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How can we adapt long-short strategies to long-only strategies?

The Momentum

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Abstract

The aim of this research paper is to test the replicability of the momentum strategy for a long-only investor. After reviewing the academic literature on the momentum effect and its rationale, we will detail our methodology to build portfolios with long-only and long-short momentum strategies on the CAC 40 and the S&P 500. The main contribution of this research paper is to figure out if a long-only investor can obtain the same performances as a less-constrained investor.

Introduction

We will focus on only one defined trading strategy: the momentum which consists in buying the “winners” over the last 12 months and shorting the losers. The main focus of this research paper is to test the ability for a constrained investor (let’s say a mutual fund with no access to leverage and to short-selling) to replicate the momentum strategy. We will compare the risk-adjusted performance and the absolute performance of the two strategies (long-short versus long-only strategy). We will look carefully at the behaviour of the long-only portfolio during a market crash and more generally we will look at the main indicators for risks (maximum drawdown, volatility, Sharpe ratio, skewness, and kurtosis).

First I will present a review of the academic literature for the momentum strategy. Then, the major part of the research paper will be composed of several portfolio constructions with review of the performances. To do so, we have downloaded and sort stock prices data on a monthly basis for the CAC 40 and the S&P 500 over a long-period of time (15 and 20 years respectively). We will explain in details the challenges that should be overcome to build the momentum strategies and we will try to figure out the potential advantages and drawbacks of the long-only strategy. Instead of adopting a binary vision (long-only investor versus long-short investor) we will also try to test long-short strategies with different market exposure. To conclude we will also present the limitations of our portfolio constructions such as the absence of transaction costs or short-sales constraints.

I) The momentum strategy: definition, rational, methodology and performance according to the literature

A) Definition and rational of the momentum strategy

The momentum strategy consists in buying stocks that have outperformed recently (“winners”) and shorting stocks that have underperformed. Usually practitioners and academics consider the performance over the past 12 months to sort the stocks between winners and losers. By definition, the momentum is a trend-following strategy and the underlying assumption is that a stock that have overperformed or outperformed the last 12 months will tend to follow the same trend the following month. While historically, the momentum strategy has been implemented for single stocks, many studies have also proven a momentum effect for other financial assets (bonds, indices, commodities, forex) across the world. In this research paper, we will only discuss and implement the momentum strategy for single stocks including in major European and American indices. However, it is worthy to note that our different strategies can be tested and implemented with the same methodology for different asset classes.

If the mechanism of this trend-following strategy is very easy to understand, it is much harder to explain its rational. First, we can stress that this trend-following strategy is in contradiction with the weak form of the Efficient Market Hypothesis stipulating that one cannot predict future stock returns from past returns. Indeed, according to Eugene Fama (1970) the current stock prices should reflect all the available information. Thus, in the context of Efficient Market Hypothesis the momentum strategy lacks from theoretical ground. To a certain extent, the momentum strategy seems similar to a chart analysis based on Wall Street maxims such as “The trend is your friend”, “Don’t fight the tape”. The momentum strategy is also counter-intuitive for value investors like Graham and Buffet who do not believe in market efficiency. For them, there are persistent discrepancies between the market prices and the intrinsic value of the companies which correspond to the “true” value of the stocks. As the momentum strategy only looks at price changes over the past 12 months, this strategy makes no sense since it does not take into account the fundamental data of the companies.

So how can we explain the rational of the momentum strategy? In *Efficiently Inefficient*, 2015, Pedersen has shown the theoretical difficulty to explain the performance of the momentum strategy using a risk premium. The momentum is a very active strategy with a high turnover since we rebalance frequently our portfolio depending on the relative prices changes over the past 12 months. As a result, if we explain the momentum for a single stock with a rational risk premium this premium will significantly vary over a short period of time. On a theoretical standpoint, it is hard to figure out why the stock’s risk should be so volatile. Pedersen suggests another explanation for momentum linked to markets inefficiency: in general investors initially underreact after good news and then overreact which creates the momentum. To explain this idea that can be counterintuitive, let’s take the case of a company that just released its annual results and suppose they are above the market expectations. Initially the momentum is produced when there is an underreaction of the

market after this good news: the price increase but it should continue to go up in the future to price correctly this information. Then, if prices are going up for several months, opportunistic investors will look at the company and start buying the stock: this delayed overreaction will add to the momentum.

Another explanation for momentum is given by behavioural finance. Even if they do not mention specifically the momentum, Shefrin and Statman demonstrate some psychological biases in “The Disposition to Sell Winners Too Early and Ride Losers Too Long: Theory and Evidence” (1985). One part of their findings deals with aversion to loss realization, a psychological bias that has been highlighted before by Kahneman and Tversky. Shefrin and Statman find empirical and theoretical evidence to illustrate that more generally, investors tend to realise their profits as soon as possible by selling the stocks that go up in order to realise a profit. However, investors stick to losers: even if the prices go down in general there is a strong psychological bias to hold the stocks hoping for a mean-reversion. Their finding could be a good behavioural explanation for the momentum. For instance, if a company delivers annual results higher than expected, the price will go up immediately but there is an underreaction due to an important selling pressure from investors willing to realise their gains. This is a well-known trend in financial markets and this psychological bias is usually referred as “profit taking”.

However, we should stress that there is no single and valid explanation for the momentum strategy. Its abnormal positive risk-adjusted return is still a puzzle since it persists over time while being one the most known price anomaly effect. As we will see in the next paragraph, the high exposure of the momentum strategy to market crash can be an explanation for the persistence of this anomaly: while on average it generates high-excess return, it has a very negative skewness.

B) Performance and robustness of this trading strategy

As the momentum strategy is a quantitative strategy based only on the relative stock prices returns over the past 12 months, this is a strategy easy to replicate and many academic studies point out its performance. Despite its relative simplicity, Barroso and Santa-Clara (2015) find that the momentum strategy offers the highest Sharpe ratio compared to the other factors of the Fama-French model (value, market, size). They use monthly returns over a very-long time period from July 1926 to December 2011 using the Kenneth French data library. For the construction of the momentum portfolios, stocks are ranked and sorted into deciles in function of their return from month $m-12$ to $m-2$. By convention, in the academic literature the past month $m-1$ is excluded to classify the stock performance. Indeed it could be a way to avoid mean-reversion for stock returns that can occur in the last month $m-1$. The Winner-Minus-Loser strategy is constructed by taking a long position in the highest decile corresponding to winner stocks and a short position in the lowest decile corresponding to “losers” stocks.

As we can see in the below table, according to the study of Barroso and Santa-Clara (2015), with a Sharpe ratio of 0.53, the momentum exceeds by far the other strategies based on the 3 Fama-French factors (market for RMRF, size for SMB and value for HML). Should we

deduce that the momentum is the best trading strategy? This is also the most volatile strategy with a standard deviation of 27.53% and a very high negative skewness of -2.47. The momentum strategy is also subject to the worst drawdown among the difference factors. Indeed by construction the momentum strategy is trend-following so it is more exposed to market crashes. The rationale is quite intuitive: on one side we are long the stocks that have outperformed the most over the last rolling 12 months. We can stipulate that the markets have high expectations for the performance of those stocks and they are more likely to go down significantly during a market crash. On the other side, we are short the stocks that have outperformed significantly over the past 12 months and if there is a significant reversal and rebound in stock markets, we will also lose on the short leg of our portfolio.

Findings of Barroso and Santa-Clara. Long-term performance for the different factors with sample returns from 1927 to 2011:

Portfolio	Maximum	Minimum	Mean	Standard deviation	Kurtosis	Skewness	Sharpe ratio
RMRF	38.27	-29.04	7.33	18.96	7.35	0.17	0.39
SMB	39.04	-16.62	2.99	11.52	21.99	2.17	0.26
HML	35.48	-13.45	4.50	12.38	15.63	1.84	0.36
WML	26.18	-78.96	14.46	27.53	18.24	-2.47	0.53

C) Our objective: validate those academic studies with different set of data and implement also a long-only strategy

The momentum strategy has been implemented and back-tested by various academic and professionals not only for equities but also for bonds, commodities and currencies for different geographic areas. As we have seen above this strategy has produced a positive risk-adjusted return over time. While the momentum strategy has been usually implemented by academics for a long-short portfolio, this does not take into account the constraints faced by many fund managers: limited leverage, no ability to short-sell (constraint for the vast majority of regulated mutual funds), investors want to have a long-only exposure... Thus our research paper will try to bring another perspective by building both a long-short and a long-only trading strategy based on the momentum for different stock indices. We will compare the performance of those two strategies but also the risk-adjusted performance and the different risk measures (volatility, Sharpe ratio, maximum drawdown, % of months with negative performance, skewness, and kurtosis). It is very important to have this comparison since the purpose of implementing a long-short strategy is to minimise the volatility and the losses in case of market crash. As the expectations for markets returns are positive due to the positive risk premium for equities so one investor tends more naturally to be long-only.

Another objective of this research paper is to identify the practical and theoretical issues that a fund manager may encounter when he will try to implement a momentum strategy. Indeed, in case someone wants to continue this work for a different set of data or implement our long-only strategy, we will detail our methodology from data collection to portfolio construction, and the issues that we have encountered.

II) Implementing the momentum strategy for both a long-short and long-only portfolio

A) Our methodology for data collection and portfolio construction:

To test the momentum strategy for different portfolios, the first step is data collection over a long-period of time, between 15 and 20 years for a given basket of stocks to smooth our results and take into account different market environments (e.g. stock market rally from 2001 to 2007, Great Financial Crisis 2008-2009, Euro Sovereign Debt crisis in 2011...). This basket of stocks should also be diversified enough to virtually eradicate the idiosyncratic risk. Thus we have considered large American and European Indices (S&P 500, CAC 40) but we have taken into account their *historical* composition. Indeed, if we look only at the past performances for the stocks included in the *current* Indices we have two issues. The first issue is the survivorship bias: by definition the S&P 500 includes the US stocks with the top 500 market capitalisation for the current year so it excludes “losers” stocks which outperformed over the past years and companies that were taken over or that went bankrupt. So a back testing of a long-short strategy versus a long-only strategy with the current index will be biased in favour of the long-only portfolio. The other issue raised by taking into account the current indices composition is the lack of data available: while data providers can provide easily the S&P 500 performance over the last century, very few stocks are listed for this period due to M&A activity, IPOs or bankruptcies.

Thus even if it is time-consuming, we have done our data collection to take into account the *historical* composition of the indices and then create a strategy that is really tradable. Using Bloomberg, for each year t we have collected on a monthly basis the prices of the constituents of the index at year t , between year $t-1$ and $t+1$ (we have also taken into account the performance at year $t+1$, first month to be able to compute the performance of our strategy). We rebalance our portfolio on a monthly basis and on a yearly basis we rebalance our portfolio to take into account only the new constituents of the index. One can argue that there are still some limitations to this approach since the constituents of the indices can change more than one time per year. However, this method is the most straightforward and provides enough consistency for stock prices data.

To construct our portfolios, for each year t and for each month m we take the constituents of the index at the beginning of the year and we compute the returns of those stocks over the past 12 months period excluding the last month, that's is to say to build our portfolio at the beginning of month m we consider the returns of the stocks between month $m-12$ and month $m-1$. Note that we follow what is done in the academic literature: indeed excluding the performance of the last month is a way to take into account the mean-reversion of stocks. By construction, we exclude from the index stocks that go public on year t and join the index straight after since we have no price data.

