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Magic Formula combined with Long/Short Portfolio Optimization

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Master Thesis in Financial Economics

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Abstract

The Magic Formula is a two factor value investing model, specialized in finding underpriced low risk investment opportunities. This study extends available data until 2015 on the ability for the Magic Formula to rank companies and beat the market. In the updated book the formula delivers 15.2% annualized returns in the period 1988–2009, when investing in the top decile of the largest 2500 companies in the U.S. This thesis finds that the Magic Formula generates 21.6% when invested in decile 1, a result that increases to 24.7% when investing in a 110/10 Market-Neutral Long/Short Portfolio. Long/short value investing gives a lower standard deviation and allows for a better sharpe ratio.

Keywords

Fundamental Analysis, Magic Formula, Value Investing, Factor Models, Behavioral Finance, Hedge Fund, Long/Short, Efficient Market Hypothesis, Adaptive Market Hypothesis, Portfolio Optimization, Inefficient Market, Low Volatility.

Citing

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1. Introduction

A 2009 guest lecture in FIE426 Asset Management by Ole Jakob Wold sparked my interest in multi factor models. Ole Jakob Wold had at that time been using a 60 factor model (Haugen & Baker 1996) to beat the market for 15 years. Alfred Berg Global Quant outperformed in value and growth markets, in small-cap and large-cap markets, in risk seeking and flight-to-quality markets. The talk was so powerful that I right there knew that my master thesis focus would be on factor models.

Later that year I bought “The Little Book That Beats the Market” (Greenblatt 2005), a fascinating book about how two factors called the Magic Formula were able to outperform the multi factor model of Haugen (1996). After having completed two bachelor degrees and a master degree in 2008, which covers the limit for student loans in Norway, I decided to embark on a second master degree august 2008 since my house were in the process of being sold. When financial services firm Lehman Brothers filed for bankruptcy September 15, the largest bankruptcy filing in U.S. history with Lehman holding over $600 billion in assets, it became more uncertain how I would finance my second master degree. Luckily, the financial meltdown caused interest rates in Norway to be reduced by 50%, so that I was able to keep it going at Norwegian School of Economics for 3 semesters. After 29 classes (217.5 ECTS) I were determined to finish my master thesis, so it is with great pride I now have been able to find a reliable data source and replicate the Magic Formula.

1.1 Problem definition

This thesis seeks to explore and analyze the benefits of combining the Magic Formula with Long/Short Portfolio Optimization. Strictly defined, it seeks to shed light on the following research question:

1) Would the Magic Formula combined with Long/Short Portfolio Optimization be able to outperform the former adjusted for risk?

1.2 Thesis outline

In this thesis chapter 2 will form the theoretical foundation. Chapter 3 will describe the method and data source. Results will be presented in chapter 5 followed by a summary in chapter 6.

2. Theory

2.1 Efficiency Market Hypothesis (EMH)

A market in which prices always reflects all accessible information is called an "efficient market" (Fama 1970). In such a market it will not be possible for an investor to beat the benchmark without taking on additional risk. The Efficient Market Hypothesis (EMH) was summarized by Fama (1970) after the hypothesis had gained popularity during the 1960s.

It has since become a fundamental financial theory with the claim that an investor cannot generate a profit with risk-adjusted returns over a longer period of time, since the investor will not be able to exploit information which is not already known in the market. The price of a stock is only influenced by new information, with the exception of market imperfection and institutional limitations (Dimson 1998) like tax and brokerage fee. These price movements are described as a "random walk" since the information is unpredictable. The EMH assumes that actors in the market are rational, liquid markets and that everyone has complete access to all accessible information.

There are three types of market efficiency: Weak, Semi-Strong and Strong EMH. Weak EMH says that stocks prices already reflect all information available through analysis of market data, for instance historical prices, trading volume and interest for short selling. Trend and technical analysis is therefore not a source to generate profits, since this is based on information that is accessible to everyone. Weak EMH says that if it was possible to predict further development in stock prices with basis in historical prices, all investors would have made this discovery and such expectations would already be reflected in the price.

Semi-Strong EMH claims that all publicly accessible information already must be reflected in the stock price. In addition to market data, is also information about accounting data, human capital, patents, etc. already is reflected in the market price. Fundamental analysis of the underlying values within the company will therefore not make any sense, since the analysis would be based on information that is already known in the market.

The strong EMH states that information which insiders in a company have, also is reflected in the stock price, in addition to market data and information about fundamentals. All information is therefore reflected in the stock price, both public information and inside information, so that even insiders with unique information will not systematically be able to generate risk-adjusted profits.

> *Two economists walk down the street and spot a $20 bill. One starts to pick it up, but the other one says: "don't bother; if the bill were real, someone would have picked it up already."*

This joke reflects a paradox in the Efficient Market Hypothesis (EMH) as explained in "On the impossibility of informationally efficient markets" (Grossman & Stiglitz 1980), which says that the market cannot be efficient if nobody analyzed the market.

The Grossman-Stiglitz (1980) paradox generated criticism towards the conservative EMH, which made Fama (1991) release an updated version of his EMH. It says that prices reflect information to the point where the marginal benefits of trading do not exceed the marginal costs (Fama 1991). Therefore, the costs of collecting and analyzing information must be covered for this to be reflected in the stock price.

The critic towards the EMH also stirred curiosity towards how much efficiency there are in the market. Black (1986) developed a hypothesis of both informed and uninformed market players, a discrepancy that is causing trades in the market. Those who correctly analyze and time new information will make money, while those who make mistakes will lose money. The market has a constant flow on new and inexperienced traders, who either learns and flourishes, or are traumatized by their loses and walk away.

2.2 Value Investing

Benjamin Graham wrote The Intelligent Investor (Graham 1949), the original book on value investing. It describes an investment methodology which has worked very well for value investor Warren Buffet. Value investors don't believe in the efficient-market hypothesis, since they believe there are ways of beating the market. Many describe themselves as contrarians, who might buy when others are selling. And vice-versa sell when a stock appears to be over-priced. Value investing is a long-term strategy, often requiring tedious work going through the books to understand the underlying intrinsic value. A basic value investing ratio is the Earning Yield (EY). Earnings yield is simply the inverse of the price earnings multiple. Value investors like stocks with a low earnings multiple and earnings yield is the inverse of that number, so investor like to see a high earnings yield. A high earnings yield tells investors that the stock is able to generate a large amount of earnings relative to the share price. Another trait about value investors is that they buy companies that they understand and typically refrain from speculative behavior. Value investors look at financial reports and study the balance sheet. They calculate for instance the profit margin and compare with the sector average. In summary, value investing is like buying Easter candy the day after Easter, you get the same intrinsic value – and only pay half the price.

2.3 Factor models

A factor model seeks to explain which factors influences stock returns. The Capital Asset Pricing Model (CAPM) is heavily anchored in finance literature and EMH as one of the most used models to calculated expected return when markets are in equilibrium. It builds on the groundbreaking work of Markowitz (1952) in the field of modern portfolio theory. Markowitz introduced us to mean-variance optimization (MVO), and CAPM was later developed by Sharpe (1964), Lintner (1965) and Mossin (1966) as an answer to what would happen if everyone invested according to the portfolio theory of Markowitz. CAPM is a model which use one beta factor, the market, to explain the systematic relationships of returns for a specific stock. Multi factor models incorporate more factors to explain fluctuations in stock prices.

CAPM has some anomalies with regards to value and size, so inspired by the intertemporal version of CAPM (Merton 1973) Fama and French developed a three factor model (1993). It includes in addition to beta, also secondary risk premiums like size (SMB) and value. Small Minus Big (SMB) reflects that small companies have greater returns because they are more risky. High Minus Low (HML) is a Book-to-Market factor, reflecting higher returns for value companies because they have hidden elements of risk that growth companies do not have.

This multi factor model have been criticized for the risk premium for size appearing to have disappeared after becoming known and that the risk premium for value have not been stable since the model was published. It has also been criticized for not capturing the momentum effect and that it in the period 1926–2001 actually has worse performance than CAPM for explaining momentum (Schwert 2003).

2.4 The Adaptive Markets Hypothesis (AMH)

In 2004 a new market theory emerged, postulating a hypothesis which built on the principles of evolution. The theory was given the name “The Adaptive Markets Hypothesis” (AMH) and with it roots in evolutionary psychology and behavioral finance (Lo 2004). Creative destruction refers to the incessant product and process innovation mechanism by which new production units replace outdated ones. It was coined by Joseph Schumpeter (1942), who considered it ‘the essential fact about capitalism’. The process of Schumpeterian creative destruction (restructuring) permeates major aspects of macroeconomic performance, not only long-run growth but also economic fluctuations, structural adjustment and the functioning of factor markets. Schumpeter wanted to develop a new type of economic theory as an alternative to the leading neoclassical equilibrium economics theory. Some of his work includes: *The Theory of Economic Development* (1912), *Business Cycles* (1939) and *Capitalism, Socialism and Democracy* (1942). His first book was clearly influenced by the 3. Kondratiev wave (Kondratiev 1925), which especially from 1892 – 1913 were described as the capitalistic “entrepreneur period” (Sundbo 1995). Schumpeter had a special interest in how combining resources in continuously new ways could create economic change and development.

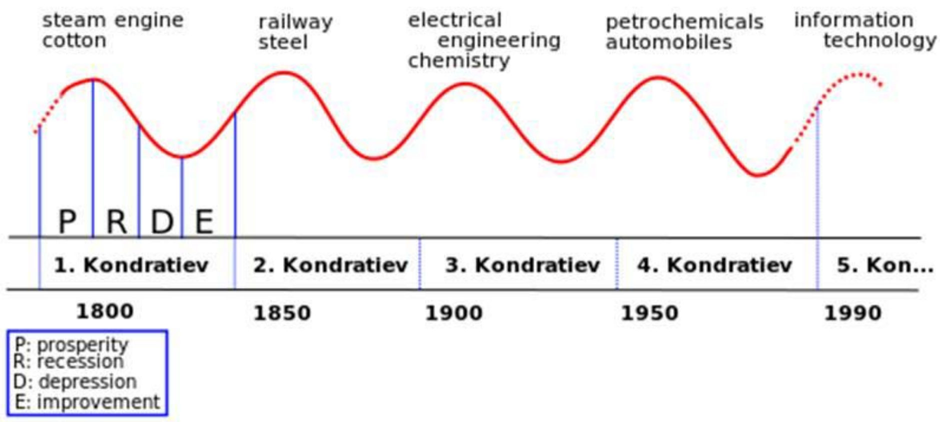

Figure 2.1: *Kondratiev Waves*

Schumpeter defined that development occurs when there is a new combination, and it is the entrepreneur who brings this new combination to market. Schumpeter has with the definition of the term innovation and through his theories made large contributions to a field called evolutionary economics. An evolutionary understanding of economics puts emphasis on cycles of progress and recession, cycles of dominating technologies, crises that are followed by innovation and entrepreneurship, and societal changes which creates losers and winners. When new combinations are introduced, pushed forward by a swarm of entrepreneurs, these innovations can become disruptive, as they outcompete existing businesses. Which brings us back to Darwin's Theory of Evolution by Natural Selection which AMH is based on.

One of the conditions which EMH builds on is that actors in the market are always rational with perfect self-control, never experience remorse, never experience cognitive glitches, etc. In the Behavioral Finance literature, we find numerous examples of the condition for rational market players not being met. As humans we are exposed to at least 50 pitfalls, which are described in the Behavioral Finance literature. AMH simply assumes that humans are normal, considering our biological and evolutionary heritage. Just like Kondratiev Waves (Kondratiev 1925) follow a repeatable pattern, we also find such cycles in the stock market. There is a continuous shift between value markets and growth markets, and bubbles repeatedly form before bursting. While EMH deny the ability to beat the market, AMH says that there are opportunities for those who are able to understand and adapt to the changes in investor preferences. The more data that can be correctly analyzed and understood, the better relative advantage such an informed investor would have. AMH allows for EMH, traditional financial models and models from Behavioral Finance to coexist within the same theoretical framework.

2.5 The Magic Formula

Joel Greenblatt published in 2005 ”The Little Book That Beats the Market” (Greenblatt 2005), a book which explains everything in such detail that his 5 children would be able to understand how to make money themselves. The book describes two factors which he calls The Magic Formula, the basis for ranking companies. First factor is

1. Return on Capital

EBIT / (Net Working Capital + Net Fixed Assets)

The ratio of pre-tax operating earnings (EBIT) to tangible capital employed (Net Working Capital + Net Fixed Assets) is calculated. Second factor is

2. Earnings Yield

EBIT / Enterprise Value

The ratio of pre-tax operating earnings (EBIT) to Enterprise Value (market value of equity + net interest-bearing debt) is calculated.

These ratios are combined to generate a new ranking which define which companies to invest in. The book compares how this simple formula compares with a more sophisticated model using 71 factors developed by Robert Haugen and Nardin Baker (1996). From 1994 through 2004, the market average was 9.38%. Buying the highest ranked stocks (best-ranked decile) based on Haugen’s 71-factor model returned 22.98%. The lowest ranked stocks (worst-ranked decile) actually lost 6.91%. A spread of 30% between best and worst decile.

