NHH

Trading and Market Microstructure

FIN11

Implementing a pair trading strategy in the Norwegian seafood industry

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Introduction

In this paper, we will present and apply a statistical arbitrage strategy called pairs trading. This is a strategy that exploits relative mispricing between two assets. We find pairs trading interesting, because it is a method that reveals mispricing and explains how to take advantage of it.

We will back-test a pairs trading strategy on two Norwegian stocks from the Seafood industry, Lerøy Seafood Group and Marine Harvest Group. The main objective is to examine whether we can apply the strategy successfully on a suitable pair, and to determine the profitability of our pairs trading compared to the market.

The paper contains a theory section where we present the concept behind pairs trading, and discuss important factors that must be considered when conducting a pairs trade. Thereby we discuss our approach and results from the trading based on a data analysis. The paper will then discuss weaknesses with our model and analysis, and finally there will be a conclusion.

Arbitrageurs

Arbitrageurs are speculators that trade on relative prices (Harris, 2003). They buy assets that seem to be relatively undervalued, and sell assets that seem to be relatively overvalued. These traders estimate the normal relationship between correlated instruments, and trade when the prices diverge from the normal relationship. Traders then buy instruments that have become relatively cheap and sell the instruments that have become relatively expensive. If the prices converge, return to the normal relation, the strategy is profitable. (Harris, 2003).

Pair Trading

Pairs trading is a well-known and popular statistical arbitrage trading strategy which is market neutral. Statistical arbitrage is defined as "A profit situation arising from pricing inefficiencies between securities. Investors identify the arbitrage situation through mathematical modeling techniques" (Whistler, 2004). The strategy was developed in the 1980's by a group of mathematicians, computer scientists and physicists assembled by Morgan Stanley. The goal was to study arbitrage opportunities in the equities markets (Gatev, Rouwenhorst, & Goetzmann, 2006).

The concept of pairs trading is relatively simple and the profits are based on mean reversion. The strategy is to identify two stocks with historically correlated prices. When the prices diverge significantly from the historical relationship, buy the stock that has become relatively cheap, and sell the stock that has become relatively expensive. Profits will be generated if history repeats itself and the prices converge. (Gatev, Rouwenhorst, & Goetzmann, 2006). The strategy assumes that relative prices are in equilibrium and a divergence from the equilibrium is followed by a corrective convergence. Pairs trading is therefore a strategy that takes advantage of temporary mispricing.

Market neutrality

Market neutral strategies are neutral to market returns, meaning that the return from the strategy is uncorrelated with the market return (Vidyamurthy, 2004). The concept of market neutrality can be explained by the Capital Asset Pricing Model (CAPM). The CAPM is a model that explains the relationship between risk and expected market return. The return on an asset can be separated in a market or systematic component, and a residual or non-systematic component. The formula that shows the separation of the returns is referred to as the security market line (SML) and is given as (Vidyamurthy, 2004)

$$r_p = \beta r_m + \theta_p$$

In the equation r_p is the return on the asset or portfolio, r_m is the return on the market portfolio, and β is a measure of the assets volatility in comparison to the market. The market or systematic component of the return is described by the term βr_m in the equation. If the beta equals 1 and the market moves 3%, the market component of the return is 3%. In this case 3% of the return can be explained by the market.

The term θ_p in the equation is the residual or non-systematic component of the return. It measures the portion of the return that is not explained by the market. In CAPM θ_p is assumed to be equal to 0 and uncorrelated to the market. (Vidyamurthy, 2004)

Market neutral portfolios can be defined as portfolios with β=0. If β=0 is applied to the SML equation the market component of the return equals 0, and the return is only affected by θ_p. Therefore, market neutral portfolios expect a mean-reverting behavior, where the value of θ_p moves back and forth around the expected value of 0. (Vidyamurthy, 2004)

Pairs traders create market neutral portfolios by trading highly correlated assets and then taking a long position in one and a short position in the other. The result of this strategy is that the portfolio has a β approximately equal to 0, thus making the strategy market neutral. Regardless of whether the market goes up or down, market neutral strategies perform consistently and results can be achieved with less volatility. (Vidyamurthy, 2004)

Pair selection

Fundamentals

According to Whistler (2004) pair traders should have a basic understanding of a few fundamental aspects. Whistler argues that knowing a few fundamental concepts can save many mistakes. When pairs are carefully chosen within identical industries, and analyzed with respect to business models and cost and revenue structures, a hypothetical convergence will have a lot of substance (Reverre, 2001)

Correlation

Stocks that historically move together are said to be correlated. Stocks that have shown strong historical correlation are assumed to remain correlated in the future (Whistler, 2004). The correlation between the prices of two stocks can be found by calculating the correlation coefficient using the formula:

$$r_{p1p2} = \frac{\sum_{i=1}^{n}(p1_i - \overline{p1})(p2_i - \overline{p2})}{\sqrt{\sum_{i=1}^{n}(p1_i - \overline{p1})^2 \sum_{i=1}^{n}(p2_i - \overline{p2})^2}}$$

The correlation coefficient ranges from -1 to 1, and measures whether two variables tend to move together. If the correlation coefficient equals -1, there is perfect negative correlation between the two variables. In this case the prices of the stocks move in opposite directions. If the price of stock A goes up, the price of stock B goes down. If the correlation coefficient is equal to 1, there is perfect positive correlation between the two variables. In this scenario, the stocks will move in the same direction. If the correlation coefficient equals 0, there are no linear relationships between two variables, and the prices move randomly.

Pair traders look for pairs of stock with a high degree of correlation. This indicates that the prices tend to move together, and that a move in the spread is likely to correct itself (Whistler, 2004). If there is no correlation between a pair of stocks, the prices would move randomly. For these stocks, any change in the spread would be completely random and less meaningless. A central idea of pairs trading is that if two stock's prices are highly correlated, any future price changes may be followed by a reversion to the mean trend (Investopedia, 2016).

Distance method

The most commonly used method in previous literature and one of the simplest ways of choosing pairs, is the difference method proposed by Gatev et. al (1999). The difference method consists of normalizing the prices of stocks within an industry, and calculate the squared normalized price difference over a period, given by

$$D = \sum_{t=!}^{T} (P_t^A - P_t^B)^2$$

P_t^i is the normalized price of a stock and is calculated using

$$P_{it}^N = \frac{P_{it} - \mu_{(p)}}{\sigma_p}$$

The pairs with the lowest sum of squared normalized difference will be the pairs with the largest co-movement and thus have great potential for use in a pair trading strategy.

Trading strategy

Once one or more suitable pairs have been identified, the trader must choose a trading strategy. The trading strategy consists of trading rules and trading signals, that determine when the pair should be traded.

Normalized spread with moving average

Stephane Reverre (2001) suggests using a normalized spread with a 30-day moving average as indicator. The normalized spread becomes an indicator for "mispricing" expressed in terms of standard deviations.

$$\Delta_{norm} = \frac{\Delta - MA_{30}}{\sigma_{30}}$$

Where Δ_{norm} is the normalized spread, Δ is the spread, MA_{30} is the 30-day moving average of Δ, and σ_{30} is the 30-day standard deviation of Δ. The reason one should use a moving average is to eliminate extreme fluctuations. A 30-day moving average is preferred because it is short enough to react to the market and long enough to reduce noise. It should be noted that previous literature also contains 50-day moving averages, and 500-minute moving averages. (Reverre, 2001)

Trading signals

Trading signals define when a position should be taken. Pairs trading is based on trading two stocks with opposite positions when the spread has diverged significantly from some mean level. Thus, the trading signal must define what a significant divergence is.

