors, consistent from month to month

e_i - the residual variance, extra variance that can't be explained by the model

According to them the factors "qualify" for being included in the clone if they reduce the tracking error on the corresponding index. Different approaches are used to find the set of appropriate factors, the focus is on the most parsimonious model along with high explanatory power of the model (R-squared) as before. The stepwise regression method is used to identify the relevant factors. The beta loadings are estimated by a linear regression method using the

historical data. The most common method is a rolling window on monthly data to allow some extent of the time-varying component, even though it is not always very successful in mimicking the returns of a hedge fund out-of sample due to the non-linearity of hedge fund's returns and not sufficiently high values of in-sample R-squared.[6]

In an attempt to increase the in-sample R-squared of the model **Fung and Hsieh** continued their factor-based replication research in 2002. They tried to replicate 5 substrategies of the fixed-income strategy including the look-back straddle as a substitute of a dynamic component. The minimal goal was achieved and the R-squared increased for most of the strategies, but they didn't test the model performance out-of-sample, i.e. didn't produce good forecasts, which automatically undermines the worthiness of their models.

Agarwal and Naik tried to replicate the return of eight different hedge funds in 2004 using stepwise regression approach. They used buy-and-hold (equity, bond, currency, commodity indices) risk factors and put and call options risk factors to account for possible non-linearity in the hedge funds' returns. The factor loadings were estimated for the ten-year period for these eight funds and then tested out-of-sample for the one-year period. The results confirmed the non-linearity factor exposure of the hedge funds' returns, since the put options on market indices risk factors came out significant adding to the explanatory power of the model.[7]

During the same period **Fung and Hsieh** continued their research combining different hedge fund startegies in a single-factor model. Seven style factors were identified from three individual hedge fund strategies. The whole time period was divided into three subperiods. As a first step, the regression was run for the first subperiod and the relative R-squared of 69% was obtained. As a next step, the same procedure was performed for the third period providing the R-squared of 80%. The third regression was run for the whole time period including all three mentioned above and resulted in the value of R-squared of only 55%, which didn't prove the overall good explanatory power of the model. The authors omitted the

[6] Martin Wiethuechter and Lajos Nemeth "Benchmarking of replicated hedge funds"from the book by G. Gregoriou and M.Kooli "Hedge fund replication".Palgrave macmillan,2012

[7] Vikas Agarwal and Naraian Naik "Risks and portfolio decisions involving hedge funds" from "The financial review" Vol.17.Issue 1,2004,pp. 63-98

out-of-sample analysis also this time and tried to identify the alternative alphas and betas in the hedge funds' returns.[8]

The next research project which was also aimed at replicating hedge fund returns by means of factor analysis was the work of **Jaeger and Wagner** in 2005. The multiple linear regression was applied to the number of hedge fund indices with different strategies from the Hedge Fund Research database. The significant risk-factors were first identified by running a data regression for the in-sample period of 5 years and used, afterwards, to form a clone for each of the range of hedge fund investment strategies with the new out-of-sample values of the risk-factor indices. The in-sample explanatory power of the models was not exceptionally high, only about 60% on average, with quite low values of 30-40% for some particular strategies. The out-of-sample performance of the clones was compared to the actual values of the investable and non-investable hedge fund indices. Out of seven replicated strategies only the clone of convertible arbitrage strategy outperformed the non-investable hedge fund indice. Surprisingly, the investable hedge fund indice was outperformed in six from these seven strategies.[9]

In 2006 **Hasanhodzic and Lo** undertook the hedge fund replication project by running a time-series regression of each of 1610 hedge funds from TASS database subdivided into different strategies on six following factors: Us Dollar Index, Bond Index, Commodity Index, Equity Index, Credit Spread Index (difference between lower-rated corporate bonds and short-term Treasury bills), Volatility Index.[10] The factor returns can be realized in practice by means of liquid instruments as futures and forwards from which the Volatility index is less liquid, since it is traded on OTC market. Though it is fair to mention that the market is constantly developing. The regression includes a component of a manager-specific alpha as an extra idiosyncratic return of each hedge fund not explained by the factors included in the model. The mean R-squared values range from 10,5% for the equity market-neutral strategy

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[8] W.Fung and D.Hsieh"Extracting portable alphas from equity long/short hedge funds"from the "Journal of investment management" Vol.2, Num.4, 2004, pp.57-75

[9] Lars Jaeger, Christian Wagner "Factor modelling and benchmarking of hedge funds: Can passive investments in hedge fund startegies deliver?" from "The Journal of Alternative Investments", Vol.8,n.3, pp. 9-36, November 7th 2005

[10] Jasmina Hasanhodzic and Andrew Lo "Can hedge fund returns be replicated?:The linear case", August 2006

to 40,4% for the dedicated short-bias strategy. The results confirm that funds with lower R-squared values have higher returns, higher Sharpe ratios which point at higher diversification benefits of these funds and, as a consequence, higher fees. The results of the regression analysis shows that negative average alpha influence on the return is significant in convertible arbitrage strategy, positive average alpha influence - in the dedicated short bias strategy. The results for all 1610 funds on average confirm that 61% of the hedge fund returns are explained by the manager-specific alpha and 39% are explained by the six factors, which still proves the idea that hedge fund replication is viable for some of the hedge fund strategies. The clones are constructed using two methods: fixed-weight clone (the estimated beta parameters are held constant during the whole period of the analysis) and rolling –window analysis (which allows some time-variance of the coefficients). The rolling–window approach allows to avoid the look-ahead bias of a fixed-weight clone at the cost of the constant rebalancing of a portfolio to match current volatility, which contradicts the assumed passive nature of hedge fund replication. Another drawback of this method is a shrinked sample of observations as a result that the factor exposures are estimated on the number observations corresponding to the window width. This shortcoming might undermine the statistical significance of the analysis. The overall message of the analysis carried out by Hasanhodzic and Lo is that fixed-weight clones can perform quite as good as funds themselves, the mean returns of many clones are higher than those of the funds, but they are often prone to higher estimating error. The rolling-windows clones outperform the underlying funds in many cases, except for emerging market, fixed arbitrage and event-driven strategies. The failure in those three strategies can be explained by the illiquidity component present in the return of the original hedge funds which the clones fall short of. On the other hand, the equal-weighted portfolio of all fixed –weight clones outperformes the equal-weighted portfolio of all underlying funds and S&P 500 index. Due to the fact that the clones, in general, provide the same correlations with factor indices as the hedge funds themselves, they are able to provide the same level of diversification and, as a consequence, more or less the same return.

Hedge fund replication methods and techniques are constantly developing and the whole idea of it in general remains in focus among the researchers. There are a lot of unanswered questions that need addressing: can hedge fund clones replace the regular hedge funds or should they serve as a supplement to the hedge fund investment? There have been recently invented new models and approaches to hedge fund replication. Among them are different

hedge fund replication strategies aimed at taking advantage of the spread between offered price and existing price of the target in mergers, distributional approach to hedge fund replication via state contingent stochastic dominance, hedge fund cloning through state space models and different adjustment of the parameter estimating methods to reflect the time-varying nature of hedge fund index returns. These relatively new methods like Bayesian state space models and Kalman filter are very technically difficult and provide at times controversial results, therefore they are quite rarely used. The most popular method is still based on the factor analysis which is a kind of compromise between being not extremely difficult and still able to provide quite satisfying results. That is the main argument for choosing this particular approach as a tool for the analysis in this thesis.

3.Hedge fund industry.

3.1 Nordic hedge fund industry and its history.

Traditionally investment funds, hedge funds, let alone other financial institutions like banks play a major role in the economy of the state. By maintaining a certain level of liquidity in the market investment funds enable market players get hold of a cheaper financing on better terms, which, in its turn, contributes to the development of the economy and infrastructure of the state as a whole. Moreover, the funds do their share covering the state budget deficit by investing in Government Treasury bills.

The Nordic hedge fund industry is relatively young and in some aspects different from the North American one due to a number of reasons, among those are certainly the regulation (as Nordic countries abide by European regulation) and the history of the development of the investment fund industry. There have been always more requirements to Nordic hedge funds concerning transparency and flexibility of their investments. The issue of liquidity is more pronounced among the North American hedge funds, since the latter have, as a general rule, a longer redemption period (on a monthly or quarterly basis, while some Nordic funds' units are traded daily). The North American funds are also more prone to avoid direct regulatory oversight and take advantage of less transparent investment schemes. They are allowed higher degree of leverage than the Nordic funds, way more lax tax regulation locating in tax havens. It is worth to point out that the post-crisis regulation made the North American hedge funds more accessible for a retail investor and stringed their flexibility to a certain extent by eliminating certain regulatory gaps.

The first idea of the European collective investment originated in Holland in 1744. The first prototype of the investment fund was created "Eendragt Maakt Magt" to help the investors to diversify their investment and thus reduce the risks. The first foreign fixed income funds were founded in England in 1868 with the establishment of "The Foreign and Colonial Government Trust". The investment risks were spread out investing in a bunch of foreign Treasury bills. The professional investment management and investment funds began first to evolve in Anglo-Saxon countries: mainly England and USA. In 1928 the idea of minimizing the investment risk via organizing small private investors in pools of capital and reinvesting them in larger equity funds came to Denmark.The first equity fund "Investor" was launched.

Subsequently, the period of the 50-60-s was marked in Denmark by the inception of the first mutual investment funds backed up by the appropriate legislation. Later on, the Danish investment regulation underwent a number of changes, until in 1982 the first Investment fund law was adopted (lov om Investeringsforeninger, n.229)[11]. The Danish investment funds are regulated and supervised by the Danish Financial Supervisory Authority (Finanstilsynet). The further development of the hedge fund industry in Europe as a whole was marked by the adoption of common European Investment Regulation in 1989 called UCITS Directive (Undertakings for Collective Investments in Transferable Securities). The Directive was improved in 2004 and again in 2011, where the main focus of the alterations was on better protection of private investors, transparency under the principles of fair competition. The latest event in the European regulation of investment funds was the adoption of the Alternative Investment Fund Manager Directive (known in Denmark as FAIF) which is aimed at stringing the rules for hedge funds and private equity funds within the EU.[12]

In 1997 the Oganization of Danish Investment funds called "Investeringforeningsrådet" was founded. It has recently been renamed into "Investeringsfondsbranche (IFB)". The IFB name reflects the category of the main product offered by the organization, namely a wide range of different investment funds (investment companies with variable capital (SIKAVer, værdipapirfonder)).The financial counselling and management is among the services provided by the organization. It is important to mention that hedge funds existed in Denmark as a category of investment funds only over the period from 2005 until recently. Now all the hedge funds should change their status to "investeringsforeninger". The amount of capital invested via IFB updated for the first quarter of 2014 is record high and accounts for 1.385 billion Danish kroner. These numbers don't account for institutional players' investments.

The Swedish funds are considered to be absolute leaders among the Nordic hedge funds, though they are also quite sternly supervised by Swedish Financial Supervisory authority (Finansinspektionen) and have more or less similar traits and issues as other Nordic hedge funds. The Swedish legislation is clearly harmonized with that of the European Union, that's why the common Directives apply to the Swedish hedge funds as well. The Swedish funds started gaining importance in the mid-90-s of the last century as the majority of other Nordic

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[11] www.investering.dk- IFB (Investeringsfondsbranche)

[12] www.ec.europa.eu

funds. According to the report of Morningstar Sweden Swedish funds have been and will be among the best performing and most attractive investment funds for the next 5 years with a total of 1254 billion Swedish kronor as of the end of 2013.[13]

3.2 The Hedge Nordic index.

The Hedge Nordic index (NHX) is an equal-weighted hedge fund index derived from the performance of hedge fund managers and advisors within the universe of Nordic hedge funds. The index is based on data reported directly to HedgeNordic by hedge fund managers themselves. HedgeNordic is the only of its kind provider of news related to hedge fund industry either globally or regarding the Nordic market, along with index data and database information on Nordic hedge funds. The index includes 152 most prominent hedge funds from all Nordic countries: Denmark, Sweden, Norway, Finland and Iceland.[14]It consists of the Nordic hedge fund composite index providing an overall picture of the performance of the Nordic hedge fund industry and 5 indices which are constructed according to the 5 main hedge fund strategies:

NHX equity -investments in equity and equity derivatives

NHX Fixed Income- investments in fixed income and derivatives

NHX Multi Strategy – less than 80% of the fund's activities come from one particular classification category

NHX Managed Futures and CTA (Commodity trading advisors)- investments in listed financial and commodity futures and foreign exchange, usually a systematic, i.e. model driven approach

NHX Fund of Funds- investment in other hedge funds

The index is measured in index values, thus the initial index value is 100. The inception date of the index is the 1st of January 2005. Only the funds which are willing to submit their entire performance history and main characteristics like Assets Under Management (AUM) before the first of June 2005 are included in the index. The hedge funds meet some requirements in order to mitigate the effects of certain hedge fund index biases, among them the most important backfilling and survivorship bias. The submission of the complete fund