The magic formula two-factor model did better in the same period. Best-ranked decile returned 24.25%, while worst-ranked decile lost 7.91%. This amounts to a spread from best to worst of more than 32%.

3. Method

The method described in The Little Book That Beats the Market (Greenblatt 2005) has been replicated with a point-in-time dataset covering 2005 – 2015.

3.1 Factor model: Magic Formula

Two factors, *Return on Capital* and *Earning Yield*, are calculated and form the basis for a ranking of all stocks. Greenblatt describe this strategy as a Magic Formula (2005). The point-in-time dataset consist of quarterly fundamentals which are used to calculate the two factors each quarter. Stocks are then ranked and divided into 10 deciles. First decile include 10% best-ranked stocks, while decile 10 consist of the 10% worst-ranked stocks. These deciles are updated each quarter. The portfolio is therefore updated 4 times per year. See appendix for a detailed printout of the output which the program analyzing 7213 files (890 MB) generates.

3.2 Long/Short Portfolio Implementation

A long/short portfolio include twice as many companies each quarter, compared with only going long or only going short. Going long is simply buying shares for holding them in the long run, with a higher price generating a profit. Going short is making money on shares experiencing a decline in value. Typically a short-term investment. Assume that a pension fund is long on Apple. They bought some shares 20 years ago and do not plan to sell them in the immediate future. Instead they can make money by letting investors borrow shares, paying an interest on the value of the shares. Instantly after borrowing shares, you sell them. When returning the shares, if the value has gone down, you make a profit. If the value has increase, you make a loss.

So if it is possible to rank winners and losers into deciles, then it is possible to make more money by both going long in decile 1 and going short in decile 10. Also called a long/short portfolio. Since the fee for going short is small, short-selling companies can actually finance investments in decile 1. This would be described as 100% long and 100% short. Many funds are restricted from short-selling, while hedge funds do not have these restrictions. But market neutral combinations are allowed. So instead of just going 100% long like a normal fund, the addition of going 10% short would finance an additional 10% long. That way, the total becomes 110% long and 10% short (110/10 long/short).

Joel Greenblatt has been operating Gotham Asset Management since 1985, a private investment firm which specialize in long/short value investing. He has funds that are 100% Net Long (170% long – 70% short), Market Neutral, 120% long – 60% short, etc.

If the ranking formula is good, funds which apply long/short strategies should be able to generate higher returns, while bringing down the standard deviation since there is a built-in hedging element. Which combined improves the sharpe ratio.

3.3 Data collection

The original plan was to use S&P Compustat Point in Time for this study, as provided by Wharton Research Data Services (WRDS). But my institution, Norwegian School of Economics, does not subscribe to this dataset. Nor Compustat Snapshot.

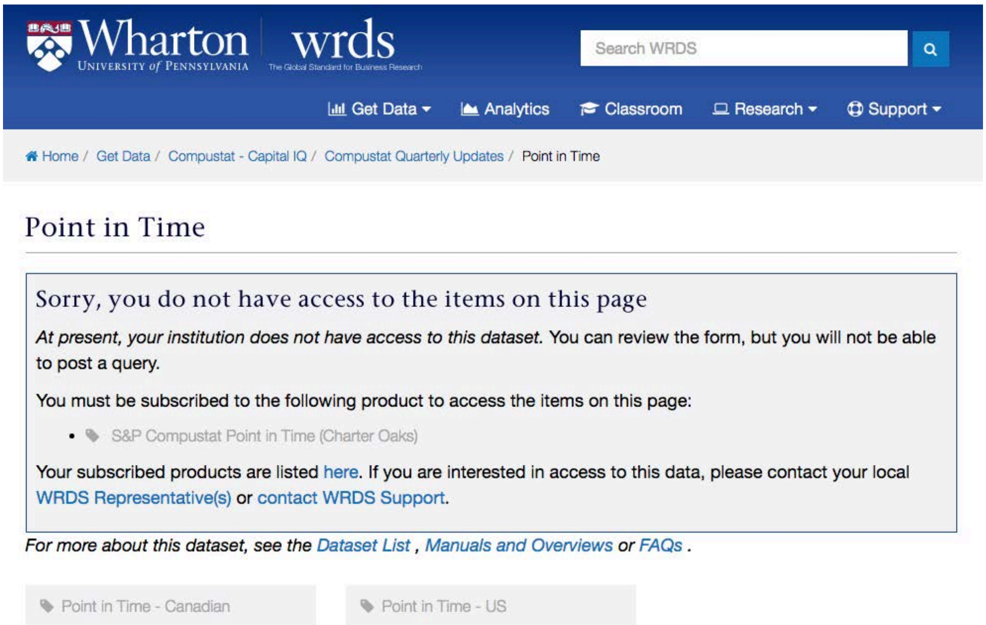

Figure 3.1: *S&P Compustat Point in Time*

Point-in-time data is requirement to eliminate the look-ahead bias. Having determined that there are no free-of-cost options out there, I decided to pay $150 to access Essential Fundamental Data (www.Sharadar.com) for 3 months. Sharadar provides investment-grade US public company fundamental data with 123 fundamental indicators and financial ratios, covering ore than 7.213 companies. Point-in-time dimension available, with time-indexing to the filing date or the fiscal period. Sharadar is an independent research and analytics firm founded in 2013. Sharadar specializes in extraction, standardization and organization of financial data from company filings. Data is collected directly from Securities and Exchange Commission through Form 10-K, and made accessible through Quandl (www.Quandl.com). Quandl is a search engine for numerical data. The site offers access to several million financial, economic and social datasets. Companies of interest have been those with a market capitalization between $50 million and $250 million, as those below have liquidity issues and those above are more likely to be correctly priced.

3.4 Portfolio Evaluation: Sharpe Ratio

When Nobel laureate William Sharpe (1964) participated in the development of the Capital Asset Pricing Model (CAPM), he needed to develop a standardized measurement of risk-adjusted returns. The Sharpe ratio is the average return earned in excess of the risk-free rate per unit of volatility or total risk. Sharpe ratio is calculated with this formula:

$$S = \frac{E(r_p) - r_f}{\sigma_p}$$

S = Sharpe ratio, $E(r_p)$ = Mean portfolio return, r_f = Risk-free rate, σ_p = Standard deviation of portfolio return. Higher Sharpe ratio indicates a better performance than other portfolios adjusted for risk.

4. Analysis and empirical results

In this chapter results of the Magic Formula ranking is presented. Each quarter the ranking is updated, creating 10 deciles with 10% of the companies in each decile. Highest ranked stocks (best-ranked decile) are put in decile 1 while the lowest ranked stocks (worst-ranked decile) are put in decile 10. Each decile starts with $1. Throughout 40 quarters (10 years) returns are accumulated for each decile. After 10 years there might be a net profit, or a loss.

4.1 10 Deciles with Magic Formula ranking

Figure 4.1 below demonstrates a nice distribution of decile 1 as best performing and decile 10 as worst performing. This is a strong indication that the Magic Formula ranking is working as intended. The figure is presented in logarithmic scale to better illustrate the relative performance of each decile.

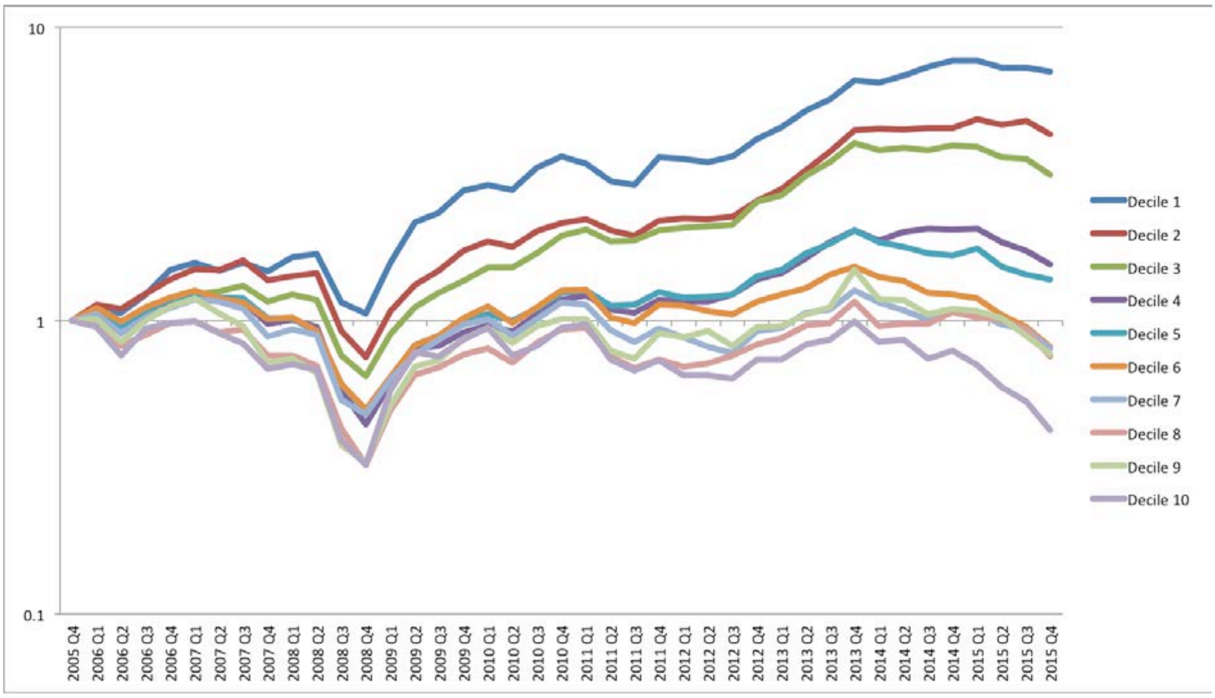

Figure 4.1: *Accumulated returns for 10 Deciles 2006 – 2015. Logarithmic scale.*

Table 4.1 below also show annualized returns, standard deviation and sharpe ratio. We find that decile 1 has the best sharpe ratio while decile 10 has the worst sharpe ratio.

	Accumulated	Annual Returns	Standard Deviation	Sharpe ratio
Decile 1	7.05	21.57%	13.40%	1.54
Decile 2	4.31	15.73%	12.63%	1.17
Decile 3	3.14	12.11%	12.11%	0.92
Decile 4	1.56	4.52%	12.98%	0.27
Decile 5	1.38	3.29%	11.89%	0.19
Decile 6	0.82	-2.01%	12.61%	-0.24
Decile 7	0.81	-2.13%	13.18%	-0.24
Decile 8	0.76	-2.73%	15.56%	-0.24
Decile 9	0.77	-2.57%	17.71%	-0.20
Decile 10	0.43	-8.20%	19.33%	-0.48

Table 4.1: *Accumulated Return, Annual Returns, Std.Dev. and Sharpe ratio*

Figure 4.2 below show the standard deviation for each decile with the lowest standard deviation in decile 5. Decile 5 has annual returns closest to 0% so that is as expected. The Magic Formula is able to pick stocks for the high-ranking deciles without a significant increase in risk, which results in a high sharpe ratio for decile 1. Which is in strong contrast to the findings of Bergeng (2012), which has the second highest standard deviation in his best decile (24.94%), behind the worst decile at 28.36%. Bergeng landed on 53 factors while replicating the multifactor model of Haugen (1996). His best decile has a sharpe ratio of .95 (compared to 1.54 in decile 1), while the worst decile has a sharpe ratio of -0.16 (with decile 10 at -0.48). Which indicates that the two-factor magic formula is able to outperform 53 factors, confirming findings Greenblatt (2005) found when comparing results with Haugen (1996).