The argument for using Δ_{norm} as indicator is, that it is assumed to be normally distributed with mean 0 and standard deviation 1 (Reverre, 2001). For a normally distributed variable 68.27% of the values lie within one standard deviation of the mean, 95.45% of the values lie within two standard deviations and 99.73% of the values lie within three standard deviations. Therefore, choosing a value for Δ_{norm} as trading signal is meaningful. Based on statistics it is possible to calculate that the chances of Δ_{norm} being larger than |1| is 31.73%, the chances of Δ_{norm} being larger than |2| is 4.55% and so forth.

Risks

Pairs trading is considered a low risk strategy because of the market neutrality. However, pairs trading is not a pure arbitrage strategy as there are certain risks associated with the strategy. According to Harris (2003) arbitrageurs face four types of risk.

Implementation risk is the risk of trading at unfavorable prices or the risk of not being able to trade at all. When using market orders, traders face execution price uncertainty, which can cause traders to trade at unfavorable prices. The prices may move against the traders before they submit the order. When traders use limit orders, they face execution risk. If the prices move before the order fills, they must resubmit and trade at unfavorable prices or cancel the arbitrage. Execution risk is especially dangerous when traders must take up positions in many stocks to successfully implement their strategy. (Harris, 2003)

Model risk, also referred to as analytic risk, which is a type of risk that occurs due to weaknesses of the trading strategy. This can happen as a result of misinterpretation, miscalculation or bad research. Model risk can be avoided by choosing trading strategy carefully. (Harris, 2003)

Basis risk is the risk that prices may move in opposite direction. Instead of converging back to the mean, the prices may diverge further. This will inflict losses on the traders, and if they cannot finance their losses, they may have to close their positions before they intended to.

Besides correctly understanding the arbitrage opportunity, there is not much traders can do to reduce the basis risk. (Harris, 2003)

Carrying cost risk is the risk that hedge portfolios will become more expensive to carry than expected. (Harris, 2003)

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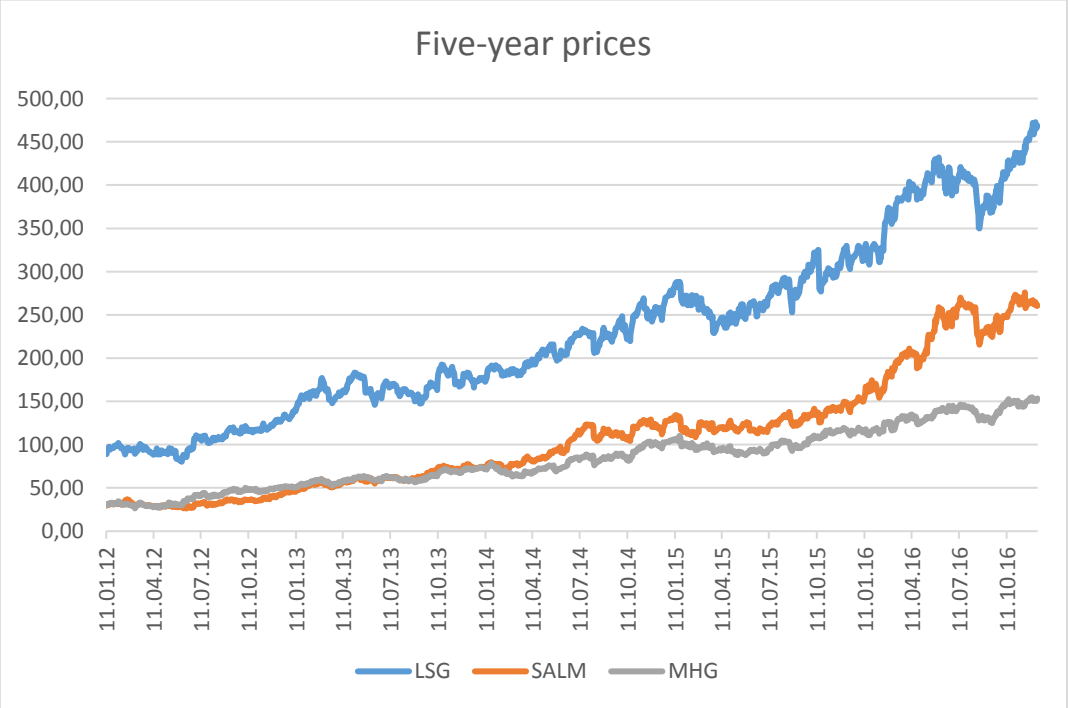
Data Analysis

Approach

Selection process

To back-test pairs trading we needed to find a suitable pair. As explained in the theory section we needed to find a pair with high correlation. Therefore, we looked at stocks within specific industries and decided to look for pairs within the Norwegian seafood industry.

There are many companies within the Norwegian seafood company, and we needed to screen out viable candidates. We decided to look at the correlation between Lerøy Seafood Group (LSG), SalMar (SALM) & Marine Harvest Group (MHG), as these are the major players within the industry. We obtained five-year historical data for the three stocks to determine if there was potential for pairs trading. Graph 1 shows the prices of all three stocks for the past five years.



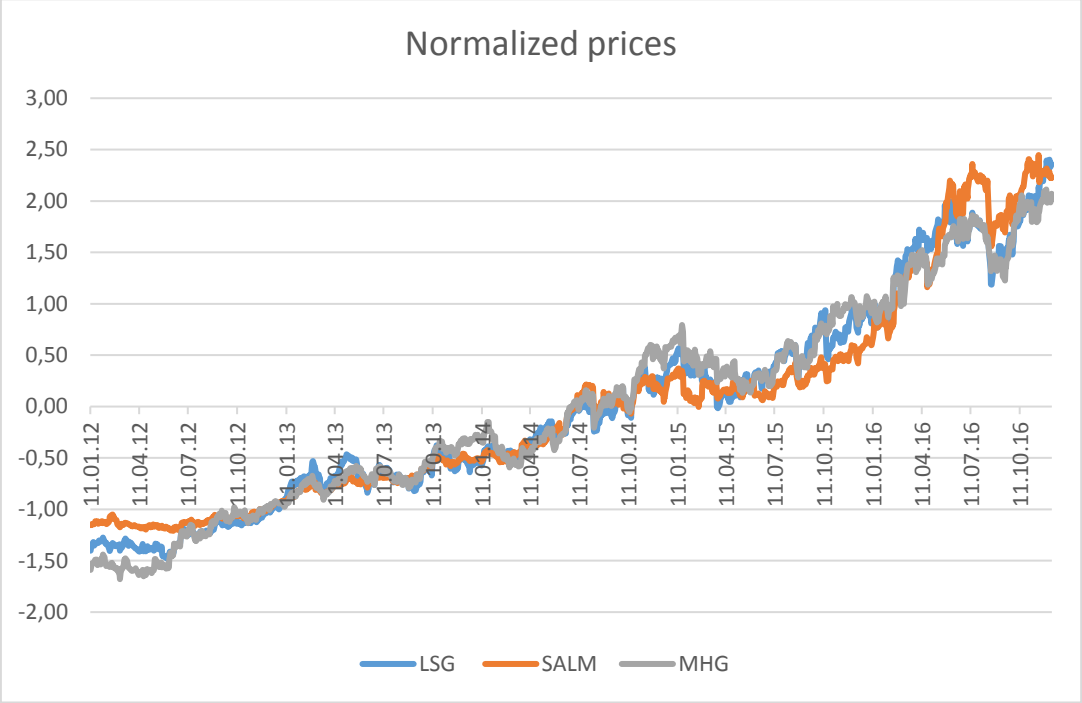
Graph 1: five-year historical data

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In order to draw conclusions about the relationship between the prices in graph 1 and calculate a meaningful correlation coefficient, we normalized the stock prices. This was done by using the formula

$$P_{it}^{N} = \frac{P_{it} - \mu_{(p)}}{\sigma_p}$$

Where P_{it}^{N} is the normalized price of stock i at time t, P_{it} is the price, $\mu_{(p)}$ is the average price and σ_p is the standard deviation of the price. Normalizing the prices allows us to bring the prices in proportion to each other and determine the relationship between them. The normalized prices of the stocks are shown in graph 2.