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[13] www.morningstar.se

[14] www.hedgenordic.com

performance history before the index inception and the acceptance of data even from the closed-down funds serve as a kind of barrier against these biases. There is also a strict control of the regularity with which the performance results are being reported to the index authorities. The data must be submitted as soon as possible after the end of the month and the delay can't be longer than a month and 5 days. Here follows a description of the most important biases which one must be aware of, while relying on the index values for the analysis:

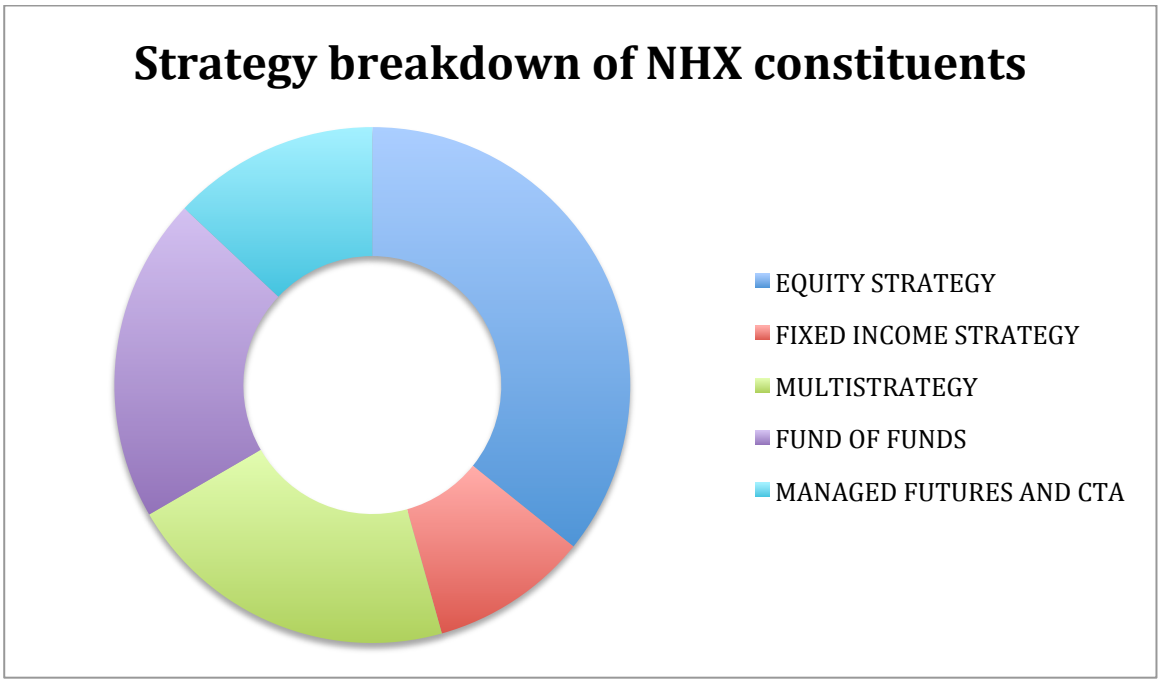
Survivorship bias is the exclusion of all funds which failed to stay afloat, while evaluating the overall hedge fund industry performance, hence creating a positive bias. For that reason the inclusion in the index of the hedge funds which already terminated their operations is crucial.

Backfilling bias arises, when the fund is included in the index long after its inception date submitting the historical data.The hedge funds tend to do it after a period of particularly strong performance, thus creating again the upward bias in index values.

Selection bias creates the problem, since the hedge funds submit their data to the index on a pure voluntarily basis. This drawback makes it difficult to reproduce the real picture of the performance of the hedge fund industry as a whole.

According to the recent industry report the Nordic hedge funds outperformed their North American peers achieving a result up 7.4% of NHX composite in 2013, the trend observed over the post-crisis years since 2007. HFRX (Hedge Fund Research index) delivered the return of only 6.4% in 2013. The best performing strategy for the past years was the Fixed Income strategy along with the Equity strategy which was the one bringing most profit in 2013, also due to the fact that the NHX composite index consists mostly of the hedge funds pursuing the equity strategy.

Figure1.Strategy breakdown of NHX constituents.



Among the worst performing strategies over the post-crisis period are the Managed Futures although another component of this strategy CTA (Commodity Trading Advisors) managed to show satisfactory results in 2013 up 0.9%, which is about 2.7% above their global peers despite all the hardships faced: the absence of short-term trend reversals and major trends.[15] Relative and Event-driven strategies are less liquid strategies which ended up being among the bad performers, but they are scarcely present in the NHX index, that's why they didn't have a strong negative impact on the Nordic hedge fund industry. The Fund of Funds strategy funds have delivered good results with the gain of 5.5% in 2013. A positive trend is observed among the Multistrategy funds, where power funds are being outperformed by the newcomers in the industry.

3.3 Optimus Small Cap equity fund.

Optimus fonder AB is the fund management group located in Stockholm founded in 2005.The group consists of Optimus Small Cap equity fund which pursues long/short equity strategy and Optimus High Yield fund which invests in high yield debt securities in the international markets. Both funds of the group are actively managed, investment units are traded every

[15] Hedgenordic Industry report 2013, published March 2014, www.hedgenordic.com

day, the funds' policy is founded on the principles of transparency, competence, qualitative analysis of the investment target companies. The group operates in the sphere of pension and private investment (capital acquisition and asset management) along with venture funds like private equity and project financing.The group is oriented at two categories of investors: institutional and private.

Optimus Small Cap fund is an object of the second part of the analysis in this thesis, where the rolling window clone approach was used. It was chosen as such, since it is the only fund from the sample obtained from Morningstar Denmark which has enough variability among its NAVs, has an adequately large sample of observations and also represents the strategy which has proven to be one of the most successful in the hedge fund replication practice.

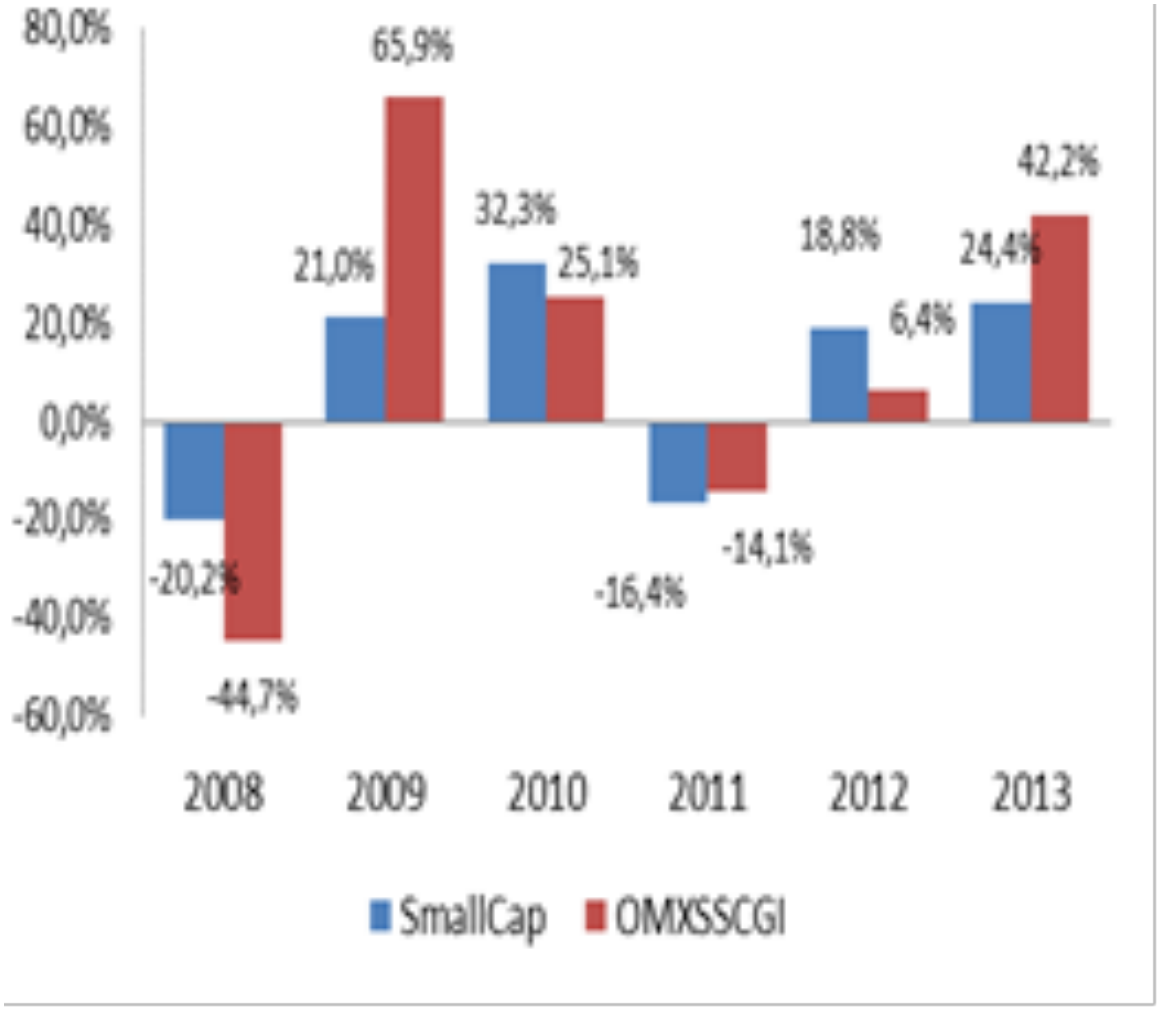
Optimus Small Cap is an actively managed equity fund which invests mainly in small and medium-sized Nordic and European equities. The focus is made on the growth companies, since those are considered to be the most profitable according to the existing research.The fund's inception took place in 2007. The target of the fund is to beat the market index which is represented by OMX Small Cap index (includes all small capitalization companies of up to 150 mln traded on NASDAQ OMX Stockholm and indices include dividends) at a lower risk, the target standard deviation limit is set within 15-35%. The dividends, unless paid out in cash upon a special request, are reinvested in the fund. The trading of fund units is available every business day. The fund is appropriate for investors who project to withdraw their investment within a five-year period. At the moment there are no exit or entry fees, but the fund has the right to charge up to 5% as a sales fee and up to 1% as a redemption fee.

Apart from that, the fund charges fixed annual management fee of 3% and 20% performance fee which is calculated on the basis of the achieved return above the return of the Swedish Treasury discount note with the maturity of 3 months.The minimum initial investment in the fund is 1000 Swedish kronor and the subsequent minimal monthly savings limit is 100 Swedish kronor.[16]

The historical performance of the fund compared to the benchmark(market index of OMX Small Cap index):

[16] www.optimusfonder.se

Figure 2. Optimus vs. OMX Small Cap index.



4. Data and methodology.

4.1 Data.

The data used for the first part of the analysis of the thesis is the monthly index values of the NHX composite (Hedge Nordic index) and its subdivisions according to five major categories: equities, fixed income, fund of funds, multi-strategy, managed futures and CTA (commodity trading advisors). The data is obtained from the website of HedgeNordic[17], where they regularly collect, elaborate and publish the data on 159 most prominent hedge funds on the Nordic market encompassing Denmark, Sweden, Norway, Iceland and Finland.

The data for the second part of the analysis is daily price values of the Swedish equity fund Optimus, i.e. its daily Net Asset Values net of all fund related fees. This hedge fund pursues long/short equity strategy. According to the existing academic research in the field of hedge fund clones the equity strategy is considered to be among the easiest to replicate. The data is kindly provided upon the personal request by the Danish subsidiary of the investment research corporation Morningstar.

All index and hedge fund return values are transformed into continuously compounded returns for the purpose of the analysis, due to some desirable properties of the latter (the sum of all continuously compounded returns for the period is equal to the return for the same period).The continuously compounded returns transform our econometric model automatically in a double-log model, which allows to lessen the problems with many econometric issues concerned with autocorrelation, heteroscedasticity, normality in the model and simplifies the interpretation of the coefficients as relative elasticities.

Along with the Nordic hedge fund values factor indices' values from the database Thomson Reuters Datastream are also used in the analysis. Those include equity indices like MSCI Nordic Small Cap Value and Growth, MSCI Nordic Large Cap Value and Growth, different bond indices, currency indices like US trade-weighted index (this indice reflects the currency exchange rates of US dollar against major world currencies weighted by the units of trade volume in each currency), risk-free rate which is in our case Euribor 3m (used as a point of

[17] www.hedgeNordic.com

reference for most of the hedge funds included in the index and the Nordic hedge funds in general), Thomson Reuters US corporate BMK B+ 10Y +/ TSY- credit spread from between 10+ years duration US industry corporate bonds and short-term Treasury bills and etc.. Apart from hedge fund indices' values which are expressed in index points, all the indices' values for the first part of the analysis are expressed in US dollars and quoted on a monthly continuously compounded basis. For the second part of the analysis the values of the indices are transformed into daily logarithmic retuns and are expressed in Swedish kronor corresponding to the currency of the underlying hedge fund.