Then we rank the returns of the different stocks and for the long-short short portfolio we decide to be long of the top performing stocks and to be short of the worst performing

stocks. For the long-only portfolio, we are only long on the top performing stocks. On a practical way to implement and backtest this strategy, there are two important parameters to determine: **the number of long and short positions, the targeted exposure to the market.**

The number of long and short positions should be large enough to eliminate or considerably reduce the idiosyncratic risk of a single stock. However it should also depend on the size of our index to preserve the quality of the momentum signal. If we choose a very large number of positions proportionally to the size of the index, there is a risk to reduce the momentum effect. Following the academic literature we have decided to have a number n of short positions equal to the number of long positions. We will study in the next part the impact of this number n given the size N of the index using different simulations. Usually in the academic literature, n is chosen such that we are short the lowest decile and we are long the highest decile.

Once we have chosen the number of long/short positions, we need to determine the targeted exposure to the market of our portfolio. For the long-only portfolio, by definition we have only a long exposure in n stocks and each stock is equally-weighted, representing $1/n$ of our total portfolio. We could have chosen that the allocation of each-stock is not equally weighted but proportional to the performance that's is to say to put more weight on the top performing stock compared to the second one, then more weight on the second best performing stock than to the third one, etc. It would make sense but we believe that an allocation proportional to the ranking of the best performing stocks increases the idiosyncratic risk or the risk of a "wrong" signal for several stocks. The equal-weight decision is motivated to smooth the performance of the momentum signal. We stress that the equal-weighted decision is not the most common method used for the construction of the momentum strategy: academics tends to prefer value weighting in order to be closer to the market portfolio and avoid to be exposed the size factor by having too much stocks of very small companies that tend to be more volatile than large firms. However, for us it makes less sense to consider a value-weighting approach since we use two major indices (S&P 500 and CAC 40), so we only consider the largest stocks and we have a very limited exposure to the size factor.

For the long-short portfolio we have several options to consider. If we want a market-neutral exposure as it is done in the academic literature for the momentum strategy, the amount of the portfolio invested in the long positions should be equal to the one invested in the short positions: thus the weight of each winner is $1/n$ and the weight of each loser is $-1/n$. We will test this strategy but we will also implement different strategies that are more in line with what practitioners do in hedge-funds. Indeed only a few hedge-funds have a market-neutral exposure with a short position equal to the long position. Usually the short position is significantly smaller than the long-position for several reasons. First the rationale of this strategy is that overall the equity market should deliver a positive risk-adjusted return on the long-run to compensate investors for the risks taken. The second limitation of market-neutral trading strategy is that the brokers usually require collateral for the short positions. Thus the overall short positions should be smaller than the long positions. If we choose for instance to have a 60% exposure to the market, the weight of each winner should be $1/n$ and the weight of each loser should be $-(1-60\%)/n$. More generally, if we target an exposure to the market of $x\%$ with x between 0 and 100%, the weight of each winner should be $1/n$ and

the weight of each loser should be $-(1-x\%)/n$. We will test the performance of our portfolio depending on x the targeted exposure to the market risk.

Given our allocation at the beginning of each month, we compute the performance at the end of the month. Then we start again the above process in order to determine the new portfolio allocation. We start with a portfolio value 100 and at the beginning of each month we reinvest the all amount of our portfolio. To compute our performance we make several important assumptions. First we assume no transactions costs: we consider that we trade very liquid stocks of 2 major indices (S&P 500, CAC 40) with marginal broker fees and price impact. We also exclude the Financial Transaction Tax (FTT) for the stocks of the CAC 40 which represents a 0.3% tax on the purchase of French traded stocks with a market capitalisation over €1billion. Even if the momentum strategy is very active with a high turnover, it makes sense to exclude in our computations the FTT since our strategy can be replicated using financial derivatives exempted of the FTT, such as CFD (Contract for Difference). Third for the performance of the long-short portfolio we assume no funding constraints or costs and no-short sales constraints. This assumption is not realistic since institutional investors need to pay fees to brokers in order to take short positions. During a financial crisis, a freeze in the repo market can occur and significantly reduce the ability for investors to short-sales. In addition, some countries can enforce a temporary ban on short-selling during markets turmoil. We will discuss in details the potential impact of those assumptions in part III. It is also worth mentioning that we compute a gross performance for our strategy without considerations of management fees or taxes.

B) Results for the long-short portfolio and the long-only portfolio

Back-testing of the strategy for the CAC 40

We decide to implement the momentum strategy first on the CAC 40. While the limited amount of the index could create an issue by increasing the idiosyncratic risk, it also allows us to do both a quantitative and qualitative analysis. Indeed using a basket of 40 stocks makes it easier to interpret and to find explanation for extreme moves in our strategy.

We use the stock prices from January 2001 to December 2016 and we implement our trading strategy from January 2002 to December 2016 over a 15-year period. While we could have obtained better results using a longer period of time, we believe that the time frame considered is long enough to test the momentum strategy with different market conditions. Indeed, from 2002 to 2016 several recessions occurred (stock market downturn of 2002, Great Financial Crisis during 2008-2009, Eurozone crisis in 2011) and were followed by other periods of rebounds in financial markets. However, it is important to stress that the period considered was characterised by many market crashes and it is reflected both on the overall performance of the CAC 40 and of the momentum strategies. Note that due to the change of currency from Franc to Euro, we were unable to find stock prices data before 2001.

First concerning the number of stocks, we have decided to move away from the convention of the momentum strategy which consists in considering only the top and the lowest decile (that is to say 4 stocks each for the CAC 40). We have considered several options for the number of stocks and 8 (meaning being long the top 20% and being short the lowest 20%) appears to be the optimal number to maximise the Sharpe ratio and minimise the maximum drawdown. Below 8 the annualised volatility is far too important and above 8 we have a lower return for the long-short portfolio. This empirical finding of considering only the 20% best/worst stocks has no theoretical ground. However we can try to interpret this result. Indeed, as the CAC 40 is a relatively small index, a portfolio consisting in only 4 stocks (top decile) will be not diversified enough and bear an important idiosyncratic risk associated with a very high volatility at the portfolio level. On the contrary a portfolio containing more than 8 stocks will consider in total more than 40% of the investment universe and the quality of the momentum signal will be impoverished. This is an ex-post result fitting to our data collection and there is absolutely no proof that 8 is the right number in every time period. What is clear is that the number percentage of stocks used to build the momentum strategy should not be fixed arbitrary to 10% of the best/10% of the worst. It depends on the total number of stocks of the index considered. In annexes, page 30 we show the performance of our long-short portfolio depending on the number of long/short positions. While the volatility of the portfolio is a decreasing function of the number of positions, the relation between the performance and the number of positions is less clear.

For now on, we will fix this number to 8 that is to say 8 short positions and 8 long positions.

We show below the comparison between the performance of the long-short momentum strategy (0% net market exposure with a short position equal to the long position), the long-only momentum strategy (100% market exposure) and the CAC 40. Please note that the short-only portfolio is not a momentum strategy by itself. Indeed in the financial industry no asset manager implement short-only strategy since it goes against the CAPM: as a risky asset, stocks should deliver positive returns. However, we include the results of the short-only portfolio to breakdown the performance of the long-only portfolio.

	Long-short portfolio	Long-only portfolio	Short-only portfolio	CAC 40
Portfolio value at maturity	100,5	221,3	43,5	105,1
Annualised Return	0,0%	5,4%	-5,4%	0,3%
Annualised Volatility	23,1%	20,1%	26,4%	17,6%
Sharpe Ratio	0,0	0,3	-0,2	0,0
Skewness	-1,6	-0,9	-2,9	-0,5
Kurtosis	8,0	2,7	17,2	0,7
% of negative months	43%	39%	52%	43%
Maximum Drawdown	-59%	-60%	-69%	-56%

First, we can notice that the long-only momentum strategy which consists only in 8 long-positions outperforms considerably both the long-short portfolio and the CAC 40 with a Sharpe Ratio of 0.3 compared to 0.0 for the long-short momentum and the reference index. The annualised return is significant at 5.4% compared to 0.0% for the long-short portfolio and the CAC 40. The most striking fact is that the annualised volatility of the long-only portfolio is lower than the long-short portfolio (respectively 20.1% and 23.1%). It seems paradoxical since the goal of a long-short strategy compared to a long-only strategy is to reduce the

market exposure and decrease the volatility. In terms of maximum drawdown, the momentum strategy is riskier than the market (59% for the long-short portfolio compared to -56% for the CAC 40). Again we notice that the long-short momentum strategy does not bring any benefit compared to the long-only portfolio which has a similar maximum drawdown (-60%). The momentum strategy seems to be quite correlated with the CAC 40 with a similar percentage of months with negative returns (43% for the long-short portfolio and the CAC 40, 39% for the long-only portfolio).

The momentum strategy is characterised by a very negative skewness of -0.9 for the long-only portfolio and even higher -1.6 for the long-short portfolio compared to a skewness of -0.5 for the CAC 40. It means that the monthly returns of the momentum strategy show an important asymmetry with important negative returns. The high frequency of extreme returns is confirmed by the very high kurtosis of the long-short portfolio and the long-only portfolio compared to the CAC 40 (respectively 8, 2.7 and 0.7).

In annexes page 27, we have put the graph with the performance of the two momentum strategies compared to the CAC 40 (rebased 100 at the beginning of January 2002). In annexes, we also show a comparison of the monthly returns. While the long-only momentum strategy overperformed significantly both the long-short strategy and the CAC 40 during long period of market rallies, it is much more subject to market crashes (example of 2002, 2008, and 2011). Graphically, we can see that the long-short momentum strategy overperformed the CAC 40 and the long-only strategy during market downturns (2002, 2007-2008, 2011) but this strategy is subjected to important crashes when the CAC 40 rebounds just after a crisis (2002, 2009).

Which months correspond to the best/worst performances of the two momentum strategies? During October 2002, the long-short momentum strategy experienced its worst performance with -35.6% while the CAC 40 was up +13.4%. Its second worst performance occurred in April 2009 (-34.3%) while the CAC 40 was up +12.6%. It confirms our graphical interpretation: the long-short momentum strategy experienced its worst performances when the reference index goes up suddenly after a long-period of market crash. The long-short strategy performed the best in June 2002 (+19.5%) during the burst of the tech bubble (CAC 40 was down -8.8%).

On the contrary, the long-only momentum strategy experienced its worst performance in November 2008 (-23.4%) while the CAC 40 plummeted (-13.5%) a few months after the collapse of Lehman Brothers. The best monthly performance was obtained in July 2009 (+14.7%) during a period of market rebound while the CAC 40 did +9.1%.

As seen above, the comparative analysis of the two momentum strategies show that the long-short strategies overperformed during market crashes but underperform significantly the long-only strategy during market rise. How can we conserve the benefits of the hedging during a crisis offered by the long-short portfolio while avoiding to be penalised by the short positions during a market rebound? One solution could be to reduce the amount invested in the short positions with a targeted market exposure superior to 0% but inferior to 100% (long-only portfolio). Please refer to page 10 for the definition of the targeted market exposure and the computations. We present below the performance of the momentum

strategy depending on the net market exposure. Graphs with the value of the strategy at maturity, annualised volatility and Sharpe Ratio can be found in annexes page 30.

Net market exposure	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Portfolio at maturity	100,5	118,1	136,0	153,7	170,6	185,9	199,1	209,7	217,1	221,0	221,3
Annualised Return	0,0%	1,1%	2,1%	2,9%	3,6%	4,2%	4,7%	5,1%	5,3%	5,4%	5,4%
Annualised Volatility	23,1%	20,7%	18,5%	16,6%	15,2%	14,4%	14,3%	14,9%	16,2%	18,0%	20,1%
Sharpe Ratio	-0,01	0,04	0,10	0,16	0,22	0,28	0,31	0,32	0,31	0,29	0,26
Skewness	-1,6	-1,6	-1,4	-1,1	-0,8	-0,5	-0,4	-0,6	-0,8	-0,9	-0,9
Kurtosis	8,0	7,4	6,3	4,6	2,5	0,9	0,7	1,5	2,3	2,7	2,7
% of negative months	43%	43%	43%	41%	41%	39%	41%	42%	43%	41%	39%
Maximum Drawdown	-59%	-52%	-48%	-47%	-46%	-46%	-48%	-50%	-53%	-55%	-60%

From our trading simulations it seems optimal in terms of absolute performance to be long-only without any short-position: indeed, we see a linear relation between the net market exposure and the value of the portfolio at maturity in December 2016. However, the optimal Sharpe ratio of 0.31 is obtained for a 70% targeted net market exposure (meaning that for an initial portfolio value 100 we invest initially only 30 in the short position) since having short positions in a limited amount is a way to reduce the volatility of the portfolio. When the amount invested in the short positions increased, we observe a rise in the annualised volatility.

How can we explain the performance of the momentum strategy depending on the performance of the CAC 40? One possible explanation for the superior performance of the momentum strategy for the long-only portfolio or the long-short portfolio with a net market exposure of 70% is that those strategies are a replication of the market with a higher Beta. To test this hypothesis we have run regressions on the monthly returns of the momentum strategy minus the risk-free rate depending on the monthly returns of the CAC 40 minus the risk-free rate. For the risk-free rate we have considered French OAT 10-year (*Obligation Assimilable du Trésor*, French Treasury bond). Our regressions use an asset pricing model similar to the standard CAPM (Capital Asset Pricing Model) with the market factor but we use the CAC 40 instead of the market portfolio.

Results of the regression for the long-short momentum strategy with 0% market exposure:

	Coefficients	Standard-error	T-statistic	P-value	Lower limit for a confidence interval =95%	Upper limit for a confidence interval =95%
Constant	-0,1%	0,00	-0,16	0,87	-0,9%	0,8%
CAC 40 risk-premium	-0,61	0,09	-7,03	0,00	-0,78	-0,44

Contrary to what we may expect for the long-short momentum strategy with an equivalent amount invested in short and in long positions, the exposure to the market factor is not neutral but deeply negative (-0.61). The high absolute value of the T-statistic (7.03) means that this coefficient is significant. The alpha of this strategy is close to 0% and not significant statistically (T-stat of -0.16).

Results of the regression for the long-only momentum strategy:

	Coefficients	Standard-error	T-statistic	P-value	Lower limit for a confidence interval =95%	Upper limit for a confidence interval =95%
Constant	0,5%	0,2%	2,07	0,04	0,0%	0,9%
CAC 40 risk-premium	0,98	0,04	22,63	0,00	0,90	1,07

As expected, the long-only momentum strategy has a positive exposure to the market factor with a coefficient very close to 1 (0.98). This exposure is statistically significant with a T-statistic of 22.63. However, the long-only momentum strategy does not only replicate the CAC 40 it delivers an important alpha (0.5% on a monthly basis) which is statistically significant with a T-statistic above 2 and a value of the monthly alpha comprised between 0% and 0.9% with a confidence interval of 95%.

Results of the regression for the long-short momentum strategy with a 70% market exposure:

	Coefficients	Standard-error	T-statistic	P-value	Lower limit for a confidence interval =95%	Upper limit for a confidence interval =95%
Constant	0,3%	0,3%	1,15	0,25	-0,2%	0,8%
CAC 40 risk-premium	0,50	0,05	9,94	0,00	0,40	0,60

While the long-short momentum strategy with a 70% market exposure offers the best Sharpe ratios, it also offers an attractive combination in terms of exposure to the market and alpha. Indeed the exposure to the market is positive (0.50) but much lower than the long-only portfolio, and at the same time it delivers a monthly alpha of 0.3%. However we need to point out that the T-statistic of the alpha for this momentum strategy is quite low (1.15) and using a 95% confidence interval we cannot be sure that the alpha is positive (between -0.2% and 0.8%).

Back-testing of the strategy for the S&P 500

We decide now to test the robustness of our findings on the CAC 40 with a much wider stock index the S&P 500. The large number of stocks almost eliminates the idiosyncratic risk and the results may or not confirm the advantages of a long-short portfolio with a limited amount invested in the short positions over a long-short momentum strategy with 0% market exposure.

We use the stock prices from January 1996 to December 2016 and we implement our trading strategy from January 1997 to December 2016 over a 20-year period. The time frame considered is long enough to test the momentum strategy with different market conditions (important rally until 2000-2001, burst of the tech bubble in 2002, Great Financial crisis in 2008, ...).

First concerning the number of stocks, we have decided to stick to the conventional momentum strategy by considering only the top and the lowest decile (that is to say 50 stocks for each category). Indeed the S&P 500 contains 500 stocks and 50 stocks provide enough diversification to eliminate the idiosyncratic risk.

For now on, we will fix this number to 50 that is to say 50 short positions and 50 long positions.

We show below the comparison between the performance of the long-short momentum strategy (0% net market exposure with a short position equal to the long position), the long-only momentum strategy (100% market exposure) and the S&P between January 1997 and December 2016 with value 100 at inception. Please note that the short-only portfolio is not a momentum strategy by itself. Indeed in the financial industry no asset manager implement short-only strategy since it goes against the CAPM: as a risky asset, stocks should deliver positive returns. However, we include the results of the short-only portfolio to breakdown the performance of the long-only portfolio.

	Long-short portfolio	Long-only portfolio	Short-only portfolio	S&P 500
Portfolio value at maturity	26,0	663,7	0,5	302,2
Annualised Return	-6,5%	9,9%	-23,0%	5,7%
Annualised Volatility	31,2%	22,2%	42,4%	15,3%
Sharpe Ratio	-0,2	0,4	-0,5	0,4
Skewness	-0,9	-0,1	-1,7	-0,6
Kurtosis	5,9	2,6	8,5	1,0
% of negative months	46%	43%	65%	40%
Maximum Drawdown	-95%	-61%	-99%	-53%

First we observe that the long-short portfolio (0% market exposure) significantly underperforms both the long-only momentum strategy and the S&P 500 with an annualised return of -6.5%, 9.9% and 5.7% respectively. The Sharpe ratio of the long-short portfolio is

negative -0.22 while the Sharpe ratio of the long-only momentum strategy equals the Sharpe ratio of the index (0.4). Indeed the long-only momentum strategy provides a higher annualised return but has also higher volatility (22.2%). The long-short portfolio does not bring any benefits: its volatility is higher (31.2%) and it has a very negative skewness (-0.89) with high kurtosis (5.89) indicating a fat left tail distribution of the monthly returns. The maximum drawdown of the long-short portfolio is very high at -95%: it seems a very risky strategy. On the contrary, the long-only momentum strategy shows a skewness inferior to the S&P 500 (-0.1 and -0.6 respectively) but a higher kurtosis and a higher percentage of negative months (43% compared to 40% for the S&P 500). The maximum drawdown of the long-only portfolio seems also quite high (-61%) compared to the index (-53%).

In annexes page 31, we have put the graph with the performance of the two momentum strategies compared to the S&P 500 (rebased 100 at the beginning of January 1997). While the long-only momentum strategy overperformed significantly both the long-short strategy and the S&P 500 during long period of market rallies, it is much more subject to market crashes (example of 2002, 2008, and 2011). Graphically, we can see that the long-short momentum strategy overperformed the S&P 500 and the long-only strategy during market downturns (2000-2001, 2007-2008, 2011, January 2016) but this strategy is subjected to important crashes when the S&P 500 rebounds just after a crisis (2009). The long-short momentum strategy also underperforms both the long-only and the S&P 500 during a steady period of market rise (2002-2007 for instance).

Performance of the momentum strategy on the S&P 500 depending on the net market exposure:

Net market exposure	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Portfolio at maturity	26,0	40,2	60,4	88,5	126,4	176,2	240,0	319,6	416,5	531,2	663,7
Annualised Return	-6,5%	-4,5%	-2,5%	-0,6%	1,2%	2,9%	4,5%	6,0%	7,4%	8,7%	9,9%
Annualised Volatility	31,2%	28,9%	26,8%	25,0%	23,4%	22,1%	21,2%	20,8%	20,8%	21,3%	22,2%
Sharpe Ratio	-0,22	-0,17	-0,10	-0,04	0,04	0,12	0,20	0,27	0,34	0,39	0,43
Skewness	-0,9	-0,7	-0,6	-0,3	-0,1	0,1	0,3	0,3	0,3	0,1	-0,1
Kurtosis	5,9	5,7	5,5	5,3	5,0	4,7	4,4	4,1	3,7	3,1	2,6
% of negative months	46%	45%	45%	44%	44%	43%	42%	41%	43%	44%	43%
Maximum Drawdown	-95%	-92%	-90%	-86%	-82%	-77%	-71%	-66%	-61%	-60%	-61%

As we have done for the CAC 40, we try to improve the performance of the momentum strategy by changing the amount invested in the short positions. Similarly to the results for the CAC 40, we find that the best absolute performance is obtained with no short positions and a long-only portfolio. In the case of the S&P 500, we also find that the long-only portfolio provides the best Sharpe at 0.43. We observe a positive relation between the net market exposure and the Sharpe ratio. That being said, having 10-20% of the portfolio invested in short positions (90-80% net market exposure) is a way to reduce the volatility and to obtain a positive skewness (0.3 for 80% net market exposure). Graphs with the value of the strategy at maturity, annualised volatility and Sharpe Ratio can be found in annexes page 31 and 32.

How can we explain the outperformance of the long-only momentum strategy given the performance of the S&P 500? One possible explanation for the superior performance of the momentum strategy for the long-only portfolio could be that it replicates the market with a

higher Beta. To test this hypothesis we have run regressions on the monthly returns of the momentum strategy minus the risk-free rate depending on the monthly returns of the S&P 500 minus the risk-free rate. For the risk-free rate we have considered 10-year US Treasury Yield. Our regressions use an asset pricing model similar to the standard CAPM (Capital Asset Pricing Model) with the market factor but we use the S&P 500 instead of the market portfolio.

Results of the regression for the long-short momentum strategy with 0% market exposure:

	Coefficients	Standard-error	T-statistic	P-value	Lower limit for a confidence interval =95%	Upper limit for a confidence interval =95%
Constant	-0,3%	0,6%	-0,56	0,58	-1,4%	0,8%
S&P 500 - Risk-free rate	-0,57	0,13	-4,52	0,00	-0,82	-0,32

Instead of having a neutral exposure to the market, the long-short momentum strategy with an equivalent amount invested in short and in long positions has a negative exposure to the market risk premium (S&P 500 minus Risk-free rate). The high absolute value of the T-statistic (4.52) means that this coefficient is significant. The alpha of this strategy is negative - 0.3% but it is not significant statistically (T-stat of -0.56). Thus with a confidence interval of 95% it is unsure if this strategy really provides alpha.

Results of the regression for the long-only momentum strategy:

	Coefficients	Standard-error	T-statistic	P-value	Lower limit for a confidence interval =95%	Upper limit for a confidence interval =95%
Constant	0,4%	0,3%	1,44	0,15	-0,2%	1,0%
S&P 500 - Risk-free rate	0,98	0,07	14,04	0,00	0,84	1,11

The long-only momentum strategy has a positive exposure to the market factor with a coefficient very close to 1 (0.98). This exposure is statistically significant with a T-statistic of 14.04. However, the long-only momentum strategy does not only replicate the S&P 500 it delivers an important alpha (0.4% on a monthly basis). We need to point out that the T-statistic is quite low for the alpha (1.44) and its monthly value is comprised between -0.2% and 1% with a confidence interval of 95%.

Results of the regression for the long-short momentum strategy with 80% market exposure:

	Coefficients	Standard-error	T-statistic	P-value	Lower limit for a confidence interval =95%	Upper limit for a confidence interval =95%
Constant	0,3%	0,3%	0,86	0,39	-0,4%	1,0%
S&P 500 - Risk-free rate	0,67	0,08	8,69	0,00	0,51	0,82

The long-short momentum strategy with short positions amounting to 20% of the long positions, has a positive exposure to the market (0.67) but much lower than the long-only portfolio, and at the same time it delivers a monthly alpha of 0.3%. However we need to

point out that the T-statistic of the alpha for this momentum strategy is quite low (0.86) and using a 95% confidence interval we cannot be sure that the alpha is positive (between -0.4% and 1.0%).

C) Are there any significant advantages for a given portfolio?

The positive risk-adjusted returns of the long-only portfolio based on the momentum strategy seem to significantly outperform the risk-adjusted returns of the long-short portfolio (with a 0% net market exposure) for all metrics both for the S&P 500 and the CAC 40. One argument to account for this outperformance is a financial and economic argument: shareholders should be remunerated for the risks taken. As a result, over the long-run we expect a positive risk-adjusted return for being long a basket of stocks. In other words, the higher the exposure to the market, the higher is the risk-adjusted returns. The long-short momentum strategy is also subject to the risk extreme positive returns in the market following a market crash: in our different simulations we have seen that the past losers often experience a significant rebound after a crisis and outperform the market. As we short those stocks, our long-short momentum strategy experience major losses. It is striking to see that the long-short momentum (0% net market exposure) strategies both on the S&P 500 and the CAC 40 experience one of their worst month in April 2009 with a performance of respectively -46.5% and -34.3%.

Based on our experimentations for the momentum strategy on two indices we can conclude that during a long period of time including different market scenarios, the long-only portfolio offers a better risk-profile compared to the long-short portfolio which delivers better performance only during periods of market crashes. Contrary to the intuition when we implement the momentum strategy, a long-short portfolio increases the volatility instead of reducing it.

One alternative that could reduce the volatility and improves the Sharpe ratio can be a long-short portfolio with a long-bias that is to say with an exposition to the long positions superior to the exposition in the short positions. If a long-short momentum strategy with short positions representing 30% of long-positions (70% net market exposure) can slightly improve the Sharpe ratio of the CAC 40, it is not the case for the S&P while the long-only portfolio delivers the best performance.

III) Limitations of the momentum strategy and additional constraints

A) The impact of transaction costs

If the momentum strategy seems to be attractive by delivering a significant risk-adjusted outperformance especially for a portfolio with a limited amount of short positions, a portfolio manager willing to implement this strategy should be aware of several caveats. In this research paper we use some simplifications to compute the performance and over a long-time period those approximations can significantly reduce the risk-adjusted performance.

First, in this study I follow the approach of the academics and I did not take into account transaction costs. I focused instead of the gross returns for the fund managers but by doing so I significantly overstate the performance. Indeed even if we select large indices (S&P 500, CAC 40) with very liquid stocks and thus low bid-ask spread, the momentum strategy is very active with a high turnover on a monthly basis. As a result the transactions costs are important over time. Lesmond, Shill and Zhou ("The illusory nature of momentum profits", 2003) demonstrate that the effective returns of the portfolio are much lower when we take into account transaction costs. In this paper, they use aggregate trade data and a theoretical model for transaction costs. However, those models are used for the "average" single stock and may overstate the effective costs for our strategy. Indeed, we have built portfolios based on the main indices with the most liquid stocks which have trading costs significantly lower compared to the "average" stock. The extreme liquidity considerably reduced both the bid-ask spread and the price impact of the transactions which can be significant for Mid & Small Caps.

Indeed, Frazzini, Israel, and Moskowitz (2015) use a very wide range of live trading data over 16 years and for various countries to measure the effective transactions costs when a portfolio manager implements trading strategies like momentum. Their key finding is that the real-world transaction costs are significantly lower than the theoretical costs obtained in the previous studies. Contrary to Lesmond, Shill and Zhou, they find that the momentum strategy delivers a robust performance when we take into account real-world transaction costs.

We have tried to test the impact of the transaction costs on our trading strategy with a monthly rebalancing for the CAC 40. First we have computed the average annual turnover of our strategy both for the long-short and the long-only portfolio. Then we have estimated the transaction costs. In order to be as realistic as possible, we have spoken to different brokers and assets managers operating in Paris (around 20 in total). They confirm that the transaction costs for large stocks (CAC 40) are very small compared to mid and small caps. Yet a short portfolio incurs higher transaction costs since you need to borrow the stocks. Following our discussions, we estimate the transaction costs to 10bps for the long-only portfolio and 14bps for the long-short portfolio. The transaction costs are 4bps higher for the long-short portfolio since half of the portfolio is invested in short positions and we can

estimate that the borrowing costs represent 8bps in addition to the 10 bps of transaction costs.

As we detail below, the long-short portfolio is more affected (+30bps) by the transaction costs than the long-only portfolio due to higher annual turnover and higher transaction costs. When we model the transaction costs, the long-only momentum strategy still appears as a valid strategy since the annual return is still very positive (+4.78%).

Estimated impact of transaction costs for the momentum strategy on the CAC 40

	Long-short portfolio	Long-only portfolio
Average annual turnover over the period	658%	618%
Estimated transaction costs	0,14%	0,10%
Impact on the performance	0,92%	0,62%
Annual return before transaction costs	0%	5,40%
Annual return after transaction costs	-0,92%	4,78%

B) The funding and short-sales constraints

For our long-short strategies we assume no short-sales costs or constraints. This assumption was convenient to evaluate the performance of our strategy but it is not realistic for several reasons. First in order to take a short position for a given stock investors need to borrow it from other investors – usually brokers and banks – and then to repurchase it later. Obviously short-sellers need to pay a significant commission corresponding to the interest cost of borrowing the shares. During market crashes or when a major event occurs for a given company, this commission tend to increase significantly and reduce considerably the ability to short-sale. In *Irrational Exuberance* Robert Shiller demonstrates the limitations of the Efficient Market Hypothesis with the presence of short-sales constraints that can explain the persistence of mispricing. The extreme example mentioned by Shiller is the mispricing during the 3Com sale of Palm in March 2000 during the dot-com bubble. During this Initial Public Offering, 3Com sold 5% of its subsidiary Palm, specialised in making personal digital assistants. The Palm shares skyrocketed and the 95% of Palm stocks had a market value superior to their parent company 3Com. The mispricing was obvious but investors had limited ability to short-sales since the interest cost of borrowing Palm rose 35% per year by July 2000.

In addition to the explicit interest cost, short-sellers are required to have some safe collateral. This is not the case in our long-short scenario where we can have a portfolio with an initial value of 100, with +100 invested in long positions of winners and -100 invested in short positions of losers. As stocks are very volatile they are not considered as safe collateral and a haircut is applied to the value of our portfolio. When we take into account both the interest cost of borrowing and the cost required by the collateral, we admit that the real return of our long-short momentum strategy is significantly lower than the one we obtain in our simulation. However due to the highly volatile nature of the interest cost of borrowing, it is especially hard to measure precisely the total impact of short-selling costs. While our baskets of very large stocks (CAC 40, S&P 500) should be relatively easy to short-sell at a moderate cost, the momentum strategy can still be very expensive to implement since by

construction we short past losers. We can assume that past losers have higher borrowing costs due to higher short interests.

Short-sales constraints can also derive from the governments. Even in developed countries some ban on short-selling can be enforced during a particularly severe market crash. For instance during the Eurozone crisis in August 2011, the European Securities and Markets Authority (ESMA) announced a temporary ban on short-selling in four European countries (France, Italy, Spain and Belgium). Our long-short strategy on the CAC 40 would have been directly affected by this restriction. While the presence of financial derivatives such as CFDs could be a way to bypass this temporary restriction, other costs are incurred by trading those derivatives products with financial intermediaries.

C) Absence of added value to justify for the level of fees?

As mentioned in the first part one of our objectives is to find the issues that a fund manager may encounter when he wants to implement a momentum strategy. In addition to transaction costs and funding, liquidity constraints, we think that the philosophy of the momentum strategy is by itself an issue for an active fund manager. We did not find this argument in the academic literature but in the current competitive context for the asset management industry we believe it is interesting to develop our reasoning. Nowadays, the traditional asset management industry is increasingly challenged by passive strategies (mainly ETFs) that can replicate either indices or strategies with exposure to different factors (momentum, value,...) with a level of fees considerably lower than the active asset managers. For instance, Blackrock has recently reduced its fees for some ETFs to only 3bps per year while the standard for active asset management for stocks is between 50 and 250bps per year for management fees plus performance fees in some cases.

As the momentum strategy is not based on fundamental analysis or complex factors, it is really easy to replicate it for a given index and many passive fund managers already offer ETFs replicating momentum. In our interpretation, the momentum strategy is so simple to replicate that it is not easy to “sell” for an active asset manager who charge an important amount of fees. As we have seen in the first part, the absence of strong theoretic ground for the momentum strategy makes it quite uneasy for an asset manager to market to investors.

Contrary to a “value” approach that can take into account non quantitative parameters such as fundamental analysis with meeting with the management and understanding of the business model of the company, the momentum approach could not justify high-level of fees due to the fact that basically every investor can replicate it (at least the long-only version). So in our view, an active asset manager using the momentum strategy should be careful when marketing his fund and try to emphasis on his added value. Adding some constraints to the momentum strategy or mixing this strategy with a value approach could be a good way in our view to bring added-value.

We have seen that the long-only portfolio clearly outperforms the long-short portfolio both for the S&P 500 and CAC 40 during a recovery period after a severe market crash. Therefore, using a quantitative ratio like the CAPE (Cyclically-Adjusted Price-to-Earnings Ratio) could be an interesting way to adjust the short exposure depending on the relative

expensiveness of the market. This could lead to a significant improvement of our momentum strategy.