Graph 2: Normalized prices of LSG, SALM & MHG

Graph 2 shows that there clearly is strong historical correlation between the three stocks. Stocks with strong historical correlation are assumed to stay correlated in the future.

Based on the normalized prices, we calculated the correlation coefficients and the results are summarized in table 1.

	LSG	*SALM*	*MHG*
LSG	1		
SALM	0.982505713	1	
MHG	0.990158124	0.971153	1

Table 1: Test for correlation

Table 1 shows that there is strong correlation between all the pairs. The strongest correlation exists between LSG and MHG. The pair has a coefficient of 0.99, which implies that the prices of these stocks move almost perfectly together. The second highest correlation is between LSG and SALM. The coefficient of 0.98 implies a weaker relationship than the first, but still implies an almost perfect relationship. The correlation between SALM and MHG is the weakest, but is still implying a very strong relationship. With respect to correlation, the pair LSG and MHG is the most viable candidate for pairs trading. However, we decided to use the distance method to confirm if LSG and MHG is the best candidate

The results from the distance method are summarized in table 2. The table shows that LSG-MHG, is the pair with the lowest sum and thus the best candidate for pairs trading.

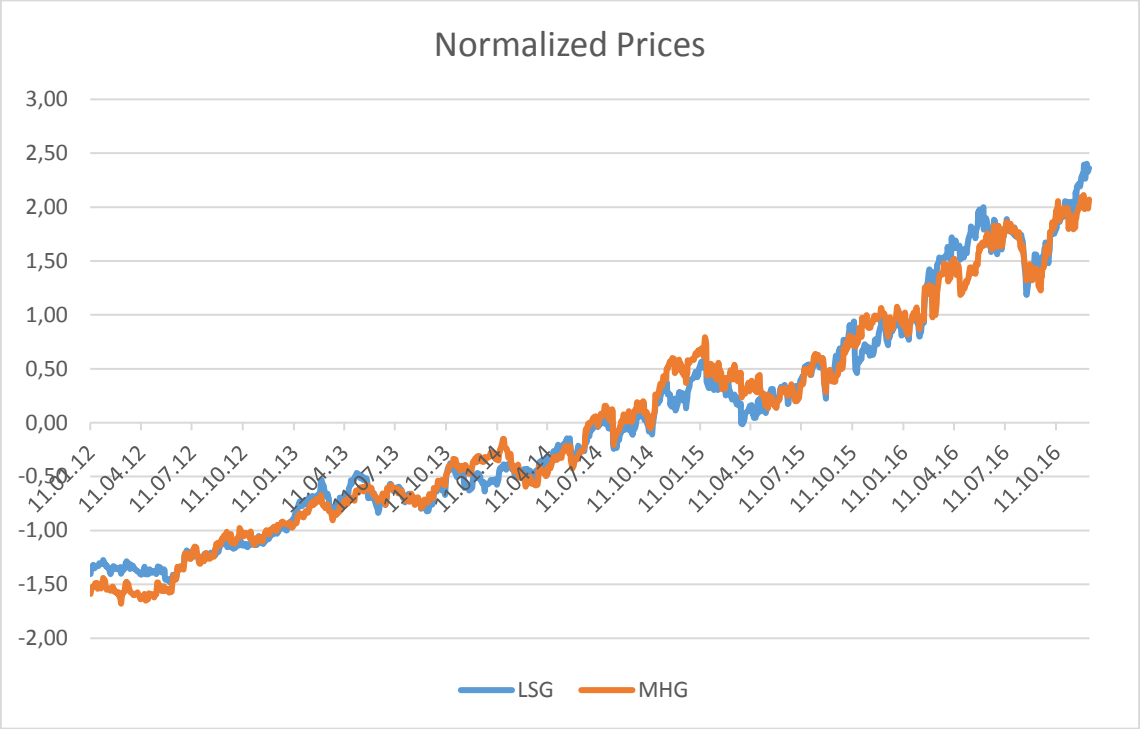
Ranking	**Pair**	**Sum of squared normalized difference**
1	LSG-MHG	24.25038243
2	LSG-SALM	43.10592267
3	SALM-MHG	71.08016096

Table 2: Results from distance method

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Trading opportunities

The normalized prices of LSG and MHG, and their movements over the past five years are shown in graph 3.

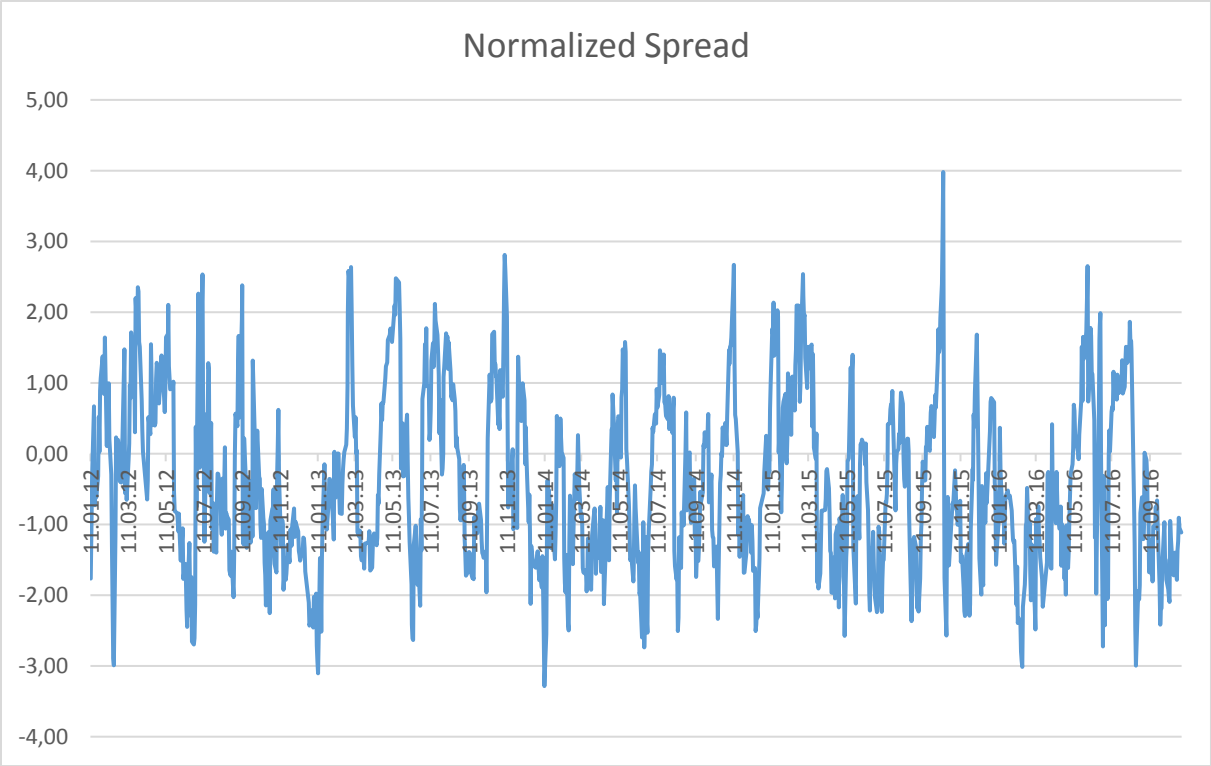


Graph 3: Normalized prices of LSG and MHG

The graph shows that the normalized prices are highly correlated and for the most part stay at the same level. However, there are certain times where the prices deviate, and we want to investigate whether we can find pair trading opportunities.