Euribor- stands for Euro Interbank Offered rate. It is an average interest rate at which the panel european banks lend one another unsecured funds denominated in european currency. The rates differ by maturities from Eonia (overnight) 1-day interest rate, 1 week rate up to 12 month maturity. The rate is an important benchmark for european market agents and is being closely monitored and updated on a daily basis.[18]

Euribor 3m values are transformed for the analysis, they are first normalized to get rid of percentages by dividing by 100. Then transformed into continuously compounded returns on a yearly basis according to the equation: ln(1+normalized rate), then divided by 12 or by 262 (work days in a year) to get the needed monthly or daily values.

MSCI Small, Large Cap Growth,Value indices are equity indices provided by Morgan Stanley capital International financial organization including the most representative Nordic small or large capitalization, growth or value companies. The Nordic small capitalization companies are normally those with market capitalization not exceeding 15 billion Danish kroner, in the international practice small caps are those with market capitalization from 500 million up to 2 billion US dollars.The growth companies have usually high value of price-to-book ratio; the investors expect from management to create more value. Those companies grow at the rate faster than the general economy. Nevertheless, they are believed to perform best only during economic upturns.

The value companies, on opposite, have huge investments in fixed assets and thus have lower value of price-to book ratio.They are normally underpriced. According to the existing empirical research they are performing relatively better during the economic downturns.

[18] www.global-rates.com

TR US CPR BMK B+ 10Y/TS - credit spread as represented by the Thomson Reuters index of the spread of US industry bonds of B+ credit rating with the maturity 10 years + and the short-term treasury bills.

MSCI Nordic Small Cap value spread- the spread of Nordic small capitalization growth and value index returns, calculated by taking the difference between the returns of Morgan Stanley Capital International small capitalization growth index and the returns of Morgan Stanley Capital International small capitalization value index.

MSCI Nordic size spread – the spread of Nordic small capitalization and large capitalization index returns, calculated by taking the difference between the index returns of Nordic small capitalization equity and large capitalization equity.

MSCI AC World Small Cap Value Equity index- is Morgan Stanley Capital International Small Capitalization All World Countries Value Equity index, it is designed to measure the performance of the small cap sector of the global equity represented by 23 developed and 21 emergent countries.

ML Convertible Emergent Markets bond index – Merrilll Lynch Convertible corporate bonds of emergent markets index, the index is designed to represent performance of the sector of convertibles of the emergent markets. As mentioned earlier in the chapters describing the relative hedge fund strategy, convertibles can be converted into equity to allow to participate in company's profit in case of the upturn and at the same time provide a guarantee of the investment as the bondholders are paid out first, in case the company files bankruptcy. Convertible is a kind of hybrid security including the bond itself which has a secured cash flow of interest payments and principal at the end of the maturity and long option on the company's equity. The company issues convertibles to be able to get cheaper financing (the coupon of this kind of bonds is lower) and more attractive finacial structure through greatly reduced debt, when the bond is converted into equity. The disadvantage for the company is the potential stock dilution, when the bond is converted into equity. Growth companies with low-credit ratings are more prone to these kind of financing.

ML European Convertible A bond index- is Merrill Lynch European Convertible bonds of High investment grade -A- bond index. The index consists of corporate bonds of the credit class A on the European market. Relatively high investment rating allows for the bond issuer to pay lower interest on debt.

US /Euro 1month deposit index – stands for United States Euro-dollar 1 month Euro currency deposit index. Eurodollars are time deposits (1 month in this case) in US dollars located in banks outside the US, thus are not subject to US regulation and allowing higher margins.

US Major currency MAR 73=100 Exchange index – is a trade-weighted world major currencies against US dollar exchange index.

CGBI WGBI Euro Government 10-15y – Citigroup World Government European bonds with the maturity of 10-15 years index is a market-capitalization weighted government bond index including the fixed-rated securities with amounts outstanding at least 25mln$ and with the remaining maturity from 10 to 15 years, the index includes the government bonds of many developed countries.

Barclays High Yield Bond index –is a market-capitalization weighted index consisting of US high-yield corporate bonds, i.e. the bonds rated below investment grade which consequently offer very high coupon to attract investors.

Credit Suisse High Yield Bond index- stands for Credit Suisse index of High Yield US Corporate bonds, i.e. the low rating class bonds with the highest coupons.The index is represented by the fund's net asset value.The fund is a closed-end fund and is a constituent of other 5 indices traded on NASDAQ stock exchange.

CME GSCI continuous second future index – stands for Chicago Mercantile Exchange continuous second future index. The underlying series of the index is Goldman Sachs Commodity index.

ICE Brent Oil future index – is Intercontinental Exchange Brent Crude Oil continuous future index. The standard contract size is 1000, the contract unit is barrel. This index belongs to ICE futures Europe series.

US Libor Capital 1 month index – is US interbank 1 month lending (Libor) rate index.

BOFA ML EMU CPR and PFN bond index – is Bank of America Merrill Lynch European Monetary Union Corporate and Pension funds' AA-rated bond index.

MSCI World – stands for Morgan Stanley Capital International World equity index which is an equity index consisting of 1612 stocks from 23 developed countries.

OMX Stockholm Small Cap Equity index – stands for OMX (Optionsmaeklarna and Helsinki Stock exchange) Swedish Small capitalization Equity index, the index has 112 constituents.

S&P Sweden SG – is Standard and Poors Swedish Small Capitalization Growth Equity index, belongs to the category of Broad Market Indices.
JPM Sweden Government bond index – stands for JP Morgan Chase Swedish Government bond index

The investible factors are given absolute preference, so the existence of a relevant Exchange-Traded Fund for equity/bond indices is a desired property. Unfortunately it is not always possible because of the cases when the investible version doesn't exist, as an example one must mention the presence of the first difference of the Euribor interest rate and the autocorrelation factors in the models. These are the exceptions made.The lagged values of the dependent variable are included in the model to allow the influence of the illiquidity factor on the hedge fund return and reflect the fact that the NAVs of hedge funds adjust to changes in securities the fund invested in much slower, one might think.

In the first part of the analysis the in-sample period is from January 2005 until the first of January 2011(non inclusive), the out-sample period is from January 2011 until September 2013. In the second part of the analysis the in-sample period is from the first October 2007 until the 18th of October 2010 (non inclusive) and the out-of-sample period covers the period from the end point of the in-sample period until the 7th of November 2013.
Due to some limitations of the data sample, the missing values for some factor indices were filled with the first value of the index available.

4.2 Methodology.

The method used in this thesis for replicating hedge fund returns is the factor-based approach. In the first part of the analysis the hedge fund index returns were replicated by means of the so-called fixed-weight clone. The main characteristic of this clone is its static nature, since the in-sample historical volaitility is assumed to be equal to that of the forecasting (out-of-sample) period. In other words, the factor sensitivities are estimated running the multiple regression for the in-sample period and held constant, while making predictions for the out-of-sample period.

The first step consists of finding relevant factors that could act as explanatory variables for the hedge fund index return. Previous academic research, described in details in the theoretical part of the thesis, serves as a main "reference point" for the factor selection.

Moreover, the description of investment strategies of all hedge funds included in the index are studied very carefully to identify the relevant asset types and categories Scandinavian hedge funds invest in. Subsequently, the significant factors are selected via backward stepwise regression analysis in R. This method consists of first running a regression on the whole range of all possible factors and then step-by-step eliminating not significant ones, until the best model is obtained. The alternative approach for factor selection could be the statistical method - Principal Components analysis.The major problem of this analytical method is the difficulty in interpreting the results, since the factors identified in the process of the analysis don't have an economic interpretation.

Those properties are considered necessary for the factors to qualify for a constituent of the clone:

- the preference is given to investible factors,
- they shouldn't necessarily represent the exact real assets the hedge funds invested in, since the approach is based on finding the assets that could possibly replicate the return of the hedge fund index, not to reveal the exact contents of its investment portfolio,
- they should include all asset classes the hedge-fund normally invests in., i.e. be exhaustive
- last but not least, they should be mutually exclusive to avoid high multicollinearity between the factors.

During the second step of the analysis the variables are being studied, determining their statistics like mean return, standard deviation, checking them for normality (if the returns are normally and independently distributed), preparing them for the analysis. Before the regression is run the variables are checked for stationarity by Dicker-Fuller test in SAS; the scatter plots of each individual variable and the returns of the hedge fund index are built to get the idea of the relationship or existing correlation between the two. After the preliminary checks the multiple linear regression is run within the in-sample period from 01/01/2005 until 01/01/2011 and the factor sensitivities are estimated according to the following equation:

$$\boldsymbol{HFindex\ return\ t} = \sum_{\boldsymbol{K=1}}^{\boldsymbol{k}} \boldsymbol{\beta jk} * \boldsymbol{Fkt} + \boldsymbol{ejk}$$

βjk-factor sensitivities of the hedge fund return

Fkt- the return of asset indices chosen as factors

ejk - the specific risk of a hedge fund

The intercept which represents alpha is excluded from the model to force the regression to fit the mean of the index returns with factors. The sum of the beta parameters is not restricted to be equal to 1, since the positions are assumed unfunded. In real life they can be taken through futures, where the only needed amount of current liquidity is a relatively insignificant cash deposit. [19]

The significant factors constitute the econometric model of the clone. The model is checked for autocorrelation, for multicollinearity, for normality, for heteroscedasticity; in case there is a suspicion of structural breaks the model is tested for that as well. Besides, the model is also checked for misspecification (Ramsey's Reset test) and for the quality of the forecast (Chow Prediction Failure test). The multiple regression analysis and some robustness checks are carried out in the statistical software SAS. Afterwards, the clone is created keeping the estimated weights of the factors constant during the out-of-sample period from 01/01/2011 until 01/09/2013:

$$\boldsymbol{return\ of\ clone\ t} = \sum_{\boldsymbol{k=1}}^{\boldsymbol{k}} \boldsymbol{\beta jk} * \boldsymbol{Fkt}$$

The forecasted values of the clone are compared to the actual values of the hedge fund inex. The performance of the clone is evaluated by pure statistical coefficients like RMSE(root mean squared error, Theil's inequality coefficient), mean return, standard deviations of the returns and on a risk-adjusted basis by comparing Sharpe ratios of the clone and that of the actual hedge fund index.

[19] Jerome Teiletche "Hedge fund replication: Does model combination help?"from "Hedge fund clones book"G. Gregoriou, M.Kooli, 2012, Palgrave Macmillan

In the second part of the analysis the procedure is similar. The factors are identified in the same way. The model undergoes the same routine checks. The difference is in the way the factor sensitivities are estimated. The goal of the new approach is to allow some time-variance in the beta parameters in order to improve the quality of the clone. For this purpose the rolling window regression is applied. As this time the data is daily NAVs of the hedge fund, the rolling window width is 262 days corresponding to the number of work days in a year. The rolling window analysis is carried out by means of the free software R and the zoo package with its time series functions.The rolling window regression is estimated within the in-sample period from the first October 2007 until the 18th of October 2010. Subsequently, the factor sensitivities, obtained as a result of the procedure, are averaged and the clone is built according to the same model as in the first part of the analysis except for the out-of-sample period. The out-of-sample period for the rolling window clone is from the 18th of October 2010 until the 7th of November 2013.The clone performance is evaluated in the same manner as in the first part of the analysis.

4.2.1 Multiple regression.

Multiple regression analysis is a statistical process for estimating the relationships among variables, mainly, the relationship between the dependent and independent variables. The focus is on the estimation of the conditional expectation of the dependent variable given the independent variables.i.e the average value of the dependent variable, while the effect of the independent variables is fixed. The function of the independent variables which is supposed to explain the variance of the dependent variable is the target of the analysis.The multiple regression used for estimation of the fixed-weight clone is linear in parameters and independent variables. In the analysis two methods for estimating the parameters of linear multiple regression are used: Ordinary Least Squares Estimation (OLS) and Maximum Likelihood (ML). In case the residuals of the model are uncorrelated, have the mean equal to ”0” and the constant variance, i.e are normally distributed, estimates derived from using both methods are the same.