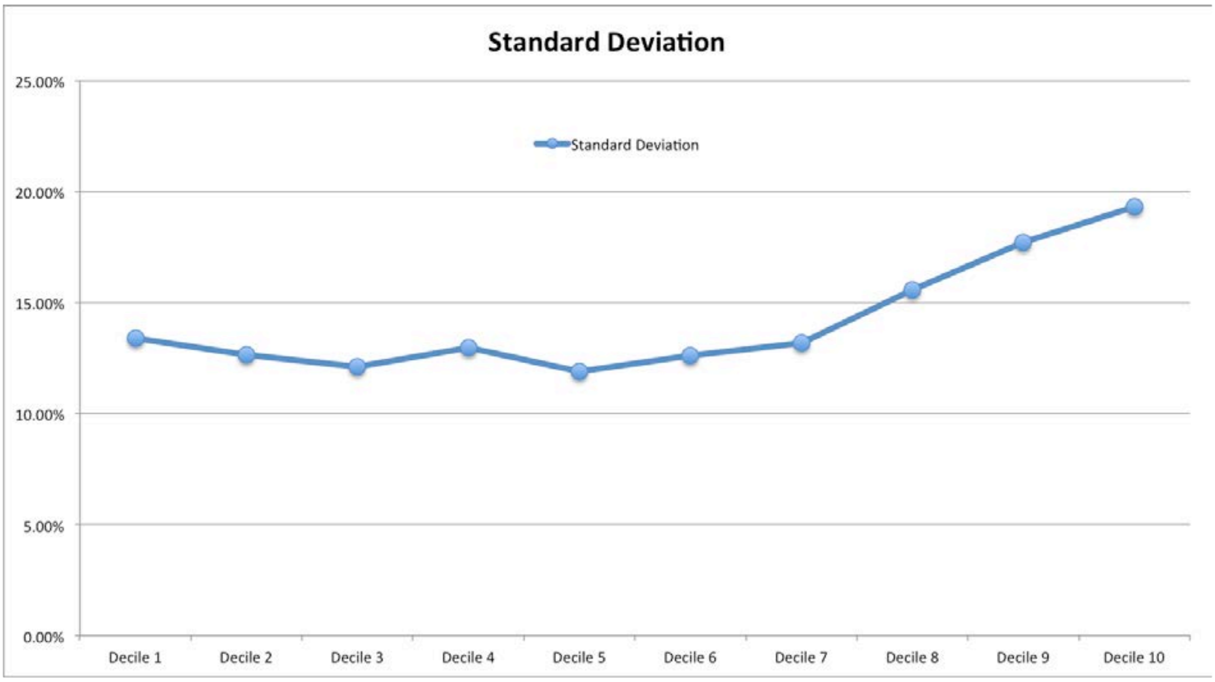

Figure 4.2: *Standard Deviation for each Decile in the period 2006 – 2015.*

4.2 Magic Formula Decile 1

Figure 4.3 shows the accumulated development of decile 1 compared to our benchmark.

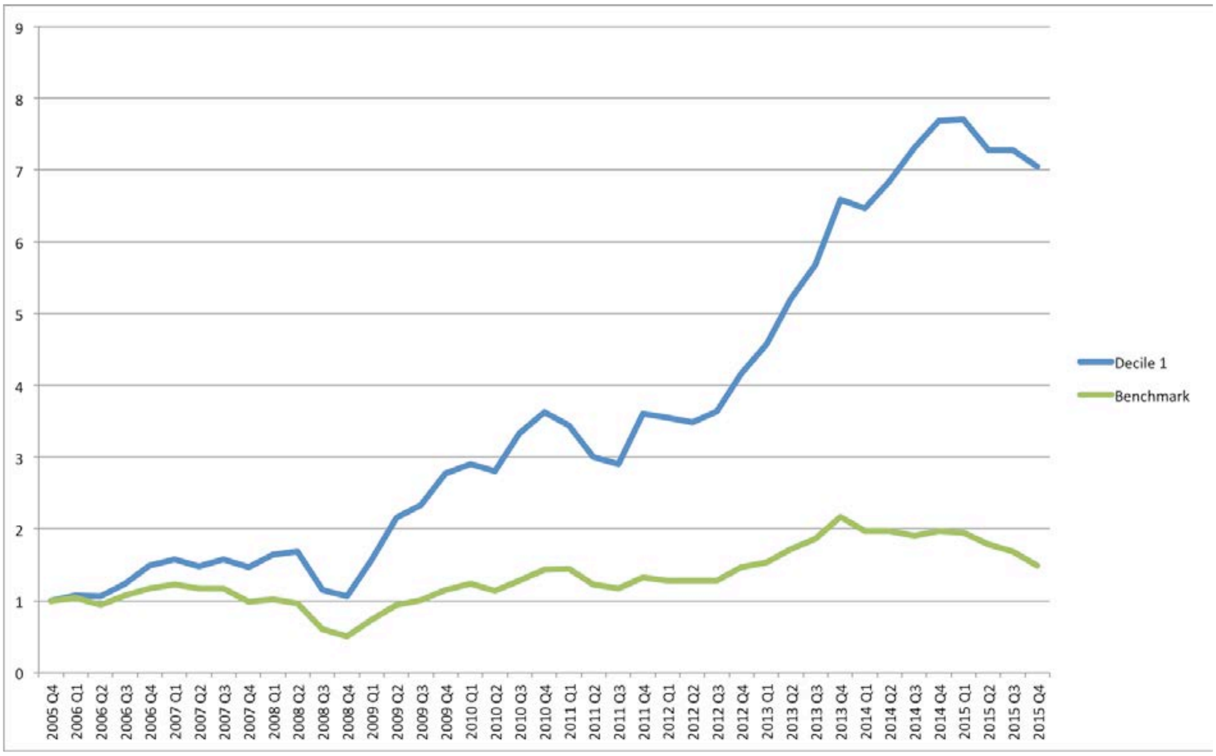

Figure 4.3: *Accumulated returns for Decile 1 and Benchmark 2006 – 2015.*

Table 4.2 shows that decile 1 is able to generate higher annualized returns than the benchmark, giving a dramatically better sharpe ratio compared to being invested in the index.

	Accumulated	Annual Returns	Standard Deviation	Sharpe ratio
Decile 1	7.05	21.57%	13.40%	1.54
Benchmark	1.49	4.05%	13.59%	0.22

Table 4.2: *Accumulated Return, Annual Returns, Std.Dev. and Sharpe ratio*

4.3 110/10 Market-Neutral Long/Short Portfolio

Figure 4.4 shows accumulated returns for decile 1, decile 10, benchmark and a 110/10 long/short portfolio. The long/short is invested long 110% in decile 1, which is offset by going short 10% in decile 10. This is called a market-neutral strategy where the dollar amounts of the long and short positions are equal. I first learned about this strategy in FIE426 Asset Management when Ole Jakob Wold gave a guest lecture in 2009, the first year of my master degree, hidden well in the appendix of his slides. Wold has been working with multifactor models since 1994, and found that adding a Market Neutral to Global Quant the sharpe and information ratio increased while retaining much the same standard deviation.

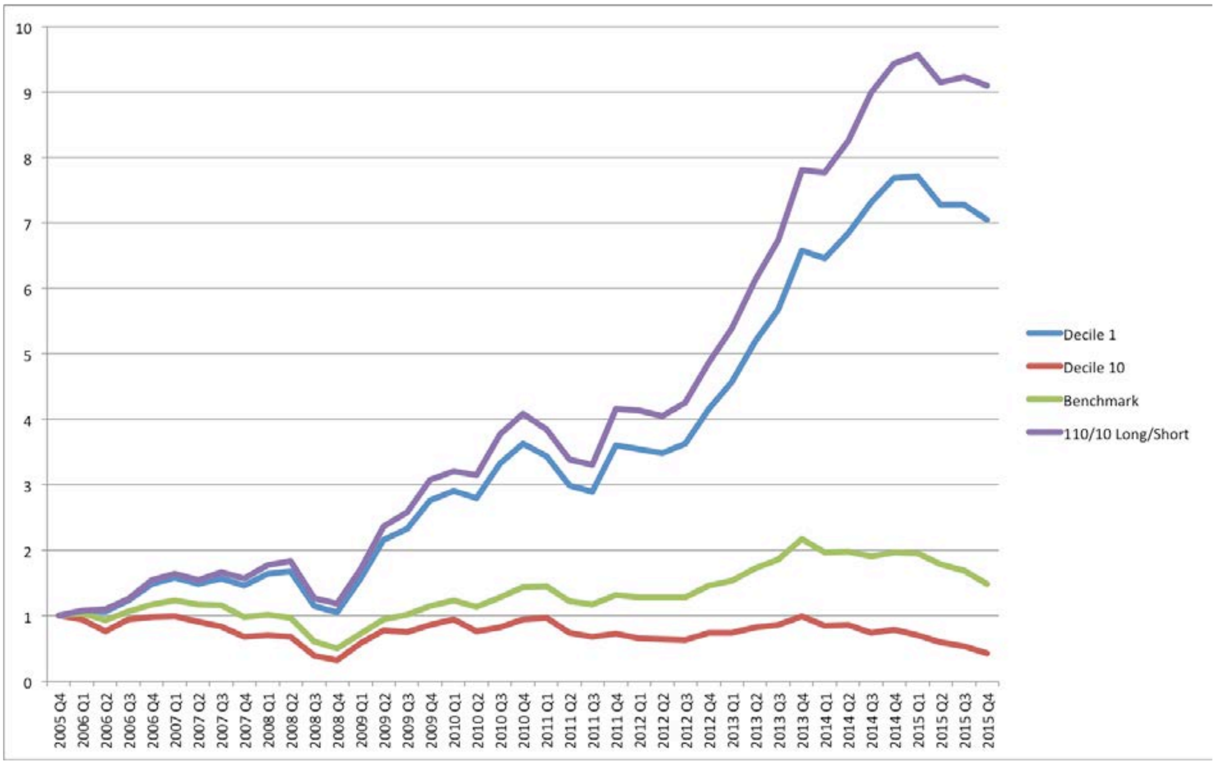

Figure 4.4: *Accumulated returns for Decile 1, Decile 10, 110/10 Long/Short and Benchmark 2006 – 2015.*

Figure 4.5 below shows accumulated returns for decile 1, decile 10, benchmark and a 110/10 long/short portfolio in logarithmic scale.

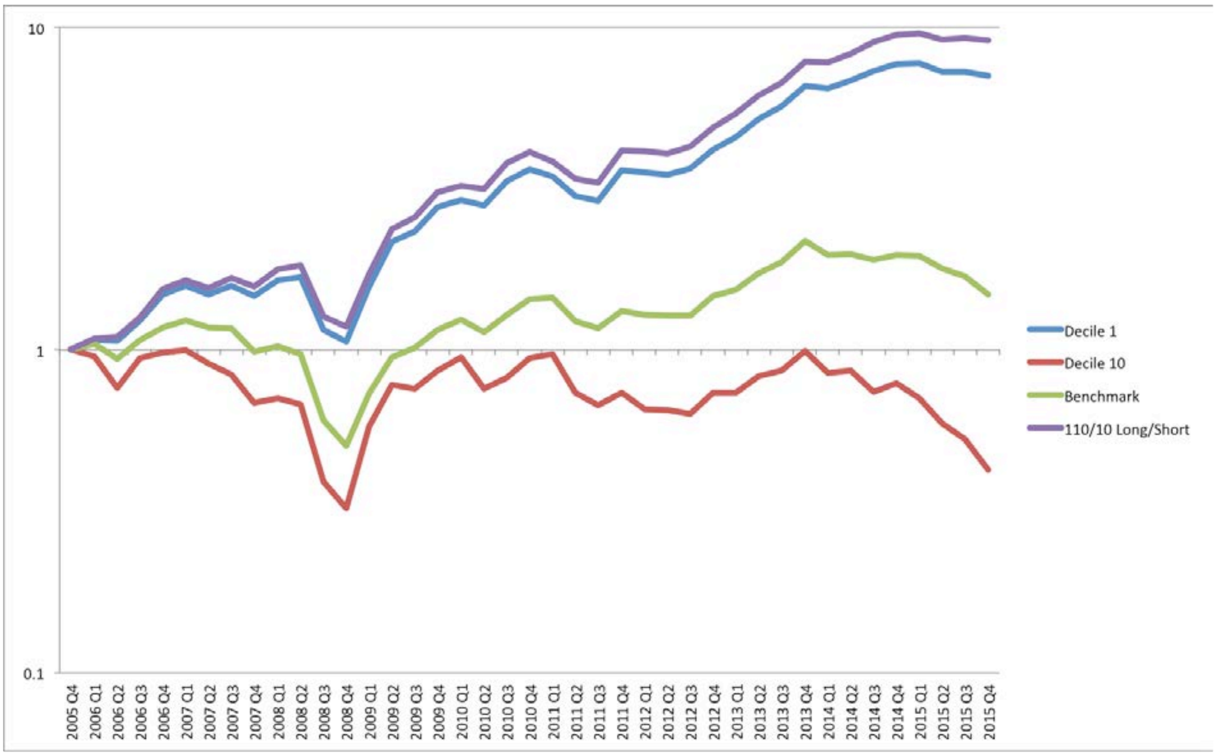

Figure 4.5: *Accumulated returns for Decile 1, Decile 10, 110/10 Long/Short and Benchmark 2006 – 2015. Logarithmic Scale.*

Bergeng found in his thesis (2012) that his market neutral long/short portfolio generated a higher standard deviation (27.55%) than decile 1 (24.94%) without being able to generate higher returns. This resulted in a lower sharpe ratio (0.89) for the long/short portfolio compared with decile 1 (0.95). The 110/10 market-neutral long/short portfolio is on the other hand able to deliver higher annualized returns, with a lower standard deviation and a higher sharpe ratio as illustrated in Table 4.3 below.

	Accumulated	Annual Returns	Standard Deviation	Sharpe ratio
Decile 1	7.05	21.57%	13.40%	1.54
Decile 10	0.43	-8.20%	19.33%	-0.48
Benchmark	1.49	4.05%	13.59%	0.22
110/10 Long/Short	9.10	24.71%	13.02%	1.82

Table 4.3: *Accumulated Return, Annual Returns, Std.Dev. and Sharpe ratio for Decile 1, Decile 10, 110/10 Long/Short and Benchmark 2006 – 2015.*

4.4 Backtesting pitfalls

When backtesting trading strategies it is important to be aware of the pitfalls which cause biases in the results and skew the outcome. Backtesting is no value if the underlying premise is false. This thesis builds on a widely published method described in detail through a book (Greenblatt 2005) which sold 300 000 copies, which has undergone rigorous testing before publication by the author who has been operating a private investment partnership since 1985.