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Graph 4 shows the normalized spread between LSG and MHG calculated as P_{LSG}^{N}-P_{MHG}^{N} over the past five years. The normalized spread was calculated in accordance with Stephane Reverre's principal, and acts as an indicator for mispricing.



Graph 4: Normalized spread between LSG and MHG

As can be seen from the graph, the normalized spread is an oscillator and the value changes often. The spread fluctuates between positive and negative values around the mean value of 0. From statistics, we know that 68.27% of the values will be within one standard deviation of the mean, and that 95.45% of the values will be within two standard deviations. This means that observation that are larger than + 2 or – 2 can be classified as extreme, and the graph confirms that there are only a few times the normalized spread crosses these thresholds. Based on this we can conclude that there exists pair trading opportunities.

Trading setup

Whistler (2004) argues that the ideal trading signal for selling the pair is + 2 standard deviations, and the ideal value for buying the pair is – 2 standard deviations. Using |2| as trading signals means we are only looking at values that have 4.55% chance of beeing observed. The position is then closed whenever the spread is equal to its mean value of 0. The terms buying and selling the pairs are directly related to how the spread is calculated. In this instance the spread is calculated as P_{LSG}-P_{MHG}, the terms buy/sell are related to the first stock, which is LSG. Selling the pair then, translates to short LSG and long MHG, while buying the pair refers to taking a long position in LSG and shorting MHG. The trading signals in our strategy are summarized in table 3

	LSG	MHG
$\Delta_{norm} > 2$	Short	Long
$\Delta_{norm} < -2$	Long	Short
$2 > \Delta_{norm} < -2$	No Position	No Postion
$\Delta_{norm} = 0$	Close position (unwind)	Close position (unwind)

Table 3: Trading signals

Profit/Loss, trading costs and return

The main indicator for the performance of the strategy is P&L and return. P&L calculation is straightforward. We calculate the difference between the price paid and received when opening the position and the price paid and received when the position is closed. We calculate the nominal P&L for all trades and then sum each to get the total profit/loss.

We decided to use Nordnet as our brokerage, the firm operates with different fees and commissions depending on the size of the trades. Nordnet command a commission of NOK 250 if a short position is not closed within intraday (Nordnet, 2016). Additionally, short trading requires that 20-60% of the investment is deposited to the margin account. Furthermore, if each individual trade is worth less than NOK 52,667, the brokerage fee for each trade is 0.15%, with a minimum value of NOK 29 (Nordnet, 2016). Because we want to minimize the loss in case we lose everything, while at the same time minimize brokerage fee per NOK invested, we calculated the optimal investment as

$$Investment = \frac{29}{0.15\%} = 19333.33$$

Thus, each trade will be NOK 19,333.33 long and short. This sum fixes the brokerage fee at NOK 29 pr. individual trade, and assuming that all short positions are longer than 1 day, our fix cost for each roundtrip trade is NOK 366.

The return is calculated as

$$r = \frac{Realized\ P\&L}{Committed\ capital}$$

The realized P&L is calculated as the difference between nominal P&L and trading costs. Market neutral portfolios are often dollar neutral portfolios. Because the long position is almost fully financed by the proceeds from the short sale (Vidyamurthy, 2004). In our calculations, we will assume that the short position finances the long positions. Additionally, we assume that the margin account safety is 40% of the investment. The committed capital will therefore be NOK 27,066.62

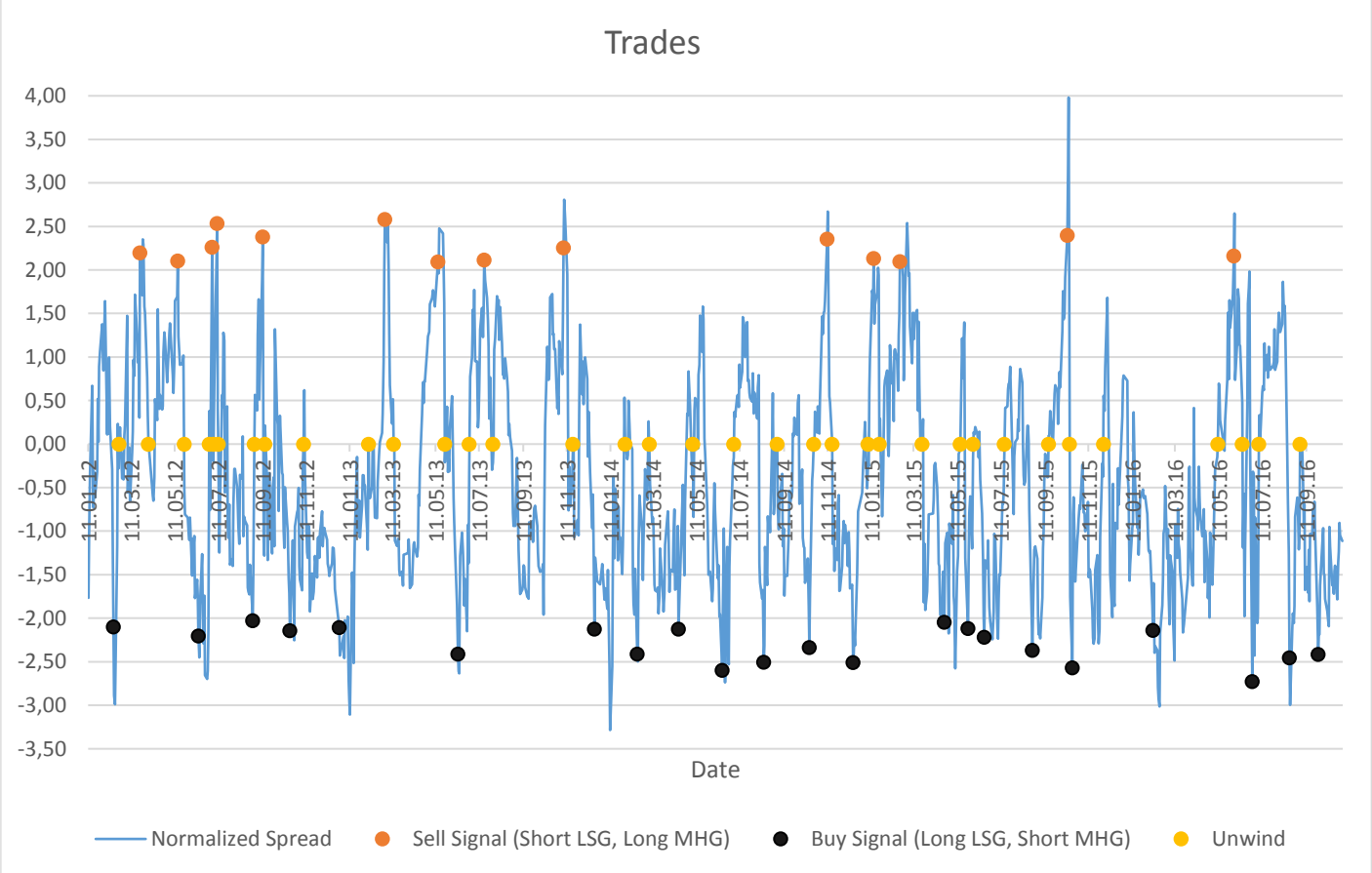
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Results

Overall results

Over the five-year period between January 2012 and December 2016, we made 36 trades in total. The realized profit was NOK 34,794.77, and the strategy yielded a net return of 128.55%.

All our trades and the spread at which the positions were opened and closed at, are summarized in graph 5. As can be seen from the graph, the positions were opened whenever the normalized spread was larger than 2 or less than -2, and closed whenever the spread returned to the mean value of 0. All trades are done according to the strategy explained in the approach section.