The multiple linear regression has the following form :

$$\boldsymbol{Yt} = \propto + \boldsymbol{\beta k} * \boldsymbol{Xkt} + \boldsymbol{ukt}$$

$\boldsymbol{Yt}$**-** dependent variable or regressand

$\propto$ **-** alpha , intercept, the mean, average effect on Yt of all the variables not included in the model

$\boldsymbol{\beta k}$ - the parameters, slope coefficients which measure the change in the dependent variable per unit change in independent variables

$\boldsymbol{Xkt}$ - independent variables or regressors, variables that are correlated with the regressand and are supposed to explain the variance of the latter

$\boldsymbol{ukt}$ - the errors, residuals of the model, the difference between the real values of the regressand and the predicted by the model values

In order to get reliable estimates of the parameters of the model, to be able to predict the future values of the dependent variable the linear multiple regression should satisfy the assumptions of the Classical Linear Regression Model , i.e. for the estimated parameters to be Best Linear Unbiased and Efficient the residuals of the model must undergo a variety of statistical tests which will be described in the course of this chapter. The neccessary assumptions of the multiple linear regression are the following:

- the parameters (βk) should be linear, though the independent variables can be non-linear
- X-values should be independent of the error term, i.e. zero covariance between the residuals of the model and the independent variables:
  $\boldsymbol{cov(ukt, X1t) = cov(ukt, X2t) = 0}$
- zero mean value of the residuals: $\boldsymbol{E(ukt\ \ Xkt) = 0}$ for all **Xkt**
- homoscedasticity or constant variance of the residuals, the parameters are still unbiased and linear, but might not be best any more, not with the minimal variance:
  var(ukt) = $\boldsymbol{\partial^2}$
- no autocorrelation between the residuals, parameters are still unbiased and linear, but might not be best any more, not with the minimal variance : $\boldsymbol{cov(ui, uj) = 0 \quad i \neq j}$
- the number of observations should be greater than the number of the parameters to be estimated
- there must be variation in the values of the X variables
- there should not be exact collinearity, no exact linear relationship between the X variables

- the model should be correctly specified[20]

The main characteristics of the quality of the econometric model as **R-squared** and **adjusted R-squared** are used as crucial model selection criteria. **R-squared** shows the percentage of variance of the dependent variable explained by the chosen combination of the independent variables, by the model; the closer its value to ”1”, the better the model. The **adjusted R-squred** shows if each variable added to the model improves its forecasting quality,i.e its explanatory power.

The statistical significance is estimated according to the rule of thumb that the value of the **t statistics** in the regression output in SAS should be bigger than ”2” in order for the parameter estimate to be statistically significant.

The tests used in the analysis include **Godfrey's general Lagrange multiplier test of autocorrelation, Whites and Koenker-Basset test of heteroscedasticity,** the stationarity of the time series of the variables is accounted for by **Dicker-Fuller Stationarity test,** the normality of the residuals is checked by **Jarque-Bera test**. The model is checked for misspecification by **Ramseys Misspecification test**. The forecasted values are being evaluated by statistical measures as **Mean value, Standard deviation**, **Root Mean Squared Error** and **Theil's Inequality Coefficient** and by the statistical test- **The Chow Prediction Failure test.** The pure finacial measure as **Sharpe ratio** is calculated for the hedge fund index and its clone, which allows to estimate their performance on a risk-adjusted basis.The multicollinearity is accounted for by the **Variance Inflation factor(VIF)** and by the **Condition index (CI)** in SAS, though, since the presence of multicollinearity is suspected, when the R-squared of the regression is high, but the parameters are not statistically significant, it is only being checked, when the signs of it mentioned above seem to be present in the model. As a general rule, the multicollinearity is obvious, when the values of **VIF** and **CI** are correspondingly higher than ”10” and ”30”; both coefficients can be calculated automatically and are included in the statistical output in SAS.

Most of the tests are automatically run in SAS, except for the **White's**, **Koenker-Basset test and Chow Prediction Failure test** which are carried out manully**.** In case heteroscedasticity

[20] Damodar N. Gujarati, Dawn C.Porter ”Basic Econometrics”, fifth edition, 2009, MacGraw-Hill

is suspected in the model the standard deviations can be corrected by dividing them by the correspondent variances obtained from the asymptotic covariance matrix which is a part of the output in SAS.Thus one gets robust/corrected standard errors for the estimated parameters and can get an idea of the statistical inference for the parameter estimates.

Godfrey's general Lagrange multiplier test of autocorrelation – the test which is automatically run in SAS, its output also includes Durbin-Watson statistic. It is assumed that the error term is defined as the following(autocorrelation):

$$u_t = p1 * u_{t-1} + p2 * u_{t-2} + p3 * u_{t-3} + p4 * u_{t-4} + vt$$

where u_t are the residuals of the model and their corresponding lags

SAS calculates the LM statistics for p = 4.

The null hypothesis is:

H_0**: p1 = p2 = p3 = p4 –**no autocorrelation of the residuals

and the LM test **(n-p)*** R^2 value should be compared with the critical value $\chi^2_{0.95\,(p)}$, where **n** is the number of observations and **p** is the number of restrictions **(** number of **p's).** As always the null is rejected if LM test value exceeds the critical value and the **p-value** is less than 5%.

White's test of heteroscedasticity – once the residuals from the model are obtained the following regression is run in SAS:

$u_t^2 = \propto + \beta jk * Ft + vt$

where u_t^2 are the residuals of the model,

vt is a new error term assumed to fulfill the OLS assumptions

we need R^2 from this regression which should be used to calculate the test statistic:

Q = $n * R^2$**,** where **n** is the number of observations

If the test statistic exceeds the critical value $\chi^2_{0.95}$ with **k** degrees of freedom (number of explanatory variables) the null hypothesis of no heteroscedasticity is rejected.

At times the test might come out significant because of the model misspecification, not because of the heteroscedasticity itself.

Koenker-Bassett heteroscedasticity test – one of the advantages of this heteroscedasticity test is that it can be used even, when the residuals of the model are not normally distributed.The auxilary regression is run in SAS according to the equation:

$u_t^2 = \propto 1 + \propto 2 * (\log of\ predicted\ Y)^2$ **+ vt**

where **predicted Y** are the estimated values from the model, in this case it is a log of predicted Y values, since the model is a double-log model.

The null hypothesis is that $\propto \mathbf{2= 0}$ **,** it can be tested by the normal t-test. If it is not rejected, then one can conclude that there is no heteroscedasticity.

Dicker-Fuller unit root stationarity test (DF) -is performed automatically in SAS. The stationarity property is important in order to get a reliable forecast of the time series. It assumes that the mean and variance of the time series is constant over time and the value of covariance between two time –periods depends only on the lag (distance) between those two periods and is not influenced by the actual time, when the covariance was measured. If the time series turns out to be nonstationary, then the common practice is to take its first difference which is supposed to be stationary. It It is crucial to get an idea of the form of the time series equation from the graph against time, it is ought to be decided whether it is a

random walk $\Delta\, \boldsymbol{x_t}\mathbf{= }\boldsymbol{\delta} * \boldsymbol{x_{t-1}}\mathbf{+ vt,}$

random walk with drift $\Delta\, \boldsymbol{x_t}\mathbf{= }\ \boldsymbol{\alpha_1}\mathbf{+ }\boldsymbol{\delta} * \boldsymbol{x_{t-1}}\mathbf{+ vt,}$

or random walk with drift around deterministic trend

$$\Delta\, \boldsymbol{x_t}\mathbf{= }\boldsymbol{\alpha_1}\mathbf{+ }\boldsymbol{\alpha_2}\mathbf{\ *t + }\boldsymbol{\delta} * \boldsymbol{x_{t-1}}\mathbf{+ vt.}$$

In the Dicker-Fuller test the hypotheses are:

$\boldsymbol{H_0}\mathbf{: }\boldsymbol{\delta}\mathbf{= 0 –}$ non stationary time series

$\boldsymbol{H_1}\mathbf{: }\boldsymbol{\delta} < \mathbf{0}$ **-**stationary time series

The estimated coefficient of $\boldsymbol{x_{t-1}}$ follows the $\boldsymbol{\tau}$ **statistic ,** not the t student distribution.The critical values are different for each specification of the DF test. If the absolute value of τ statistic exceed the DF critical τ value, the p-values are less than 5%, then one might confirm that the time series is stationary.

Jarque-Bera normality test(JB) – is automatically performed in SAS, is an asymptotic, large sample test.The test computes the skewness and kurtosis of the OLS residuals according to the formula:

$$\boldsymbol{JB = n} * (\boldsymbol{S^2/6 + (K - 3)^2/24})$$

where **n**- sample size

S-skewness coefficient

K- kurtosis coefficient

The test is a joint hypothesis that both **S** and **K** are equal to ”0” and ”3”, which is a basic assumption of normal distribution. The null hypothesis is the normality of the residuals. The JB statistic follows chi-squared distribution with 2 degrees of freedom. If the p-value of the JB statistic is less than 5%, then the nypothesis of the normality of the residuals is rejected.

Ramseys RESET misspecification test is also performed automatically in SAS. It tests if there is still some correlation between the residuals and the predicted values of the dependent variable.The predicted values of the dependent variable are reintroduced in the regression in some form (could be squared or raised in the power of 3) and the regression is run to get the new value of R-squared.The F-test is used to see if the difference of the original R-squared and new R-squared is significant. If the computed F-value is significant at 5% level, one can accept the hypothesis that the original model is misspecified.

Chow's Prediction Failure test – is computed manually to see if there is significant diffrence between the actual and the predicted values by the model.It is an alternative to the test of structural breaks, but with the difference that the exact date of structural break is unknown.The statistical significance of the difference is tested by F-test:

$$\boldsymbol{F = ((\sum u_t^{2*} - \sum u_t^2)/\, n_2)/((\sum u_t^2)/(n_1 - k))}$$

where $\boldsymbol{n_1}$ is the number of observations in the in-sample period

$\boldsymbol{n_2}$ is the number of observations in the out-of –sample period

$\sum \boldsymbol{u_t^{2*}}$ is the residual sum of squares, when the equation is estimated for all the observations $\boldsymbol{(n_1+n_2)}$

$\sum \boldsymbol{u_t^2}$ is the residual sum of squares ,when the equation is estimated for the first $\boldsymbol{n_1}$ observations

k is the number of parameters estimated

The F statistic follows the F distribution with $\boldsymbol{n_1}$ and $\boldsymbol{n_2}$ degrees of freedom. If it exceeds the critical value, then one can conclude that the forecast is bad, there is significant difference between actual and predicted values.

The statistical and financial measures of evaluation are calculated according to formulas:

$$\textbf{RMSE} = \sqrt{\frac{1}{T} * \sum_{t=1}^{T} (Y_{t-}\ \boldsymbol{Ypredicted_t})^2}$$

where $\boldsymbol{Y_t}$ is the real value of the explained variable (real hedge fund(or index)return)

$\boldsymbol{Ypredicted_t}$ is the forecasted value of the explained variable (return of a clone)

T is a number of observation points

$$\textbf{U (Theil's Inequality Coefficient) =}$$

$$= \frac{\textbf{RMSE}}{\sqrt{\frac{1}{T}*\sum_{t=1}^{T} Ypredicted^2} + \sqrt{\frac{1}{T}*\sum_{t=1}^{T} Y_t^2}}$$

$$\textbf{Sharpe ratio} = \frac{(\textbf{mean return} - \textbf{risk free rate})}{\boldsymbol{\delta}}$$

where $\boldsymbol{\delta}$ is a standard deviation of returns (including both systematic and non-systematic risk)

$$\textbf{t-statistic of the Sharpe ratio} = \sqrt{n} * \boldsymbol{Sharpe\ ratio}$$

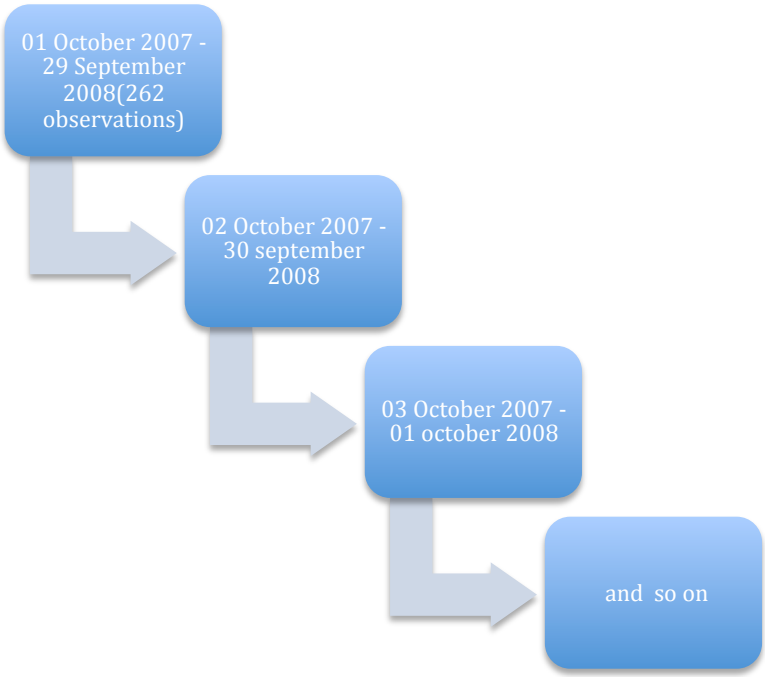
where $\boldsymbol{n}$ is the number of the observations in a sample

4.2.2. Rolling-window analysis.

The rolling-window is a statistical technique which allows a researcher to estimate the regression coefficients more thoroughly taking into account the time-changing aspects of the data. The core of the analysis is in the way the beta sensitivities are being estimated – instead of creating one model for predicting the variables for a single time-period, models for each window of the obseravtions are created. Hence, the method allows to reproduce the pattern of the historical volatility of the data sample with a better precision.The window should be of certain size: for example, 12 or 36 monthly observations, 262 daily observations corresponding to a number of work days in a year. The window of a fixed number of

observations slides down the sample at a given interval (again the fixed number of observations) at a time. In our case the window is fixed at the size of 262 daily observations and slides down one observation at a time. After the estimates of different model parameters have been determined, they are being averaged. The model obtained this way is expected to have better forecasting qualities. As a general rule, the rolling –window tecnique is used for testing the sustainability of the results of the statistical analysis. But the method is common and widely used in the world hedge fund replication practice.The scematic example of the analysisis is below:

Figure 3. Rolling –window analysis scheme.