Conclusion

The purpose of this research paper was to test the replicability of the momentum strategy - which is by convention a long-short strategy - to long-only investors. After presenting some possible explanations for the momentum factor, we have tested the robustness of this strategy with real data on the CAC 40 and the S&P 500. Contrary to our initial intuition, the long-only momentum strategy clearly outperforms the long-short momentum both in terms of absolute performance and Sharpe ratio. As a result the momentum strategy is not only replicable for a long-term investor but it also provides better performance. We also find that having limited short positions could sometimes reduce the volatility of the strategy.

We are aware of the limitations of our portfolio simulations such as the absence of transaction costs or no modelling of short-sales constraints. However, those constraints tend to affect more the long-short portfolios so overall it reinforces our findings that the long-only momentum strategy can outperform the long-short momentum strategy.

We want to present a way to continue and improve our work on the momentum strategy for the long-only and long-short investors by considering the performance of the overall index. Indeed our strategies are very dynamic with a monthly rebalancing but we always consider a static net market exposure whatever the market conditions (either 100% of market exposure for the long-only portfolio, 0% or more for the long-short one). In the analysis of our performance we have shown that the performance of the long-only portfolio is negatively affected by the short positions during the market rebound that tend to follow most crashes. One quantitative way to improve our results could be to implement a dynamic market exposure depending on the past performance of the index and the mean-reversion that can be observed on the long-run. For instance, if a very severe market crash occurs we should increase our long-position and reduce our short position. On the contrary after a long market rally, it would make sense to increase our short position. This time-varying net market exposure could be improved by using financial ratios such as the CAPE (cyclically adjusted price-to-earnings ratio), also called the Shiller P/E to detect eventual mispricing in the market. When the Shiller P/E is above its historical average, the investor applying a long-short momentum strategy could increase the short position while it should reduce the short position while the Shiller P/E is below the historical average.

Thanks

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Annexes

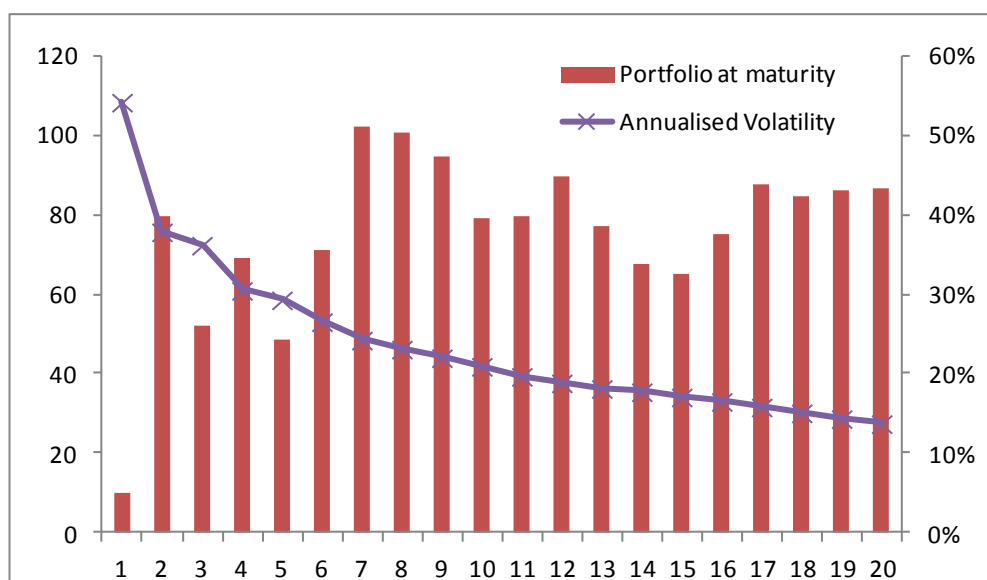
Back-testing of the strategy for the CAC 40

All our results for the CAC 40 correspond to the implementation of the strategy between January 2002 and December 2016. We use the stock prices from January 2001 to December 2016.

Performance of our long-short momentum strategy on the CAC 40 with a 0% net exposure to the market depending on the number of long/short positions:

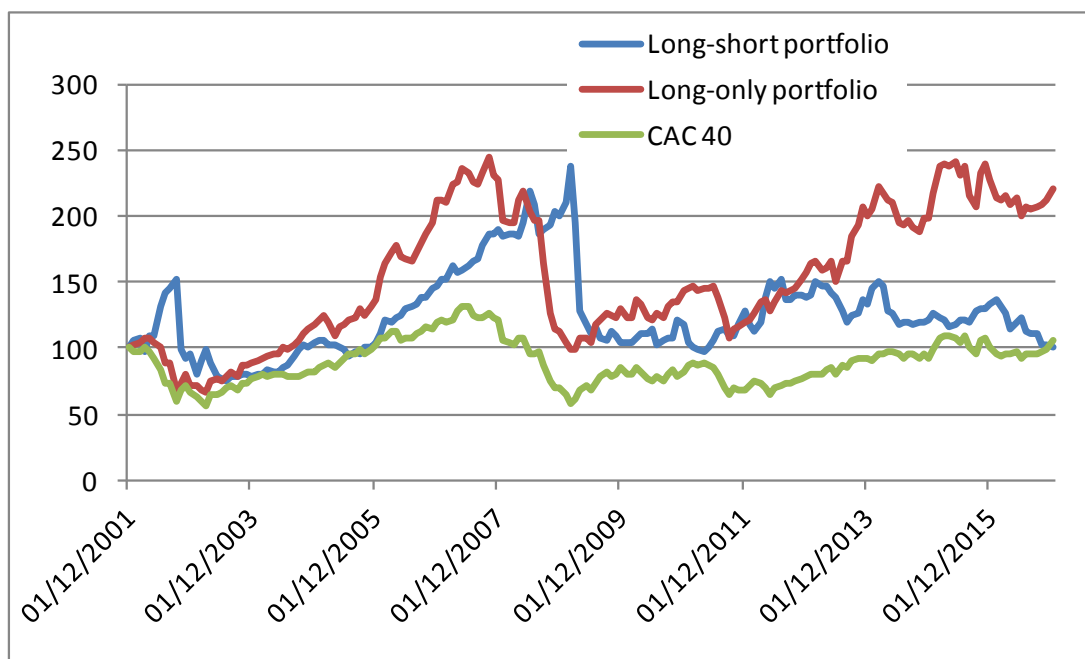
Number of long/short positions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Portfolio at maturity	9,8	79,6	52,1	69,2	48,3	71,3	102,2	100,5	94,4	78,8	79,5	89,5	77,2	67,4	65,1	75,1	87,5	84,6	86,1	86,8
Annualised Return	-14%	-1,5%	-4,3%	-2,4%	-4,7%	-2,2%	0,1%	0,0%	-0,4%	-1,6%	-1,5%	-0,7%	-1,7%	-2,6%	-2,8%	-1,9%	-0,9%	-1,1%	-1,0%	-0,9%
Annualised Volatility	54,2%	37,9%	36,2%	30,5%	29,3%	26,6%	24,3%	23,1%	22,1%	21,0%	19,7%	18,9%	18,2%	17,8%	17,1%	16,6%	15,9%	15,1%	14,4%	13,8%
Sharpe Ratio	-0,3	0,0	-0,1	-0,1	-0,2	-0,1	0,0	0,0	0,0	-0,1	-0,1	-0,1	-0,1	-0,2	-0,2	-0,1	-0,1	-0,1	-0,1	-0,1
Skewness	-1,0	-1,2	-1,7	-1,5	-2,1	-2,0	-1,7	-1,6	-1,8	-2,0	-1,9	-1,7	-1,7	-1,7	-1,6	-1,6	-1,4	-1,4	-1,3	-1,3
Kurtosis	3,9	4,1	7,0	5,8	10,5	9,3	8,1	8,0	9,2	10,1	9,4	8,2	8,1	8,3	7,3	7,4	6,2	5,7	5,2	5,1
% of negative months	43%	43%	43%	42%	44%	42%	43%	43%	44%	48%	47%	47%	47%	47%	48%	46%	46%	47%	46%	45%
Maximum Drawdown	-98%	-83%	-88%	-80%	-76%	-68%	-62%	-59%	-57%	-59%	-60%	-53%	-54%	-56%	-53%	-49%	-46%	-45%	-46%	-43%

Value at maturity of our long-short momentum strategy and annualised volatility depending on the number of long/short positions:



From now on for the CAC 40, we will consider momentum strategies with 8 long positions and 8 short positions.

Comparison of the performance of the long-short momentum strategy (0% market exposure) with the long-only momentum strategy and the CAC 40 (rebased 100 at the end of December 2001):



Comparison of the monthly returns of the long-short momentum strategy (0% market exposure) with the long-only momentum strategy and the CAC 40:

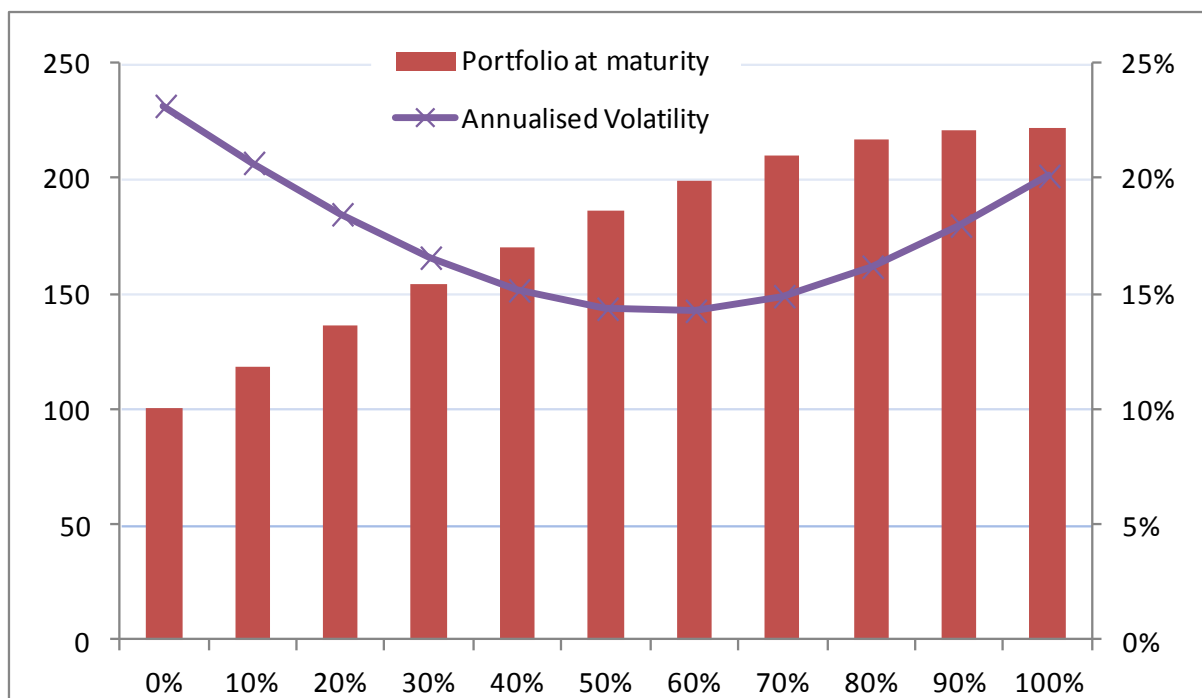
Date	Long-short portfolio	Long-only portfolio	CAC 40
31/01/2002	6,7%	1,6%	-3,5%
28/02/2002	1,2%	2,9%	0,0%
31/03/2002	-9,3%	2,2%	5,0%
30/04/2002	12,5%	0,3%	-4,8%
31/05/2002	-0,5%	-3,0%	-4,2%
30/06/2002	19,5%	-3,1%	-8,8%
31/07/2002	8,4%	-12,5%	-12,4%
31/08/2002	2,1%	0,3%	-1,4%
30/09/2002	5,3%	-22,7%	-17,5%
31/10/2002	-35,6%	8,3%	13,4%
30/11/2002	-5,5%	7,4%	5,6%
31/12/2002	3,7%	-10,8%	-7,9%
31/01/2003	-16,7%	-0,2%	-4,1%
28/02/2003	11,6%	-3,5%	-6,3%
31/03/2003	9,8%	-2,7%	-4,9%
30/04/2003	-9,7%	12,4%	12,8%
31/05/2003	-11,7%	2,3%	1,3%
30/06/2003	-2,6%	-2,4%	3,1%
31/07/2003	-1,5%	5,5%	4,1%
31/08/2003	4,4%	3,8%	3,2%
30/09/2003	-0,4%	-3,7%	-5,3%
31/10/2003	2,5%	10,3%	7,6%
30/11/2003	-0,9%	0,6%	1,5%
31/12/2003	-0,8%	1,7%	3,9%
31/01/2004	1,5%	2,3%	2,3%
29/02/2004	0,0%	2,4%	2,4%
31/03/2004	3,5%	0,6%	-2,7%
30/04/2004	-1,5%	1,9%	1,4%
31/05/2004	0,3%	0,3%	-0,1%
30/06/2004	4,5%	5,8%	1,7%

31/07/2004	1,9%	-1,3%	-2,3%
31/08/2004	7,3%	2,3%	-1,4%
30/09/2004	5,9%	4,2%	1,3%
31/10/2004	3,4%	4,0%	1,8%
30/11/2004	-1,5%	4,3%	1,3%
31/12/2004	3,3%	2,1%	1,8%
31/01/2005	1,1%	3,4%	2,4%
28/02/2005	0,8%	3,1%	2,9%
31/03/2005	-3,5%	-4,0%	1,0%
30/04/2005	-0,5%	-9,2%	-3,8%
31/05/2005	-1,7%	6,2%	5,3%
30/06/2005	-1,7%	1,6%	2,6%
31/07/2005	-3,8%	3,4%	5,3%
31/08/2005	3,5%	0,0%	-1,2%
30/09/2005	-1,7%	6,0%	4,6%
31/10/2005	4,0%	-3,1%	-3,6%
30/11/2005	0,2%	5,4%	3,0%
31/12/2005	3,4%	3,7%	3,2%
31/01/2006	7,5%	12,1%	4,9%
28/02/2006	9,2%	6,9%	1,1%
31/03/2006	-2,3%	4,7%	4,4%
30/04/2006	3,0%	3,5%	-0,6%
31/05/2006	2,0%	-4,9%	-5,0%
30/06/2006	3,5%	-1,4%	0,7%
31/07/2006	1,9%	-0,7%	0,9%
31/08/2006	0,7%	4,0%	3,1%
30/09/2006	3,7%	4,0%	1,6%
31/10/2006	0,7%	3,5%	1,9%
30/11/2006	4,4%	5,1%	-0,4%
31/12/2006	1,9%	8,8%	4,0%
31/01/2007	2,5%	0,0%	1,2%
28/02/2007	0,7%	-0,5%	-1,6%
31/03/2007	6,9%	5,9%	2,1%
30/04/2007	-3,2%	1,2%	5,8%
31/05/2007	0,7%	4,0%	2,4%
30/06/2007	2,2%	-1,1%	-0,8%
31/07/2007	2,4%	-3,2%	-5,0%
31/08/2007	1,4%	-0,5%	-1,5%
30/09/2007	5,8%	4,0%	0,9%
31/10/2007	4,2%	4,8%	2,3%
30/11/2007	0,2%	-5,3%	-3,0%
31/12/2007	2,2%	-1,6%	-1,0%
31/01/2008	-3,3%	-13,6%	-13,3%
29/02/2008	1,0%	-0,9%	-1,6%
31/03/2008	0,3%	0,3%	-1,7%
30/04/2008	-0,8%	8,2%	6,1%
31/05/2008	5,7%	3,6%	0,4%
30/06/2008	11,8%	-6,9%	-11,6%
31/07/2008	-4,4%	-3,4%	-1,0%
31/08/2008	-10,7%	0,3%	2,1%
30/09/2008	1,5%	-16,9%	-10,0%
31/10/2008	2,0%	-23,4%	-13,5%
30/11/2008	5,7%	-8,5%	-6,4%
31/12/2008	-1,8%	-2,1%	-1,4%
31/01/2009	5,0%	-7,3%	-7,6%
28/02/2009	13,3%	-5,4%	-9,1%
31/03/2009	-18,1%	0,3%	3,9%
30/04/2009	-34,3%	7,8%	12,6%
31/05/2009	-8,1%	1,0%	3,7%
30/06/2009	-6,2%	-4,2%	-4,2%
31/07/2009	5,4%	14,7%	9,1%
31/08/2009	-8,2%	2,5%	6,6%
30/09/2009	-1,8%	4,4%	3,9%
31/10/2009	7,8%	-1,7%	-4,9%
30/11/2009	-4,5%	-1,2%	2,0%
31/12/2009	-3,3%	5,0%	7,0%
31/01/2010	-0,8%	-4,9%	-5,0%
28/02/2010	-0,7%	-0,1%	-0,8%
31/03/2010	4,8%	10,8%	7,2%
30/04/2010	2,1%	-1,5%	-4,0%
31/05/2010	0,5%	-8,1%	-8,1%
30/06/2010	2,2%	-1,5%	-1,8%
31/07/2010	-10,2%	4,3%	5,8%
31/08/2010	4,3%	-2,7%	-4,2%

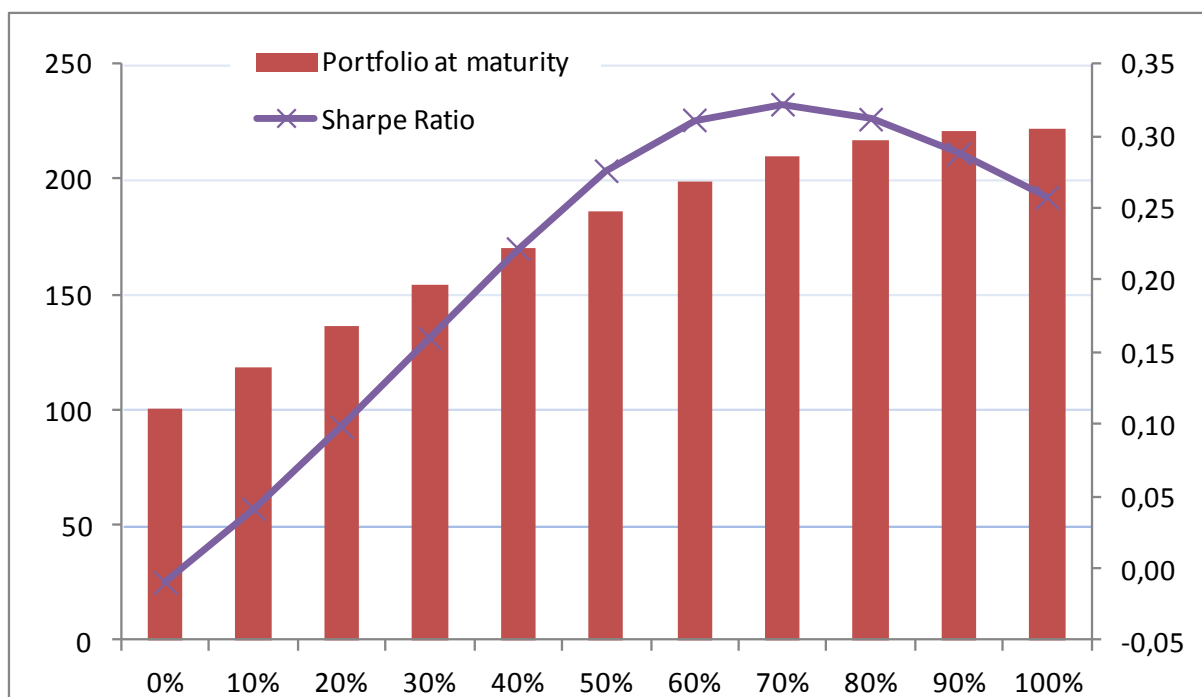
30/09/2010	1,8%	6,8%	6,4%
31/10/2010	0,0%	2,7%	3,2%
30/11/2010	11,5%	0,6%	-5,8%
31/12/2010	-2,6%	5,7%	5,4%
31/01/2011	-11,5%	0,7%	5,3%
28/02/2011	-3,8%	1,7%	2,6%
31/03/2011	-0,8%	-2,3%	-2,9%
30/04/2011	-1,6%	1,0%	3,0%
31/05/2011	2,7%	-0,4%	-2,4%
30/06/2011	5,8%	1,9%	-0,6%
31/07/2011	5,3%	-5,5%	-7,8%
31/08/2011	1,9%	-11,9%	-11,3%
30/09/2011	-3,6%	-12,5%	-8,4%
31/10/2011	-0,1%	7,1%	8,7%
30/11/2011	6,8%	0,3%	-2,7%
31/12/2011	8,6%	3,0%	0,2%
31/01/2012	-7,2%	1,7%	4,4%
29/02/2012	-4,3%	4,7%	4,7%
31/03/2012	6,3%	7,1%	-0,8%
30/04/2012	15,9%	0,6%	-6,2%
31/05/2012	8,6%	-6,3%	-6,1%
30/06/2012	-4,3%	5,6%	6,0%
31/07/2012	5,2%	5,8%	3,0%
31/08/2012	-9,8%	-0,4%	3,7%
30/09/2012	-0,2%	0,9%	-1,7%
31/10/2012	1,9%	1,2%	2,2%
30/11/2012	1,0%	5,3%	3,7%
31/12/2012	-1,5%	3,2%	2,4%
31/01/2013	1,5%	4,2%	2,5%
28/02/2013	6,3%	1,2%	-0,3%
31/03/2013	-1,4%	-4,6%	0,2%
30/04/2013	-0,8%	0,9%	3,4%
31/05/2013	-2,9%	3,6%	2,4%
30/06/2013	-2,0%	-8,9%	-5,3%
31/07/2013	-8,5%	10,4%	6,8%
31/08/2013	-5,8%	-0,1%	-1,5%
30/09/2013	4,4%	10,9%	5,3%
31/10/2013	1,1%	4,6%	3,8%
30/11/2013	7,5%	7,1%	-0,1%
31/12/2013	-2,5%	-3,3%	0,0%
31/01/2014	10,3%	2,6%	-3,0%
28/02/2014	2,9%	8,1%	5,8%
31/03/2014	-2,4%	-2,3%	-0,4%
30/04/2014	-12,7%	-1,8%	2,2%
31/05/2014	-1,9%	-1,1%	0,7%
30/06/2014	-5,7%	-7,0%	-2,1%
31/07/2014	0,5%	-1,5%	-4,0%
31/08/2014	-0,1%	2,2%	3,2%
30/09/2014	-1,0%	-2,6%	0,8%
31/10/2014	1,3%	-1,8%	-4,1%
30/11/2014	-0,4%	5,2%	3,7%
31/12/2014	2,1%	0,5%	-2,7%
31/01/2015	3,7%	9,7%	7,8%
28/02/2015	-2,3%	9,3%	7,5%
31/03/2015	-1,6%	0,2%	1,7%
30/04/2015	-4,1%	-0,3%	0,3%
31/05/2015	2,0%	1,4%	-0,8%
30/06/2015	2,0%	-4,3%	-4,3%
31/07/2015	0,6%	3,0%	6,1%
31/08/2015	-2,4%	-9,7%	-8,5%
30/09/2015	7,5%	-3,9%	-4,2%
31/10/2015	1,4%	12,8%	9,9%
30/11/2015	0,0%	2,9%	1,2%
31/12/2015	2,3%	-5,1%	-6,5%
31/01/2016	3,3%	-6,2%	-4,7%
29/02/2016	-3,6%	-0,4%	-1,4%
31/03/2016	-4,2%	1,7%	0,7%
30/04/2016	-9,3%	-3,8%	1,0%
31/05/2016	3,6%	3,1%	1,7%
30/06/2016	3,2%	-7,0%	-6,0%
31/07/2016	-8,3%	3,7%	4,8%
31/08/2016	-1,7%	-0,9%	0,0%
30/09/2016	0,0%	1,1%	0,2%
31/10/2016	-6,8%	0,7%	1,4%

30/11/2016	-1,5%	2,0%	1,5%
31/12/2016	-1,1%	3,9%	6,2%

Value at maturity of the momentum strategy and annualised volatility depending on the net market exposure:



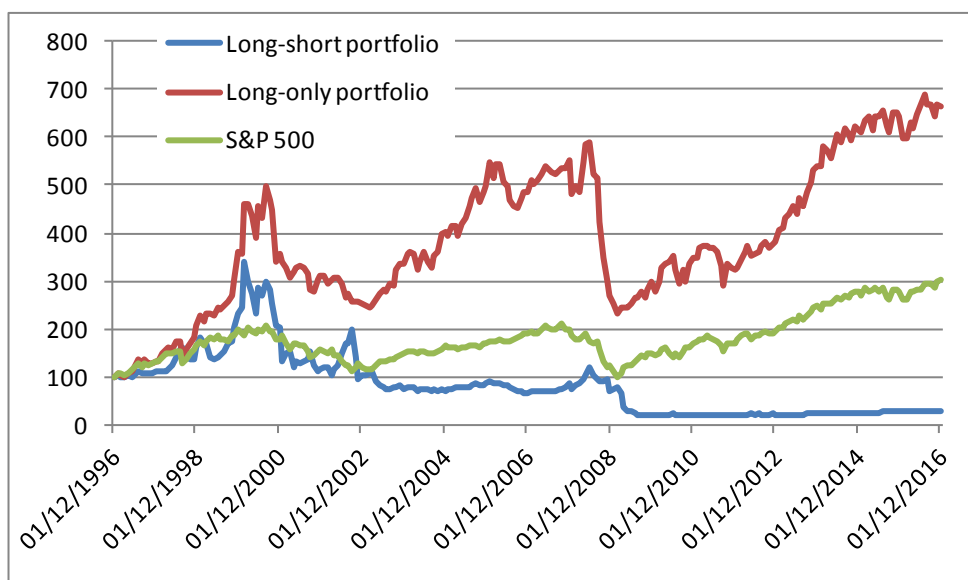
Value at maturity of the momentum strategy and Sharpe ratio depending on the net market exposure:



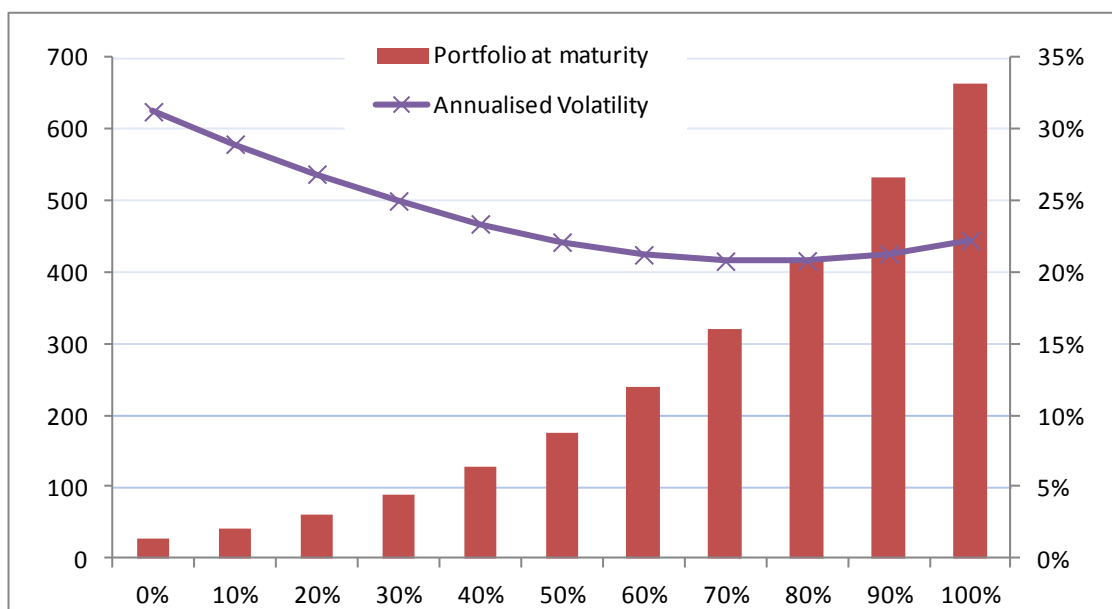
Back-testing of the strategy for the S&P 500

All our results for the S&P 500 correspond to the implementation of the strategy between January 1997 and December 2016. We use the stock prices from January 1996 to December 2016.

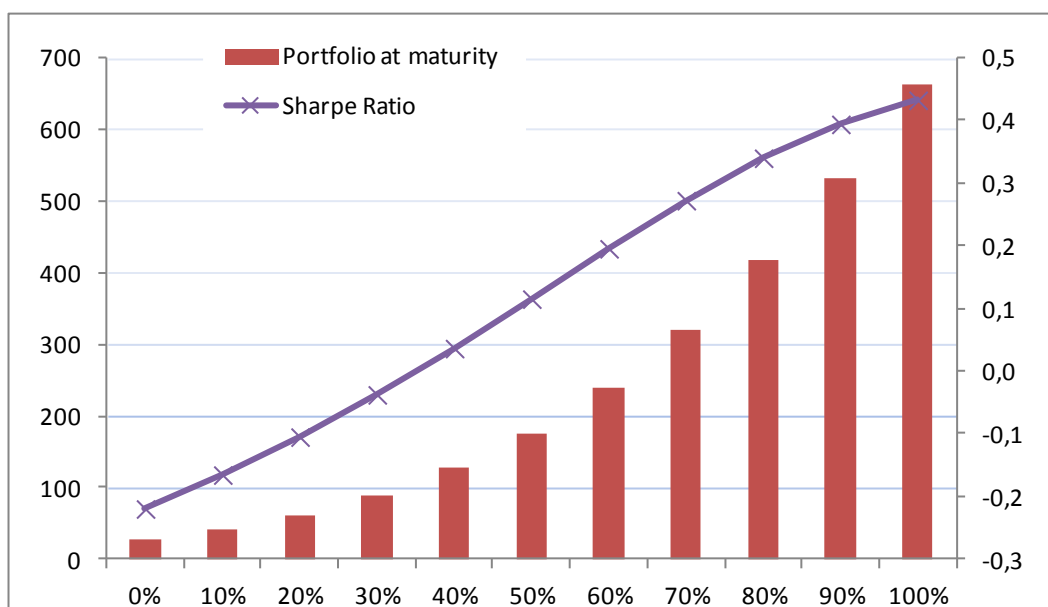
Comparison of the performance of the long-short momentum strategy (0% market exposure) with the long-only momentum strategy and the S&P 500 (rebased 100 at the end of December 1996):



Value at maturity of the momentum strategy and annualised volatility depending on the net market exposure:



Value at maturity of the momentum strategy and Sharpe ratio depending on the net market exposure:



Comparison of the monthly returns of the long-short momentum strategy (0% market exposure) with the long-only momentum strategy and the S&P 500:

Date	Long-short portfolio	Long-only portfolio	S&P 500
31/01/1997	4,3%	6,9%	6,1%
28/02/1997	-5,5%	-2,7%	0,6%
31/03/1997	-1,1%	-4,6%	-4,3%
30/04/1997	6,3%	7,2%	5,8%
31/05/1997	-4,3%	5,2%	5,9%
30/06/1997	3,4%	5,2%	4,3%
31/07/1997	6,3%	14,7%	7,8%
31/08/1997	-2,7%	-4,2%	-5,7%
30/09/1997	2,4%	5,8%	5,3%
31/10/1997	-2,6%	-8,0%	-3,4%
30/11/1997	0,4%	1,8%	4,5%
31/12/1997	3,1%	2,0%	1,6%
31/01/1998	-0,3%	2,0%	1,0%
28/02/1998	0,9%	10,2%	7,0%
31/03/1998	2,6%	7,9%	5,0%
30/04/1998	0,8%	1,9%	0,9%
31/05/1998	6,8%	-2,0%	-1,9%
30/06/1998	16,8%	10,0%	3,9%
31/07/1998	9,9%	0,2%	-1,2%
31/08/1998	2,7%	-18,2%	-14,6%
30/09/1998	-5,1%	11,4%	6,2%
31/10/1998	-10,7%	6,0%	8,0%
30/11/1998	0,0%	7,2%	5,9%
31/12/1998	19,5%	15,0%	5,6%
31/01/1999	11,0%	10,3%	4,1%
28/02/1999	-6,9%	-6,6%	-3,2%
31/03/1999	1,4%	9,1%	3,9%
30/04/1999	-17,8%	0,1%	3,8%
31/05/1999	-4,3%	-2,5%	-2,5%
30/06/1999	3,3%	7,9%	5,4%
31/07/1999	4,6%	-1,8%	-3,2%
31/08/1999	5,7%	3,2%	-0,6%
30/09/1999	9,9%	3,3%	-2,9%
31/10/1999	4,1%	5,1%	6,3%
30/11/1999	15,7%	12,4%	1,9%
31/12/1999	15,0%	18,0%	5,8%
31/01/2000	4,1%	-1,2%	-5,1%
29/02/2000	40,2%	29,3%	-2,0%
31/03/2000	-12,6%	0,4%	9,7%
30/04/2000	-7,7%	-5,3%	-3,1%
31/05/2000	-15,4%	-10,2%	-2,2%
30/06/2000	22,3%	16,1%	2,4%
31/07/2000	-5,2%	-5,2%	-1,6%
31/08/2000	10,9%	15,8%	6,1%

30/09/2000	-5,1%	-5,9%	-5,3%
31/10/2000	-11,1%	-4,6%	-0,5%
30/11/2000	-18,5%	-23,9%	-8,0%
31/12/2000	-1,3%	4,6%	0,4%
31/01/2001	-35,5%	-4,2%	3,5%
28/02/2001	12,3%	-3,8%	-9,2%
31/03/2001	3,2%	-6,4%	-6,4%
30/04/2001	-22,1%	3,9%	7,7%
31/05/2001	12,2%	2,7%	0,5%
30/06/2001	-2,3%	0,9%	-2,5%
31/07/2001	1,6%	-0,7%	-1,1%
31/08/2001	3,2%	-4,6%	-6,4%
30/09/2001	13,2%	-10,3%	-8,2%
31/10/2001	-18,5%	-1,4%	1,8%
30/11/2001	-9,8%	8,3%	7,5%
31/12/2001	0,6%	3,3%	0,8%
31/01/2002	3,7%	-0,2%	-1,6%
28/02/2002	2,4%	-5,3%	-2,1%
31/03/2002	-14,1%	2,8%	3,7%
30/04/2002	12,0%	1,2%	-6,1%
31/05/2002	7,0%	0,1%	-0,9%
30/06/2002	20,0%	-3,7%	-7,2%
31/07/2002	14,7%	-9,9%	-7,9%
31/08/2002	-1,6%	2,6%	0,5%
30/09/2002	18,0%	-5,1%	-11,0%
31/10/2002	-28,9%	-1,2%	8,6%
30/11/2002	-32,1%	0,5%	5,7%
31/12/2002	8,3%	-2,3%	-6,0%
31/01/2003	0,4%	-1,4%	-2,7%
28/02/2003	4,6%	-1,0%	-1,7%
31/03/2003	0,9%	1,9%	0,8%
30/04/2003	-16,9%	4,7%	8,1%
31/05/2003	-11,3%	4,9%	5,1%
30/06/2003	-2,6%	2,2%	1,1%
31/07/2003	-4,3%	-0,4%	1,6%
31/08/2003	-1,3%	4,9%	1,8%
30/09/2003	3,2%	-0,8%	-1,2%
31/10/2003	3,1%	10,5%	5,5%
30/11/2003	1,4%	4,3%	0,7%
31/12/2003	-7,9%	-0,4%	5,1%
31/01/2004	4,5%	6,9%	1,7%
29/02/2004	-1,9%	0,8%	1,2%
31/03/2004	0,5%	-1,1%	-1,6%
30/04/2004	-8,3%	-8,8%	-1,7%
31/05/2004	3,9%	5,1%	1,2%
30/06/2004	4,2%	5,8%	1,8%
31/07/2004	-4,7%	-6,3%	-3,4%
31/08/2004	-2,5%	-2,9%	0,2%
30/09/2004	6,9%	6,7%	0,9%
31/10/2004	-6,6%	2,3%	1,4%
30/11/2004	3,9%	10,6%	3,9%
31/12/2004	-4,6%	1,0%	3,2%
31/01/2005	6,1%	-1,4%	-2,5%
28/02/2005	2,6%	4,6%	1,9%
31/03/2005	5,4%	0,6%	-1,9%
30/04/2005	-0,6%	-5,2%	-2,0%
31/05/2005	-4,0%	5,6%	3,0%
30/06/2005	3,5%	3,4%	0,0%
31/07/2005	0,1%	6,2%	3,6%
31/08/2005	4,8%	3,5%	-1,1%
30/09/2005	5,7%	4,0%	0,7%
31/10/2005	-4,2%	-5,5%	-1,8%
30/11/2005	-1,0%	4,3%	3,5%
31/12/2005	2,9%	3,0%	-0,1%
31/01/2006	6,1%	9,4%	2,5%
28/02/2006	-6,2%	-5,7%	0,0%
31/03/2006	3,4%	5,2%	1,1%
30/04/2006	-0,7%	0,2%	1,2%
31/05/2006	-4,8%	-6,7%	-3,1%
30/06/2006	-0,1%	-1,6%	0,0%
31/07/2006	-5,0%	-6,4%	0,5%
31/08/2006	-7,8%	-2,5%	2,1%
30/09/2006	-5,0%	-0,3%	2,5%
31/10/2006	-1,5%	4,6%	3,2%
30/11/2006	-2,0%	2,5%	1,6%
31/12/2006	0,1%	-0,2%	1,3%

31/01/2007	2,6%	4,8%	1,4%
28/02/2007	-0,4%	-1,5%	-2,2%
31/03/2007	0,7%	1,5%	1,0%
30/04/2007	2,4%	2,4%	4,3%
31/05/2007	1,8%	3,6%	3,3%
30/06/2007	-3,0%	-0,8%	-1,8%
31/07/2007	-1,0%	-1,5%	-3,2%
31/08/2007	3,4%	-0,8%	1,3%
30/09/2007	2,6%	1,8%	3,6%
31/10/2007	2,7%	1,0%	1,5%
30/11/2007	5,2%	-0,7%	-4,4%
31/12/2007	7,1%	3,3%	-0,9%
31/01/2008	-12,6%	-13,0%	-6,1%
29/02/2008	9,7%	3,5%	-3,5%
31/03/2008	4,6%	-2,1%	-0,6%
30/04/2008	12,6%	12,6%	4,8%
31/05/2008	6,8%	6,7%	1,1%
30/06/2008	16,5%	0,8%	-8,6%
31/07/2008	-12,6%	-10,9%	-1,0%
31/08/2008	-6,7%	-1,6%	1,2%
30/09/2008	-4,3%	-17,6%	-9,1%
31/10/2008	-2,8%	-18,3%	-16,9%
30/11/2008	3,8%	-14,2%	-7,5%
31/12/2008	-24,6%	-9,6%	0,8%
31/01/2009	2,4%	-6,7%	-8,6%
28/02/2009	10,1%	-7,7%	-11,0%
31/03/2009	-18,9%	4,9%	8,5%
30/04/2009	-46,5%	0,8%	9,4%
31/05/2009	-22,4%	-0,3%	5,3%
30/06/2009	4,7%	3,2%	0,0%
31/07/2009	-9,0%	5,4%	7,4%
31/08/2009	-20,8%	-0,1%	3,4%
30/09/2009	-6,0%	4,9%	3,6%
31/10/2009	3,4%	-4,6%	-2,0%
30/11/2009	0,3%	5,7%	5,7%
31/12/2009	1,3%	5,5%	1,8%
31/01/2010	-5,0%	-6,8%	-3,7%
28/02/2010	7,1%	7,9%	2,9%
31/03/2010	3,1%	9,5%	5,9%
30/04/2010	2,9%	2,9%	1,5%
31/05/2010	-0,4%	1,7%	-8,2%
30/06/2010	4,5%	3,1%	-5,4%
31/07/2010	-7,5%	-7,9%	6,9%
31/08/2010	-5,1%	-9,5%	-4,7%
30/09/2010	1,1%	10,0%	8,8%
31/10/2010	-5,5%	-7,4%	3,7%
30/11/2010	6,3%	11,8%	-0,2%
31/12/2010	0,0%	4,2%	6,5%
31/01/2011	-3,1%	0,0%	2,3%
28/02/2011	3,3%	5,6%	3,2%
31/03/2011	1,8%	1,8%	-0,1%
30/04/2011	-3,4%	-0,1%	2,8%
31/05/2011	-2,2%	-1,4%	-1,4%
30/06/2011	2,4%	-0,1%	-1,8%
31/07/2011	0,8%	-2,1%	-2,1%
31/08/2011	2,7%	-7,7%	-5,7%
30/09/2011	-0,9%	-13,2%	-7,2%
31/10/2011	-1,1%	15,4%	10,8%
30/11/2011	0,4%	-1,8%	-0,5%
31/12/2011	0,9%	-1,5%	0,9%
31/01/2012	-7,8%	1,2%	4,4%
29/02/2012	-1,6%	5,3%	4,1%
31/03/2012	3,8%	4,6%	3,1%
30/04/2012	8,3%	3,4%	-0,7%
31/05/2012	8,4%	-5,3%	-6,3%
30/06/2012	-2,8%	1,4%	4,0%
31/07/2012	2,1%	0,5%	1,3%
31/08/2012	-2,0%	3,8%	2,0%
30/09/2012	-1,2%	1,8%	2,4%
31/10/2012	0,5%	-2,6%	-2,0%
30/11/2012	3,2%	1,8%	0,3%
31/12/2012	-4,1%	1,2%	0,7%
31/01/2013	-2,1%	6,3%	5,0%
28/02/2013	1,3%	1,7%	1,1%
31/03/2013	2,6%	5,1%	3,6%
30/04/2013	-0,7%	1,7%	1,8%

31/05/2013	0,0%	4,0%	2,1%
30/06/2013	-1,3%	-4,1%	-1,5%
31/07/2013	2,1%	7,5%	4,9%
31/08/2013	-1,7%	-3,5%	-3,1%
30/09/2013	3,9%	6,2%	3,0%
31/10/2013	2,1%	5,0%	4,5%
30/11/2013	5,4%	4,9%	2,8%
31/12/2013	-1,7%	1,6%	2,4%
31/01/2014	1,6%	-0,7%	-3,6%
28/02/2014	4,3%	8,4%	4,3%
31/03/2014	-4,1%	-1,9%	0,7%
30/04/2014	-4,7%	-2,4%	0,6%
31/05/2014	4,6%	5,3%	2,1%
30/06/2014	0,1%	2,8%	1,9%
31/07/2014	-1,0%	-2,4%	-1,5%
31/08/2014	0,8%	5,1%	3,8%
30/09/2014	0,4%	-2,2%	-1,6%
31/10/2014	-2,9%	-1,9%	2,3%
30/11/2014	2,6%	4,7%	2,5%
31/12/2014	-0,7%	-1,2%	-0,4%
31/01/2015	4,1%	-1,2%	-3,1%
28/02/2015	-1,2%	4,3%	5,5%
31/03/2015	2,4%	1,4%	-1,7%
30/04/2015	-6,7%	-4,3%	0,9%
31/05/2015	6,0%	4,9%	1,0%
30/06/2015	1,3%	-0,6%	-2,1%
31/07/2015	6,6%	2,4%	2,0%
31/08/2015	-1,0%	-5,4%	-6,3%
30/09/2015	5,0%	-1,9%	-2,6%
31/10/2015	-2,3%	6,7%	8,3%
30/11/2015	-0,3%	0,2%	0,1%
31/12/2015	9,5%	-1,2%	-1,8%
31/01/2016	-1,2%	-7,3%	-5,1%
29/02/2016	-2,9%	-0,1%	-0,4%
31/03/2016	-4,3%	5,9%	6,6%
30/04/2016	-3,0%	-1,8%	0,3%
31/05/2016	3,7%	4,5%	1,5%
30/06/2016	7,9%	3,4%	0,1%
31/07/2016	-2,3%	3,0%	3,6%
31/08/2016	-4,8%	-3,4%	-0,1%
30/09/2016	0,3%	0,4%	-0,1%
31/10/2016	-1,7%	-4,0%	-1,9%
30/11/2016	-2,9%	3,9%	3,4%
31/12/2016	0,0%	-0,6%	1,8%