Graph 5: Normalized spread, trading signals and all trades from January 2012-December 2016

Graph 5 also shows that the spread generally stayed within +/- 2 standard deviations, and rarely diverged beyond that threshold. This suggest that the trading signals were successful at determining extreme divergence. We could obviously have chosen a lower value for the signal, which would have resulted in more trades, this would in turn affect our P&L. Had we chosen a higher signal we would probably made a larger profit per trade, but we believe the resulting low number of trades would offset the positive effect.

The last buy signal is not followed by a signal to unwind the position. The explanation is that with the data we have, the prices have not yet converged to zero. Since we did not want to have any open positions when the trading period ended, we closed the position at the prices offered at the closing of the last trading day.

Profit/Loss

Table 4 is a detailed summary of our trading, and shows each individual trade. The table shows when the positions were opened and closed, as well as highlighting which positions we took in the two stocks. We have also calculated the nominal P&L for each individual position and trade, as well as the cumulative P&L over the trading period.

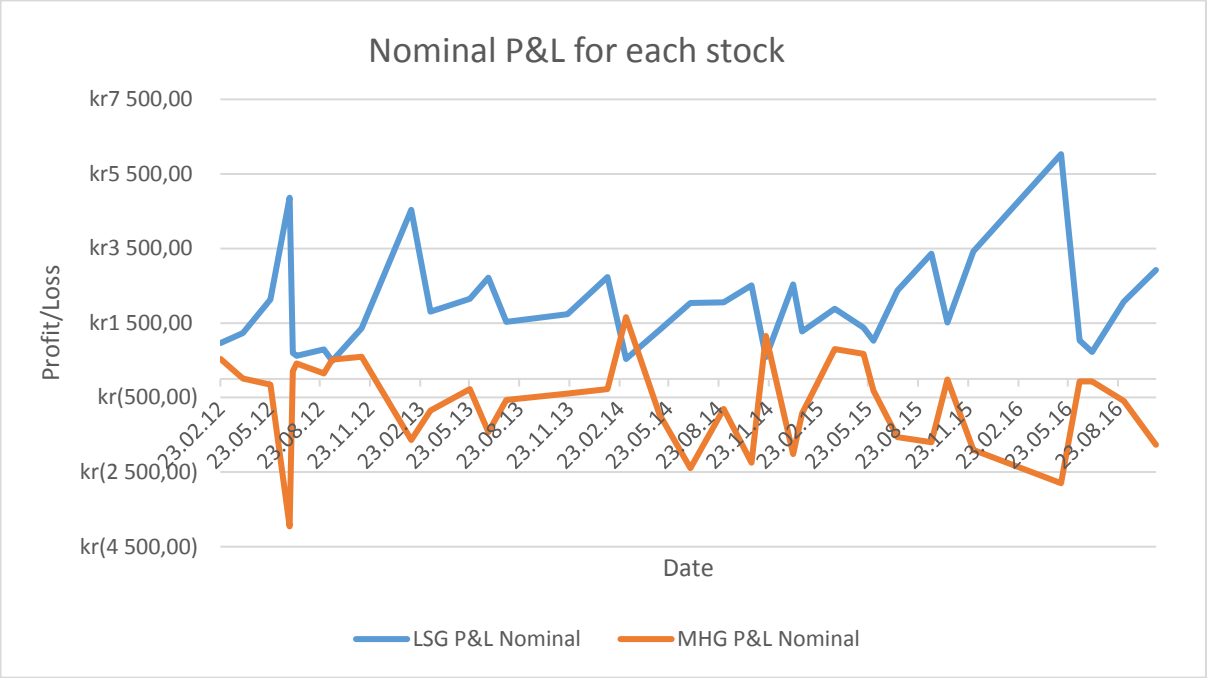
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Trade	Date	Positions		Price		Volume		P&L			Cumulative P&L
		LSG	MHG	LSG	MHG	LSG	MHG	LSG	MHG	Total	
1	15.02.12	Long	Short	90,50	31,00	213,62	623,66				
	23.02.12	Close	Close	95,00	30,14			kr 961,31	kr 536,34	kr 1 497,65	kr 1 497,65
2	23.03.12	Short	Long	98,00	29,90	197,28	646,60				
	04.04.12	Close	Close	91,75	29,92			kr 1 232,99	kr 12,93	kr 1 245,92	kr 2 743,58
3	15.05.12	Short	Long	95,25	31,06	202,97	622,45				
	24.05.12	Close	Close	84,75	30,82			kr 2 131,23	-kr 149,39	kr 1 981,84	kr 4 725,42
4	13.06.12	Long	Short	85,50	34,10	226,12	566,96				
	28.06.12	Close	Close	107,00	41,08			kr 4 861,60	-kr 3 957,38	kr 904,22	kr 5 629,64
5	02.07.12	Short	Long	111,00	41,70	174,17	463,63				
	04.07.12	Close	Close	107,00	42,14			kr 696,70	kr 204,00	kr 900,69	kr 6 530,33
6	09.07.12	Short	Long	109,50	40,40	176,56	478,55				
	11.07.12	Close	Close	106,00	41,26			kr 617,96	kr 411,55	kr 1 029,51	kr 7 559,85
7	28.08.12	Long	Short	109,50	44,94	176,56	430,20				
	30.08.12	Close	Close	114,00	44,60			kr 794,52	kr 146,27	kr 940,79	kr 8 500,64
8	11.09.12	Short	Long	120,00	46,80	161,11	413,11				
	14.09.12	Close	Close	117,00	48,06			kr 483,33	kr 520,51	kr 1 003,85	kr 9 504,48
9	19.10.12	Long	Short	114,00	47,80	169,59	404,46				
	07.11.12	Close	Close	122,00	46,32			kr 1 356,72	kr 598,61	kr 1 955,33	kr 11 459,81
10	27.12.12	Long	Short	130,00	51,30	148,72	376,87				
	06.02.13	Close	Close	160,50	55,65			kr 4 535,90	-kr 1 639,38	kr 2 896,52	kr 14 356,33
11	01.03.13	Short	Long	177,00	59,40	109,23	325,48				
	13.03.13	Close	Close	160,50	56,80			kr 1 802,26	-kr 846,24	kr 956,02	kr 15 312,35
12	14.05.13	Short	Long	180,00	63,00	107,41	306,88				
	24.05.13	Close	Close	160,00	62,10			kr 2 148,15	-kr 276,19	kr 1 871,96	kr 17 184,31
13	11.06.13	Long	Short	146,00	58,40	132,42	331,05				
	27.06.13	Close	Close	166,50	62,70			kr 2 714,61	-kr 1 423,52	kr 1 291,10	kr 18 475,40
14	18.07.13	Short	Long	170,50	61,50	113,39	314,36				
	30.07.13	Close	Close	157,00	59,70			kr 1 530,79	-kr 565,85	kr 964,94	kr 19 440,34
15	06.11.13	Short	Long	189,00	69,55	102,29	277,98				
	19.11.13	Close	Close	172,00	68,15			kr 1 738,98	-kr 389,17	kr 1 349,81	kr 20 790,15
16	19.12.13	Long	Short	166,00	71,15	116,47	271,73				
	31.01.14	Close	Close	189,50	72,15			kr 2 736,95	-kr 271,73	kr 2 465,22	kr 23 255,37
17	17.02.14	Long	Short	181,00	70,00	106,81	276,19				
	06.03.14	Close	Close	186,00	64,00			kr 534,07	kr 1 657,14	kr 2 191,21	kr 25 446,58
18	16.04.14	Long	Short	192,50	68,80	100,43	281,01				
	06.05.14	Close	Close	205,50	72,15			kr 1 305,63	-kr 941,38	kr 364,25	kr 25 810,84
19	16.06.14	Long	Short	204,00	75,40	94,77	256,41				
	02.07.14	Close	Close	225,50	84,75			kr 2 037,58	-kr 2 397,44	-kr 359,85	kr 25 450,98
20	13.08.14	Long	Short	207,00	80,30	93,40	240,76				
	01.09.14	Close	Close	229,00	83,65			kr 2 054,75	-kr 806,56	kr 1 248,19	kr 26 699,17
21	16.10.14	Long	Short	219,50	82,50	88,08	234,34				
	22.10.14	Close	Close	248,00	92,10			kr 2 510,25	-kr 2 249,70	kr 260,55	kr 26 959,73
22	10.11.14	Short	Long	265,00	96,75	72,96	199,83				
	17.11.14	Close	Close	257,00	102,50			kr 583,65	kr 1 149,01	kr 1 732,66	kr 28 692,38
23	16.12.14	Long	Short	244,00	95,70	79,23	202,02				
	06.01.15	Close	Close	276,00	105,70			kr 2 535,52	-kr 2 020,20	kr 515,32	kr 29 207,70
24	14.01.15	Short	Long	288,00	106,10	67,13	182,22				
	22.01.15	Close	Close	269,00	101,00			kr 1 275,46	-kr 929,31	kr 346,15	kr 29 553,85
25	20.02.15	Short	Long	272,00	94,20	71,08	205,24				
	23.03.15	Close	Close	245,50	98,10			kr 1 883,58	kr 800,42	kr 2 684,00	kr 32 237,85
26	23.04.15	Long	Short	239,00	93,95	80,89	205,78				
	15.05.15	Close	Close	256,00	90,70			kr 1 375,17	kr 668,80	kr 2 043,97	kr 34 281,82
27	26.05.15	Long	Short	245,00	89,25	78,91	216,62				
	02.06.15	Close	Close	258,00	90,70			kr 1 025,85	-kr 314,10	kr 711,75	kr 34 993,58
28	18.06.15	Long	Short	248,50	92,10	77,80	209,92				
	16.07.15	Close	Close	279,00	99,55			kr 2 372,90	-kr 1 563,88	kr 809,02	kr 35 802,60
29	24.08.15	Long	Short	253,00	92,75	76,42	208,45				
	16.09.15	Close	Close	297,00	100,90			kr 3 362,32	-kr 1 698,83	kr 1 663,49	kr 37 466,09
30	12.10.15	Short	Long	320,00	108,80	60,42	177,70				
	15.10.15	Close	Close	295,00	108,70			kr 1 510,42	-kr 17,77	kr 1 492,65	kr 38 958,73
31	19.10.15	Long	Short	277,00	108,50	69,80	178,19				
	02.12.15	Close	Close	326,00	119,20			kr 3 419,98	-kr 1 906,60	kr 1 513,37	kr 40 472,10
32	09.02.16	Long	Short	311,00	114,10	62,17	169,44				
	10.05.16	Close	Close	408,00	130,60			kr 6 030,01	-kr 2 795,79	kr 3 234,22	kr 43 706,32
33	01.06.16	Short	Long	430,00	139,80	44,96	138,29				
	13.06.16	Close	Close	407,00	139,30			kr 1 034,11	-kr 69,15	kr 964,96	kr 44 671,28
34	27.06.16	Long	Short	388,00	138,40	49,83	139,69				
	06.07.16	Close	Close	402,60	138,90			kr 727,49	-kr 69,85	kr 657,65	kr 45 328,93
35	18.08.16	Long	Short	350,40	127,80	55,18	151,28				
	02.09.16	Close	Close	388,00	131,70			kr 2 074,58	-kr 589,98	kr 1 484,60	kr 46 813,52
36	27.09.16	Long	Short	379,50	136,20	50,94	128,97				
	31.10.16	Close	Close	436,90	149,90			kr 2 924,20	-kr 1 766,96	kr 1 157,24	kr 47 970,77