4.2.3 R – free statistical software as a tool for the analysis.

After some preliminary research and having received a piece of advice from people working with different statistical programmes engaged in time-series analysis, it was decided to go ahead with **the rolling –window analysis** in R. It might seem a daunting task for an inexperienced user to start writing your own codes in R, since the interface is not really user-friendly, in the sense it is not ”point-and-click”. It has modest graphic abilities and less ”good-looking” output comparing to SAS, for instance. Nevertheless, it has one crucial property – at

least in the opinion of this project's author, it is far more suitable for working with time-series data.

The software is completely free and can be easily installed through the CRAN Mirrow managing tool with the list of mirror sites subdivided into different countries. It includes numerous packages which can be installed as well and are designed to work with different kind of data and perform different kinds of analysis. There is a vast amount of "vignettes" and guides found on the official R site to help a researcher in her work.[21]

The rolling-window analysis in this thesis is carried out using the functions included in zoo time-series package. The following steps outline the analysis: first loading the data and converting it into a zoo object, then using the "rollapply" function for the multiple regression with the rolling window (the code is provided in the appendix with comments (see Figure 26 in Appendices) and the final step - exporting the results to the .csv file which can be easily analysed further in Excel.

R is also used for the selection of the significant factor variables for the models of the clones. Here the **backward stepwise regression method** is applied. The code in this case is less complicated and the procedure starts off by running the multiple regression with all factors which were chosen based on the investment strategy of the hedge fund and relevant academic research. Afterwards, the "step" function is applied in the backward direction providing a huge output of models, where the final one is the best with the lowest value of AIC coefficient, decent R-squared and highly statistically significant beta estimates.

4.2.4. SAS – statistical software as a tool for the analysis.

Another statistical package used for the analysis is the SAS Enterprise Guide version 5.1 provided by Copenhagen Business school.

SAS was first created over the period from 1966 to 1976 and since that time has developed into the complete set of customer intelligence statistics software.The first "point-and-click" programme was introduced in 2004. Now there is a large variety of different programmes for data mining, forecasting and etc. SAS software provides a good graphical output, includes numerous robustness tests to the regression output, there is room for different regression

[21] www.r-project.org

methods as the basic OLS and the Maximum likelihood . The interface allows to manipulate the data (editing, creating new variables) more easily. All the mentioned above are the reasons, why SAS statistics was used in combination with R for constructing the clones' models, doing robustness checks, creating graphical plots for the analytical part of this thesis.

5. First part of the analysis.

5.1 NHX composite clone.

The first model built is the clone of the return of NHX composite index. After having studied the investment strategies of included in the index hedge funds, the significant correlations between the returns of the NHX index and the equity returns of 3 Nordic equity indices: MSCI Nordic Large Cap value and growth, MSCI Nordic Small Cap value and the credit spread (which is here represented by the difference between theThomson Reuters US corporate industry bonds of B+ credit rating with the maturity 10 years + and the short-term treasury bills) were revealed by backward stepwise regression analysis in R. The factor exposures are identified by running a multiple linear regression within the in-sample period from 01/01/2005 until 01/01/2011 in SAS.

$$\boldsymbol{NHX\ composite} =$$
$$\boldsymbol{\beta 1 * MSCInordic\ LG + \beta 2 * MSCInordic\ L\ V + \beta 3 * MSCInordic\ SV + \beta 4 *}$$
$$\boldsymbol{TR\ US\ CPR\ BMK\ B\ inv\ grade\ 10\ years\ spread + Ejk}$$

NHX composite*- the continuously compounded returns of NHX composite index*
βjk*- the factor sensitivities, factor weights of the clone*
MSCI nordic LG*-Morgan Stanley Capital International equity index of the Nordic large capitalization growth companies*
MSCI nordic LV- *Morgan Stanley Capital International equity index of the Nordic large capitalization value companies*
MSCI nordic S V- *Morgan Stanley Capital International equity index of the Nordic small capitalization value companies*
TR US CPR BMK B + 10y + to TSY spread *– Thomson Reuters United States index representing the credit spread of industry long-term bonds of the investment class B+ and the short –term Treasury bills*
Ejk*-errors of the model*

As the first step of the analysis, the time series of all variables are examined for stationarity using the Dicker-Fuller test in SAS. The probabilities of the model with the single mean (that's

what it looks like according to the graph of the relevant variable versus time) are less than 5%, we can reject the null hypothesis of the non-stationarity.

The correlations between the returns of the NHX index and the factors are studied initially using the scatter plots in SAS, which gives an idea of the kind of relationship between the variables and its sign.

The results of the multiple regression are the following:

Ordinary Least Squares Estimates			
SSE	0.00567153	DFE	67
MSE	0.0000846	Root MSE	0.00920
SBC	-451.34333	AIC	-460.39404
MAE	0.00741335	AICC	-459.78798
MAPE	218.827086	HQC	-456.79486
Durbin-Watson	1.9146	Regress R-Square	0.5820
		Total R-Square	0.5820
NOTE: No intercept term is used. R-squares are redefined.			

Root MSE	0.00920	R-Square	0.5820
Dependent Mean	0.00391	Adj R-Sq	0.5571
Coeff Var	235.02589		

The R-squared value is 58.2% which means that the factor model above explains 58.2% of the variance in the NHX composite returns. The value of **the adjusted R-squared** which indicates if each variable added improves the model is **55.71%.** The F statistic of the model (the probability that all coefficients of the model are zero) proves that the model is a ”good fit”, since it is significant at 5% level (the p-value is less than 5%).

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
MSCI Nordic L V cont ret	1	-0.0872	0.0217	-4.02	0.0001
MSCI Nordic L G cont ret	1	0.0916	0.0243	3.77	0.0004

MSCI Nordic small cap value cont	1	0.0838	0.0142	5.90	<.0001
TR US CRP BMK B+ 10Y/TSY SPD	1	-0.0351	0.0153	-2.29	0.0254

All factor coefficients of the model are significant at the 5% confidence level; the t statistics exceed the critical value t=1.96 , the signs of the coefficients are as expected. The exposure to MSCI Nordic Small Cap Value is positive and highly significant, which is typical for the long/short equity hedge fund strategy. This is totally plausible, since the majority of the hedge funds included in the NHX composite index pursues Equity strategy. The hegde funds exposure to Scandinavian large capitalization growth stocks is positive and significant, since those are expected to grow in value and funds go long in them, but the sign of the significant exposure to Scandinavian large capitalization value stocks is directly opposite, which again proves the fact that funds go short in large value stocks and is totally in line with the previous academic research on the topic.[22] The exposure to the credit spread is negative and significant, since the bigger the spread, the lower is the liquidity on the market, the higher the probability of default, the more expensive financing the companies get, the lower the value of the company and, consequently, of the company's stock, which might lower return on the investment strategies.

The next step is checking the model for autocorrelation by **Godfrey –Lagrange test** in SAS (the relative probabilities way above 5% indicate that the null nypothesis of no autocorrelation can't be rejected). The normality of the residuals is accounted for by the relative test in SAS -the probability exceeds by far 5% threshold, thus the returns are normally distributed. The heteroscedasticity have been tested twice manually by **White's test** by which the null hypothesis of no heteroscedasticity was rejected, which could indicate an omitted variable in the model, and by **Koenker-Bassett test** which allowed to infer right the opposite, i.e. no heteroscedasticity in the model. After having corrected the standard errors of the factors for heteroscedasticity, all their signs and statistical significance were confirmed. The Partial Correlation and Autocorrelation diagrams of the residuals were studied to get an

[22] Lars Jaeger, Christian Wagner "Factor modelling and benchmarking of hedge funds: Can passive investments in hedge fund strategies deliver?", November 7, 2005

idea if they seem to be white noise, so the model managed to explain as much variance in the dependent variable as possible (see residuals' graphs in the appendix).

The Ramsey's model misspecification test was run in SAS. All carried out tests confirm the goodness-of-fit of the model.

According to the multiple regression results the returns of NHX index can be replicated by going long in MSCI Nordic Large Cap Growth index, MSCI Nordic Small Cap Value index, going short in MSCI Nordic Large Value index and TR US Corporate Bond /Treasury bill spread.

As a final step, the return values (the values of the clone) in the out-of-sample period from 01/01/2011 until 01/09/2013 are forecasted keeping the estimated factor weights constant. The forecasts are evaluated by calculating the **RMSE** (root mean squared error) and **Theil's Inequality coefficient**.

RMSE=0.006

U (Theil's inequality coefficient)=0.398 (which is much less than 1, thus not bad at all)

The F-statistic of the **CHOW prediction value test** is **0.54111**,while the critical value is between **(2.53;2.45),** thus, the null hypothesis can't be rejected and there is no significant difference between actual and forecasted values of the returns of the NHX composite index.

The problem is encountered first, when trying to evaluate forecast on the risk-adjusted basis, i.e. by comparing Sharpe ratios. As a risk-free rate the average of the monthly continuously compounded values of the Euribor 3m are taken. **The means and standard deviation** of the index and the clone are:

	NHX composite index	clone
Mean		
Monthly	**0.0014**	**0.00028**
Yearly	**0.0169**	**0.00330**
Standard deviation		
Monthly	**0.0094**	**0.0082**
Yearly	**0.0326**	**0.0285**

The **Sharpe ratios** for the out-of-sample period from 01 January 2011 until 01 September 2013 are:

	monthly	yearly
NHX composite	-0.07	-0.24
Clone	-0.21	-0.75
Risk-free(Euribor 3m)	0.0021	0.0249

After having compared the Sharpe ratios, it turns out that the clone has considerably underperformed the NHX composite index (see Figure 3 in Appendices) , but if to take the statistical significance of the Sharpe ratios into consideration one is expected to conclude that both Sharpe ratios are not significantly different at 5% confidence level from a risk-free rate (in our case Euribor 3 month).

t statistic of the Sharpe ratio= (number of observations in the sample)^0.5* Sharpe ratio

t stat of the NHX composite return values = -0.404 < 1.96

t stat of the clone = -1.25 < 1.96 (significant only at 20% level)

The t statistics of both Sharpe ratios show that the returns of both the NHX index and its clone are not significantly different from the risk-free rate. The interpretation is rather complicated, since the negative Sharpe ratios get even smaller (more negative) as the standard deviation gets smaller, but low standard deviations are not that bad. This happens because the slope of the regression line to the risk-free rate in case of negative excess returns is negative. The negative excess index returns normally occur under the bear market conditions. There is research on this issue which confirms that the lower unattractive Sharpe ratio in the bear market turns out exactly the opposite in the bull market. Hence, the clone is expected to perform considerably better under stabilized market conditions.[23] Besides, one can add to explaining the issue of the statistical significance of the Sharpe ratios that the returns of the

[23] Hendrik Scholz, Marco Wilkins "Interpreting Sharpe ratios. The market climate bias", 2005, working paper of the Catholic University of Eichstaett-Ingolstadt

hedge fund index and its clone are very sensitive comparing to the risk-free rate in the sample period. The modest size of the out-of-sample could also cause this problem.

5.2 NHX equity clone.

The equity clone is built for the purpose of replicating the Nordic hedge funds equity index. Based on the main investment assets and categories described in the funds' strategies and taking into account the existing empirical research on the equity replicating strategies the backward stepwise regression analysis was carried out in R and six explanatory factors were identified: MSCI Nordic Small Cap value, US/Euro 1 month index, ML Convertible Emergent markets bond index, MSCI AC World Small Cap Value Equity index, Convertible European High Investment grade-A bond index and size spread (difference between the returns of MSCI Nordic Small Caps and MSCI Nordic Large Caps).

The time series of the factors were checked by Dicker-Fuller test in SAS for stationarity and none of them was confirmed non stationary. The multiple linear regression equation which is run in SAS within the in-sample period from 01/01/2005 until 01/01/2011 is the following:

$$NHX\ equity\ index =$$
$$= \beta 1 * MSCI\ Nordic\ Small\ Cap\ value + \beta 2 * size\ spread +$$
$$+\beta 3 * MSCI\ AC\ World\ Small\ Cap\ value + \beta 4 *$$
$$ML\ Convertible\ Emergent\ market\ bond\ index + \beta 5 *$$
$$ML\ European\ Convertible\ A\ bond\ index + \beta 6 * Us\ /Euro\ 1\ month\ index + Ejk$$

NHX Equity index *-Nordic Hedge funds' Equity index*

βjk- *the relative factor exposure*

MSCI Nordic Small Cap value –*Morgan Stanley Capital International equity index of Nordic Small Capitalization value companies*

Size spread *– size spread of Nordic Small Capitalization stocks calculated as a difference between MSCI Nordic Small Cap equity index and MSCI Nordic Large Cap equity index*

MSCI AC World Small Cap value- *Morgan Stanley Capital International Equity index of Worldwide Small Capitalization value companies*

ML Convertible Emergent market bond index- *Merrill Lynch Convertible bonds of the companies in the emergent markets index*

ML European Convertible A bond index- *Merrill Lynch Convertible European bonds of the high investment grade A index*

Us euro 1$ month index- *Eurodollar 1 month deposit in US dollars index*

Ejk*-errors of the model*

As a next step, the regression was run in SAS by Ordinary Least Squares method and the results are the following:

Ordinary Least Squares Estimates			
SSE	0.00912815	DFE	68
MSE	0.0001342	Root MSE	0.097
SBC	-421.81678	AIC	-428.60482
MAE	0.00934845	AICC	-428.24661
MAPE	200.587827	HQC	-425.90543
Durbin-Watson	1.7462	Regress R-Square	0.7308
		Total R-Square	0.7308
NOTE: No intercept term is used. R-squares are redefined.			

The **R-squared of the model is 73.08%** which proves that the variance of the returns of NHX equity index is explained quite well by the model consisting of these five factors.The **R-adjusted** is **68.22%,** which is again a positive characteristic of the model.

Root MSE	0.01159	R-Square	0.7308
Dependent Mean	0.00471	Adj R-Sq	0.6822
Coeff Var	246.13396		

All parameter estimates of the model are statistically significant at the 5% level, the t statistics exceed the critical t value of 1.96.There is a negative highly significant exposure to Convertible Emergent market bond index, negative exposure to size spread calculated as the difference between MSCI Nordic Small Capitalization equity index and MSCI Nordic Large Capitalization equity index, positive highly significant exposure to Nordic Small Capitalization

value stocks and to Worldwide Small Capitalization value stocks, positive exposure to US/EURO 1$ deposit index. All the results are as expected, underpinned by the theoretical research and have quite similar features comparing to the NHX composite clone,f.ex long exposure to Small Capitalization value stocks.The Convertible bond indices' factors along with the size spread were included in the model to capture the non-linearities of the returns of the hedge funds.

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
US/Euro 1$ month deposit index	1	1.6101	0.489	3.291	0.01662
MSCI Nordic Small cap value	1	0.17555	0.01838	9.552	<.0001
ML Convertible Emergent market bond	1	-0.21858	0.06246	-3.499	0.000878
MSCI AC World Small cap	1	0.19198	0.0544	3.528	0.000802
Size spread	1	-0.07553	0.0269	-2.806	0.00672
ML Convertible European A bond index	1	0.1472	0.0677	2.173	0.033663

The model has been checked for autocorrelation by **Godfrey-Lagrange test** in SAS- the result denies the presence of autocorrelated errors in the model.The heteroscedasticity has been accounted for manually by **Koenker-Basset test** which didn't provide any evidence for heteroscedasticity of the residuals. The normality was checked and approved by the built-in test in SAS.The residuals' plots were studied to make sure the model is a "good fit"(see the residuals' graphs in the appendix). The model was tested for misspecification by **Ramsey's test** in SAS which confirmed the goodness of fit of the model and by **Chow Prediction Failure test** manually which approved the good forecasting properties of the same.
The forecasts were made for the out-of-sample period from 01.01.2011 until 01.09.2013 and evaluated by Root Mean Squared Error and Theil's Inequality coefficient - both evidenced that the model's forecast is good.

RMSE = 0.0109

U = 0.388

The **means and standard deviations** are:

	NHX equity index	clone
Mean		
Monthly	**0.0015**	**0.00229**
Yearly	**0.0185**	**0.0275**
Standard deviation		
Monthly	**0.0132**	**0.015**
Yearly	**0.0459**	**0.052**

The **Sharpe ratios** are:

	monthly	yearly
NHX equity	**-0.039**	**-0.138**
clone	**0.014**	**0.049**
Risk-free (Euribor 3m)	**0.021**	**0.0249**

The clone outperformes the NHX equity index for the period (see Figure 7 in Appendices), but the Sharpe ratios are not significant at 5% level. The **t statistics** for the Sharpe ratios of the NHX equity index is **-0.229** and **0.08** for the clone. The picture is similar to that of the NHX composite index, the results are very sensitive comparing to risk-free rate (Euribor 3 m) in the sample.

5.3 NHX Fixed Income.

The fixed income strategy replicated is represented in this case by two substrategies – the convertible and relative arbitrage. In the process of data analysis problems were encountered due to the outliers in the time series of the logarithmic returns of the NHX Fixed Income index during the period of the financial crisis of 2008-2010, though after running Dicker –Fuller test

in SAS the time series were confirmed stationary.The model was built using the following factors: first difference of Euribor 3 m, third lag of the NHX Fixed Income itself, Credit Suisse High Yield Bond index, Morgan Stanley Capital International Nordic Small Capitalization Value Equity index.

All the included factors except for the autoregressive component –the third lag of the NHX Fixed Income- were checked for stationarity, only Euribor 3m time series was confirmed non stationary and, consequently, was transformed into first difference. The multiple regression was run in SAS within the in-sample period from 01/01/2005 until 01/01/2011 according to the equation :

$$\boldsymbol{HNX\ FIxed\ Income} =$$
$$= \boldsymbol{\beta 1} * \boldsymbol{MSCI\ Nordic\ small\ Cap\ Value\ equity\ index} +$$
$$+\boldsymbol{\beta 2} * \boldsymbol{Credit\ Suisse\ High\ Yield\ Bond\ index} +$$
$$+\boldsymbol{\beta 3} * \boldsymbol{AR3} + \boldsymbol{\beta 4} * \boldsymbol{1DIF\ Euribor\ 3m} + \boldsymbol{ejk}$$

NHX Fixed Income –*Nordic Hedge Fund Fixed Income index*

βjk- *factor sensitivities*

MSCI Nordic Small Cap Value index*-Morgan Stanley Capital International Small Cap Value equity index*

Credit Suisse High Yield Bond index - *Credit Suisse low investment grade high yield bond index*

AR3- *third lag of the NHX Fixed Income index*

1DIF Euribor 3m – *first difference of the Euribor 3 month rate*

ejk- *errors of the model*

The results of the regression are the following:

Ordinary Least Squares Estimates			
SSE	0.01762193	DFE	64
MSE	0.0002753	Root MSE	0.01659
SBC	-351.69842	AIC	-360.57645

MAE	0.01259537	AICC	-359.94153
MAPE	444.578758	HQC	-357.0587
Durbin-Watson	1.8296	Regress R-Square	0.5380
		Total R-Square	0.5380
NOTE: No intercept term is used. R-squares are redefined.			

The **R-squared** of the regression is 53.80% which means that the model explains 53.80% of the variance of the NHX Fixed Income returns.The **adjusted R-squared** is **50.92%** which shows how well each added variable improves the explanatory power of the model is quite satisfactory as well:

Root MSE	0.01659	R-Square	0.5380
Dependent Mean	0.00218	Adj R-Sq	0.5092
Coeff Var	761.10071		

The **Fstatistic** of the model which checks if all coefficients are significantly different from zero and, thus accounts for the overall significance of the model, confirms its goodness of fit at the 5% level(the p-value is very small).

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	0.02052	0.00513	18.63	<.0001
Error	64	0.01762	0.00027534		
Uncorrected Total	68	0.03815			

All the factor coefficients are significant at 5% level. The results show that there is significant positive exposure to MSCI Nordic Small Cap value equity index, to Credit Suisse High Yield Bond index, to the third lag of NHX FIxed Income which is a sign of autocorrelation of returns and indicates liquidity risk and late reaction of the NHX Fixed Income index to the change in the prices of the underlying securities which constitute its investment portfolio. Though, it is

worth noticing, the model doesn't include contemporaneous values of the NHX Fixed Income, which is a positive property for forecasting purposes. There is an evidence of highly significant negative exposure to the first difference of Euribor 3 m.

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
MSCI Nordic small cap value cont	1	0.1131	0.0238	4.75	<.0001
1difEuribor	1	-54.1879	12.2311	-4.43	<.0001
lag_3_NHX Fixed Income	1	0.3453	0.0931	3.71	0.0004
CREDIT SUISSE HI.YLD.BD. FD.NAV	1	0.0806	0.0377	2.14	0.0365

The model was checked for autocorrelation by **Godfrey-Lagrange test** in SAS, no autocorrelation was confirmed. The normality was checked and approved by the built-in test in SAS (see the residuals' diagrams in the appendix).The heteroscedasticity is accounted for by the **Koenker-Basset test of heteroscedasticity** carried out manually. The null hypothesis of heteroscedasticity was not rejected.

The forecast was made for the period from 01/01/2011 until 01/09/2013. The forecasted values were evaluated by statistical methods (RMSE and Theil's Inequality coefficient). Both confirmed the model has quite good forecasting qualities.

RMSE = 0.013

U = 0.0801 (the value is very close to 0, which is a sign of a very good forecast)

The Chow Prediction Failure test confirmed that there is no significant difference between predicted by the model and the actual values of NHX Fixed Income return. The Fstatistic of 0.35 doesn't exceed the critical values (1.74;1.64).

The means and standard deviations are:

	NHX fixed income index	clone
Mean		
Monthly	**0.0086**	**0.0053**
Yearly	**0.1033**	**0.0636**
Standard deviation		
Monthly	**0.0068**	**0.0109**
Yearly	**0.0238**	**0.0379**

The Sharpe ratios of the clone and the index are:

	monthly	annually
NHX Fixed Income	0.94	3.28
clone	0.294	1.02
Risk-free rate(Euribor 3m)	**0.021**	**0.0249**

The clone underperforms the NHX Fixed Income return considerably (see Figure 11 in Appendices) and the Sharpe ratio is statistically significant at 5% level only for the NHX Fixed Income itself, the Sharpe for the clone is significant only at 10% level. **The t statistic of the clone** is **1.69** and the **t statistic of the NHX Fixed Income index** is **5.44.**

5.4 NHX multistrategy index.

The multistrategy is replicated by running multiple regression using the following factors, previously identified by backward stepwise regression analysis in R: NASDAQ OMX Nordic Energy equity index, NASDAQ OMX 120 equity index, US $ Major Currency MAR 73=100 Exchange index, MSCI Nordic Large Capitalization value companies, Citigroup European Government bonds with maturity 10-15 years index and Barclays High Yield Corporate bond index. All the factors' time series were checked for stationarity by the Dickey-Fuller test in SAS. None of them was confirmed non-stationary. Afterwards the regression was run according to the equation:

$$NHX\ Multistrategy =$$
$$= \beta 1 * MSCI\ Nordic\ Small\ Cap\ Value$$
$$+\beta 2 * US\$\ Major\ currency\ Exchange\ index +$$
$$\beta 3 * MSCI\ AC\ World\ Large\ Cap\ Value\ + \beta 4 * MSCI\ Nordic\ LV +$$
$$+\beta 5 * CGBI\ WGBI\ Euro\ Government\ index + \beta 6 * Barclays\ High\ Yield\ Corp\ bond\ index + ejk$$

NHX multistrategy index- *Nordic hegde funds' multistrategy index*

$\beta 1, \beta 2, \beta 3, \beta 4, \beta 5, \beta 6$- *factor exposures*

MSCI Nordic Small Cap Value Equity index – *Morgan Stanley Capital International Small Capitalization Value Equity index*

$US\$\ Major\ currency\ MAR\ 73 = 100$ ***Exchange index-*** *US dollar trade-weighted against world major currencies index*

MSCI AC World Large Cap Value Equity index- *Morgan Stanley Capital International All Countries World large capitalization value equity index*

MSCI Nordic LV index - *Morgan Stanley Capital International Nordic Large Capitalization value equity index*

CGBI WGBI Euro Government index -*Citigroup European Government Global bond with maturity from 10 to 15 years index*

Barclays High Yield Corp bond index- *Barcalys Corporate High Yield bond index*

ejk - *errors of the model*

The results of the regression in SAS are:

Ordinary Least Squares Estimates			
SSE	0.00432144	DFE	65
MSE	0.0000665	Root MSE	0.00815
SBC	-462.12078	AIC	-475.69686
MAE	0.00611318	AICC	-474.38436
MAPE	191.756609	HQC	-470.29809
Durbin-Watson	2.3424	Regress R-Square	0.5172
		Total R-Square	0.5172
NOTE: No intercept term is used. R-squares are redefined.			

The **R-squared** of the regression is **0.5172** which is not very high, but satisfactory. The model explains about **51.72%** of variance in the return of **NHX Multistrategy.** The **adjusted R-squared** is **47.27%:**

Root MSE	0.00815	R-Square	0.5172
Dependent Mean	0.00470	Adj R-Sq	0.4727
Coeff Var	173.46421		

The **F-test** points to the rejection of the hypothesis that all coefficients of the model can be simultaneously equal to zero (p-value is very small), thus the model is approved.

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	6	0.00463	0.00077162	11.61	<.0001
Error	65	0.00432	0.00006648		
Uncorrected Total	71	0.00895			

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
MSCI Nordic small cap value cont	1	0.0582	0.0118	4.93	<.0001
MSCI AC world value L V cont re	1	0.0868	0.0283	3.06	0.0032
US $ MAJOR CURRENCY MAR 73=100 (	1	0.2690	0.0867	3.10	0.0028
MSCI Nordic L V cont ret	1	-0.0560	0.0207	-2.71	0.0086
CGBI WGBI EURO GOVT 10-15Y ($) -	1	0.1490	0.0508	2.93	0.0046
BARCLAYS HIGH YIELD CORPORATE -	1	0.4220	0.1300	3.25	0.0019

All coefficients are significant at 5% level. There is a positive significant exposure to MSCI Nordic Small Cap Value Equity index, MSCI AC World Large Cap Value Equity index, US major currency MAR 73=100 index, CGBI WGBI Euro Govt 10-15Y index, Barclays High Yield Corporate bond index and negative significant exposure to Morgan Stanley Capital International Nordic Large Capitalization Value Equity index. The model underwent a series of routine checks like the previous models. The **Godfrey-Lagrange test** didn't provide any evidence of autocorrelation. The p-values are bigger than 5 % , so the null hypothesis of autocorrelation is not rejected up to 4 lags (see the residuals' plots in appendix).The normality of the residuals is confirmed too by **Jarque-Bera test** in SAS. The p-value is higher than 5%, so the null hypothesis of non-normality is not rejected.The Ramsey's reset test of misspecification was performed in SAS. All p-values are greater than 5 % , so the model didn't point at any evidence of the misspecification.The result of the Chow Prediction Failure test didn't point at any significant difference between actual and predicted values of the NHX multistrategy return.

The values of **RMSE** and **Theil's Inequality coefficient** are:

RMSE = 0.0072 - quite satisfactory

U = 0.436- satisfactory, but the perfect value should be as close to "0" as possible.

The means and standard deviations are:

	NHX multistrategy index	clone
Mean		
Monthly	**0.0022**	**0.0040**
Yearly	**0.0268**	**0.0485**
Standard deviation		
Monthly	**0.0094**	**0.0059**
Yearly	**0.0325**	**0.0206**

The **Sharpe ratios** are:

	monthly	yearly
NHXmultistrategy index	**0.0171**	**0.0592**
clone	**0.3296**	**1.1419**
Risk –free (Euribor 3m)	**0.0021**	**0.0249**

The **t statistic for NHX multistrategy** is **0.098**, which indicates that the Sharpe ratio of **NHX Multistrategy** is not significant at 5 % level, **the t statistic of the clone** is **1.89**, which confirms that the clone's Sharpe ratio is significant at 10% level.The clone considerably outperforms NHX multistrategy index (see Figure 15 in Appendices), but the Sharpe ratios are not statistically significant at 5% level.

5.5 NHX managed futures and CTA.

The next replicated strategy of the Nordic Hedge fund index is the managed futures and CTA(Commodity Trading Advisor). Having studied the relevant description of the strategies of the underlying hedge funds and subsequently carried out the backward stepwise regression anlysis in R, the model was built consisting of three factors: CME GSCI cont 2nd future index, Ice Brent Crude Oil cont index and US LIBOR Capital 1 month index.This strategy is considered to be among the most challenging for replication according to the existing research, since by definition- those hedge funds use mainly derivative instruments in their investment strategies-the empirical model should be non-linear. Thus, it is a daunting task replicating it by means of the common linear multiple regression, but the results obtained were quite satisfactory. The multiple regression is run in SAS according to the equation:

$$\boldsymbol{NHX\ managed\ futures\ and\ CTA = \beta 1 * CME\ GSCI\ cont\ 2nd\ future\ sett\ index + \beta 2 * Ice\ Brent\ Crude\ Oil\ cont\ index + \beta 3 * US\ Libor\ Capital\ 1\ month + ejk}$$

NHX managed futures and CTAs *-Nordic Hedge fund managed futures and CTAs index*

$\boldsymbol{\beta 1, \beta 2. \beta 3}$ *- factor sensitivities*

CME GSCI cont 2nd future index- *Goldman Sachs Commodity continuous second future index*

Ice Brent Crude Oil cont index -*Ice Brent Crude Oil continuous future index*

US LIbor Capital 1 month - *US Libor 1 month lending interbank rate index*

Ejk- *errors of the model*

The results of the regression are the following:

Ordinary Least Squares Estimates			
SSE	0.02777005	DFE	68
MSE	0.0004084	Root MSE	0.02021
SBC	-342.82255	AIC	-349.61059
MAE	0.01538541	AICC	-349.25238
MAPE	152.828873	HQC	-346.9112
Durbin-Watson	2.0731	Regress R-Square	0.1154
		Total R-Square	0.1154
NOTE: No intercept term is used. R-squares are redefined.			

The R-squared of the regression is only 11.54% which is quite modest characteristic of the quality of the model. The **R-adjusted** is **7.64%,** which is a very small, signalizing the poor quality of the model.

Root MSE	0.02021	R-Square	0.1154
Dependent Mean	0.00477	Adj R-Sq	0.0764
Coeff Var	423.93814		

The F-statistic is quite satisfactory as well providing the evidence that it is very unlikely that all the coefficients of the model can be equal to zero simultaneously.

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	0.00362	0.00121	2.96	0.0384
Error	68	0.02777	0.00040838		
Uncorrected Total	71	0.03139			

Variable	**DF**	**Estimate**	**Standard Error**	**t Value**	**Approx Pr > |t|**
US LIBOR CAPITAL. INDEX 1 MONTH	1	2.0837	0.8223	2.53	0.0136
CME-GSCI CONT. 2ND FUTURE - SETT	1	-0.2063	0.0995	-2.07	0.0419
ICE-BRENT CRUDE OIL CONT. INDEX	1	0.1412	0.0741	1.91	0.0610

All three coefficients are significant at 5% level(except for the Ice Brent Crude Oil continuous second future index which is significant only at 10% level) and indicate that NHX managed futures index has a negative significant exposure to Goldman Sachs Commodity continuous second future index, positive significant exposure to Ice Brent Crude Oil continuous future index and US LIBOR Capital 1 month rate index.

The model was checked for autocorrelation by the usual **Godfrey-Lagrange test**, the p-values exceed by far 5% threshold, which means that there is no autocorrelation. The same conclusion can be drawn based on the normality (**Jarque-Bera test**). The outcome of the test confirms that the residuals are normally distributed. The **Koenker-Basset heteroscedasticity test** turned out negative as well.**The Ramseys misspecification test** in SAS didn't provide the evidence of the model misspecification.**The Chow prediction failure** test didn't confirm significant difference between actual and forecasted values (F statistic doesn't exceed the F critical value).
The evaluation of the forecast for the out-of-sample period from 01/01/2011 until 01/09/2013 is the following :

RMSE = 0.0271

U(Theil's Inequality coefficient) = 2.577 (which is not good at all, the value is way larger than 1)

The means and standard deviations are:

	NHX managed futures and CTA	clone
Mean		
Monthly	**-0.0036**	**0.0021**
Yearly	**-0.0435**	**0.0257**
Standard deviation		
Monthly	**0.0251**	**0.0048**
Yearly	**0.0869**	**0.0168**

The **Sharpe ratios** for the NHX managed futures and CTAs and the clone are the following:

	monthly	yearly
NHX managed futures and CTAs	**-0.2272**	**-0.7873**
clone	**0.0137**	**0.0477**

Risk-free (Euribor 3m)	**0.002**	**0.0249**

The clone seem to outperform the NHX managed futures index and CTA index considerably (see Figure 19 in Appendices). Concerning statistical significance of the Sharpe ratios:

t stat of the index = -1.305

t stat of the clone = 0.079

Thus, the Sharpe ratio of the NHX managed futures and CTA index is weakly significant, only at 20% level. The t-statistics of the clone is very small, thus undermining the statistical significance of the obtained result.

5.6 NHX Fund of Funds index.

The substrategy of the Nordic hedge fund index Funds of Funds concludes the first part of the analysis, where the replication is performed by means of the fixed-weight clone. The backward stepwise regression analysis was carried out in R and as a result the clone is built using three factor variables: BOFA ML EMU CPR and PFN bond index, US major currency trade-weighted index and MSCI world according to the regression equation run in SAS:

$$\boldsymbol{NHX\ Fund\ of\ Funds} =$$

$$= \boldsymbol{\beta 1} * \boldsymbol{BOFA\ ML\ EMU\ CPR\ and\ PFN} + \boldsymbol{\beta 2} * \boldsymbol{US\ major\ currency\ index} +$$

$$+ \boldsymbol{\beta 3} * \boldsymbol{MSCI\ world\ index} + \boldsymbol{ejk}$$

$\boldsymbol{\beta 1}, \boldsymbol{\beta 2}, \boldsymbol{\beta 3}$ - *factor sensitivities*

NHX Fund of Funds- *Nordic hedge funds'index which follow Fund of Funds strategy*

BOFA ML EMU COPR and PFN index – *Bank of America Merryll Lynch European Monetary Union corporate and pension fund bonds index*

Us major currency index- *US dollar trade-weighted against major currencies index*

MSCI world-*Morgan Stanley Capital International World equity index*

Ejk- *errors of the model*

The results of the regression are:

Ordinary Least Squares Estimates			
SSE	0.00668751	DFE	68
MSE	0.0000983	Root MSE	0.00992
SBC	-443.90641	AIC	-450.69444
MAE	0.00742707	AICC	-450.33624
MAPE	125.206304	HQC	-447.99506
Durbin-Watson	2.1144	Regress R-Square	0.3232
		Total R-Square	0.3232
NOTE: No intercept term is used. R-squares are redefined.			

The **R-squared** is **32.32%** which is quite satisfactory. The model consistng of these three factors explains 32.32% variance of the NHX Fund of Funds return.**The R-adjusted** is **29.34%.**

Root MSE	0.00992	R-Square	0.3232
Dependent Mean	0.00216	Adj R-Sq	0.2934
Coeff Var	459.31740		

The F-test doesn't provide evidence that all coefficients in the model can be simultaneously equal to zero. The p-value is less than 5%.

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.00319	0.00106	10.83	<.0001
Error	68	0.00669	0.00009835		
Uncorrected Total	71	0.00988			

All the parameters of the model are significant at the 5% level . NHX Fund of funds index has significant positive exposure to all three factors to BOFA ML EMU Corporate and Pension funds bonds index, US Dollar Major Currency exchange index, to MSCI World index.

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
BOFA ML EMU CORP & PFN IDX_0002	1	0.1606	0.0377	4.26	<.0001
US $ MAJOR CURRENCY MAR 73=_0001	1	0.1350	0.0680	1.99	0.0511
MSCI world continuous returns	1	0.1226	0.0284	4.32	<.0001

As a next step, the model was checked for **autocorrelation, heteroscedasticity**, **normality** and none of the tests turned out positive.

The Ramseys Misspecification test was no different from the rest, as well as **The Chow Prediction failure** test. According to all routine tests the model is a good fit.

The statistical evaluation delivered the following:

RMSE = 0.0055

U= 0.46 (quite satisfactory value of the coefficient)

The **means and standard deviations** are:

	NHX Fund of Funds	clone
Mean		
Monthly	**0.0008**	**0.0018**
Yearly	**0.0100**	**0.0217**
Standard deviation		
Monthly	**0.0060**	**0.0058**
Yearly	**0.0211**	**0.0203**

The **Sharpe ratios** are**:**

	monthly	yearly
NHX Fund of Funds	-0.20	-0.70
clone	-0.04	-0.15
Risk-free (Euribor 3m)	0.002	0.0249

The clone outperforms the NHX Fund of Funds index (see Figure 23 in Appendices), even though the Sharpe ratio is negative. The **t statistic for the Sharpe ratio of NHX Fund of Funds index** is **-1.16** and the **t statistic for the Sharpe ratio of the clone** is **-0.255**, which is an evidence of the fact that Sharpe ratios are not significant at 5% level. Here the same argument can be used as for the clone of the NHX composite index - the Sharpe ratios have opposite dynamics under conditions of the bear market, i.e. when the negative excess hedge fund returns are prevailing in the market (see page 40). In this case the standard deviations of the clone and the index are nearly the same, those of the clone are slightly lower. The mean return of the clone is definitely higher than that of the hedge fund itself. If the same tendency persists in the future, under more favourable market conditions the clone is expected to considerably outperform the index. So the only issue is the statistical significance of the Sharpe ratios.