Look-ahead bias

One of the biggest issues when backtesting occurs when doing a simulation on data not yet made public at the time of prediction about the future. Studies with this look-ahead bias will be able to beat the benchmark by using information not available at the time of investment. A real challenge for doing this study properly has been to secure Point-in-Time data. An inquiry to S&P Global Market Intelligence revealed that an academic license to access Compustat Point-in-Time data through their delivered via our Xpressfeed platform would cost $13 000 (per October 2016), which is out of budget for a student.

Survivorship bias

If companies systematically become eliminated from a database, it is fair to say that the database suffers from survivorship bias. Backtesting with survivorship bias will therefore induce artificially higher results, since the database has been cleaned up. This study utilized a Point-in-Time database from Sharadar, which includes data ”As Reported”. The data therefore reflects information accessible at any point in time, with no post-modification.

Transaction costs

Yearly returns of 21.57% with quarterly updates to the portfolio will certainly not experience a signification reduction when deducting transaction costs. The long/short portfolio would make the portfolio larger, but that doesn’t necessarily mean significantly higher transaction costs. The Tiered Pricing Structure at Interactive Brokers is based on a commission per share, with low volume (per month) priced at USD 0.0035 and high volume at USD 0.0005. Which means that companies with a low share price would generate higher transaction costs. These companies can easily be excluded from the dataset should transaction costs become unreasonably high. Transaction costs are in any case capped at 0.5%. Which suggest that the 110/10 long/short portfolio with an annual return of 24.71% should still outperform decile 1 after correcting for transaction costs.

5. Summary and conclusion

Shortly after I started my finance studies at Norwegian School of Economics in 2008 the world experienced a credit crunch. Worst financial crisis in recent history. A collapse which should not be possible in an efficient market. It was clear to me that financial theory didn't match reality. Classes like Behavioral Finance and books like The Black Swan: The Impact of the Highly Improbable (Taleb 2007) gave me a better understanding of market psychology, and theories like Adoptive Market Hypothesis (AMH) made more sense than EMH. In 2010 Greenblatt released The Little Book That Still Beats the Market (Greenblatt 2010), explaining that the S&P 500 index is down the past decade. Something was seriously wrong with the market, but strategies like the Magic Formula gave hope for an alternative to passive index investing. So I set course to replicate the investment strategy and investigate if a long/short portfolio would improve risk-adjusted returns.

5.1 Summary

According to EMH it is not possible to beat the market. Still, there is a little book that does it. And there is an updated book that still does it. My study confirms that the Magic Formula still works. It has been interesting to observe in the data that the 2nd worst quarter for decile 1 came in 2011, shortly after the second book was released. At that time www.MagicFormulaInvesting.com had been made publicly available, so that anyone could find out which companies had top ranking. Greenblatt mentions in his second book (2010) that he received a lot of feedback with inquires about making a long/short portfolio, to which he responded that annualized returns from 1988–2009 would indeed increase. By 0.2%. Annualized returns in decile 1 increased from 15.2% to 15.4%. A 100/100 long/short combination. Joel Greenblatt says: "By being long and short at the same time, you can minimize your risks, still make lots of money, and you won't have to worry about whether the market goes up or down" (2010). There is a catch though. All money (100%) would be lost somewhere during year 2000. Which doesn't quite make sense, since his private investment management firm exclusively does various combinations of long/short funds. I get the feeling that there is something Joel Greenblatt doesn't want to spell out in plain text, which give rise to my research question:

1) Would the Magic Formula combined with Long/Short Portfolio Optimization be able to outperform the former adjusted for risk?

I find that the 110/10 long/short portfolio generates a 3.14% higher annualized return compared with a pure long investment in decile 1. That wouldn't be all that impressive in itself if overall risk in the portfolio were bigger. But the opposite is the case. Standard deviation is lower and sharpe ratio is higher. So it is safe to say that the long/short portfolio outperforms decile 1 adjusted for risk.

EMH says that if a long/short portfolio optimization using publicly known information cannot outperform the market adjusted for risk, as other investors else would already have done it until all potential for profits would be gone. My study confirms that it is still possible to beat the market with an adaptive strategy. The configuration of the Magic Formula used in this study adapts to changes in the market once a quarter allowing for a portfolio to be constructed with the ability to beat our benchmark. A long/short constellation further improves risk-adjusted returns. A strategy that adapts to preferences of investors would provide support for the Adaptive Market Hypothesis (AMH), but there are not enough factors in this study to make such a claim. The Magic Formula is a two factor value investing model, specialized in finding low risk investment opportunities. Low risk stocks have been found to outperform the market (Baker & Haugen 2012).

5.2 Conclusion

Even after two books (Greenblatt 2005; 2010), selling hundreds of thousands of books, the Magic Formula is still able to beat the market. This two-factor formula is a value investing model. It specializes in finding underpriced companies which has high pre-tax operating earnings compared to tangible capital employed and company value. In an efficient market the profit potential is supposed to become diluted when the opportunity for making money enters public domain. When dividing decile 1 in two, the data reveals that the first half actually underperforms the second half by 3.4%. What Asness (2016) calls a "factor crash" seems to have happened a quarter in 2011 shortly after the second book were released (Greenblatt 2010), when first half of decile 1 experienced a 21% decline (just 10% behind worst quarter in 2008) compared to a 6% drop for the second half of decile 1. It appears that there has been a shift towards the second half of decile 1, as it has outperformed measured by sharpe ratio since that disastrous quarter. This indicates some efficiency in the market, but the formula performs so well that it is barely noticeable.

5.3 Recommendations for Future Research

The website of Gotham Asset Management shown great creativity when it comes to various long/short constellations. By calculating for instance sharpe ratio and information ratio, it is possible to arrive at other combinations of long/short that might give better returns adjusted for risk. It would be interesting to extend this research with methods from artificial intelligence to arrive at the optimal long/short ratio in this 10-year period, while maintaining great attention to avoid over-fitting.

The performance is comparable to the multi factor model of Haugen (1996), so the Magic Formula can quite possibly be improved by adding more factors.

6. References

Asness, C. S. (2016). *My Factor Philippic*. Available at SSRN 2799441.

Baker, N. L., & Haugen, R. A. (2012). *Low risk stocks outperform within all observable markets of the world*. Available at SSRN 2055431.

Bergeng, John Eivind (2012). *Relativ aksjeavkastning: Endringer og trender i markedsaktørenes relative aksjepreferanser*. Master Thesis. Norwegian School of Economics.

Black, F. (1986). *Noise*. Journal of Finance, 41(3), 529-543.

Dimson, E. (1988). *Stock market anomalies*. Journal of Finance, 44(3), 295-325.

Fama, Eugene F. (1970). *Efficient Capital Markets: A Review of Theory and Empirical Work*. Journal of Finance, 25(1), 383-417.

Fama, E. F. (1991). *Efficient Capital Markets: II*. The Journal of Finance, 46(5), 1575-1671.

Fama, E. F. & French, K. R. (1993). *Common risk factors in the returns on stocks and bonds*. Journal of Financial Economics, 33(1), 3-56.

Graham, B. (1949). *The Intelligent Investor*. HarperBusiness.

Greenblatt, Joel (2005). *The little book that beats the market*. John Wiley & Sons.

Greenblatt, Joel (2010). *The little book that still beats the market*. John Wiley & Sons.

Grossman, S. & Stiglitz, J. (1980). *On the impossibility of informationally efficient markets*. American Economic Review, 70(4), 393-408.

Haugen, Robert A., & Baker, Nardin L. (1996). *Commonality in the determinants of expected stock returns*. Journal of Financial Economics, 41(3), 401-439.

Kondratiev, N. D. (1925). *The major economic cycles*. Voprosy Konjunktury, 1(1), 28-79.

Lintner, J. (1965). *The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets*. The Review of Economic and Statistics, 47(1), 13-37.

Lo, Andrew W. (2004). *The Adaptive Markets Hypothesis*. Journal of Portfolio Management, 30(5), 15-29.

Markowitz, H. (1952). *Portfolio Selection*. The Journal of Finance, 7(1), 77-91.

Merton, Robert C. (1973). *An Intertemporal Capital Asset Pricing Model*. Econometrica, 41(5), 867-887.

Mossin, J. (1996). *Equilibrium in Capital Asset Market*. Econometrica, 34(4), 768-783.

Schumpeter, J. A. (1912). *Theorie der wirtschaftlichen Entwicklung. (The Theory of Economic Development)*. Leipzig: Duncker & Humblot.

Schumpeter, J. A. (1939). *Business cycles: a theoretical, historical, and statistical analysis of the capitalist process*. McGraw-Hill.

Schumpeter, J. A. (1942). *Capitalism, Socialism, and Democracy*. New York: Harper & Bros.

Schwert, G. W. (2003). *Anomalies and market efficiency*. Handbook of the Economics of Finance, in: G.M. Constantinides & M. Harris & R. M. Stulz (ed.), Handbook of the Economics of Finance, edition 1, volume 1, chapter 15, pp. 939-974 Elsevier.

Sharpe, W. F. (1964). *Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk*. The Journal of Finance, 17(4), 425-442.

Sundbo, J. (1995). *Innovasjonsteori - tre paradigmer*. Gentofte: Jurist- og Økonomforbundets Forlag.

Taleb, N. N. (2007). *The black swan: The impact of the highly improbable*. Penguin.

7. Appendix

The following sections show the output generated by the program. Quarterly reports are color coded with blue on quarters that generate a positive return, and red for those quarters which has a negative return based on calculated mean. Median is also calculated, as well as standard deviation and sharpe ratio for each quarter. One decile is always 10% of the benchmark, which the first quarter is 58 companies. From a universe of 7213 companies, those with a market cap below \$50 and above \$250 are excluded. Companies with data missing for calculating the two factors, Earnings Yield and Return on Capital, are also excluded. Which gives a decent sized portfolio of 58 companies first quarter. The highest number of companies in any decile during the period is 83.

Portfolio history shows mean for the entire period per quarter, accumulated returns, annualized returns, median for the entire period updated each quarter, standard deviation, sharpe ratio, total number of companies throughout the lifetime of the fund and how many quarters the fund has been operational (out of a total of 40).

The last printout is the annualized return last four quarters, updated each quarter. This give a better indication of how the fund has performed the past year, before in the last line calculating the mean, median, standard deviation, best rolling year and max drawdown.

7.1 Magic Formula Decile 1

```
*** agent quarterly reports (portfolioRankLong = [0]) ***
2005-12-31 : mean = 1.0707, median = 1.0521, std = 0.2129, sharpe = 4.9824, size = 58
2006-03-31 : mean = 0.9961, median = 0.9967, std = 0.1840, sharpe = 5.3585, size = 62
2006-06-30 : mean = 1.1555, median = 1.1423, std = 0.2560, sharpe = 4.4753, size = 68
2006-09-30 : mean = 1.2066, median = 1.1305, std = 0.5359, sharpe = 2.2329, size = 64
2006-12-31 : mean = 1.0614, median = 1.0123, std = 0.3006, sharpe = 3.4978, size = 62
2007-03-31 : mean = 0.9393, median = 0.9466, std = 0.2433, sharpe = 3.8197, size = 64
2007-06-30 : mean = 1.0641, median = 1.0146, std = 0.2838, sharpe = 3.7135, size = 69
2007-09-30 : mean = 0.9309, median = 0.9335, std = 0.2650, sharpe = 3.4753, size = 73
2007-12-31 : mean = 1.1218, median = 1.0698, std = 0.3022, sharpe = 3.6788, size = 83
2008-03-31 : mean = 1.0223, median = 1.0086, std = 0.2474, sharpe = 4.0924, size = 83
2008-06-30 : mean = 0.6840, median = 0.6277, std = 0.2887, sharpe = 2.3349, size = 78
2008-09-30 : mean = 0.9194, median = 0.8816, std = 0.4069, sharpe = 2.2351, size = 81
2008-12-31 : mean = 1.4837, median = 1.3539, std = 0.5959, sharpe = 2.4729, size = 83
2009-03-31 : mean = 1.3751, median = 1.2222, std = 0.6366, sharpe = 2.1444, size = 83
2009-06-30 : mean = 1.0794, median = 1.0223, std = 0.3504, sharpe = 3.0524, size = 80
2009-09-30 : mean = 1.1872, median = 1.1445, std = 0.3142, sharpe = 3.7466, size = 81
2009-12-31 : mean = 1.0498, median = 1.0034, std = 0.2289, sharpe = 4.5423, size = 79
2010-03-31 : mean = 0.9634, median = 0.9800, std = 0.1871, sharpe = 5.0967, size = 77
2010-06-30 : mean = 1.1907, median = 1.1272, std = 0.3316, sharpe = 3.5602, size = 78
2010-09-30 : mean = 1.0880, median = 1.0526, std = 0.3657, sharpe = 2.9476, size = 75
2010-12-31 : mean = 0.9473, median = 0.9580, std = 0.2635, sharpe = 3.5567, size = 75
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2011-03-31 : mean = 0.8723, median = 0.8913, std = 0.2211, sharpe = 3.9001, size = 71
2011-06-30 : mean = 0.9677, median = 0.9668, std = 0.2057, sharpe = 4.6568, size = 72
2011-09-30 : mean = 1.2431, median = 1.1685, std = 0.4534, sharpe = 2.7199, size = 71
2011-12-31 : mean = 0.9849, median = 0.9468, std = 0.2728, sharpe = 3.5738, size = 68
2012-03-31 : mean = 0.9808, median = 0.9846, std = 0.2390, sharpe = 4.0620, size = 70
2012-06-30 : mean = 1.0436, median = 0.9994, std = 0.2826, sharpe = 3.6569, size = 66
2012-09-30 : mean = 1.1461, median = 1.1148, std = 0.3625, sharpe = 3.1341, size = 65
2012-12-31 : mean = 1.0966, median = 1.0568, std = 0.2529, sharpe = 4.2961, size = 64
2013-03-31 : mean = 1.1385, median = 1.1397, std = 0.2591, sharpe = 4.3553, size = 62
2013-06-30 : mean = 1.0913, median = 1.0405, std = 0.3900, sharpe = 2.7727, size = 58
2013-09-30 : mean = 1.1600, median = 1.0893, std = 0.4490, sharpe = 2.5613, size = 57
2013-12-31 : mean = 0.9817, median = 0.9401, std = 0.2266, sharpe = 4.2884, size = 56
2014-03-31 : mean = 1.0587, median = 1.0523, std = 0.2203, sharpe = 4.7598, size = 60
2014-06-30 : mean = 1.0682, median = 1.0402, std = 0.3419, sharpe = 3.0946, size = 62
2014-09-30 : mean = 1.0512, median = 1.0000, std = 0.3450, sharpe = 3.0178, size = 61
2014-12-31 : mean = 1.0030, median = 0.9945, std = 0.1913, sharpe = 5.1908, size = 60
2015-03-31 : mean = 0.9446, median = 0.9632, std = 0.2770, sharpe = 3.3743, size = 60
2015-06-30 : mean = 0.9992, median = 0.9580, std = 0.2287, sharpe = 4.3246, size = 58
2015-09-30 : mean = 0.9693, median = 0.9414, std = 0.2657, sharpe = 3.6111, size = 59

*** portfolio history ***
2005-12-31 : mean = 1.0707 (accu. = 1.0707, annu. = 1.3142), median = 1.0707, std = 0.0000,
sharpe = inf, size = 58, quarters = 1
2006-03-31 : mean = 1.0334 (accu. = 1.0665, annu. = 1.1375), median = 1.0334, std = 0.0373,
sharpe = 3.4193, size = 120, quarters = 2
2006-06-30 : mean = 1.0741 (accu. = 1.2324, annu. = 1.3213), median = 1.0707, std = 0.0651,
sharpe = 4.7808, size = 188, quarters = 3
2006-09-30 : mean = 1.1072 (accu. = 1.4870, annu. = 1.4870), median = 1.1131, std = 0.0804,
sharpe = 5.9294, size = 252, quarters = 4
2006-12-31 : mean = 1.0981 (accu. = 1.5783, annu. = 1.4407), median = 1.0707, std = 0.0742,
sharpe = 5.8001, size = 314, quarters = 5
2007-03-31 : mean = 1.0716 (accu. = 1.4825, annu. = 1.3001), median = 1.0661, std = 0.0900,
sharpe = 3.2243, size = 378, quarters = 6
2007-06-30 : mean = 1.0705 (accu. = 1.5774, annu. = 1.2975), median = 1.0641, std = 0.0834,
sharpe = 3.4494, size = 447, quarters = 7
2007-09-30 : mean = 1.0531 (accu. = 1.4684, annu. = 1.2118), median = 1.0627, std = 0.0906,
sharpe = 2.2270, size = 520, quarters = 8
2007-12-31 : mean = 1.0607 (accu. = 1.6473, annu. = 1.2484), median = 1.0641, std = 0.0881,
sharpe = 2.7052, size = 603, quarters = 9
2008-03-31 : mean = 1.0569 (accu. = 1.6841, annu. = 1.2318), median = 1.0627, std = 0.0844,
sharpe = 2.6286, size = 686, quarters = 10
2008-06-30 : mean = 1.0230 (accu. = 1.1520, annu. = 1.0528), median = 1.0614, std = 0.1340,
sharpe = 0.3193, size = 764, quarters = 11
2008-09-30 : mean = 1.0143 (accu. = 1.0592, annu. = 1.0193), median = 1.0419, std = 0.1315,
sharpe = 0.0711, size = 845, quarters = 12
2008-12-31 : mean = 1.0505 (accu. = 1.5715, annu. = 1.1492), median = 1.0614, std = 0.1778,
sharpe = 0.7832, size = 928, quarters = 13
2009-03-31 : mean = 1.0736 (accu. = 2.1610, annu. = 1.2463), median = 1.0627, std = 0.1906,
sharpe = 1.2396, size = 1011, quarters = 14
2009-06-30 : mean = 1.0740 (accu. = 2.3325, annu. = 1.2534), median = 1.0641, std = 0.1842,
sharpe = 1.3217, size = 1091, quarters = 15
2009-09-30 : mean = 1.0811 (accu. = 2.7692, annu. = 1.2900), median = 1.0674, std = 0.1804,
sharpe = 1.5521, size = 1172, quarters = 16
2009-12-31 : mean = 1.0793 (accu. = 2.9071, annu. = 1.2854), median = 1.0641, std = 0.1752,
sharpe = 1.5724, size = 1251, quarters = 17
2010-03-31 : mean = 1.0728 (accu. = 2.8007, annu. = 1.2572), median = 1.0627, std = 0.1723,
sharpe = 1.4346, size = 1328, quarters = 18
2010-06-30 : mean = 1.0790 (accu. = 3.3347, annu. = 1.2886), median = 1.0641, std = 0.1697,
sharpe = 1.6413, size = 1406, quarters = 19
2010-09-30 : mean = 1.0795 (accu. = 3.6281, annu. = 1.2940), median = 1.0674, std = 0.1655,
sharpe = 1.7165, size = 1481, quarters = 20
2010-12-31 : mean = 1.0732 (accu. = 3.4369, annu. = 1.2651), median = 1.0641, std = 0.1639,
sharpe = 1.5564, size = 1556, quarters = 21
2011-03-31 : mean = 1.0640 (accu. = 2.9980, annu. = 1.2209), median = 1.0627, std = 0.1655,
sharpe = 1.2745, size = 1627, quarters = 22
2011-06-30 : mean = 1.0599 (accu. = 2.9012, annu. = 1.2035), median = 1.0614, std = 0.1631,
sharpe = 1.1867, size = 1699, quarters = 23
2011-09-30 : mean = 1.0675 (accu. = 3.6065, annu. = 1.2384), median = 1.0627, std = 0.1638,
sharpe = 1.3944, size = 1770, quarters = 24
2011-12-31 : mean = 1.0642 (accu. = 3.5522, annu. = 1.2248), median = 1.0614, std = 0.1613,
sharpe = 1.3321, size = 1838, quarters = 25
2012-03-31 : mean = 1.0610 (accu. = 3.4839, annu. = 1.2117), median = 1.0556, std = 0.1590,
sharpe = 1.2689, size = 1908, quarters = 26
2012-06-30 : mean = 1.0603 (accu. = 3.6357, annu. = 1.2107), median = 1.0498, std = 0.1560,
```

```
sharpe = 1.2866, size = 1974, quarters = 27
2012-09-30 : mean = 1.0634 (accu. = 4.1667, annu. = 1.2261), median = 1.0556, std = 0.1540,
sharpe = 1.4032, size = 2039, quarters = 28
2012-12-31 : mean = 1.0645 (accu. = 4.5693, annu. = 1.2331), median = 1.0614, std = 0.1515,
sharpe = 1.4731, size = 2103, quarters = 29
2013-03-31 : mean = 1.0670 (accu. = 5.2022, annu. = 1.2459), median = 1.0627, std = 0.1495,
sharpe = 1.5779, size = 2165, quarters = 30
2013-06-30 : mean = 1.0678 (accu. = 5.6774, annu. = 1.2512), median = 1.0641, std = 0.1472,
sharpe = 1.6388, size = 2223, quarters = 31
2013-09-30 : mean = 1.0707 (accu. = 6.5857, annu. = 1.2657), median = 1.0674, std = 0.1457,
sharpe = 1.7546, size = 2280, quarters = 32
2013-12-31 : mean = 1.0680 (accu. = 6.4653, annu. = 1.2539), median = 1.0641, std = 0.1443,
sharpe = 1.6900, size = 2336, quarters = 33
2014-03-31 : mean = 1.0677 (accu. = 6.8445, annu. = 1.2539), median = 1.0627, std = 0.1422,
sharpe = 1.7158, size = 2396, quarters = 34
2014-06-30 : mean = 1.0677 (accu. = 7.3112, annu. = 1.2553), median = 1.0641, std = 0.1401,
sharpe = 1.7504, size = 2458, quarters = 35
2014-09-30 : mean = 1.0673 (accu. = 7.6855, annu. = 1.2543), median = 1.0627, std = 0.1382,
sharpe = 1.7679, size = 2519, quarters = 36
2014-12-31 : mean = 1.0655 (accu. = 7.7086, annu. = 1.2471), median = 1.0614, std = 0.1367,
sharpe = 1.7340, size = 2579, quarters = 37
2015-03-31 : mean = 1.0623 (accu. = 7.2819, annu. = 1.2324), median = 1.0600, std = 0.1363,
sharpe = 1.6321, size = 2639, quarters = 38
2015-06-30 : mean = 1.0607 (accu. = 7.2763, annu. = 1.2257), median = 1.0587, std = 0.1349,
sharpe = 1.5994, size = 2697, quarters = 39
2015-09-30 : mean = 1.0584 (accu. = 7.0531, annu. = 1.2157), median = 1.0549, std = 0.1340,
sharpe = 1.5358, size = 2756, quarters = 40

annual mean = 1.4870
annual mean = 1.4741
annual mean = 1.3900
annual mean = 1.2800
annual mean = 0.9875
annual mean = 1.0437
annual mean = 1.1360
annual mean = 0.7303
annual mean = 0.7213
annual mean = 0.9540
annual mean = 1.2831
annual mean = 2.0248
annual mean = 2.6145
annual mean = 1.8499
annual mean = 1.2960
annual mean = 1.4297
annual mean = 1.3102
annual mean = 1.1823
annual mean = 1.0704
annual mean = 0.8700
annual mean = 0.9941
annual mean = 1.0335
annual mean = 1.1621
annual mean = 1.2532
annual mean = 1.1553
annual mean = 1.2863
annual mean = 1.4932
annual mean = 1.5616
annual mean = 1.5805
annual mean = 1.4150
annual mean = 1.3157
annual mean = 1.2878
annual mean = 1.1670
mean = 1.2982, median = 1.2831, std = 0.3606, max = 2.6145, min = 0.7213
```

7.2 Magic Formula Decile 10

```
*** agent quarterly reports (portfolioRankLong = [9]) ***
2005-12-31 : mean = 0.9512, median = 0.9342, std = 0.2254, sharpe = 4.1752, size = 58
2006-03-31 : mean = 0.8014, median = 0.7923, std = 0.2057, sharpe = 3.8480, size = 62
2006-06-30 : mean = 1.2345, median = 1.2058, std = 0.3898, sharpe = 3.1411, size = 68
```

```
2006-09-30 : mean = 1.0427, median = 0.9956, std = 0.3599, sharpe = 2.8697, size = 64
2006-12-31 : mean = 1.0146, median = 1.0343, std = 0.2098, sharpe = 4.7892, size = 62
2007-03-31 : mean = 0.9086, median = 0.8658, std = 0.2875, sharpe = 3.1254, size = 64
2007-06-30 : mean = 0.9262, median = 0.9341, std = 0.2637, sharpe = 3.4748, size = 69
2007-09-30 : mean = 0.8157, median = 0.7396, std = 0.4382, sharpe = 1.8387, size = 73
2007-12-31 : mean = 1.0385, median = 0.9944, std = 0.4282, sharpe = 2.4017, size = 83
2008-03-31 : mean = 0.9559, median = 0.9122, std = 0.3633, sharpe = 2.6035, size = 83
2008-06-30 : mean = 0.5747, median = 0.5131, std = 0.2882, sharpe = 1.9590, size = 78
2008-09-30 : mean = 0.8266, median = 0.7711, std = 0.4287, sharpe = 1.9050, size = 81
2008-12-31 : mean = 1.7984, median = 1.7040, std = 0.6347, sharpe = 2.8176, size = 83
2009-03-31 : mean = 1.3426, median = 1.1964, std = 0.6916, sharpe = 1.9268, size = 83
2009-06-30 : mean = 0.9746, median = 0.8816, std = 0.3833, sharpe = 2.5165, size = 80
2009-09-30 : mean = 1.1339, median = 1.0256, std = 0.4732, sharpe = 2.3749, size = 81
2009-12-31 : mean = 1.0994, median = 1.0593, std = 0.3209, sharpe = 3.3950, size = 79
2010-03-31 : mean = 0.8029, median = 0.8324, std = 0.2318, sharpe = 3.4215, size = 77
2010-06-30 : mean = 1.0823, median = 1.0255, std = 0.3057, sharpe = 3.5081, size = 78
2010-09-30 : mean = 1.1493, median = 1.0891, std = 0.3689, sharpe = 3.0880, size = 75
2010-12-31 : mean = 1.0253, median = 0.9954, std = 0.3399, sharpe = 2.9874, size = 75
2011-03-31 : mean = 0.7615, median = 0.7624, std = 0.2896, sharpe = 2.5949, size = 71
2011-06-30 : mean = 0.9155, median = 0.9167, std = 0.3033, sharpe = 2.9857, size = 72
2011-09-30 : mean = 1.0882, median = 1.0524, std = 0.4180, sharpe = 2.5796, size = 71
2011-12-31 : mean = 0.8895, median = 0.8882, std = 0.2017, sharpe = 4.3607, size = 68
2012-03-31 : mean = 0.9952, median = 0.9331, std = 0.5096, sharpe = 1.9335, size = 70
2012-06-30 : mean = 0.9756, median = 0.9434, std = 0.3621, sharpe = 2.6664, size = 66
2012-09-30 : mean = 1.1594, median = 1.1434, std = 0.4999, sharpe = 2.2992, size = 65
2012-12-31 : mean = 1.0040, median = 0.9786, std = 0.2815, sharpe = 3.5310, size = 64
2013-03-31 : mean = 1.1234, median = 0.9967, std = 0.4552, sharpe = 2.4461, size = 62
2013-06-30 : mean = 1.0363, median = 0.9710, std = 0.4125, sharpe = 2.4880, size = 58
2013-09-30 : mean = 1.1542, median = 1.0370, std = 0.4819, sharpe = 2.3743, size = 57
2013-12-31 : mean = 0.8521, median = 0.8196, std = 0.2373, sharpe = 3.5485, size = 56
2014-03-31 : mean = 1.0167, median = 0.9906, std = 0.3715, sharpe = 2.7096, size = 60
2014-06-30 : mean = 0.8624, median = 0.8868, std = 0.2808, sharpe = 3.0356, size = 62
2014-09-30 : mean = 1.0646, median = 1.0569, std = 0.4141, sharpe = 2.5464, size = 61
2014-12-31 : mean = 0.8974, median = 0.8868, std = 0.2438, sharpe = 3.6403, size = 60
2015-03-31 : mean = 0.8360, median = 0.7509, std = 0.3676, sharpe = 2.2469, size = 60
2015-06-30 : mean = 0.8957, median = 0.9408, std = 0.3326, sharpe = 2.6629, size = 58
2015-09-30 : mean = 0.8016, median = 0.6930, std = 0.3782, sharpe = 2.0933, size = 59

*** portfolio history ***
2005-12-31 : mean = 0.9512 (accu. = 0.9512, annu. = 0.8186), median = 0.9512, std = 0.0000,
sharpe = -inf, size = 58, quarters = 1
2006-03-31 : mean = 0.8763 (accu. = 0.7623, annu. = 0.5811), median = 0.8763, std = 0.0749,
sharpe = -5.7266, size = 120, quarters = 2
2006-06-30 : mean = 0.9957 (accu. = 0.9411, annu. = 0.9222), median = 0.9512, std = 0.1796,
sharpe = -0.4886, size = 188, quarters = 3
2006-09-30 : mean = 1.0075 (accu. = 0.9813, annu. = 0.9813), median = 0.9969, std = 0.1569,
sharpe = -0.1832, size = 252, quarters = 4
2006-12-31 : mean = 1.0089 (accu. = 0.9956, annu. = 0.9965), median = 1.0146, std = 0.1403,
sharpe = -0.0961, size = 314, quarters = 5
2007-03-31 : mean = 0.9922 (accu. = 0.9046, annu. = 0.9354), median = 0.9829, std = 0.1334,
sharpe = -0.5593, size = 378, quarters = 6
2007-06-30 : mean = 0.9828 (accu. = 0.8379, annu. = 0.9039), median = 0.9512, std = 0.1257,
sharpe = -0.8445, size = 447, quarters = 7
2007-09-30 : mean = 0.9619 (accu. = 0.6835, annu. = 0.8267), median = 0.9387, std = 0.1299,
sharpe = -1.4109, size = 520, quarters = 8
2007-12-31 : mean = 0.9704 (accu. = 0.7098, annu. = 0.8587), median = 0.9512, std = 0.1248,
sharpe = -1.2123, size = 603, quarters = 9
2008-03-31 : mean = 0.9689 (accu. = 0.6785, annu. = 0.8563), median = 0.9536, std = 0.1185,
sharpe = -1.2973, size = 686, quarters = 10
2008-06-30 : mean = 0.9331 (accu. = 0.3899, annu. = 0.7100), median = 0.9512, std = 0.1600,
sharpe = -1.8746, size = 764, quarters = 11
2008-09-30 : mean = 0.9242 (accu. = 0.3223, annu. = 0.6856), median = 0.9387, std = 0.1560,
sharpe = -2.0790, size = 845, quarters = 12
2008-12-31 : mean = 0.9915 (accu. = 0.5796, annu. = 0.8455), median = 0.9512, std = 0.2770,
sharpe = -0.5938, size = 928, quarters = 13
2009-03-31 : mean = 1.0166 (accu. = 0.7782, annu. = 0.9309), median = 0.9536, std = 0.2818,
sharpe = -0.2808, size = 1011, quarters = 14
2009-06-30 : mean = 1.0138 (accu. = 0.7584, annu. = 0.9289), median = 0.9559, std = 0.2725,
sharpe = -0.2976, size = 1091, quarters = 15
2009-09-30 : mean = 1.0213 (accu. = 0.8600, annu. = 0.9630), median = 0.9652, std = 0.2654,
sharpe = -0.1771, size = 1172, quarters = 16
2009-12-31 : mean = 1.0259 (accu. = 0.9454, annu. = 0.9869), median = 0.9746, std = 0.2581,
sharpe = -0.0896, size = 1251, quarters = 17
2010-03-31 : mean = 1.0135 (accu. = 0.7591, annu. = 0.9406), median = 0.9652, std = 0.2560,
```

```
sharpe = -0.2711, size = 1328, quarters = 18
2010-06-30 : mean = 1.0171 (accu. = 0.8215, annu. = 0.9595), median = 0.9746, std = 0.2497,
sharpe = -0.2024, size = 1406, quarters = 19
2010-09-30 : mean = 1.0237 (accu. = 0.9442, annu. = 0.9886), median = 0.9946, std = 0.2450,
sharpe = -0.0874, size = 1481, quarters = 20
2010-12-31 : mean = 1.0238 (accu. = 0.9681, annu. = 0.9938), median = 1.0146, std = 0.2391,
sharpe = -0.0676, size = 1556, quarters = 21
2011-03-31 : mean = 1.0119 (accu. = 0.7372, annu. = 0.9461), median = 0.9946, std = 0.2399,
sharpe = -0.2664, size = 1627, quarters = 22
2011-06-30 : mean = 1.0077 (accu. = 0.6749, annu. = 0.9339), median = 0.9746, std = 0.2355,
sharpe = -0.3231, size = 1699, quarters = 23
2011-09-30 : mean = 1.0110 (accu. = 0.7345, annu. = 0.9499), median = 0.9946, std = 0.2311,
sharpe = -0.2602, size = 1770, quarters = 24
2011-12-31 : mean = 1.0062 (accu. = 0.6534, annu. = 0.9342), median = 0.9746, std = 0.2277,
sharpe = -0.3331, size = 1838, quarters = 25
2012-03-31 : mean = 1.0057 (accu. = 0.6502, annu. = 0.9359), median = 0.9849, std = 0.2233,
sharpe = -0.3318, size = 1908, quarters = 26
2012-06-30 : mean = 1.0046 (accu. = 0.6344, annu. = 0.9348), median = 0.9756, std = 0.2192,
sharpe = -0.3431, size = 1974, quarters = 27
2012-09-30 : mean = 1.0102 (accu. = 0.7355, annu. = 0.9571), median = 0.9854, std = 0.2171,
sharpe = -0.2438, size = 2039, quarters = 28
2012-12-31 : mean = 1.0099 (accu. = 0.7384, annu. = 0.9590), median = 0.9952, std = 0.2133,
sharpe = -0.2389, size = 2103, quarters = 29
2013-03-31 : mean = 1.0137 (accu. = 0.8295, annu. = 0.9754), median = 0.9996, std = 0.2107,
sharpe = -0.1642, size = 2165, quarters = 30
2013-06-30 : mean = 1.0145 (accu. = 0.8597, annu. = 0.9807), median = 1.0040, std = 0.2074,
sharpe = -0.1414, size = 2223, quarters = 31
2013-09-30 : mean = 1.0188 (accu. = 0.9923, annu. = 0.9990), median = 1.0093, std = 0.2055,
sharpe = -0.0534, size = 2280, quarters = 32
2013-12-31 : mean = 1.0138 (accu. = 0.8455, annu. = 0.9799), median = 1.0040, std = 0.2044,
sharpe = -0.1474, size = 2336, quarters = 33
2014-03-31 : mean = 1.0139 (accu. = 0.8596, annu. = 0.9824), median = 1.0093, std = 0.2014,
sharpe = -0.1372, size = 2396, quarters = 34
2014-06-30 : mean = 1.0095 (accu. = 0.7413, annu. = 0.9664), median = 1.0040, std = 0.2001,
sharpe = -0.2181, size = 2458, quarters = 35
2014-09-30 : mean = 1.0111 (accu. = 0.7892, annu. = 0.9740), median = 1.0093, std = 0.1975,
sharpe = -0.1821, size = 2519, quarters = 36
2014-12-31 : mean = 1.0080 (accu. = 0.7082, annu. = 0.9634), median = 1.0040, std = 0.1957,
sharpe = -0.2382, size = 2579, quarters = 37
2015-03-31 : mean = 1.0035 (accu. = 0.5921, annu. = 0.9463), median = 0.9996, std = 0.1950,
sharpe = -0.3265, size = 2639, quarters = 38
2015-06-30 : mean = 1.0007 (accu. = 0.5303, annu. = 0.9370), median = 0.9952, std = 0.1933,
sharpe = -0.3777, size = 2697, quarters = 39
2015-09-30 : mean = 0.9957 (accu. = 0.4251, annu. = 0.9180), median = 0.9854, std = 0.1933,
sharpe = -0.4758, size = 2756, quarters = 40

annual mean = 0.9813
annual mean = 1.0467
annual mean = 1.1867
annual mean = 0.8903
annual mean = 0.6965
annual mean = 0.7129
annual mean = 0.7500
annual mean = 0.4654
annual mean = 0.4716
annual mean = 0.8166
annual mean = 1.1470
annual mean = 1.9451
annual mean = 2.6682
annual mean = 1.6311
annual mean = 0.9754
annual mean = 1.0832
annual mean = 1.0979
annual mean = 1.0240
annual mean = 0.9712
annual mean = 0.8215
annual mean = 0.7779
annual mean = 0.6749
annual mean = 0.8820
annual mean = 0.9399
annual mean = 1.0013
annual mean = 1.1302
annual mean = 1.2758
annual mean = 1.3552
```

```
annual mean = 1.3491
annual mean = 1.1451
annual mean = 1.0363
annual mean = 0.8623
annual mean = 0.7953
mean = 1.0487, median = 0.9813, std = 0.4101, max = 2.6682, min = 0.4654
```

7.3 Benchmark

```
*** agent quarterly reports (portfolioRankLong = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]) ***
2005-12-31 : mean = 1.0457, median = 1.0136, std = 0.2314, sharpe = 4.4761, size = 580
2006-03-31 : mean = 0.8972, median = 0.8941, std = 0.1998, sharpe = 4.4414, size = 620
2006-06-30 : mean = 1.1401, median = 1.1051, std = 0.3199, sharpe = 3.5329, size = 680
2006-09-30 : mean = 1.0982, median = 1.0473, std = 0.3496, sharpe = 3.1123, size = 640
2006-12-31 : mean = 1.0487, median = 1.0296, std = 0.2268, sharpe = 4.5807, size = 620
2007-03-31 : mean = 0.9540, median = 0.9429, std = 0.2540, sharpe = 3.7164, size = 640
2007-06-30 : mean = 0.9938, median = 0.9784, std = 0.2849, sharpe = 3.4529, size = 690
2007-09-30 : mean = 0.8426, median = 0.8430, std = 0.2870, sharpe = 2.9013, size = 730
2007-12-31 : mean = 1.0392, median = 1.0093, std = 0.2725, sharpe = 3.7770, size = 830
2008-03-31 : mean = 0.9465, median = 0.9447, std = 0.2734, sharpe = 3.4257, size = 830
2008-06-30 : mean = 0.6257, median = 0.6129, std = 0.2627, sharpe = 2.3437, size = 780
2008-09-30 : mean = 0.8321, median = 0.7980, std = 0.3752, sharpe = 2.1911, size = 810
2008-12-31 : mean = 1.4496, median = 1.3071, std = 0.5831, sharpe = 2.4691, size = 830
2009-03-31 : mean = 1.2959, median = 1.2063, std = 0.4749, sharpe = 2.7079, size = 830
2009-06-30 : mean = 1.0697, median = 1.0260, std = 0.3149, sharpe = 3.3649, size = 800
2009-09-30 : mean = 1.1406, median = 1.0792, std = 0.3688, sharpe = 3.0661, size = 810
2009-12-31 : mean = 1.0719, median = 1.0426, std = 0.2578, sharpe = 4.1195, size = 790
2010-03-31 : mean = 0.9163, median = 0.9236, std = 0.2123, sharpe = 4.2686, size = 770
2010-06-30 : mean = 1.1334, median = 1.0899, std = 0.2831, sharpe = 3.9687, size = 780
2010-09-30 : mean = 1.1160, median = 1.0650, std = 0.3297, sharpe = 3.3551, size = 750
2010-12-31 : mean = 1.0113, median = 1.0016, std = 0.2281, sharpe = 4.3904, size = 750
2011-03-31 : mean = 0.8438, median = 0.8412, std = 0.2233, sharpe = 3.7349, size = 710
2011-06-30 : mean = 0.9548, median = 0.9553, std = 0.2287, sharpe = 4.1316, size = 720
2011-09-30 : mean = 1.1318, median = 1.0942, std = 0.3386, sharpe = 3.3130, size = 710
2011-12-31 : mean = 0.9695, median = 0.9508, std = 0.2318, sharpe = 4.1402, size = 680
2012-03-31 : mean = 0.9952, median = 0.9768, std = 0.3042, sharpe = 3.2384, size = 700
2012-06-30 : mean = 1.0012, median = 0.9850, std = 0.2748, sharpe = 3.6068, size = 660
2012-09-30 : mean = 1.1455, median = 1.0992, std = 0.3489, sharpe = 3.2549, size = 650
2012-12-31 : mean = 1.0489, median = 1.0130, std = 0.2526, sharpe = 4.1124, size = 640
2013-03-31 : mean = 1.1231, median = 1.0702, std = 0.3141, sharpe = 3.5438, size = 620
2013-06-30 : mean = 1.0814, median = 1.0388, std = 0.3401, sharpe = 3.1506, size = 580
2013-09-30 : mean = 1.1627, median = 1.0929, std = 0.3895, sharpe = 2.9594, size = 570
2013-12-31 : mean = 0.9070, median = 0.9143, std = 0.2151, sharpe = 4.1703, size = 560
2014-03-31 : mean = 1.0051, median = 0.9862, std = 0.2364, sharpe = 4.2095, size = 600
2014-06-30 : mean = 0.9626, median = 0.9505, std = 0.2851, sharpe = 3.3413, size = 620
2014-09-30 : mean = 1.0343, median = 1.0005, std = 0.3458, sharpe = 2.9625, size = 610
2014-12-31 : mean = 0.9913, median = 0.9821, std = 0.2253, sharpe = 4.3552, size = 600
2015-03-31 : mean = 0.9140, median = 0.9038, std = 0.3033, sharpe = 2.9804, size = 600
2015-06-30 : mean = 0.9451, median = 0.9431, std = 0.2742, sharpe = 3.4102, size = 580
2015-09-30 : mean = 0.8820, median = 0.8768, std = 0.3410, sharpe = 2.5573, size = 590

*** portfolio history ***
2005-12-31 : mean = 1.0457 (accu. = 1.0457, annu. = 1.1959), median = 1.0457, std = 0.0000,
sharpe = inf, size = 580, quarters = 1
2006-03-31 : mean = 0.9715 (accu. = 0.9383, annu. = 0.8803), median = 0.9715, std = 0.0743,
sharpe = -1.7460, size = 1200, quarters = 2
2006-06-30 : mean = 1.0277 (accu. = 1.0698, annu. = 1.0941), median = 1.0457, std = 0.1000,
sharpe = 0.8408, size = 1880, quarters = 3
2006-09-30 : mean = 1.0453 (accu. = 1.1748, annu. = 1.1748), median = 1.0720, std = 0.0918,
sharpe = 1.7949, size = 2520, quarters = 4
2006-12-31 : mean = 1.0460 (accu. = 1.2320, annu. = 1.1817), median = 1.0487, std = 0.0821,
sharpe = 2.0900, size = 3140, quarters = 5
2007-03-31 : mean = 1.0307 (accu. = 1.1754, annu. = 1.1137), median = 1.0472, std = 0.0824,
sharpe = 1.2583, size = 3780, quarters = 6
2007-06-30 : mean = 1.0254 (accu. = 1.1681, annu. = 1.0929), median = 1.0457, std = 0.0774,
sharpe = 1.0704, size = 4470, quarters = 7
2007-09-30 : mean = 1.0026 (accu. = 0.9843, annu. = 0.9921), median = 1.0198, std = 0.0943,
sharpe = -0.1897, size = 5200, quarters = 8
2007-12-31 : mean = 1.0066 (accu. = 1.0228, annu. = 1.0101), median = 1.0392, std = 0.0897,
```

```
sharpe = 0.0009, size = 6030, quarters = 9
2008-03-31 : mean = 1.0006 (accu. = 0.9681, annu. = 0.9871), median = 1.0165, std = 0.0870,
sharpe = -0.2634, size = 6860, quarters = 10
2008-06-30 : mean = 0.9665 (accu. = 0.6058, annu. = 0.8334), median = 0.9938, std = 0.1360,
sharpe = -1.2990, size = 7640, quarters = 11
2008-09-30 : mean = 0.9553 (accu. = 0.5040, annu. = 0.7958), median = 0.9739, std = 0.1354,
sharpe = -1.5819, size = 8450, quarters = 12
2008-12-31 : mean = 0.9934 (accu. = 0.7307, annu. = 0.9080), median = 0.9938, std = 0.1851,
sharpe = -0.5512, size = 9280, quarters = 13
2009-03-31 : mean = 1.0150 (accu. = 0.9469, annu. = 0.9845), median = 1.0165, std = 0.1947,
sharpe = -0.1309, size = 10110, quarters = 14
2009-06-30 : mean = 1.0186 (accu. = 1.0129, annu. = 1.0034), median = 1.0392, std = 0.1885,
sharpe = -0.0349, size = 10910, quarters = 15
2009-09-30 : mean = 1.0262 (accu. = 1.1553, annu. = 1.0367), median = 1.0425, std = 0.1849,
sharpe = 0.1446, size = 11720, quarters = 16
2009-12-31 : mean = 1.0289 (accu. = 1.2384, annu. = 1.0516), median = 1.0457, std = 0.1797,
sharpe = 0.2314, size = 12510, quarters = 17
2010-03-31 : mean = 1.0227 (accu. = 1.1347, annu. = 1.0285), median = 1.0425, std = 0.1766,
sharpe = 0.1047, size = 13280, quarters = 18
2010-06-30 : mean = 1.0285 (accu. = 1.2860, annu. = 1.0544), median = 1.0457, std = 0.1736,
sharpe = 0.2557, size = 14060, quarters = 19
2010-09-30 : mean = 1.0329 (accu. = 1.4352, annu. = 1.0749), median = 1.0472, std = 0.1703,
sharpe = 0.3813, size = 14810, quarters = 20
2010-12-31 : mean = 1.0318 (accu. = 1.4514, annu. = 1.0735), median = 1.0457, std = 0.1663,
sharpe = 0.3821, size = 15560, quarters = 21
2011-03-31 : mean = 1.0233 (accu. = 1.2247, annu. = 1.0375), median = 1.0425, std = 0.1671,
sharpe = 0.1649, size = 16270, quarters = 22
2011-06-30 : mean = 1.0203 (accu. = 1.1694, annu. = 1.0276), median = 1.0392, std = 0.1640,
sharpe = 0.1072, size = 16990, quarters = 23
2011-09-30 : mean = 1.0250 (accu. = 1.3235, annu. = 1.0478), median = 1.0425, std = 0.1621,
sharpe = 0.2333, size = 17700, quarters = 24
2011-12-31 : mean = 1.0227 (accu. = 1.2832, annu. = 1.0407), median = 1.0392, std = 0.1592,
sharpe = 0.1929, size = 18380, quarters = 25
2012-03-31 : mean = 1.0217 (accu. = 1.2770, annu. = 1.0383), median = 1.0252, std = 0.1562,
sharpe = 0.1814, size = 19080, quarters = 26
2012-06-30 : mean = 1.0209 (accu. = 1.2785, annu. = 1.0371), median = 1.0113, std = 0.1533,
sharpe = 0.1766, size = 19740, quarters = 27
2012-09-30 : mean = 1.0254 (accu. = 1.4645, annu. = 1.0560), median = 1.0252, std = 0.1523,
sharpe = 0.3021, size = 20390, quarters = 28
2012-12-31 : mean = 1.0262 (accu. = 1.5362, annu. = 1.0610), median = 1.0392, std = 0.1497,
sharpe = 0.3406, size = 21030, quarters = 29
2013-03-31 : mean = 1.0294 (accu. = 1.7254, annu. = 1.0754), median = 1.0425, std = 0.1482,
sharpe = 0.4414, size = 21650, quarters = 30
2013-06-30 : mean = 1.0311 (accu. = 1.8658, annu. = 1.0838), median = 1.0457, std = 0.1461,
sharpe = 0.5051, size = 22230, quarters = 31
2013-09-30 : mean = 1.0352 (accu. = 2.1695, annu. = 1.1017), median = 1.0472, std = 0.1456,
sharpe = 0.6293, size = 22800, quarters = 32
2013-12-31 : mean = 1.0313 (accu. = 1.9678, annu. = 1.0855), median = 1.0457, std = 0.1451,
sharpe = 0.5205, size = 23360, quarters = 33
2014-03-31 : mean = 1.0306 (accu. = 1.9778, annu. = 1.0835), median = 1.0425, std = 0.1430,
sharpe = 0.5143, size = 23960, quarters = 34
2014-06-30 : mean = 1.0286 (accu. = 1.9039, annu. = 1.0764), median = 1.0392, std = 0.1414,
sharpe = 0.4693, size = 24580, quarters = 35
2014-09-30 : mean = 1.0288 (accu. = 1.9693, annu. = 1.0782), median = 1.0367, std = 0.1394,
sharpe = 0.4892, size = 25190, quarters = 36
2014-12-31 : mean = 1.0278 (accu. = 1.9522, annu. = 1.0750), median = 1.0343, std = 0.1377,
sharpe = 0.4722, size = 25790, quarters = 37
2015-03-31 : mean = 1.0248 (accu. = 1.7843, annu. = 1.0628), median = 1.0228, std = 0.1371,
sharpe = 0.3856, size = 26390, quarters = 38
2015-06-30 : mean = 1.0227 (accu. = 1.6864, annu. = 1.0551), median = 1.0113, std = 0.1359,
sharpe = 0.3316, size = 26970, quarters = 39
2015-09-30 : mean = 1.0192 (accu. = 1.4873, annu. = 1.0405), median = 1.0082, std = 0.1359,
sharpe = 0.2243, size = 27560, quarters = 40

annual mean = 1.1748
annual mean = 1.1781
annual mean = 1.2527
annual mean = 1.0919
annual mean = 0.8378
annual mean = 0.8302
annual mean = 0.8236
annual mean = 0.5186
annual mean = 0.5121
annual mean = 0.7144
```

```
annual mean = 0.9781
annual mean = 1.6721
annual mean = 2.2920
annual mean = 1.6948
annual mean = 1.1984
annual mean = 1.2697
annual mean = 1.2423
annual mean = 1.1720
annual mean = 1.0794
annual mean = 0.9093
annual mean = 0.9222
annual mean = 0.8841
annual mean = 1.0427
annual mean = 1.0933
annual mean = 1.1066
annual mean = 1.1972
annual mean = 1.3511
annual mean = 1.4593
annual mean = 1.4813
annual mean = 1.2809
annual mean = 1.1463
annual mean = 1.0204
annual mean = 0.9077
mean = 1.1314, median = 1.1066, std = 0.3383, max = 2.2920, min = 0.5121
```

7.4 110/10 Market-Neutral Long/Short Portfolio

```
*** agent quarterly reports (portfolioRankLong = [0], portfolioRankShort = [9]) ***
2005-12-31 : mean = 1.0826, median = 1.0291, std = 0.3406, sharpe = 3.1493, size = 116
2006-03-31 : mean = 1.0156, median = 1.0256, std = 0.2888, sharpe = 3.4824, size = 124
2006-06-30 : mean = 1.1476, median = 1.0016, std = 0.4466, sharpe = 2.5475, size = 136
2006-09-30 : mean = 1.2230, median = 1.0224, std = 0.8667, sharpe = 1.3995, size = 128
2006-12-31 : mean = 1.0661, median = 0.9947, std = 0.4736, sharpe = 2.2298, size = 124
2007-03-31 : mean = 0.9423, median = 1.0039, std = 0.3881, sharpe = 2.4020, size = 128
2007-06-30 : mean = 1.0778, median = 1.0155, std = 0.4476, sharpe = 2.3857, size = 138
2007-09-30 : mean = 0.9424, median = 1.0299, std = 0.4274, sharpe = 2.1816, size = 146
2007-12-31 : mean = 1.1302, median = 1.0165, std = 0.4937, sharpe = 2.2690, size = 166
2008-03-31 : mean = 1.0290, median = 1.0178, std = 0.3888, sharpe = 2.6211, size = 166
2008-06-30 : mean = 0.6950, median = 1.0113, std = 0.5962, sharpe = 1.1488, size = 156
2008-09-30 : mean = 0.9287, median = 1.0066, std = 0.6446, sharpe = 1.4252, size = 162
2008-12-31 : mean = 1.4522, median = 0.9689, std = 1.1144, sharpe = 1.2941, size = 166
2009-03-31 : mean = 1.3783, median = 1.0186, std = 1.0908, sharpe = 1.2544, size = 166
2009-06-30 : mean = 1.0899, median = 1.0309, std = 0.5542, sharpe = 1.9484, size = 160
2009-09-30 : mean = 1.1925, median = 1.0281, std = 0.5399, sharpe = 2.1903, size = 162
2009-12-31 : mean = 1.0449, median = 0.9957, std = 0.3648, sharpe = 2.8369, size = 158
2010-03-31 : mean = 0.9794, median = 1.0262, std = 0.2989, sharpe = 3.2432, size = 154
2010-06-30 : mean = 1.2015, median = 1.0121, std = 0.5617, sharpe = 2.1212, size = 156
2010-09-30 : mean = 1.0818, median = 0.9863, std = 0.5821, sharpe = 1.8413, size = 150
2010-12-31 : mean = 0.9395, median = 0.9866, std = 0.4165, sharpe = 2.2318, size = 150
2011-03-31 : mean = 0.8834, median = 1.0138, std = 0.3834, sharpe = 2.2781, size = 142
2011-06-30 : mean = 0.9730, median = 1.0000, std = 0.3258, sharpe = 2.9559, size = 144
2011-09-30 : mean = 1.2586, median = 1.0473, std = 0.7597, sharpe = 1.6435, size = 142
2011-12-31 : mean = 0.9945, median = 1.0108, std = 0.4262, sharpe = 2.3097, size = 136
2012-03-31 : mean = 0.9793, median = 1.0032, std = 0.3793, sharpe = 2.5555, size = 140
2012-06-30 : mean = 1.0504, median = 1.0113, std = 0.4450, sharpe = 2.3380, size = 132
2012-09-30 : mean = 1.1447, median = 1.0227, std = 0.5951, sharpe = 1.9067, size = 130
2012-12-31 : mean = 1.1059, median = 1.0129, std = 0.4096, sharpe = 2.6754, size = 128
2013-03-31 : mean = 1.1400, median = 1.0203, std = 0.4402, sharpe = 2.5672, size = 124
2013-06-30 : mean = 1.0968, median = 1.0096, std = 0.6183, sharpe = 1.7577, size = 116
2013-09-30 : mean = 1.1606, median = 1.0015, std = 0.7274, sharpe = 1.5818, size = 114
2013-12-31 : mean = 0.9947, median = 1.0170, std = 0.3558, sharpe = 2.7675, size = 112
2014-03-31 : mean = 1.0628, median = 1.0086, std = 0.3530, sharpe = 2.9826, size = 120
2014-06-30 : mean = 1.0888, median = 1.0350, std = 0.5369, sharpe = 2.0092, size = 124
2014-09-30 : mean = 1.0498, median = 0.9906, std = 0.5435, sharpe = 1.9131, size = 122
2014-12-31 : mean = 1.0136, median = 1.0206, std = 0.2997, sharpe = 3.3490, size = 120
2015-03-31 : mean = 0.9555, median = 1.0239, std = 0.4409, sharpe = 2.1447, size = 120
2015-06-30 : mean = 1.0096, median = 1.0084, std = 0.3591, sharpe = 2.7835, size = 116
2015-09-30 : mean = 0.9861, median = 1.0298, std = 0.4201, sharpe = 2.3233, size = 118
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*** portfolio history ***
2005-12-31 : mean = 1.0826 (accu. = 1.0826, annu. = 1.3739), median = 1.0826, std = 0.0000,
sharpe = inf, size = 116, quarters = 1
2006-03-31 : mean = 1.0491 (accu. = 1.0995, annu. = 1.2090), median = 1.0491, std = 0.0335,
sharpe = 5.9334, size = 240, quarters = 2
2006-06-30 : mean = 1.0819 (accu. = 1.2618, annu. = 1.3635), median = 1.0826, std = 0.0539,
sharpe = 6.5595, size = 376, quarters = 3
2006-09-30 : mean = 1.1172 (accu. = 1.5432, annu. = 1.5432), median = 1.1151, std = 0.0769,
sharpe = 6.9360, size = 504, quarters = 4
2006-12-31 : mean = 1.1070 (accu. = 1.6452, annu. = 1.4893), median = 1.0826, std = 0.0717,
sharpe = 6.6815, size = 628, quarters = 5
2007-03-31 : mean = 1.0795 (accu. = 1.5503, annu. = 1.3395), median = 1.0744, std = 0.0897,
sharpe = 3.6716, size = 756, quarters = 6
2007-06-30 : mean = 1.0793 (accu. = 1.6710, annu. = 1.3409), median = 1.0778, std = 0.0831,
sharpe = 3.9831, size = 894, quarters = 7
2007-09-30 : mean = 1.0622 (accu. = 1.5748, annu. = 1.2549), median = 1.0720, std = 0.0899,
sharpe = 2.7229, size = 1040, quarters = 8
2007-12-31 : mean = 1.0697 (accu. = 1.7798, annu. = 1.2920), median = 1.0778, std = 0.0874,
sharpe = 3.2251, size = 1206, quarters = 9
2008-03-31 : mean = 1.0657 (accu. = 1.8313, annu. = 1.2738), median = 1.0720, std = 0.0839,
sharpe = 3.1459, size = 1372, quarters = 10
2008-06-30 : mean = 1.0320 (accu. = 1.2727, annu. = 1.0916), median = 1.0661, std = 0.1332,
sharpe = 0.6128, size = 1528, quarters = 11
2008-09-30 : mean = 1.0234 (accu. = 1.1820, annu. = 1.0573), median = 1.0475, std = 0.1307,
sharpe = 0.3619, size = 1690, quarters = 12
2008-12-31 : mean = 1.0564 (accu. = 1.7165, annu. = 1.1809), median = 1.0661, std = 0.1698,
sharpe = 1.0062, size = 1856, quarters = 13
2009-03-31 : mean = 1.0794 (accu. = 2.3659, annu. = 1.2790), median = 1.0720, std = 0.1834,
sharpe = 1.4662, size = 2022, quarters = 14
2009-06-30 : mean = 1.0801 (accu. = 2.5786, annu. = 1.2874), median = 1.0778, std = 0.1772,
sharpe = 1.5649, size = 2182, quarters = 15
2009-09-30 : mean = 1.0871 (accu. = 3.0750, annu. = 1.3242), median = 1.0802, std = 0.1738,
sharpe = 1.8084, size = 2344, quarters = 16
2009-12-31 : mean = 1.0846 (accu. = 3.2129, annu. = 1.3160), median = 1.0778, std = 0.1689,
sharpe = 1.8124, size = 2502, quarters = 17
2010-03-31 : mean = 1.0788 (accu. = 3.1469, annu. = 1.2902), median = 1.0720, std = 0.1659,
sharpe = 1.6891, size = 2656, quarters = 18
2010-06-30 : mean = 1.0852 (accu. = 3.7810, annu. = 1.3231), median = 1.0778, std = 0.1637,
sharpe = 1.9123, size = 2812, quarters = 19
2010-09-30 : mean = 1.0850 (accu. = 4.0905, annu. = 1.3254), median = 1.0798, std = 0.1596,
sharpe = 1.9763, size = 2962, quarters = 20
2010-12-31 : mean = 1.0781 (accu. = 3.8431, annu. = 1.2923), median = 1.0778, std = 0.1588,
sharpe = 1.7777, size = 3112, quarters = 21
2011-03-31 : mean = 1.0693 (accu. = 3.3948, annu. = 1.2489), median = 1.0720, std = 0.1604,
sharpe = 1.4893, size = 3254, quarters = 22
2011-06-30 : mean = 1.0651 (accu. = 3.3030, annu. = 1.2310), median = 1.0661, std = 0.1581,
sharpe = 1.3978, size = 3398, quarters = 23
2011-09-30 : mean = 1.0731 (accu. = 4.1571, annu. = 1.2680), median = 1.0720, std = 0.1595,
sharpe = 1.6177, size = 3540, quarters = 24
2011-12-31 : mean = 1.0700 (accu. = 4.1341, annu. = 1.2549), median = 1.0661, std = 0.1570,
sharpe = 1.5597, size = 3676, quarters = 25
2012-03-31 : mean = 1.0665 (accu. = 4.0487, annu. = 1.2400), median = 1.0555, std = 0.1550,
sharpe = 1.4843, size = 3816, quarters = 26
2012-06-30 : mean = 1.0659 (accu. = 4.2526, annu. = 1.2392), median = 1.0504, std = 0.1521,
sharpe = 1.5067, size = 3948, quarters = 27
2012-09-30 : mean = 1.0687 (accu. = 4.8681, annu. = 1.2537), median = 1.0582, std = 0.1501,
sharpe = 1.6238, size = 4078, quarters = 28
2012-12-31 : mean = 1.0700 (accu. = 5.3835, annu. = 1.2614), median = 1.0661, std = 0.1476,
sharpe = 1.7026, size = 4206, quarters = 29
2013-03-31 : mean = 1.0723 (accu. = 6.1374, annu. = 1.2737), median = 1.0720, std = 0.1457,
sharpe = 1.8100, size = 4330, quarters = 30
2013-06-30 : mean = 1.0731 (accu. = 6.7317, annu. = 1.2790), median = 1.0778, std = 0.1434,
sharpe = 1.8757, size = 4446, quarters = 31
2013-09-30 : mean = 1.0759 (accu. = 7.8125, annu. = 1.2930), median = 1.0798, std = 0.1419,
sharpe = 1.9937, size = 4560, quarters = 32
2013-12-31 : mean = 1.0734 (accu. = 7.7710, annu. = 1.2821), median = 1.0778, std = 0.1405,
sharpe = 1.9374, size = 4672, quarters = 33
2014-03-31 : mean = 1.0731 (accu. = 8.2594, annu. = 1.2820), median = 1.0720, std = 0.1384,
sharpe = 1.9651, size = 4792, quarters = 34
2014-06-30 : mean = 1.0735 (accu. = 8.9926, annu. = 1.2853), median = 1.0778, std = 0.1364,
sharpe = 2.0181, size = 4916, quarters = 35
2014-09-30 : mean = 1.0729 (accu. = 9.4409, annu. = 1.2833), median = 1.0720, std = 0.1346,
sharpe = 2.0309, size = 5038, quarters = 36
2014-12-31 : mean = 1.0713 (accu. = 9.5689, annu. = 1.2766), median = 1.0661, std = 0.1331,
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sharpe = 2.0027, size = 5158, quarters = 37
2015-03-31 : mean = 1.0682 (accu. = 9.1432, annu. = 1.2623), median = 1.0645, std = 0.1326,
sharpe = 1.9023, size = 5278, quarters = 38
2015-06-30 : mean = 1.0667 (accu. = 9.2309, annu. = 1.2560), median = 1.0628, std = 0.1313,
sharpe = 1.8745, size = 5394, quarters = 39
2015-09-30 : mean = 1.0647 (accu. = 9.1026, annu. = 1.2471), median = 1.0566, std = 0.1302,
sharpe = 1.8212, size = 5512, quarters = 40

annual mean = 1.5432
annual mean = 1.5196
annual mean = 1.4100
annual mean = 1.3243
annual mean = 1.0205
annual mean = 1.0818
annual mean = 1.1813
annual mean = 0.7616
annual mean = 0.7506
annual mean = 0.9645
annual mean = 1.2919
annual mean = 2.0261
annual mean = 2.6016
annual mean = 1.8718
annual mean = 1.3301
annual mean = 1.4663
annual mean = 1.3302
annual mean = 1.1961
annual mean = 1.0788
annual mean = 0.8736
annual mean = 1.0163
annual mean = 1.0757
annual mean = 1.1926
annual mean = 1.2875
annual mean = 1.1710
annual mean = 1.3022
annual mean = 1.5159
annual mean = 1.5830
annual mean = 1.6048
annual mean = 1.4435
annual mean = 1.3458
annual mean = 1.3359
annual mean = 1.2084
mean = 1.3244, median = 1.3022, std = 0.3557, max = 2.6016, min = 0.7506
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