Table 4: Overview of all trades, including prices, volume, p&l and cumulative p&l

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We decided to split the P&L that was generated from each stock. P&L from the positions in MHG and LSG occur both from long and short positions. As can be seen from graph 7, all our positions in LSG resulted in a profit, while most of the positions in MHG resulted in a loss.

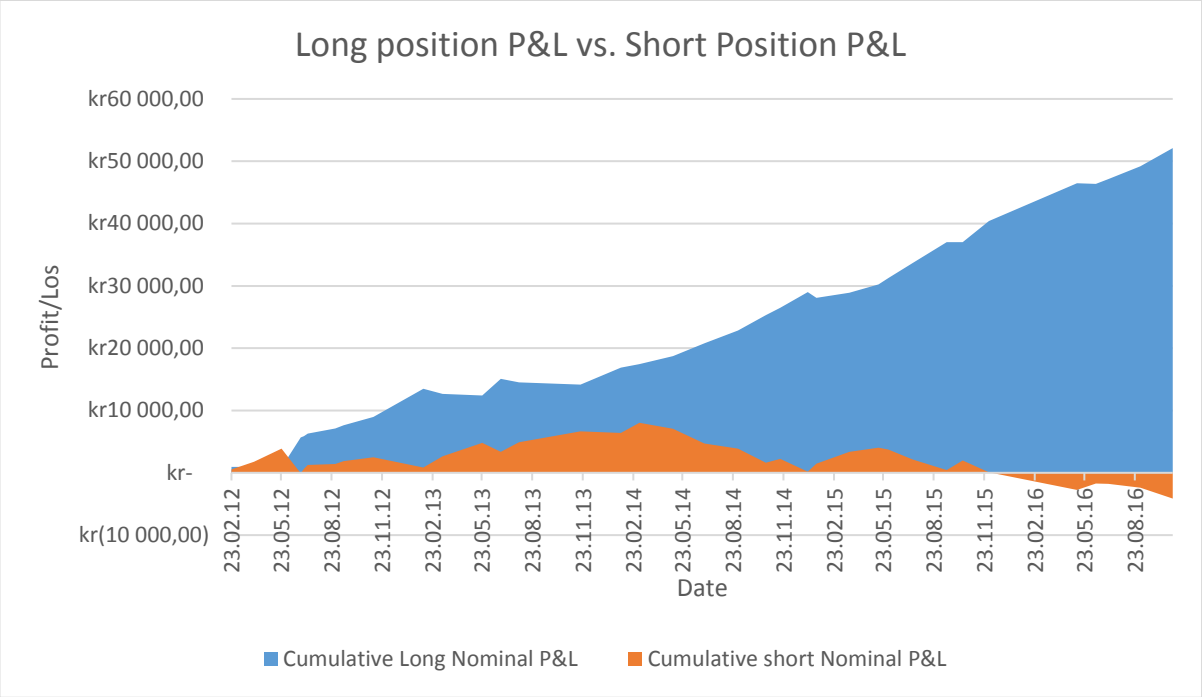


Graph 6; Profit/Loss generated by each stock

This suggests that LSG moves in accordance with our assumptions, while 25 out of 36 times the price of MHG moves against our assumptions. The fact that we had 22 successful long positions in LSG suggest that the strategy considers LSG to be undervalued relative to MHG in 61.1% of our positions. This undervaluation can be explained by three different scenarios. If the price of LSG does not move, and the price of MHG rises, LSG is considered undervalued. If the price of LSG drops, while the price of MHG does not move, LSG is considered undervalued. If the price of LSG drops and the price of MHG rises, LSG is considered undervalued. Based on our computer skills and knowledge we are not able to determine what causes the undervaluation of LSG.

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Out of all our trades, only 12 resulted in a positive return from both positions. This means that only 33.33% of our trades were such that the actual price developments for both stocks were consistent with our expectations.