As a matter of fact, the fixed-weight clones show quite satisfactory results and outperform the relative hedge fund indices in Equity, Multistrategy and Managed Futures and CTA substrategies, the Fund of Funds clone's performance is quite in line with that of the relative hedge fund index. Regarding the statistical significance of the results, i.e the Sharpe ratios of the hedge fund indices and their clones, one must point at some problems encountered. Only Multistrategy clone's performance measured by Sharpe ratio was confirmed statistically significant at approximately 10% level.

The clones failed to outperform the NHX composite index and the NHX Fixed income index, but here one faces the same problem of the statistical inference – only the Sharpe ratios for the NHX Fixed Income both index itself and its clone are confirmed statistically significant at correspondingly 1% and 10% level. The result of the NHX composite clone is significant at 20% level, while the performance of the NHX composite index itself is not statistically significant at all.The Fixed income hedge fund strategy turns out to be the most profitable

during the period of the post-crisis recession of 2011-2013. This is plausible, since under the conditions of extreme uncertainty and undermined investor confidence fixed income instruments represent safe haven for investors. The overwhelmingly negative Sharpes of the hedge fund indices for the same period and of some of the clones can be explained by the same fact that the period of the analysis covers the deep financial crisis of 2008 and the subsequent recession, let alone the European peripheral debt crisis of 2011 which significantly increased equity and credit volatility in European markets.

6. Second part of the analysis.

6.1 Optimus long/short equity fund clone.

The main goal of the second part of the analysis is to compare two different approaches to hedge fund cloning, i.e. the fixed-weight clones – as in the first part of the analysis - and the rolling window clone approach to hedge fund replication. For this purpose the daily observations of the NAVs of the Swedish long/short equity fund Optimus were used and subsequently transformed into daily logarithmic returns. The daily observations were taken in order to increase the sample size to be able to apply more sophisticated statistic approach along with an attempt to reduce the problem of the statistical inference for the Sharpe ratio. In total the sample consists of 1596 daily observations. It is important to mention that there are certain limitations regarding the data for the second part of the analysis. Due to the non-sufficient variability among the daily NAVs of the hedge funds, it was not possible to make rolling window clones for all important hedge fund strategies. The rolling window analysis can only be performed on a relatively big sample of data and needs sufficient variability among the observations, in our case among the net asset daily values of a hedge fund.The only hedge fund, from the modest data sample obtained from Morningstar Denmark, which qualified for the analysis was the Swedish hedge fund Optimus pursuing long/short equity strategy. Consequently, this fund was chosen for the analysis.

The time –varying characteristics of the returns of the hedge fund are assumed to be captured better by a rolling window approach. The factor sensitivities are estimated continuously through a window of one year which slides down through the sample one observation at a time.Thus, the historical volatility of the returns is reproduced more closely. Afterwards, the estimates of factor sensitivities are averaged and used for the clone construction.

The daily logarthmic returns of the Swedish long/short equity fund Optimus are regressed on 4 equity/bond indices by rolling window approach within the in-sample period from the 7th of October 2007 until the 18th of october 2010. The width of the window is 262 days which corresponds to the number of work days in a year. The factors were chosen based on the previous knowledge about replication of the equity strategies of the hedge funds and on the investment strategy of the hedge fund itself.The model was estimated in SAS, after the best fitting factor variables were identified by the backward stepwise regression method in R. The regression is run in SAS according to the following formula:

$$\boldsymbol{Optimus\ equity\ fund\ return} =$$
$$= \boldsymbol{\beta 1} * \boldsymbol{OMX\ Stockholm\ Small\ Cap} + \boldsymbol{\beta 2} * \boldsymbol{JPM\ Sweden\ Govt\ bond} +$$
$$\boldsymbol{\beta 3} * \boldsymbol{first\ lag\ of\ Optimus\ return} + \boldsymbol{\beta 4} * \boldsymbol{S\&P\ Sweden\ SG} + \boldsymbol{ejk}$$

$\boldsymbol{\beta 1}, \boldsymbol{\beta 2}, \boldsymbol{\beta 3}, \boldsymbol{\beta 4}$ - *factor sensitivities*

Optimus hedge fund return- *Swedish hedge fund which follows long/short equity strategy investing mostly in Nordic Small Caps*

OMX Stockholm Small Cap – *OMX (Optionsmaeklarna and Helsinki Stock Exchange) Swedish Small Cap Equity index*

JPM Sweden Government bond- *JPMorgan Swedish Government bond index*

lag1 Optimus – *the first lag of the hedge fund Optimus returns*

S&P SwedenSG- *Standard and Poors Swedish Small Cap Growth equity index*

Ejk- *errors of the model*

The R-squared and R-adjusted of the model are correspondingly 30.13% and 29.78%, which means that only up to 30% of variance in the Optimus hedge fund returns are explained by the model.

Root MSE	0.00668	R-Square	0.3013
Dependent Mean	-0.00000300	Adj R-Sq	0.2978
Coeff Var	-222212		

The F-value of the model confirms the goodness-of-fit of the model. The probability that both beta coefficients can be simultaneously zero is highly insignificant:

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	4	0.01519	0.00380	85.17	<.0001
Error	790	0.03522	0.00004458		
Uncorrected Total	794	0.05041			

All the beta-coefficients of the model are significant at the 5% confidence level, showing significant positive exposure to JP Morgan Sweden Government bond index, Standard and Poor's Sweden Small Capitalization Growth Equity index, highly significant positive exposure to OMX Stockholm Small Capitalization Equity index. There is significant negative exposure to the first lag of the hedge fund Optimus return itself. The significant positive exposure to Small Cap equity indices is as expected - the fund's strategy is mainly oriented at investing in small capitalization, especially growth small capitalization companies, while going long in the small capitalization value equity is a common trait of equity replicators known from the previous academic research.The significant exposure of the Optimus returns to its own lagged values indicates the presence of the illiquidity risk of the hedge fund. This illiquidity risk is caused by the lagged pricing of the underlying securities.[24]The negative factor exposure means that in order to replicate the strategy one must go short in a particular security and the positive exposure - quite the opposite - go long in a particular security. Worth to remind the fact that the positions are assumed to be taken via derivatives, mainly futures, with only the amount of the margin deposit required in cash, that's why the sum of the weights is not restricted to be equal to 1.

[24]Lars Jaeger, Christina Wagner "Factor modelling and benchmarking of hedge funds:Can passive investments in hedge fund strategies deliver?", November 7, 2005

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
OMX STOCKHOLM SMALL CAP (SEK) -	1	0.1901	0.0446	4.26	<.0001
JPM SWEDEN GOVT. BOND IN SWED.KR	1	0.1517	0.0750	2.02	0.0436
LAG_Optimus	1	-0.1254	0.0298	-4.20	<.0001
S&P SWEDEN :S :G - TOT RETURN IN	1	0.1466	0.0293	5.00	<.0001

The routine robustness checks confirmed the goodness-of-fit of the model. The values of the usual statistical measures are satisfactory.

RMSE = 0.00607

U(Theil's inequality coefficient) = 0.5483

The model was subsequently used for the regression with the rolling window of one year (262 work days) in R for the period from the 1st October 2007 until 18th October 2010. The results are the following averaged beta coefficients:

means of the beta coefficients			
X1	X2	X3	X4
0.60772086	0.00055639	0.26985485	0.00037145

Afterwards, the fixed-weight and rolling –window clones were built for the out-of-sample period from the 18th of October 2010 until the 7th of November 2013. The results of both can be compared on a risk-adjusted basis to the return of the hedge fund Optimus itself:

MEANS	daily	annually
Optimus	0.0003	0.0793
Fixed clone	0.0001	0.0281
Rolling window	0.0009	0.2464

clone		
STANDARD DEVIATIONS		
Optimus	0.0080	0.1295
Fixed clone	0.0030	0.0492
Rolling window clone	0.0110	0.1792
RISK-FREE RATE	0.0000555	0.0145
SHARPE RATIOS		
Optimus	0.0309	0.5000
Fixed clone	0.0171	0.2770
Rolling window clone	0.0709	1.2937
T STAT		
Optimus	0.8745	
Fixed clone	0.4840	
Rolling window clone	2.2607	

Both clones performed quite well, the fixed-weight clone failed to outperform the equity fund Optimus, though the significance of the result is quite shaky - the **t-statistic** is only **0.48**, which is way far from the reliable 5 % confidence level.The result of the equity fund Optimus itself is not statistically significant either - the **t-statistic** is **0.8745**. The rolling window clone considerably outperformed both the fixed-weight clone and the equity fund itself and also showed statistically significant results at 5% confidence level - the **t-statistic** of the rolling-window clone is **2.2607** (see Figure 25 in Appendices).

The results achieved by the fixed-weight clone are quite satisfactory, especially if one takes into consideration the fact that the equity fund Optimus doesn't charge a sales and redemption fee at the moment, which are not deducted from the published hedge fund's NAV (net asset value). The maximum sales fee of 5% and the redemption fee of 1% are assumed

under the fund's policy, so in case the fees are reintroduced the fixed-weight clone's performance will look even more convincing.

The rolling –window clone in this case confirmed to be more suitable for the replication purposes due to its brilliant performance, mainly explained by its better variance-reproducing ability. One might note that rolling-window clone has a 3-5 percentage points higher standard deviation than the underlying fund, but the considerably higher mean return is a solid payoff for the additional risk. Quite the opposite are the statistics of the fixed-weight clone, here we observe considerably lower standard deviation than the underlying fund and slightly lower mean return. The issue of the statistical significance of the Sharpe ratio for the equity fund Optimus and for the fixed-weight clone persists even in this case, after the sample has been increased considerably (797 observations- an out-of-sample size). As mentioned earlier, one may explain it by the high sensitivity to the risk-free rate within the sample.

7. Conclusion.

The analysis of this thesis is inspired by the desire to achieve nearly the same return as the Nordic hedge funds avoiding the costly fees and some negative traits related to the limited liquidity of the investment in a hedge fund. The hedge fund replication is a relatively new topic of the academic research. Many different approaches were applied to constructing successful and less so hedge fund clones.The most recent methods are distinguished by their technical difficulty, the necessity of constant rebalancing, which sometimes undermines the benefits of the whole idea of hedge fund replication.That's why the focus in this thesis is on more "straightforward" approaches like the fixed-weight clone based on the multiple linear regression and the rolling-window clone based on the same linear regression, but implementing the rolling window technique.

The carried-out analysis has proved that it is possible to achieve the same or sometimes even higher return than a hedge fund. For many strategies the results were quite satisfactory. The fixed-weight clones outperformed the index in 4 out of 7 cases: in equity, managed futures and CTA, Fund-of –Funds and multistrategy. The main issue is the statistical significance of the results. Only the multistrategy clone's results are statistically significant at 10 %.

The fixed-weight clones underperformed the relative indices in composite and fixed income strategy, where the clones' performance was statistically significant at correspondingly 20% and 10% confidence level.

The best results were achieved in the case of Optimus long/short equity fund replication. Although the fixed-weight clone underperformed the index, its overall performance was quite satisfactory. The whole picture improves if one considers the possibility of reintroducing sales and redemption fees at maximum (according to the fund's policy they can be respectively 5% and 1%), in this case the fixed-weight clone might even deliver performance quite in line with the fund itself.

The clear winner of this replication analysis is the rolling-window clone. It outperformed by far both the fund Optimus and its fixed-weight clone.

The result is also statistically significant at 5 % confidence level. The main drive behind the superior performance is the better volatility reproducing properties of the rolling -window approach. Talking about the volatility one must warn that the volatility reproduced by both types of clones is still historical volatility. It is well known that there is no guarantee that the same volatility will persist in the future, even though in the short run it is the most likely outcome. There is always a global market risk component in this sense.

Is hedge fund replication worth doing? Can we really consistently outperform the hedge fund returns? The answer can be both yes and no. The most reasonable answer can be replicating the return as a supplement to the hedge fund investment. There still exists a strong evidence of the manager's alpha – the extra return which can't be achieved by the replication techniques. The clones will also most likely underperform under the conditions of prolonged downturn in equity markets due to their inferior flexibility in comparison to hedge funds. The replication indices adjust their weightings and systematic exposures more slowly than a typical hedge fund. [25]But all in all, under normalized market conditions they do bring considerable benefits to investors.

[25] "Attack of the hedge fund clones"Thomas Della Casa, Mark Rechsteiner, Ayako Lehmann, July 2008, Man Investments

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