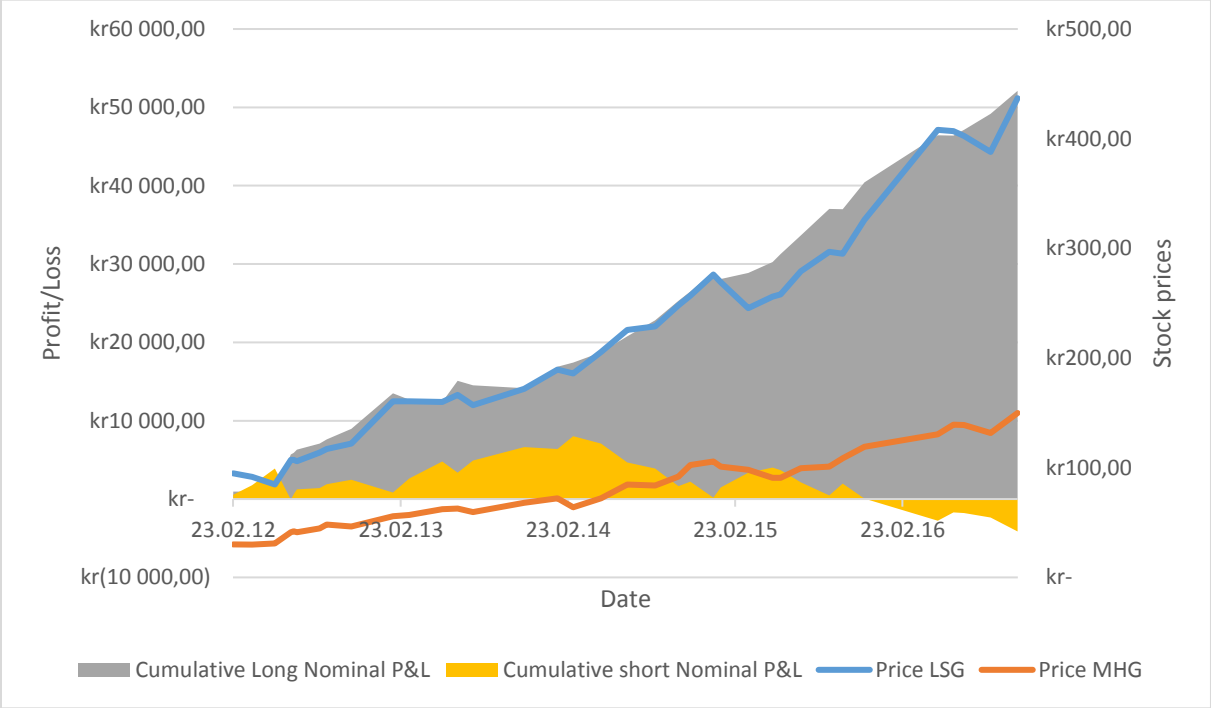


Graph 7: Cumulative profit from long and short positions

As can be seen from graph 7, the short positions generated a relatively small profit for a long period, but in the end, they incurred a loss. This suggests that most of the profit was not generated due to mean reversion. We believe the reason most of our profit is generated by long positions, and the losses are incurred by short position, is that prices exhibit a positive trend over most of the trading period.

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Graph 8 shows that there seem to be some correlation between price drops and short position P&L. However, the correlation between long position profits and rising market prices is clearer. It would therefore be interesting to see in which degree our pair was market neutral.

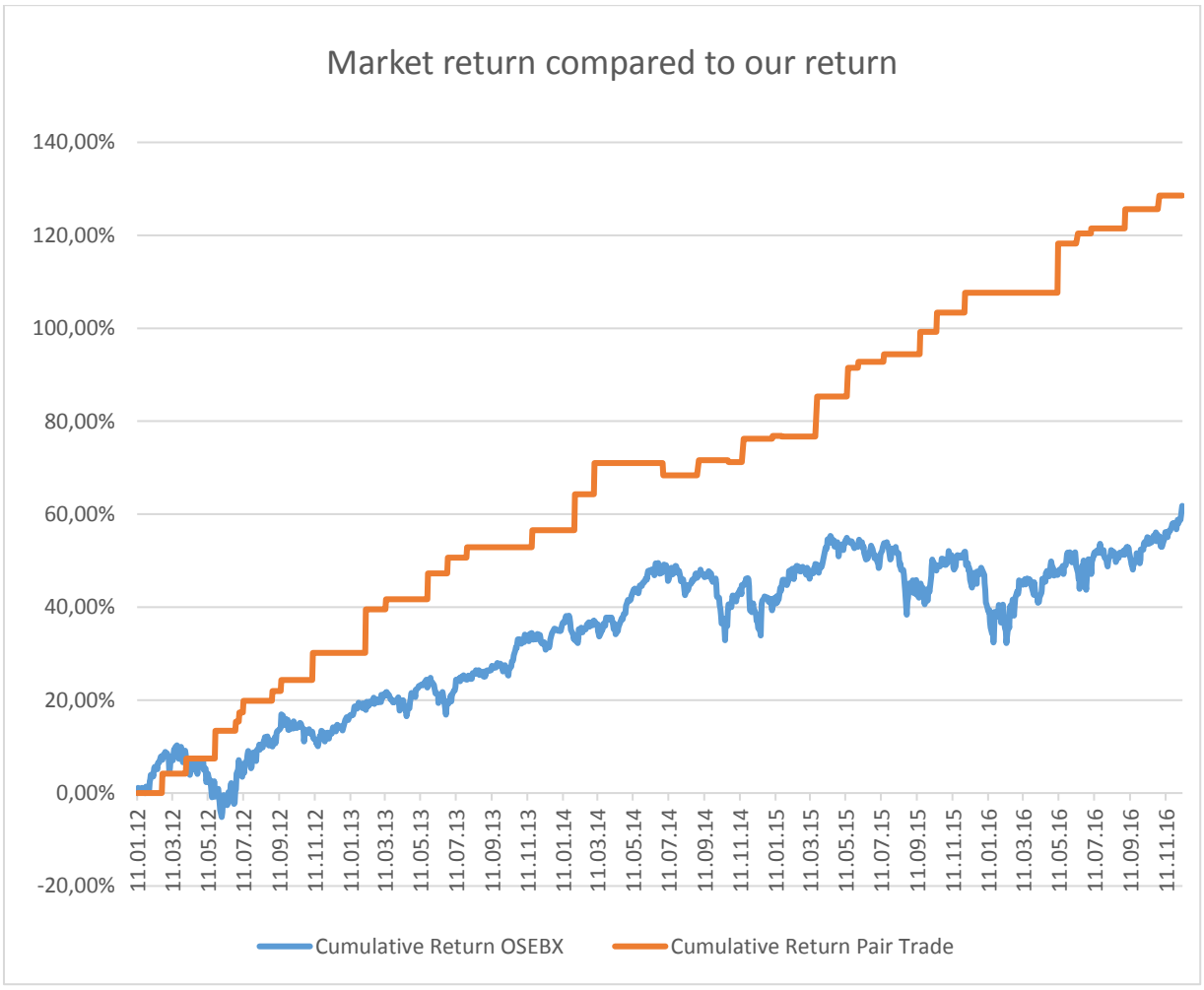


Graph 8: Cumulative profits from long and short position compared to market prices

As explained in the theory section, a market neutral portfolio has beta equal to 0. The estimated five-year betas based on our data are 0.68 for LSG and 0.87 MHG (when computing the beta values we used OSEBX as an indicator for the market). We are a bit puzzled by the fact that the difference between the betas is this large considering the high correlation. This would mean that if we invested the same amount in a long and a short position, and let our chosen position be untouched for five years, our pair trade would have a of beta +/- 0.19, depending on which stock we shorted and longed. A long position in MHG and short position in LSG would have a beta equal to 0.19. Trades with the opposite positions would have a beta equal to -0.19. This could incur that the return on our trades are somewhat correlated to the market. However, each stock's beta will differ over time, and it is difficult to estimate the exact beta value of our 36 positions, which would be necessary to determine how market neutral our positions were.

Comparison to market return

Graph 9 shows a comparison between the cumulative return of OSEBX compared to our cumulative return. Over the five-year period, OSEBX yielded a return of 61.79% while our pair trading strategy yielded 128.55%. If we had invested NOK 27,066.66, the capital committed in our pairs trading, in OSEBX in january 2012, our profit would have been NOK 16,724.49. Which means that our pair trading beat the market with NOK 18,070.28 over the five-year period. Graph 9 also shows that our return is trending upwards, regardless of which direction the market moves.



Graph 9: Comparison between cumulative market return and cumulative pair trading return

It is clear that the pair trading strategy is outperforming the market at this point. However, it would be interesting to examine the risk associated with OSEBX and our pair. The five-year standard deviation of the return is 6.48% for OSEBX and 7.24% for our pair. Suggesting that the pair trading strategy is riskier than investing in the index. However, we calculated the Sharpe ratio for both the market return and pair trading return. Sharpe ratio is the average return in excess of the risk-free rate per unit risk (Investopedia, 2016). We used the coupon rate paid by a five-year Norwegian government bond in 2012, which was 1.59%, as risk free return. The Sharpe ratio for the market return is 1.54 and 4.67 for pair trading. This suggest that the even though pair trading is riskier, the excess return per unit risk is considerably larger for our pair trade than for OSEBX.

Weaknesses of the strategy/model

Even though the risk calculation seems very positive, we believe they are misleading in some manners as they exclude some important risk factors. Pairs trading is extremely susceptible to execution risk. In our model, every trade is executed at closing prices. In reality, these prices are probably not obtainable. Additionally, each pair trade is done by simultaneously executing two orders, with opposite positions, that are equal in size. The probability for price movement before both positions are established is high, and therefore there is a big chance of obtaining less favorable prices than expected. Our model simulates a marked where there is only one price per day, and whenever there is a trading signal we are guaranteed execution at this price. We are therefore not affected by the continuous and unpredictable price movements. This simplification by eliminating the execution risk is probably a factor in our overall performance. However, the prices we trade at are static and the trades are not always executed at the exact signal, which means that the execution price risk is to some degree included.

Even though our strategy is based on well-documented theory and is chosen after conducting extensive research, we are exposed to model risk. Our calculations are based on our knowledge and understanding of the available data. The calculations, results, and interpretations are limited to our skills and inexperience. There is also possible that we have miscalculated and misinterpreted when processing the data. Our strategy is also considered to be one of the simplest pair trading strategies. We chose our strategy based on our ability to successfully implement it. A more advanced model may have resulted in more accurate calculations and given a more detailed picture.

Our model is also excluding carrying cost risk. Our model assumes that we can finance our short positions indefinitely. There are no situations where our short position becomes more expensive than our presupposed estimate. In periods with unfavorable price movements, it would probably be reasonable to have a stop-loss function in our model. We are calmly waiting for convergence, and pay little attention to the increased carrying cost of an unexpected long holding period.

In the comparison of profit from our pair trade and the OSEBX index, we have not included the extra effort and time it would take for us to manage our pair trade compared to the OSEBX. We are trading manually and we spend a lot of time and effort on monitoring the spread. Therefore, our opportunity cost is high. For non-professional traders, the opportunity cost may outweigh the gains from managing a pair trade. However, professional pair traders are using effective and advanced computer technology and algorithms.

The research behind our pair selection could have been more extensive. We have paid little attention to fundamental analysis of the two companies. We could have looked at the cost structure, capital structure, growth ratios, price earnings ratios and so forth. This could be important in estimating how the two companies stock prices would react to changes in exogenous variables.

Conclusion

In this paper, we have managed to back-test a pairs trading strategy by successfully implementing it on Lerøy Seafood Group and Marine Harvest Group, between 2012 and 2016. We consider this strategy to be one of the simplest, but this was the strategy we thought we had the best chance of implementing successfully. Even though the strategy is considered simple, it is based on concepts presented in recognized literature. A more advanced model could however have resulted in more accurate calculations and given a more detailed picture.

Our results suggest that it is possible to generate profits by conducting pairs trading. The chosen pair and strategy yields a profit that is more than twice as large as OSEBX over the five-year period. The Sharpe ratio for our pair is also considerably higher than for OSEBX. The result seems overwhelming and too good to be true. Which is probably right. The fact that we are back-testing and have chosen a simple strategy, makes our results and analysis vulnerable to weaknesses. Because we are back-testing the strategy and not implementing it in real time, some important risk factors are omitted. Which most likely makes the return and Sharpe ratio overly optimistic.

Even though our pair trading turned out to be profitable, it is difficult to draw a conclusion whether this is an effective strategy, based on trading one pair. Our cumulative long profit is much larger than our cumulative short profit, which indicates that the rising trends for both stocks have played a significant factor in the generated profit. The profit is obviously affected by this, and may suggest that we were quite lucky with our pair selection. Had we simply longed both stocks at the beginning of the trading period, with the same amount invested as in our pair trade, we would have achieved a profit equaling NOK 114,692, and a return of 423.74%. Which suggests that a simple passive strategy can be more profitable. However, the risk is considerably larger, and these price developments are impossible to predict.

In this paper, we have given a brief presentation of pairs trading, its implementation and discussed some of the problems related to our chosen strategy. We would like to point out that there are many aspects of pairs trading that have not been touched upon in this paper, but most of these are, at this point, beyond our knowledge, skills and experience.

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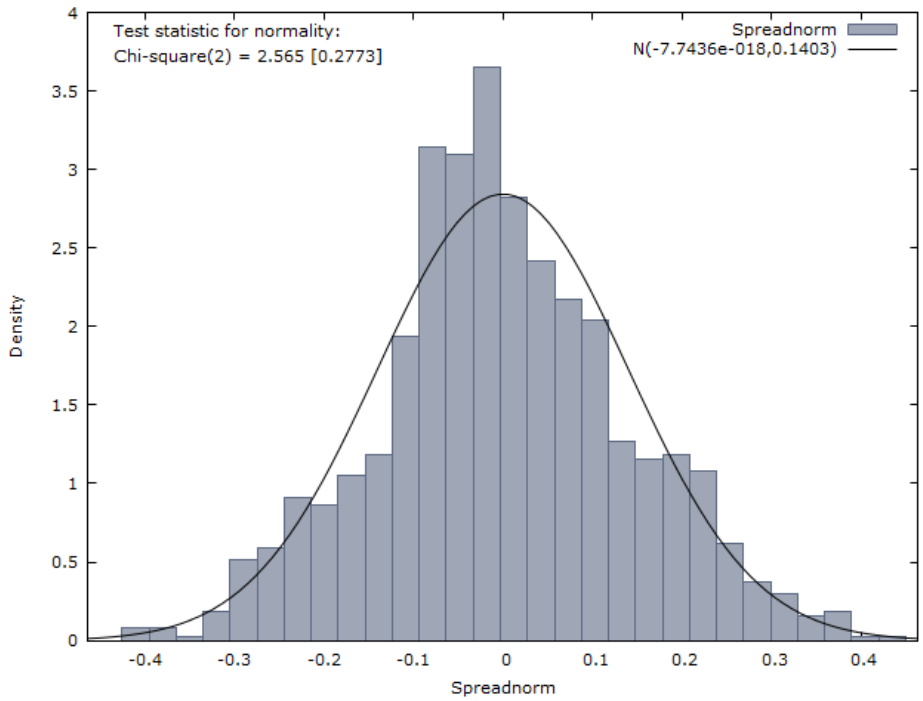
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Appendix

Test for normality of normalized spread:



Test for normality of return:

