Does Momentum systematically predict returns for Equity allocation?

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Abstract

In this document we describe the performance of an allocation strategy across markets in Equity space. We present the behavior and predictive power of the Momentum predictor variable using a positive expected effect along dimensions of rationale, profitability, implementability, robustness, and risk characteristics. In the final section we provide our conclusion and recommendation.

Contents

1 Rationale

Economic rationale: The economic underpinning of momentum is that market participants are subject to over- and underreaction due behavioral biases as overconfidence, respresentativeness bias, conservatism bias and herding behavior. Further, the segmentation of markets and the actions of central banks sometimes cause a slow diffusion of information across markets, also causing momentum to emerge in markets.
Many academic studies have shown this effect across markets, regions, assets and even back to the 1800s. The common academic definition is to take a 12-month trend (and filter for short-term microstructure biases), since it is a salient window that many investors (often unconsciously) have in their minds.
We believe that a trend is best captured a combination of the magnitude, reliability and consistency of a trend, and accordingly we propose to focus at a 25-25-50 combination of these measured over a 12-monthminus 1 week window. We long (short) the futures with the highest (lowest) past 12-month minus 1 week return (determined by average of the cross-sectional ranks of the magnitude, reliability and consistency of momentum), long (short) the top (bottom) 30% (our base case in cross-sectional strategies), and risk control each market as reflected in conditional aggregate volatilities.

2 Data

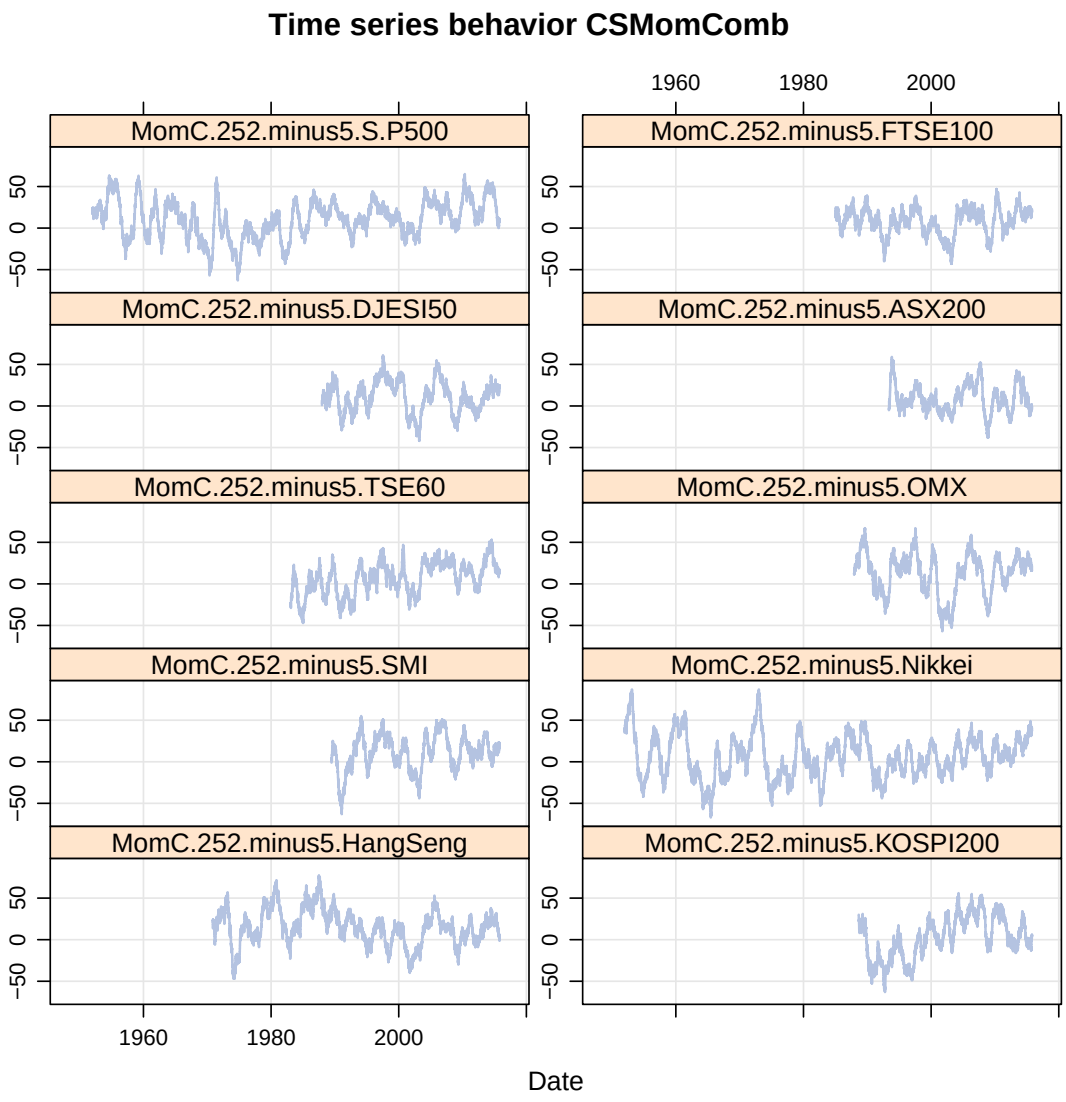
Our main sample spans daily returns between the start dates of each series listed in table **??** and 2015-08-31, and includes the major liquid futures in Equity. The markets for which we analyse performance are summarized in the column "Markets" of table **??**, together with the weights used to aggregate results across the markets that we consider.

	Markets	EquityCS	StartDate
1	S.P500	0.10	1989-01-04
2	FTSE100	0.10	1989-01-04
3	DJESI50	0.10	1989-01-04
4	ASX200	0.10	1993-05-21
5	TSE60	0.10	1989-01-04
6	OMX	0.10	1989-01-04
7	SMI	0.10	1989-06-23
8	Nikkei	0.10	1989-01-04
9	HangSeng	0.10	1989-01-04
10	KOSPI200	0.10	1989-01-04

Table 1: Series in the sample

3 The Signal

In this Section we examine the behavior of the variable and its transformation to signal to gain intuition on the creation of a signal. More detailed results on among others the stability of the distribution and autocorrelation structure of the variable can be found in the Appendix. The first figure below shows the time-series behavior of CSMomComb per market (when applicable). The second figure below contains the correlation of CSMomComb over markets.


Time series behavior CSMomComb
MomC.252.minus5.S.P500
MomC.252.minus5.FTSE100
MomC.252.minus5.DJESI50
MomC.252.minus5.ASX200
MomC.252.minus5.TSE60
MomC.252.minus5.OMX
MomC.252.minus5.SMI
MomC.252.minus5.Nikkei
MomC.252.minus5.HangSeng
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1960
1980
2000
−50
0
50
Date

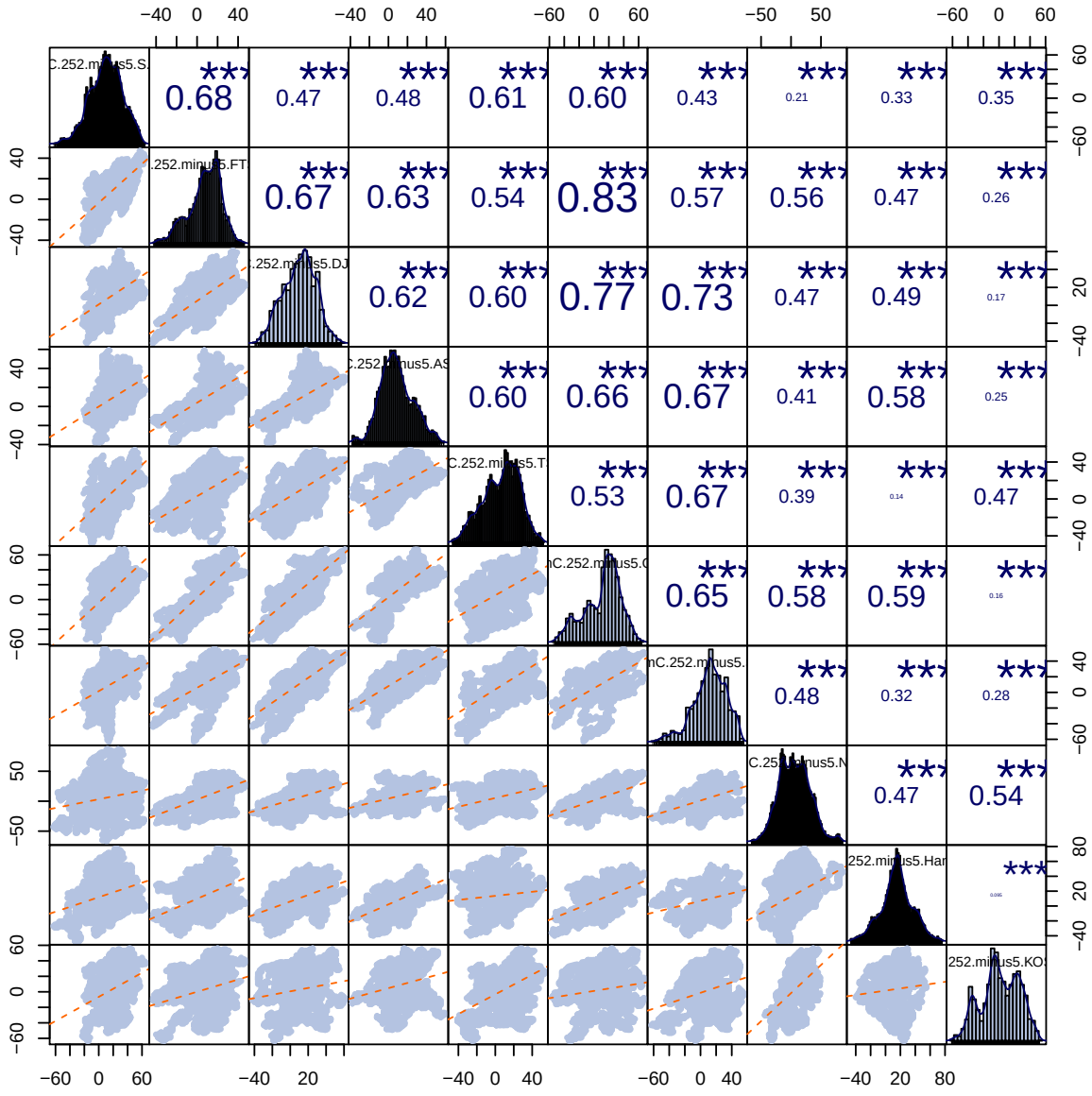


Figure 1: Correlation of the raw variables

Table **??** below shows summary statistics of the transformed variable. The transformation from variable to signal is based on a cross-sectional ranking, and then the middle 0.4 percent is assigned a neutral position, and the (1-0.4)/2 a long / short position.

	MomM.252.minus5.S.P500	MomM.252.minus5.FTSE100	MomM.252.minus5.DJESI50	MomM.252.minus5.ASX200
n	16657.00	8045.00	7264.00	5852.00
mean	0.06	-0.23	-0.07	-0.04
sd	0.76	0.56	0.62	0.61
q.0%	-1.00	-1.00	-1.00	-1.00
q.25%	-0.75	-0.50	-0.50	-0.50
q.50%	0.00	-0.25	0.00	0.00
q.75%	1.00	0.00	0.50	0.50
q.100%	1.00	1.00	1.00	1.00

Table 2: Summary statistics of the ranked predictive variable: part 1

	MomM.252.minus5.TSE60	MomM.252.minus5.OMX	MomM.252.minus5.SMI	MomM.252.minus5.Nikkei
n	8547.00	7273.00	6872.00	16656.00
mean	-0.15	0.23	0.11	-0.10
sd	0.61	0.69	0.69	0.77
q.0%	-1.00	-1.00	-1.00	-1.00
q.25%	-0.50	-0.25	-0.50	-1.00
q.50%	0.00	0.50	0.00	-0.25
q.75%	0.25	1.00	0.75	0.50
q.100%	1.00	1.00	1.00	1.00

Table 3: Summary statistics of the ranked predictive variable: part 2

	MomM.252.minus5.HangSeng	MomM.252.minus5.KOSPI200
n	11727.00	7084.00
mean	0.25	-0.11
sd	0.64	0.79
q.0%	-1.00	-1.00
q.25%	-0.25	-1.00
q.50%	0.25	-0.25
q.75%	1.00	0.75
q.100%	1.00	1.00

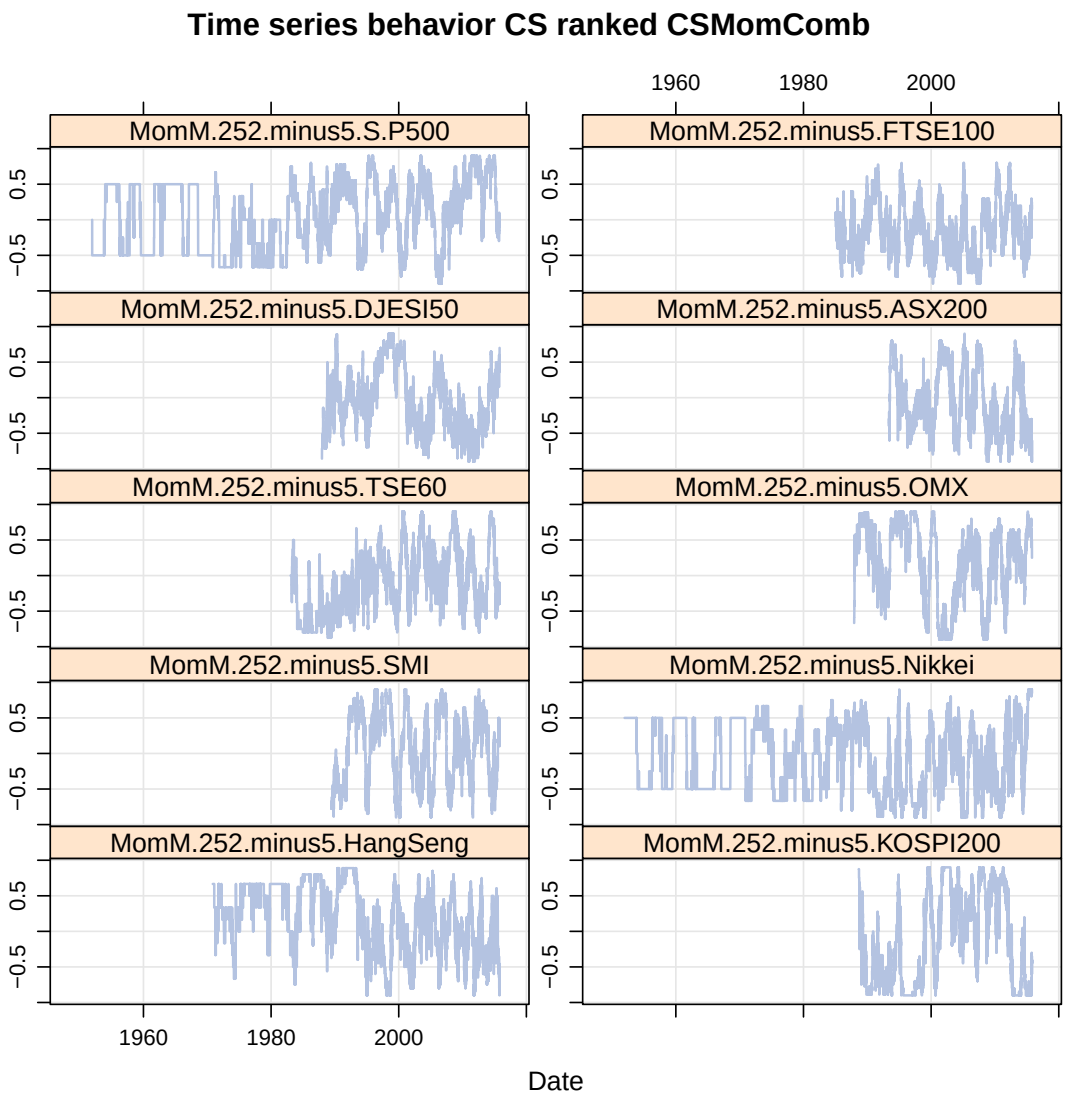
Table 4: Summary statistics of the ranked predictive variable: part 3

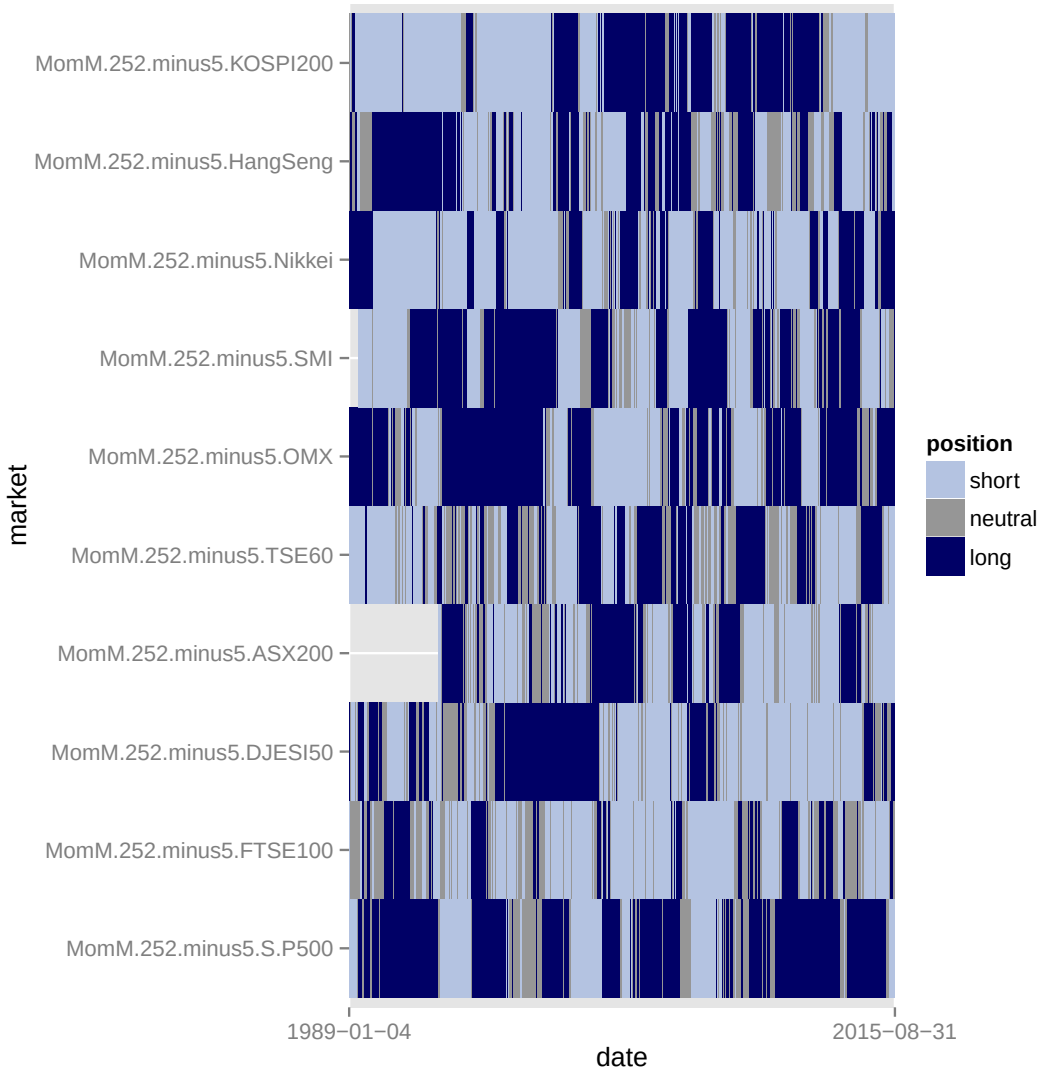
The (daily) percentage of longs vs. shorts per market are summarized in table **??** below. The impact of tilts (long or short) to a particular market are examined in more detail latwer in this report.

Next we look at the time-series behavior, distribution and comovement of the signal. In the first figure below we show the time-series behavior of the cross-sectional ranks. In the second figure below we show the time-series behavior of the signal. In the third figure below we show the distribution of the signal per market. The fourth figure below contains the correlation of the signal across markets.

	Market	longPos	shortPos	neutral
1	S.P500	0.61	0.21	0.18
2	FTSE100	0.21	0.5	0.28
3	DJESI50	0.35	0.47	0.18
4	ASX200	0.32	0.47	0.21
5	TSE60	0.33	0.4	0.27
6	OMX	0.56	0.3	0.14
7	SMI	0.49	0.37	0.14
8	Nikkei	0.3	0.59	0.11
9	HangSeng	0.41	0.37	0.22
10	KOSPI200	0.41	0.51	0.08

Table 5: Position summary per market


Time series behavior CS ranked CSMomComb
MomM.252.minus5.S.P500
MomM.252.minus5.FTSE100
MomM.252.minus5.DJESI50
MomM.252.minus5.ASX200
MomM.252.minus5.TSE60
MomM.252.minus5.OMX
MomM.252.minus5.SMI
MomM.252.minus5.Nikkei
MomM.252.minus5.HangSeng
MomM.252.minus5.KOSPI200
0.5
−0.5
1960
1980
2000
Date


MomM.252.minus5.KOSPI200
MomM.252.minus5.HangSeng
MomM.252.minus5.Nikkei
MomM.252.minus5.SMI
MomM.252.minus5.OMX
MomM.252.minus5.TSE60
MomM.252.minus5.ASX200
MomM.252.minus5.DJESI50
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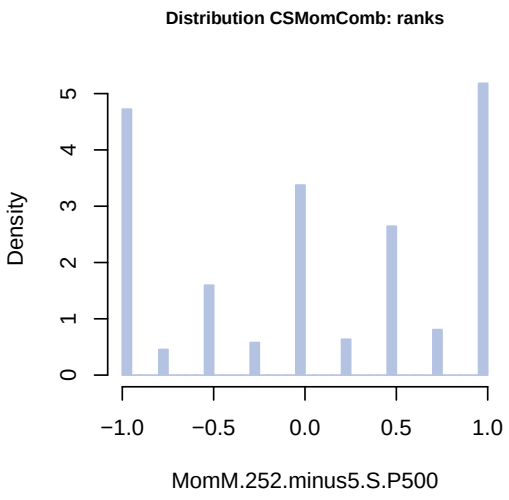
market
1989−01−04
2015−08−31
date
position
short
neutral
long


Distribution CSMomComb: ranks
Density
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3
4
5
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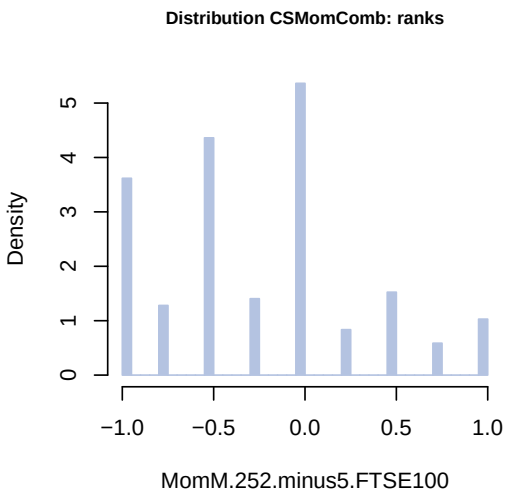
−0.5
0.0
0.5
1.0
MomM.252.minus5.S.P500


Distribution CSMomComb: ranks
Density
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4
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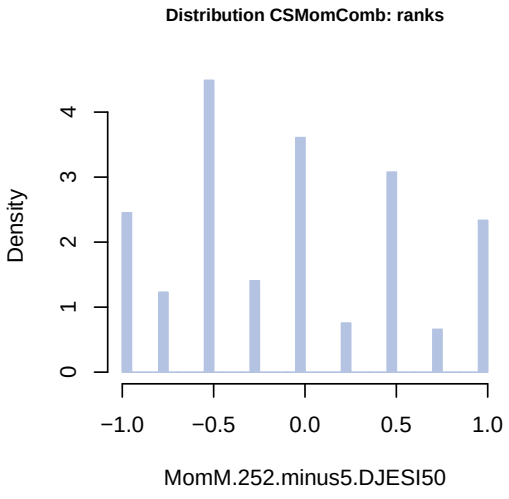
0.5
1.0
MomM.252.minus5.FTSE100


Distribution CSMomComb: ranks
Density
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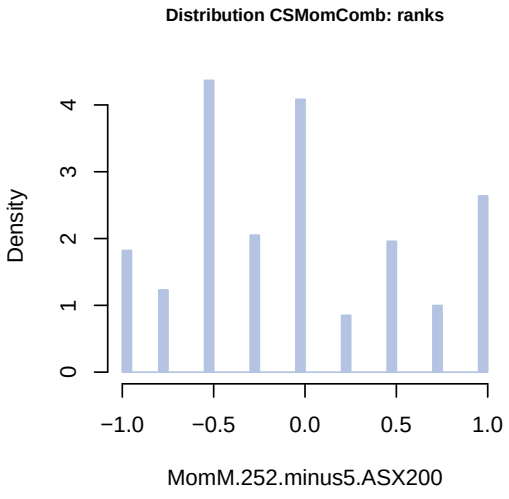
3
4
−1.0
−0.5
0.0
0.5
1.0
MomM.252.minus5.DJESI50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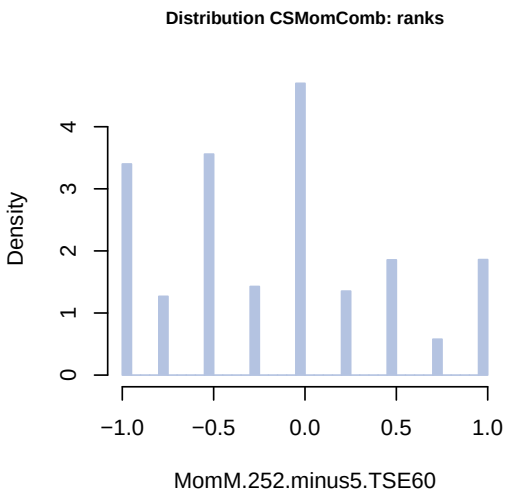
Distribution CSMomComb: ranks
Density
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4
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−0.5
0.0
0.5
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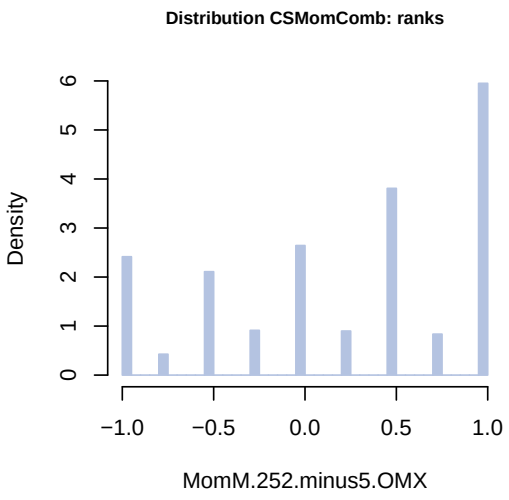
MomM.252.minus5.TSE60


Distribution CSMomComb: ranks
Density
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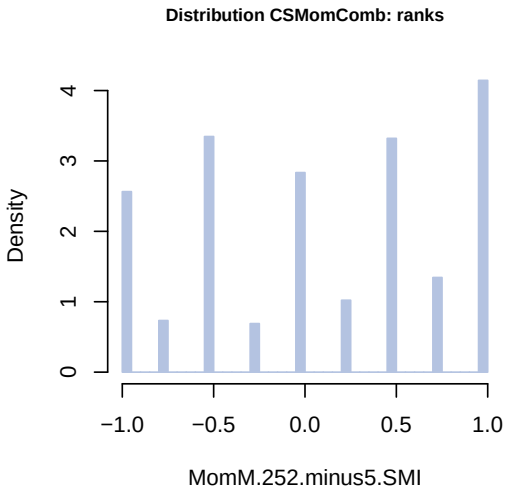
MomM.252.minus5.OMX


Distribution CSMomComb: ranks
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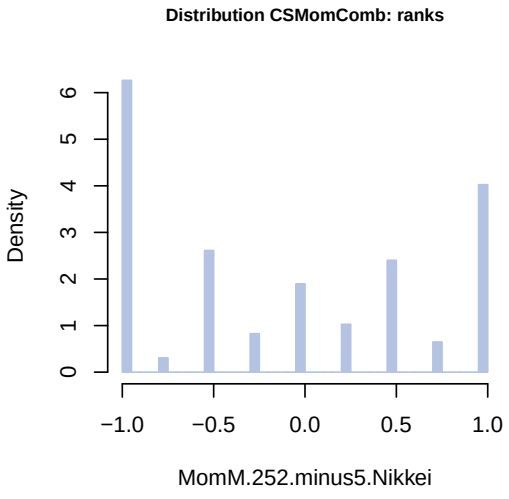
Distribution CSMomComb: ranks
Density
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3
4
5
6
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−0.5
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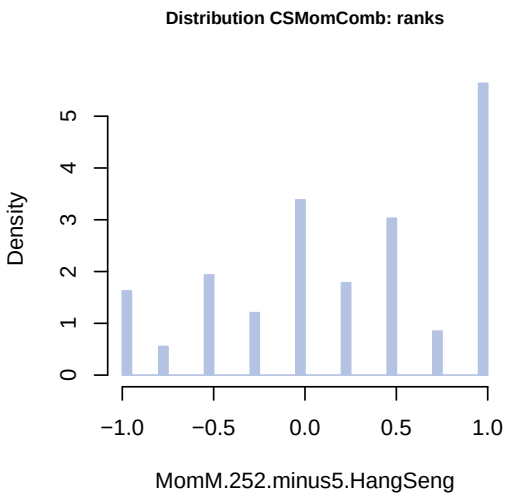
MomM.252.minus5.Nikkei


Distribution CSMomComb: ranks
Density
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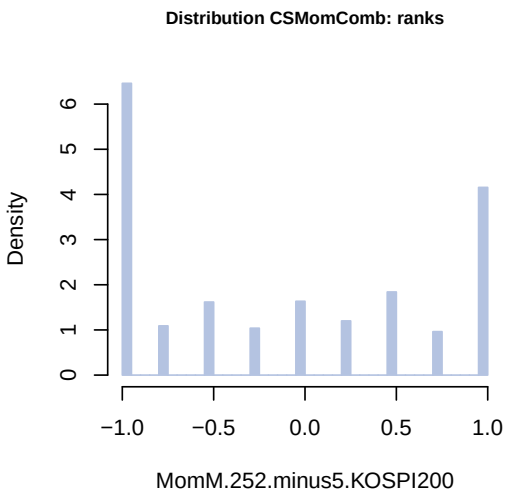
2
3
4
5
−1.0
−0.5
0.0
0.5
1.0
MomM.252.minus5.HangSeng


Distribution CSMomComb: ranks
Density
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2
3
4
5
6
−1.0
−0.5
0.0
0.5
1.0
MomM.252.minus5.KOSPI200

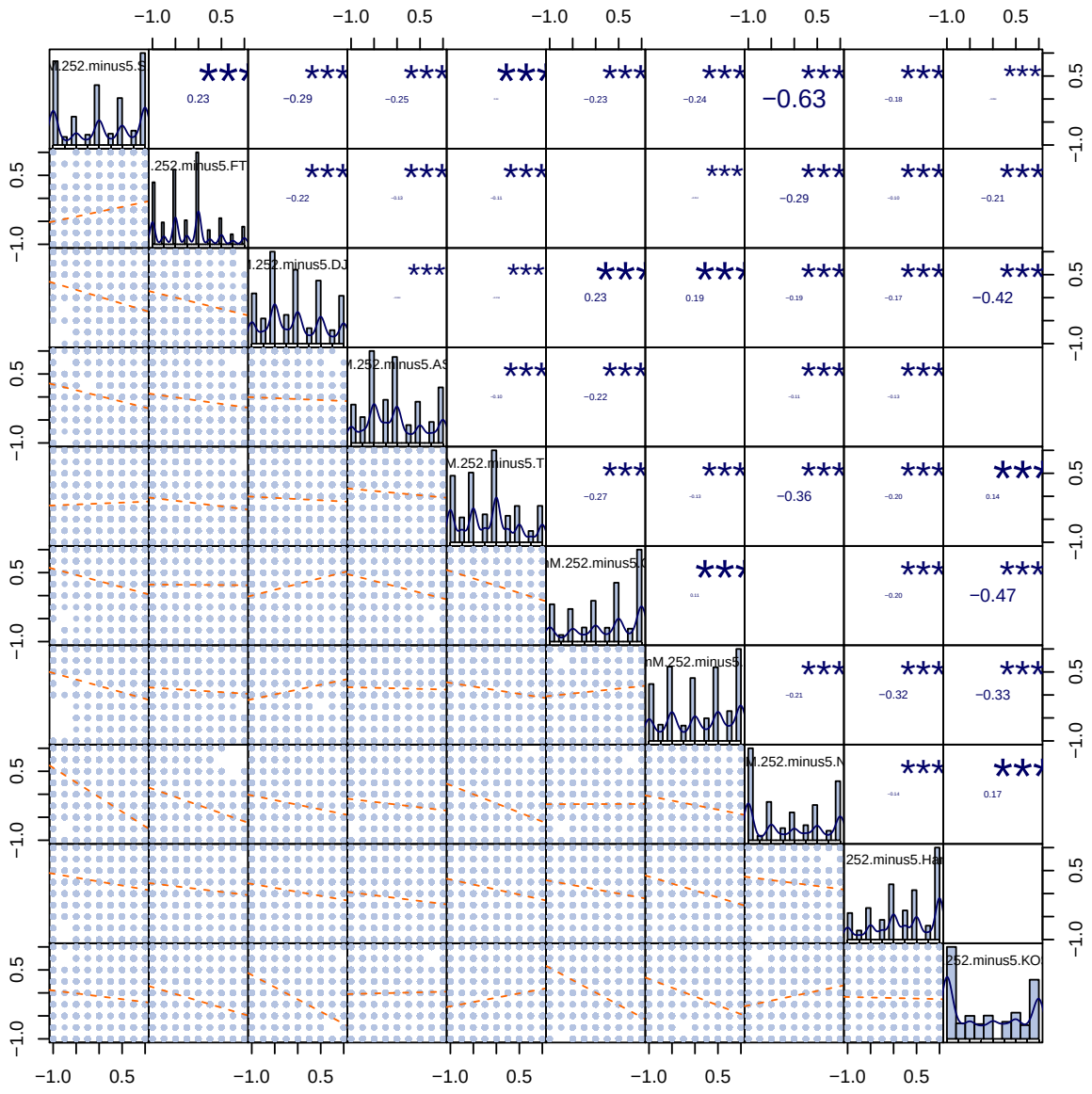


Figure 2: Correlation of the signal over markets

4 Performance

In this Section we analyse the performance of the signal for Equity using Daily rebalancing of positions. Position are scaled by the aggregate volatility of the market using an EWMA across all markets.[1]

4.1 Summary of the predictive performance

Table **??** summarizes the main risk and performance metrics deemed relevant for evaluating strategies for the standard data frequency (daily, left columns) and the monthly data frequency (right columns).

[1] The volatilty scaling is done at a with a Monthly frequency and takes into account a 1 day implementation lag and a floor of 0.666666666666667 percent of the long-term median volatility in order to limit leverage.

	1	2
N.obs	6954.00	318.00
Annualized Return (geometric)	0.22	0.23
Annualized Return (arithmetic)	0.22	0.23
Median Return	0.16	0.12
Annualized Volatility	0.44	0.40
Skewness	-0.04	0.56
Kurtosis	4.23	3.16
Information Ratio	0.50	0.58
p-value Information Ratio	0.00	0.00
Downside Risk	0.32	0.24
Sortino	0.69	0.96
VolofVol	0.00	0.00
MaxDD	-1.26	-1.04
P_Loss	0.48	0.44
HitRatio	0.52	0.56
p-value HitRatio	0.01	0.02
Stability: R2Time	76.16	76.15

Table 6: Table with a summary of performance measures for the aggregation over markets

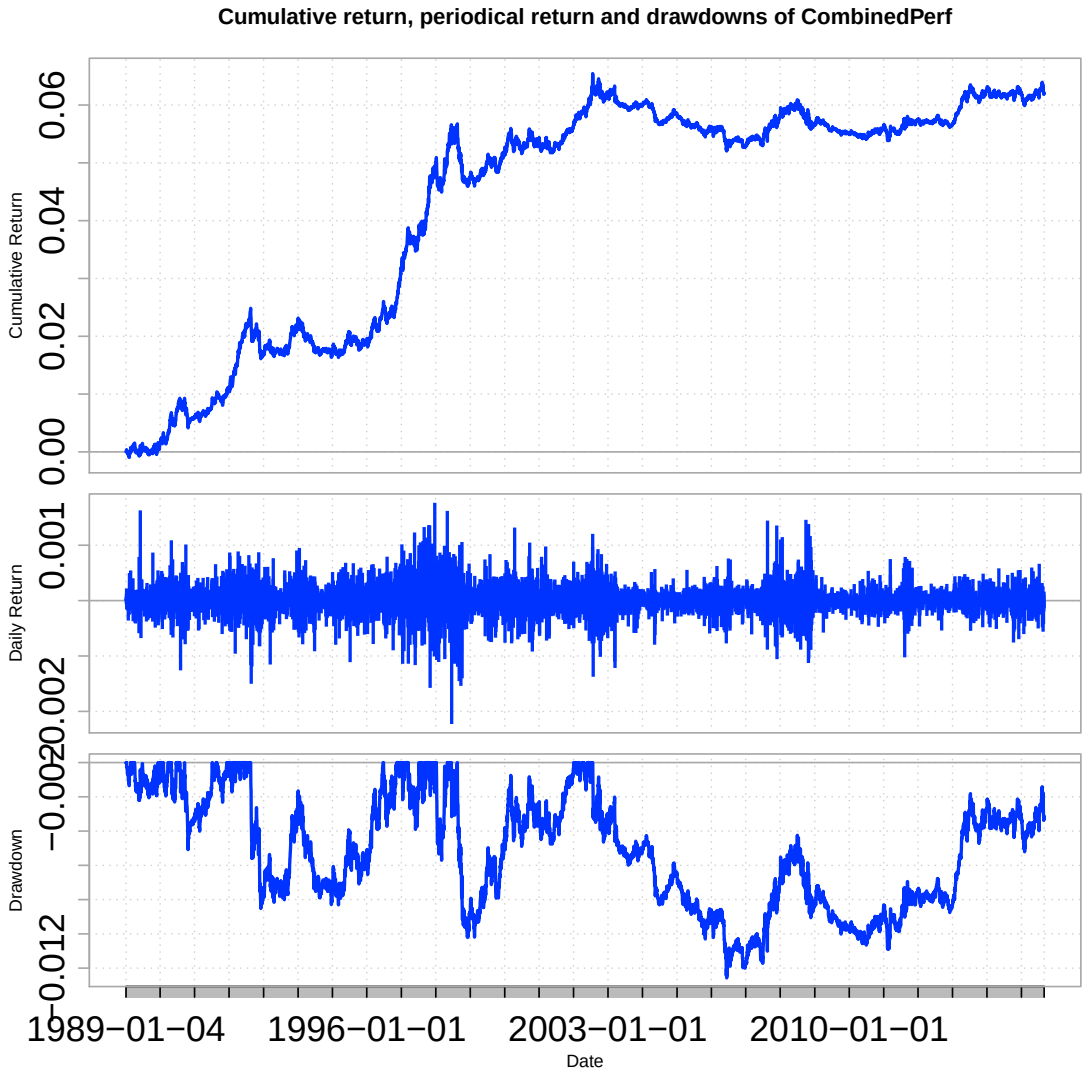


Figure 3: Performance charts of the aggregated strategy

The two figures below depict performance of the strategy over time in terms of performance and hitratios.

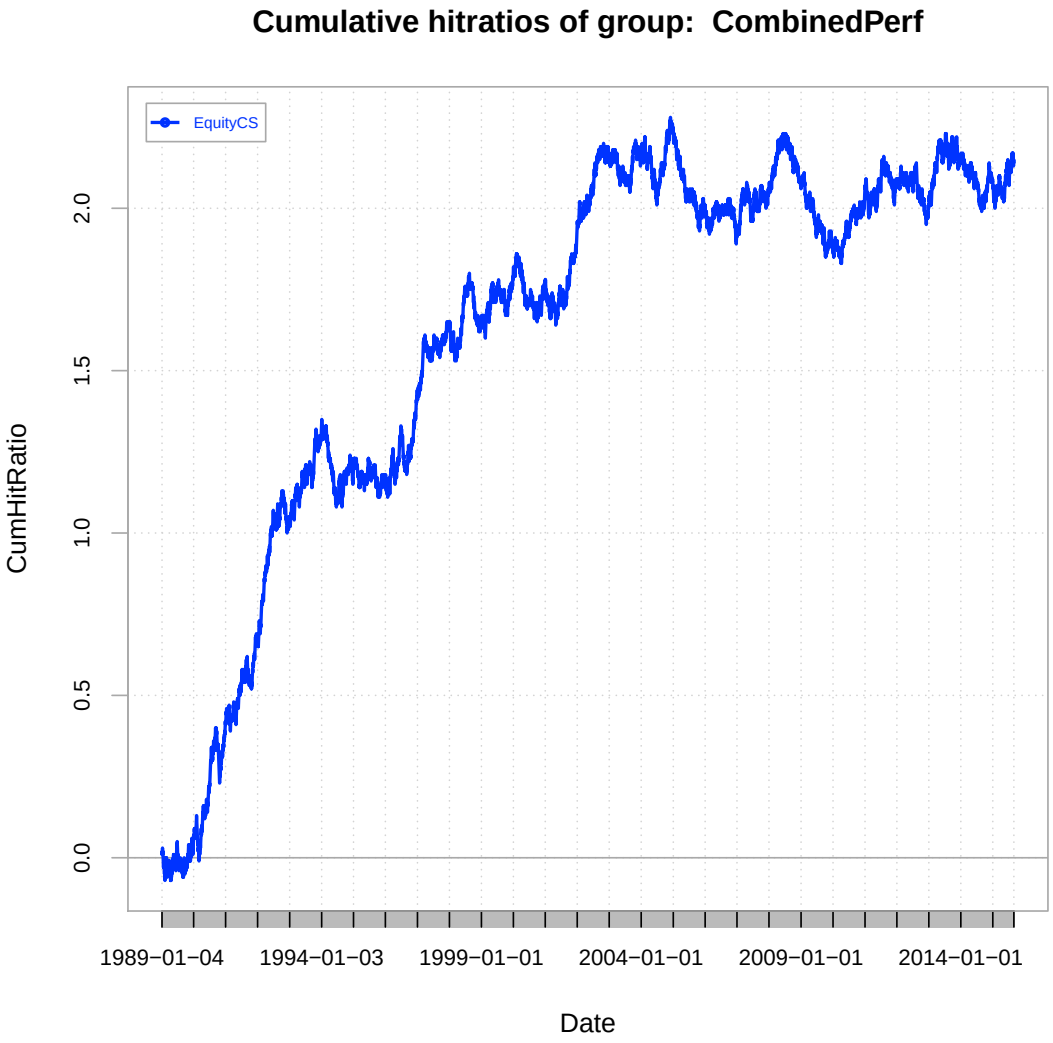


Figure 4: Cumulative hitratio of the aggregated strategy

4.2 In depth overview of the predictive performance

To get a more complete assesment of the strategy we next look at a broader range of performance metrics. Table ?? provides a detailed summary of the performance of the strategy.[2]

	x
N.obs	6954.00
Annualized Return (geometric)	0.22
Annualized Return (arithmetic)	0.22
Median Return	0.16
Annualized Volatility	0.44
Skewness	-0.04
Kurtosis	4.23
Information Ratio	0.50
p-value Information Ratio	0.00
Downside Risk	0.32
Sortino	0.69
VolofVol	0.00
MaxDD	-1.26
P_Loss	0.48
HitRatio	0.52
p-value HitRatio	0.01
Pos.(+)	0.24
Pos.(-)	0.24
Stability: R2Time	76.16
TimingIR	0.50
Annualized Turnover	1.82
MeanAbsPosition	0.06
TurnoverScaled	30.79
BE_trcost%	0.12
HurdleRatio	
IR (est.)	0.54
corr MSCI.World	-0.06
beta MSCI.World	-0.00
corr MSCI.EM	-0.01
beta MSCI.EM	-0.00
corr Barclays.US.Aggr.	0.04
beta Barclays.US.Aggr.	0.00
corr DJ.UBS	-0.00
beta DJ.UBS	-0.00
corr HFRX	0.06
beta HFRX	0.01

Table 7: Table with a detailed overview of the performance of the strategy

[2]Note that the 'BE trcost' stands for break even transaction costs; if the difference between bid prices and mid prices would be equal to the this figure, the strategy would had delivered a zero performance.

4.3 Impact of long-short bias

Tilts to a particular market can cause spurious results from the backtest. Next, we analyze the impact of any tilt via correcting the Information Ratio (IR) for position tilts. The results are presented in the table below.

	S.P500	FTSE100	DJESI50	ASX200	TSE60	OMX	SMI	Nikkei	HangSeng	KOSPI200	EquityCS
Pos.(+)	0.61	0.21	0.35	0.32	0.33	0.56	0.49	0.30	0.41	0.41	0.24
Pos.(0)	0.18	0.28	0.18	0.21	0.27	0.14	0.14	0.11	0.22	0.08	0.52
Pos.(-)	0.21	0.50	0.47	0.47	0.40	0.30	0.37	0.59	0.37	0.51	0.24
IR	0.33	-0.34	0.11	-0.12	-0.22	0.57	0.26	-0.05	0.19	0.23	0.50
Timing IR	0.34	-0.34	0.11	-0.12	-0.22	0.58	0.27	-0.03	0.20	0.24	0.50

Table 8: The impact of a position bias on the performance of the strategy

4.4 Regression Analysis

Another way to test our rationale is to regress the transformed CSMomComb variable on returns on each market. Table **??** summarizes the result of this analysis when markets are aggregated (taking into account the resulting clustering of observations at the time and market dimension). The next figure depicts the results.

	EquityCS
consOLS	0.05
t_consOLS	1.83
coefOLS	2.17
t_coefOLS	1.80
R2	0.02
consQR	0.03
t_consQR	5.81
coefQR	2.01
t_coefQR	10.95
consRR	0.07
t_consRR	3.25
coefRR	4.07
t_coefRR	4.16

Table 9: Results of regressing the transformed variable on instrument returns

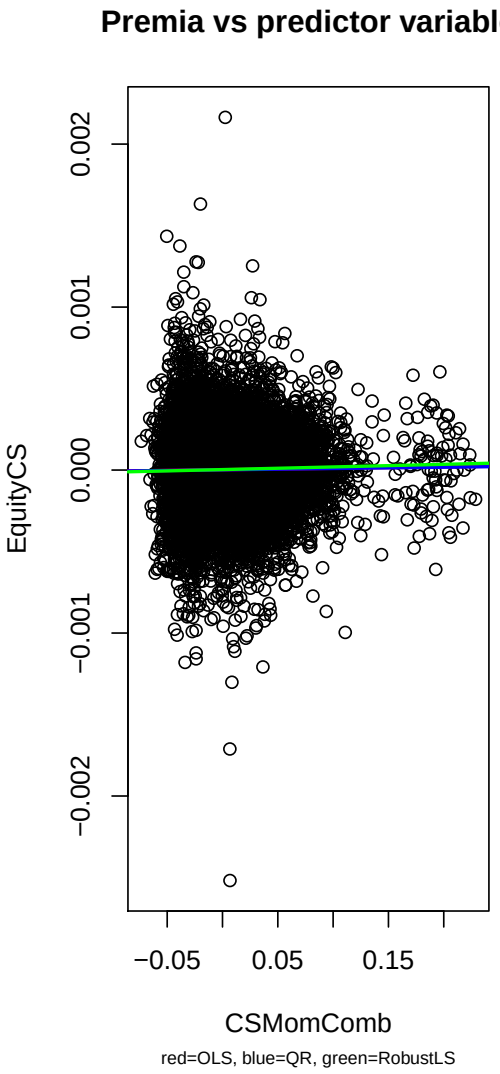


Figure 5: Regressing the transformed variable on instrument returns

4.5 Reliability of performance

To have an assessment of the confidence we can have in the performance, we have above looked at the Information Ratios, its p-values, the Hit Ratios, its p-values, and the estimated Information Ratio. To further assess the reliability of the performance along multiple dimensions we next look at a combined (monthly) Information Ratio and Hit Ratio test in table **??**. The column "P-value Norm." shows the probability that a randomly drawn return from a normal distribution will show both a superior information ratio and hitratio than the strategy. There are 10,000 different return series drawn with the same length as timeseries of the strategy returns. The column "P-value Emp." shows the probability that a randomly drawn return from the de-meaned distribution of the strategy returns will show both a superior information ratio and hitratio than the strategy. Due to the long calculation time we draw 1,000 different timeseries from the de-meaned strategy returns (with replacing) in this exercise. In case the strategy returns are normally distributed the p-values should converge to the same number.

	IR (arim.)	HR	Skewness	Kurtosis	P-value Norm.	P-value Emp.
EquityCS	0.58	55.66%	0.56	3.16	0.00%	0.00%

Table 10: Table with the combined test on Information Ratio and Hit Ratio

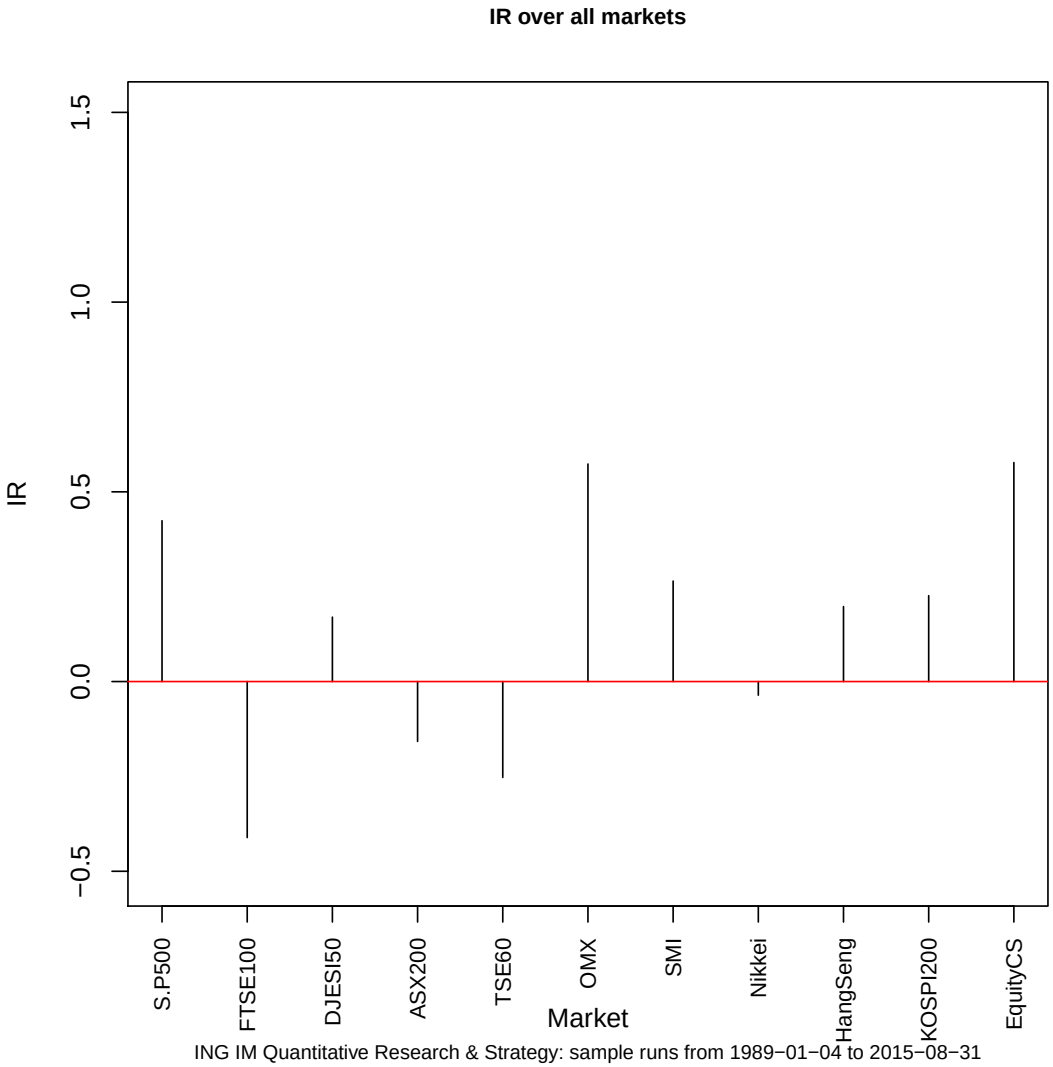


Figure 6: IR of strategy returns per market

4.6 Individual Markets Contributions

The next three figures show the Information Ratio (IR) of the strategy returns for each individual market, and the cumulative performance and hit ratio contributions per market over time.

Figure 7: Strategy performance per market

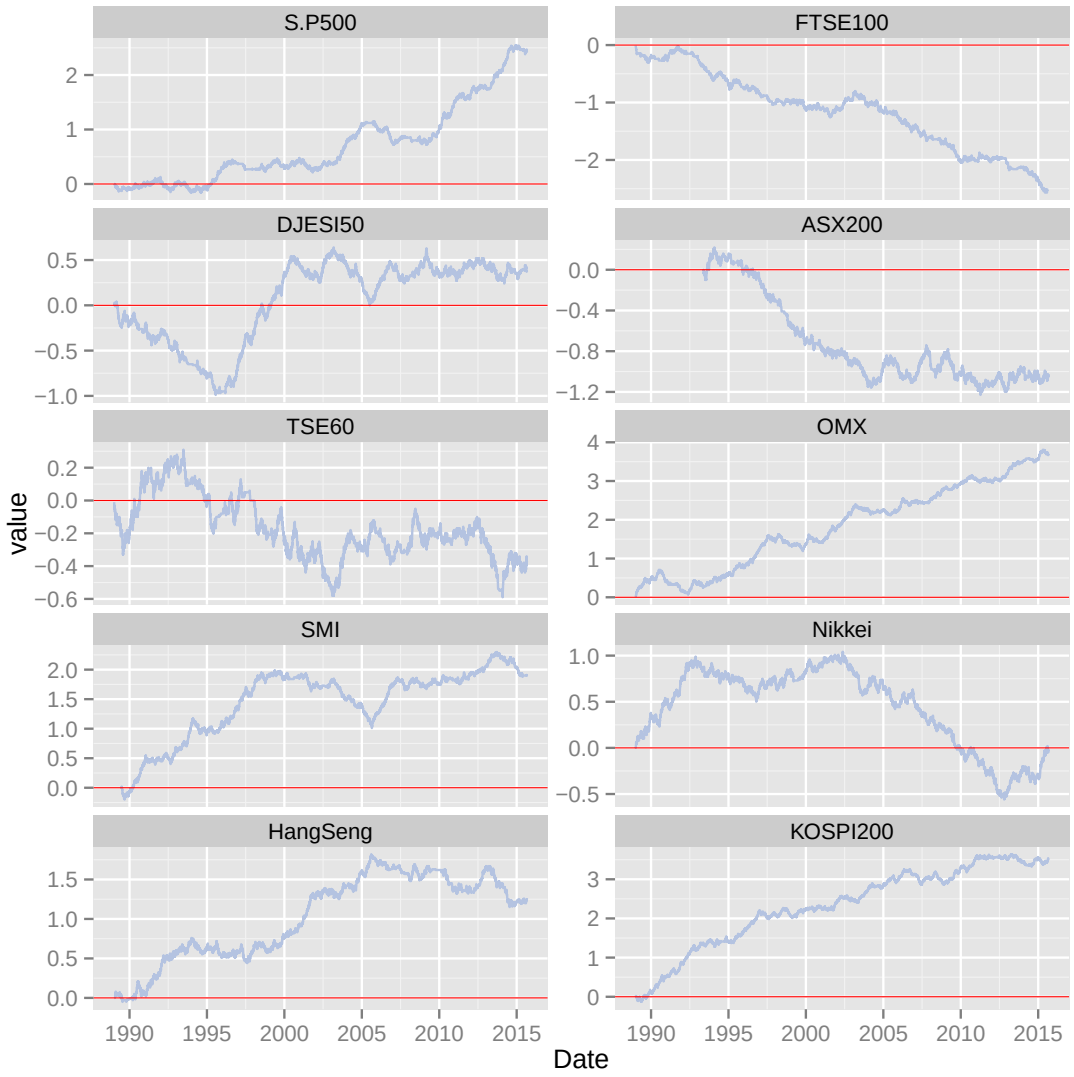


Figure 8: Cumulative hit rate per market

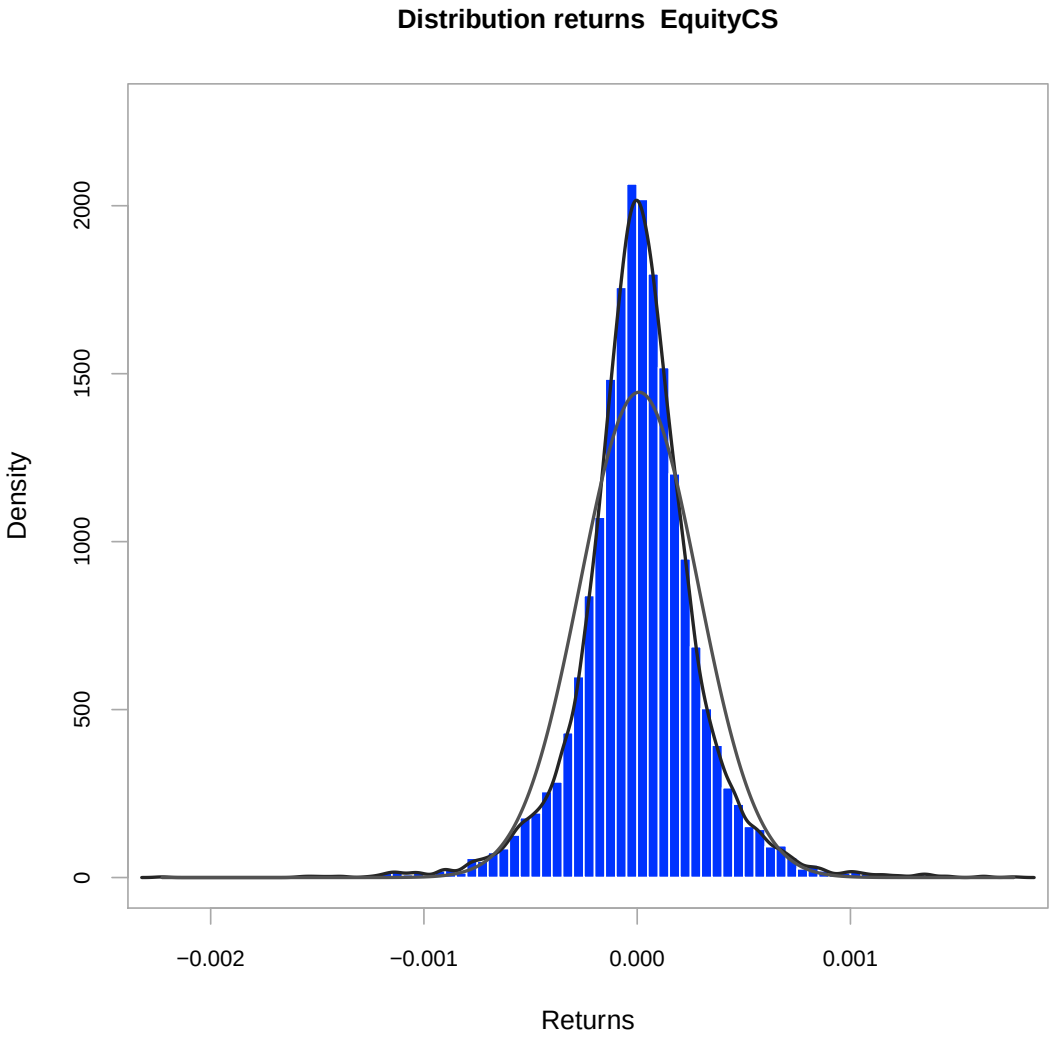


Figure 9: Distribution of strategy returns

4.7 Risk

The risk characteristics of the strategy, besides summarized in the numbers in table **??**, can be inferred from the return distributions of the strategies shown below.

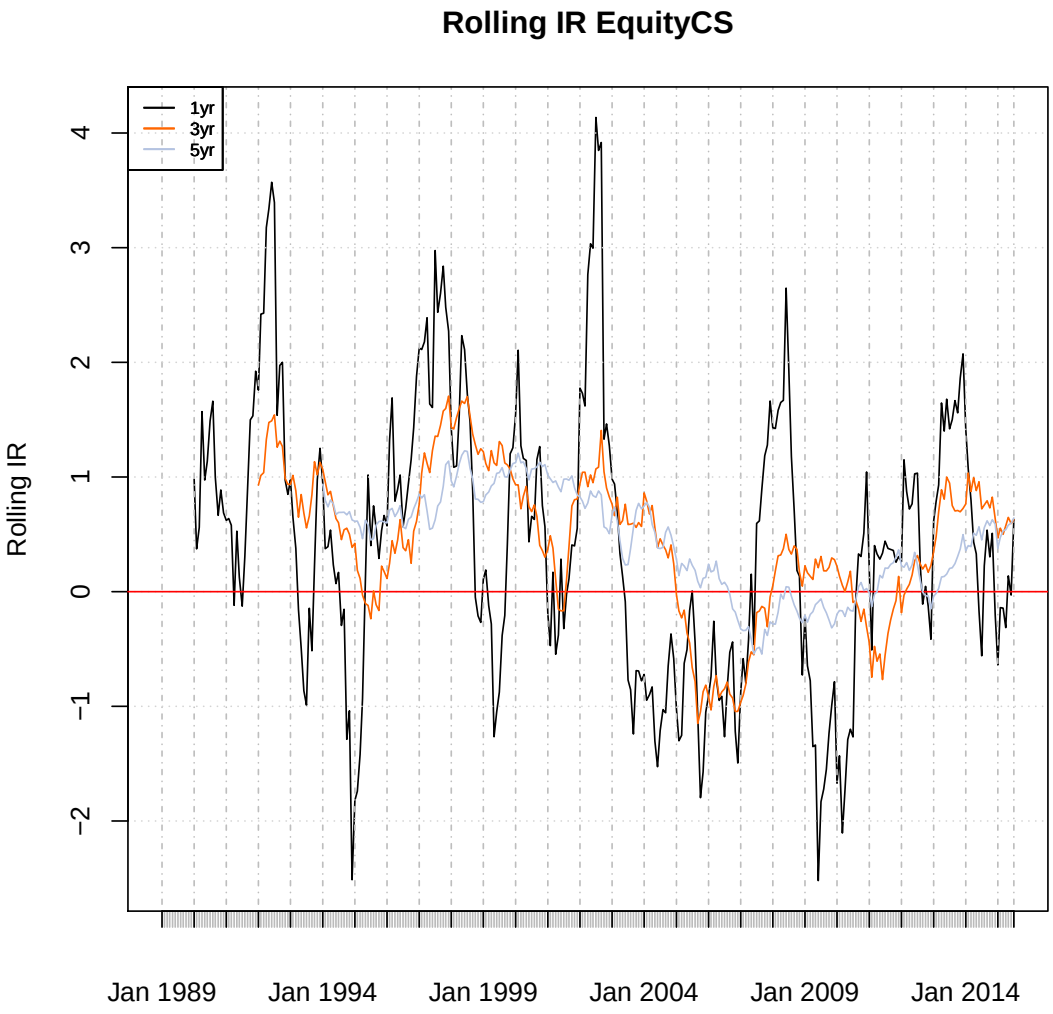
4.8 Subperiod Performances

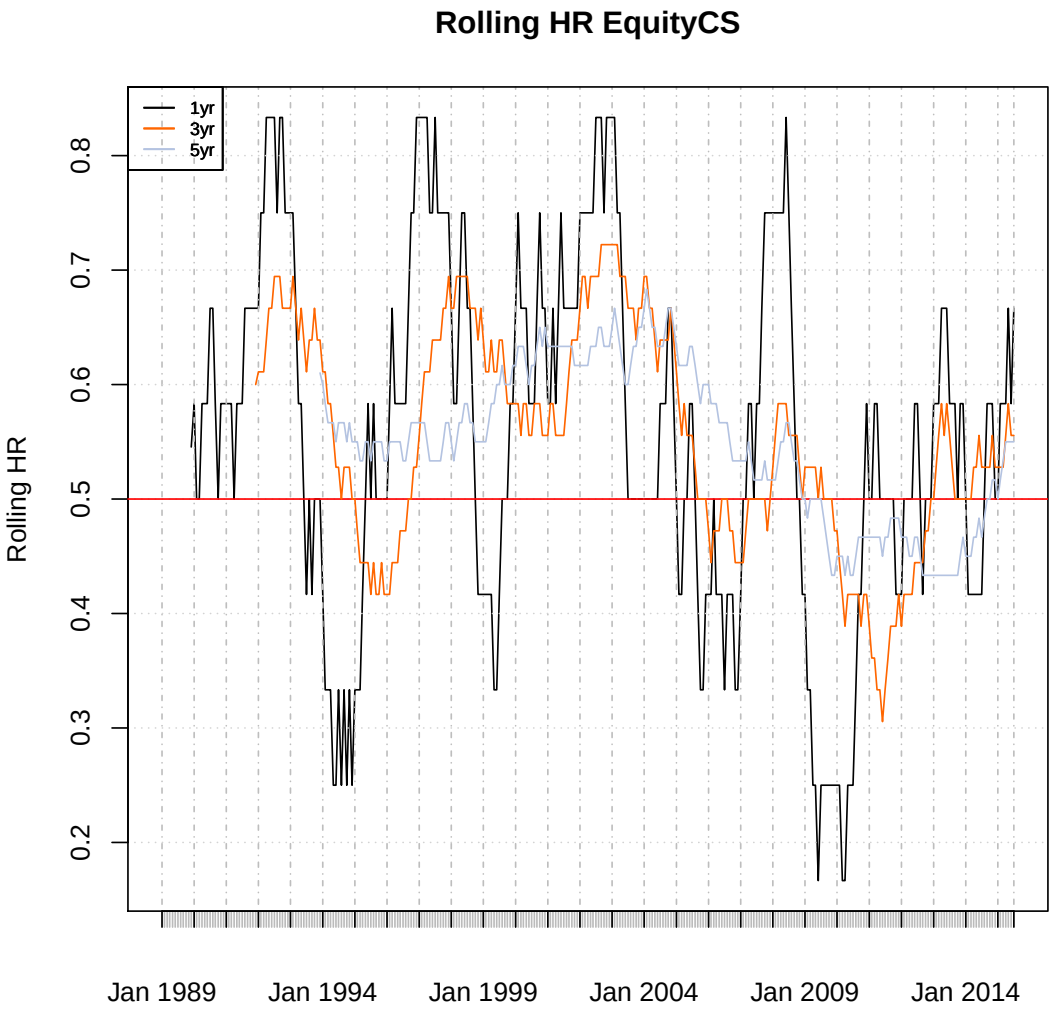
To assess the robustness of the performance, we examine in this Section the performance over time. The tables below summarizes monthly and annual return contributions.

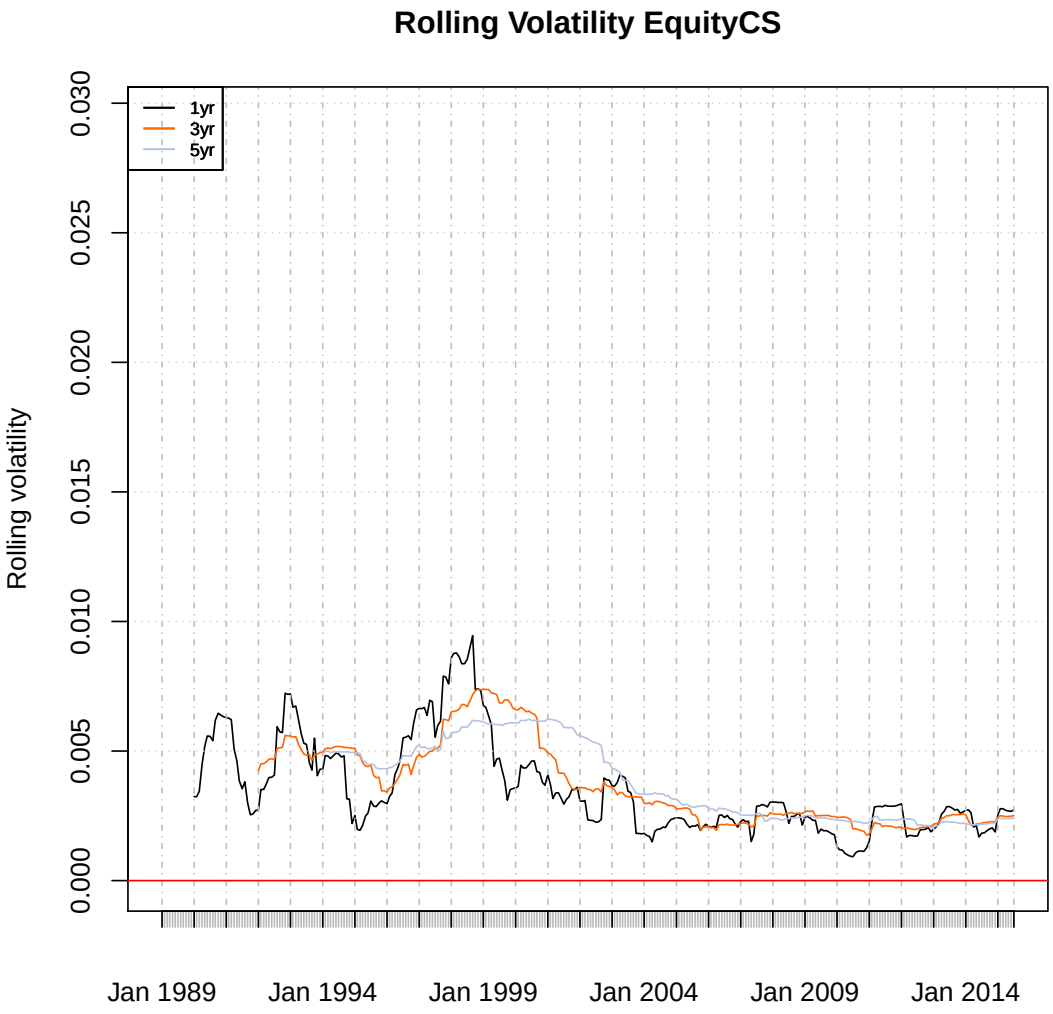
Table 11: Calendar returns table EquityCS

Strategy	1	2	3	4	5	6	7	8	9	10	11	12	YTD	CM
1989	-0.07	0.12	0.07	-0.14	-0.01	0.14	-0.04	-0.09	0.05	0.05	-0.06	0.13	0.15	0.15
1990	0.11	-0.08	0.14	0.36	-0.21	0.27	0.16	-0.02	-0.23	-0.14	0.08	0.00	0.43	0.58
1991	0.06	-0.07	0.10	-0.06	0.09	0.07	0.06	0.14	-0.07	-0.03	0.09	0.13	0.52	1.11
1992	0.02	0.30	0.10	0.27	0.24	0.16	0.02	-0.32	0.14	-0.01	-0.35	0.04	0.61	1.72
1993	0.11	0.04	-0.08	-0.08	0.05	-0.01	-0.04	0.13	-0.01	0.33	-0.08	0.18	0.54	2.27
1994	-0.02	-0.19	-0.07	-0.02	-0.09	-0.09	0.00	-0.09	0.06	-0.01	0.00	-0.05	-0.55	1.70
1995	0.07	-0.07	0.00	0.06	0.14	0.14	-0.14	0.00	0.00	-0.08	0.08	-0.01	0.20	1.91
1996	0.04	0.18	0.14	-0.19	0.21	0.23	-0.30	0.09	0.12	0.02	0.32	0.35	1.24	3.17
1997	0.22	0.17	0.19	-0.12	-0.17	0.20	0.23	-0.09	0.26	0.65	0.04	0.13	1.72	4.95
1998	-0.28	-0.09	0.21	0.24	0.36	0.10	-0.06	-0.23	-0.23	-0.22	-0.08	0.09	-0.20	4.74
1999	-0.01	-0.04	0.00	0.15	-0.03	0.16	0.02	0.02	-0.15	-0.01	0.21	0.11	0.45	5.21
2000	0.10	0.17	-0.20	0.09	-0.04	-0.14	0.13	0.01	0.04	0.03	-0.03	0.03	0.21	5.43
2001	-0.19	0.08	0.03	-0.15	0.02	0.08	-0.06	0.10	0.09	0.14	-0.03	0.09	0.20	5.64
2002	0.16	0.06	0.00	0.00	0.08	0.07	0.18	0.04	0.14	-0.25	0.01	0.02	0.49	6.16
2003	0.02	0.04	-0.07	-0.13	0.00	-0.02	-0.05	0.02	0.05	0.00	0.01	0.00	-0.14	6.01
2004	0.03	0.01	-0.06	-0.10	-0.13	-0.07	0.01	0.04	0.05	0.07	0.07	-0.05	-0.14	5.86
2005	-0.07	-0.06	-0.05	0.05	-0.09	0.00	0.05	-0.05	-0.09	-0.05	0.09	0.05	-0.23	5.62
2006	-0.04	-0.02	0.05	-0.05	-0.18	0.01	-0.03	0.05	-0.01	-0.02	-0.07	0.00	-0.31	5.29
2007	0.07	0.04	0.01	0.04	-0.06	-0.10	0.22	0.05	0.08	0.06	-0.05	0.14	0.50	5.82
2008	0.00	0.04	0.05	0.06	-0.05	0.11	-0.06	-0.08	-0.04	-0.07	-0.07	-0.05	-0.16	5.66
2009	0.11	-0.07	0.02	-0.07	-0.05	-0.05	0.04	-0.05	-0.01	0.00	-0.01	-0.01	-0.14	5.51
2010	0.03	-0.02	-0.05	0.00	0.00	-0.03	0.04	0.06	0.04	0.00	0.01	0.07	0.13	5.65
2011	-0.08	-0.16	0.18	-0.02	-0.01	-0.02	0.07	0.04	0.03	-0.01	-0.02	0.08	0.09	5.74
2012	-0.09	0.03	0.06	-0.05	0.00	0.03	0.07	-0.09	-0.03	0.02	-0.05	0.03	-0.08	5.66
2013	0.11	0.07	0.10	0.17	-0.05	0.13	0.00	-0.07	0.00	0.00	0.00	0.09	0.55	6.24
2014	-0.05	-0.02	0.01	0.05	-0.07	0.03	-0.07	0.07	0.06	-0.04	0.04	-0.05	-0.04	6.20
2015	-0.18	0.10	0.01	0.01	0.05	-0.01	0.10	-0.09					0.00	6.20
Month	0.01	0.02	0.03	0.01	0.00	0.05	0.02	-0.01	0.01	0.02	0.01	0.06		

To gain further insight into the performance over subperiods, the following figure depicts the rolling Information Ratios (IR) and Hit Ratios (HR) over different horizons.


Rolling IR EquityCS
1yr
3yr
5yr
Rolling IR
4
3
2
1
0
−1
−2
Jan 1989
Jan 1994
Jan 1999
Jan 2004
Jan 2009
Jan 2014


Rolling HR EquityCS
1yr
3yr
5yr
Rolling HR
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Jan 1989
Jan 1994
Jan 1999
Jan 2004
Jan 2009
Jan 2014


Rolling Volatility EquityCS
1yr
3yr
5yr
Rolling volatility
0.000
0.005
0.010
0.015
0.020
0.025
0.030
Jan 1989
Jan 1994
Jan 1999
Jan 2004
Jan 2009
Jan 2014

4.9 Structural Breaks

An alternative way to assess the robustness of performance over time is by examining the presence of structural breaks in the strategy returns. Table **??** summarizes the results of structural break test on the performances of the strategies. We perform three different tests: a (sup)F-test, the CUSUM test and the MOSUM test. In the (sup)F-test the best-fitting breakpoint is determined. In the column R1 the average return in the period before the breakpoint is given and in the column R2 the average return in the period after the breakpoint is shown. In the column P-val F, the p-value of the F-test is shown. The next 2 columns report the p-values of the CUSUM test and the MOSUM test. The null hypothesis in these tests is that there is no breakpoint. If the p-value is below the x % level, we can reject the null hypothesis with a significance of (100-x) %. The results of the structural break test are also depicted in the figures in the Appendix.

Table **??** summarizes the results of the structural breaks analysis on the signs of returns. In the columns H1 and H2 we report the hitratio before and after the breakpoint, respectively.

	Break point	R1	R2	F stat	P-val F	P-val CUSUM	P-val MOSUM
1	1998-06-16	0.56%	0.03%	9.4	3.5%	48.6%	16.6%

Table 12: Structural break test results on the performances of the strategies

	Break point	H1	H2	F stat	P-val F	P-val CUSUM	P-val MOSUM
1	1994-01-04	55.17%	50.71%	8.5	5.2%	28.2%	29.4%

Table 13: Structural break test results on the signs of the performances of the strategies

4.10 Risk Budgetting Mechanism

Next, we examine the impact of various risk budgetting mechanism (being No vol control). First, table **??** shows the Information Ratio (IR) for every market and on aggregate for various risk budgetting schemes.

The next tables show more elaborated performance statistics of the various risk budgetting schemes for the aggregated strategy across markets.

	IR No vol control	IR Past 1-month vol.	IR Past 3-month vol.	IR Past 6-month vol.	IR EWMA	IR Beta	IR Average vol. market	IR EWMA systematic vol.
S.P500	0.38	0.55	0.52	0.52	0.46	0.44	0.42	0.41
FTSE100	-0.41	-0.32	-0.38	-0.41	-0.39	-0.36	-0.41	-0.42
DJESI50	0.05	0.09	0.09	0.13	0.17	0.10	0.17	0.14
ASX200	-0.21	-0.26	-0.26	-0.22	-0.23	-0.17	-0.16	-0.15
TSE60	-0.32	-0.03	-0.11	-0.15	-0.21	-0.20	-0.25	-0.20
OMX	0.42	0.63	0.60	0.59	0.60	0.49	0.57	0.53
SMI	0.12	0.23	0.20	0.23	0.26	0.20	0.26	0.27
Nikkei	-0.15	-0.04	-0.06	-0.05	-0.02	-0.08	-0.04	-0.03
HangSeng	0.07	0.34	0.33	0.26	0.24	0.26	0.20	0.29
KOSPI200	0.11	0.22	0.23	0.24	0.21	0.24	0.23	0.22
EquityCS	0.48	0.68	0.61	0.60	0.60	0.51	0.58	0.57

Table 14: Table with the Information Ratio of various risk budgetting schemes

	No.vol.control	Past.1.month.vol	Past.3.month.vol	Past.6.month.vol	EWMA	Beta	Average.vol..market	EWMA.systematic.vol.
N.obs	318.00	318.00	318.00	318.00	318.00	318.00	318.00	318.00
Annualized Return (geometric)	1.85	0.26	0.23	0.22	0.21	0.04	0.23	0.27
Annualized Return (arithmetic)	1.92	0.26	0.23	0.22	0.21	0.04	0.23	0.27
Median Return	1.22	0.17	0.17	0.19	0.14	0.03	0.12	0.15
Annualized Volatility	3.87	0.38	0.37	0.37	0.35	0.09	0.40	0.47
Skewness	0.25	0.14	0.28	0.16	0.09	1.00	0.56	1.34
Kurtosis	2.68	2.36	1.98	1.83	1.81	6.86	3.16	8.61
Information Ratio	0.48	0.68	0.61	0.60	0.60	0.51	0.58	0.57
p-value Information Ratio	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Downside Risk	2.39	0.21	0.21	0.21	0.21	0.03	0.24	0.24
Sortino	0.77	1.26	1.08	1.07	1.01	1.30	0.96	1.10
VolofVol	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaxDD	-12.16	-1.12	-1.05	-1.03	-0.91	-0.23	-1.04	-0.99
P_Loss	0.44	0.45	0.45	0.45	0.44	0.46	0.44	0.46
HitRatio	0.56	0.55	0.55	0.55	0.56	0.54	0.56	0.54
p-value HitRatio	0.02	0.03	0.05	0.04	0.02	0.07	0.02	0.09
Stability: R2Time	73.58	71.17	69.56	72.46	72.77	72.10	76.15	73.33

Table 15: Performance statistics Risk Budgetting methods: EquityCS

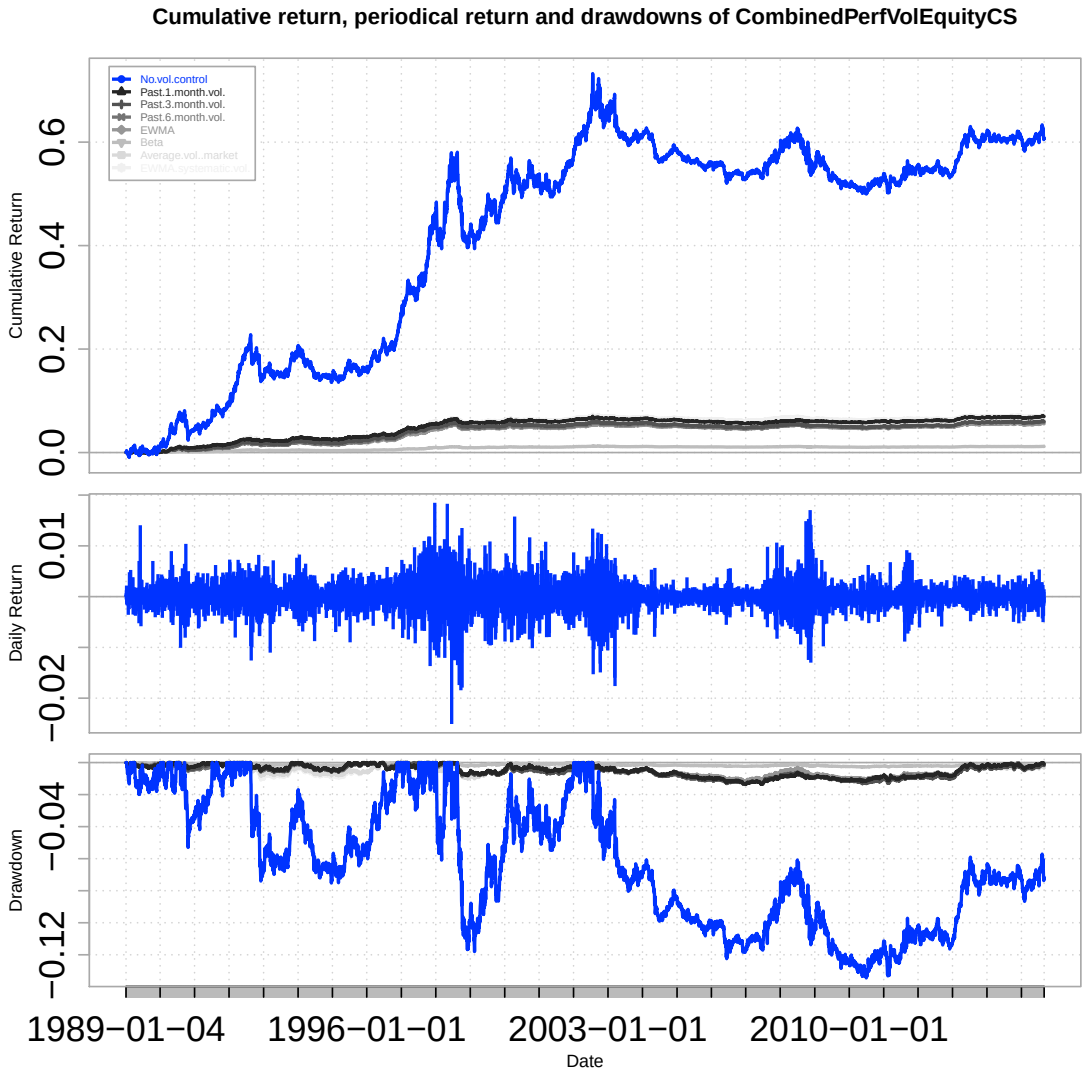


Figure 10: Cumulative strategy returns of various RB methods: EquityCS

The figures below depicted the cumulative performance of the various risk budgetting schemes for the aggregated strategy across markets. Finally, the rolling Information Ratio and volatility of the aggregated strategy across markets for the various risk budgetting schemes are depicted below.

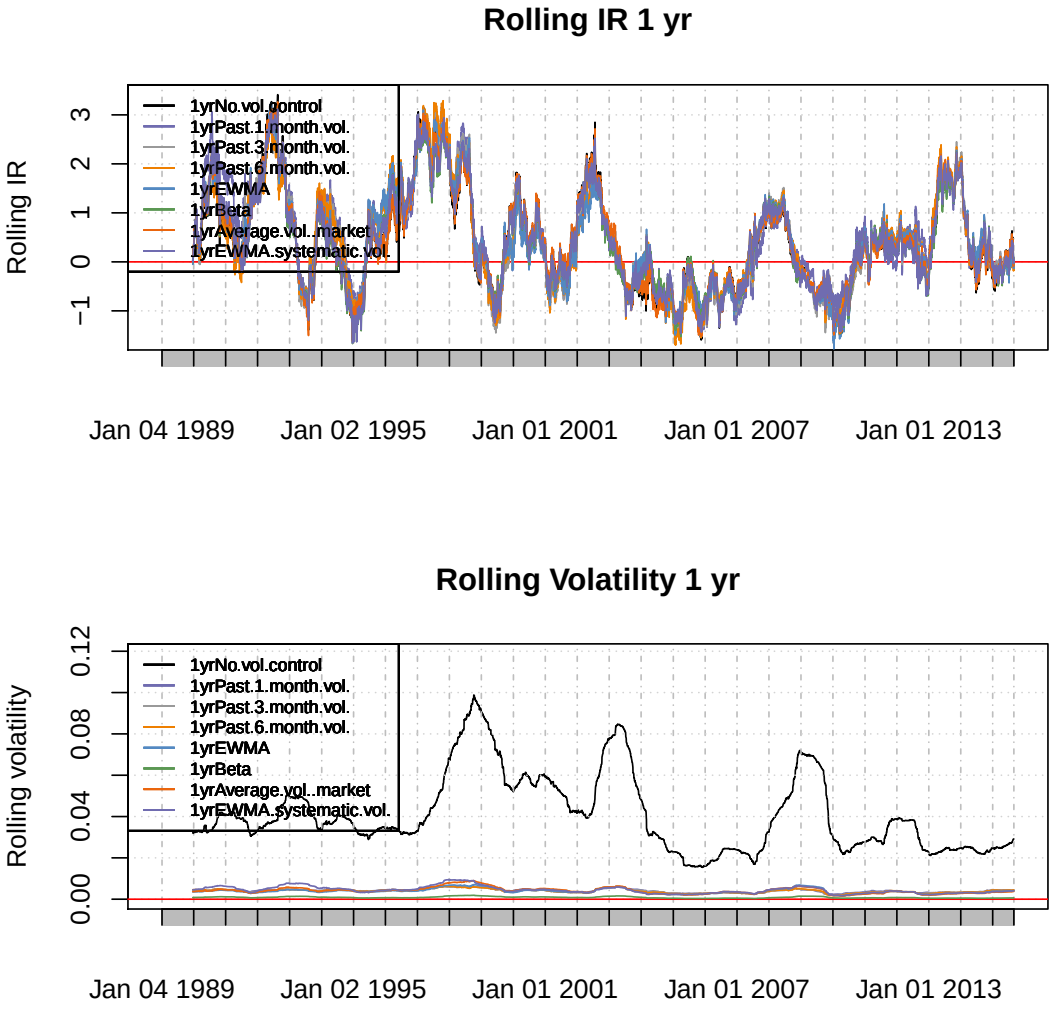


Figure 11: Rolling IR and volatility for various RB methods: EquityCS

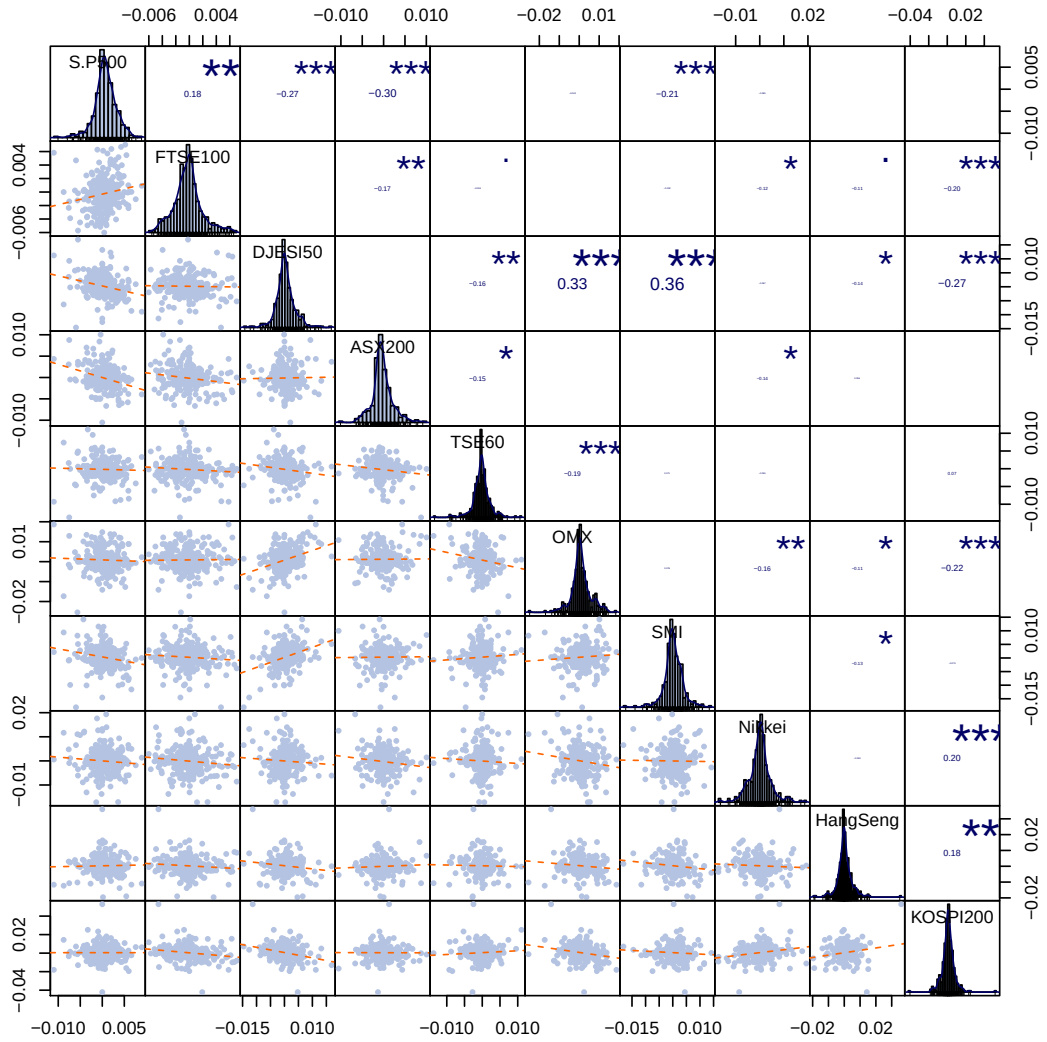


Figure 12: Correlation between strategy returns

4.11 Comovement

The figure below shows how the strategy returns over various markets relate to each other (in terms of correlations). The next figure shows how they relate in terms of clustering. In both figures we consider monthly data to minimze the impact of non-synchronous trading.

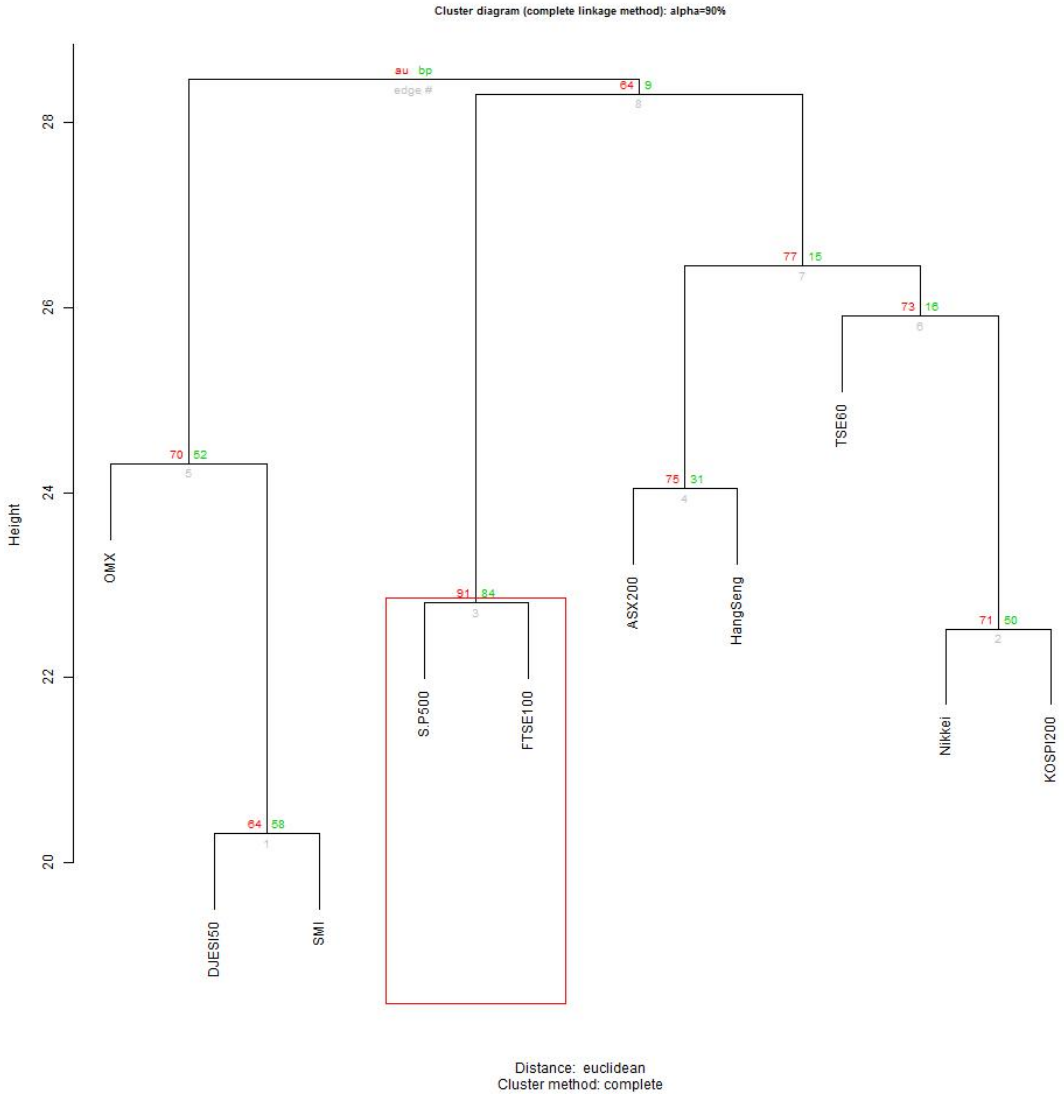


Figure 13: Dendogram of the strategy returns over markets

5 Signal Analysis

In this Section we analyze the relation between our views (signals) and strategy returns in more detail, using various ways to translate a rank into a signal, and looking at the performance conditional upon various values of the variable, rank, or signal.

5.1 Sign vs. Magnitude

First, we examine the performance for the following signal implementations: -1/0/+1 (Strategy), pure long/short (L/S; which capture only the direction), or a rank-based position (Rank/sum(Rank); which account for the magnitude of a signal). The results are summarized in table **??** and figures that follow.

Strategy	EquityCS	L/S EquityCS.1	Rank/sum(Rank) EquityCS.2
N.obs	318.00	318.00	318.00
Annualized Return (geometric)	0.23	0.29	0.18
Annualized Return (arithmetic)	0.23	0.29	0.18
Median Return	0.12	0.22	0.12
Annualized Volatility	0.40	0.56	0.31
Skewness	0.56	0.23	0.39
Kurtosis	3.16	1.01	2.28
Information Ratio	0.58	0.51	0.58
p-value Information Ratio	0.00	0.00	0.00
Downside Risk	0.24	0.35	0.17
Sortino	0.96	0.83	1.03
VolofVol	0.00	0.00	0.00
MaxDD	-1.04	-1.45	-0.87
P_Loss	0.44	0.45	0.43
HitRatio	0.56	0.55	0.57
p-value HitRatio	0.02	0.05	0.01
Stability: R2Time	76.15	83.33	71.08

Table 16: Comparing different signal implementation strategies

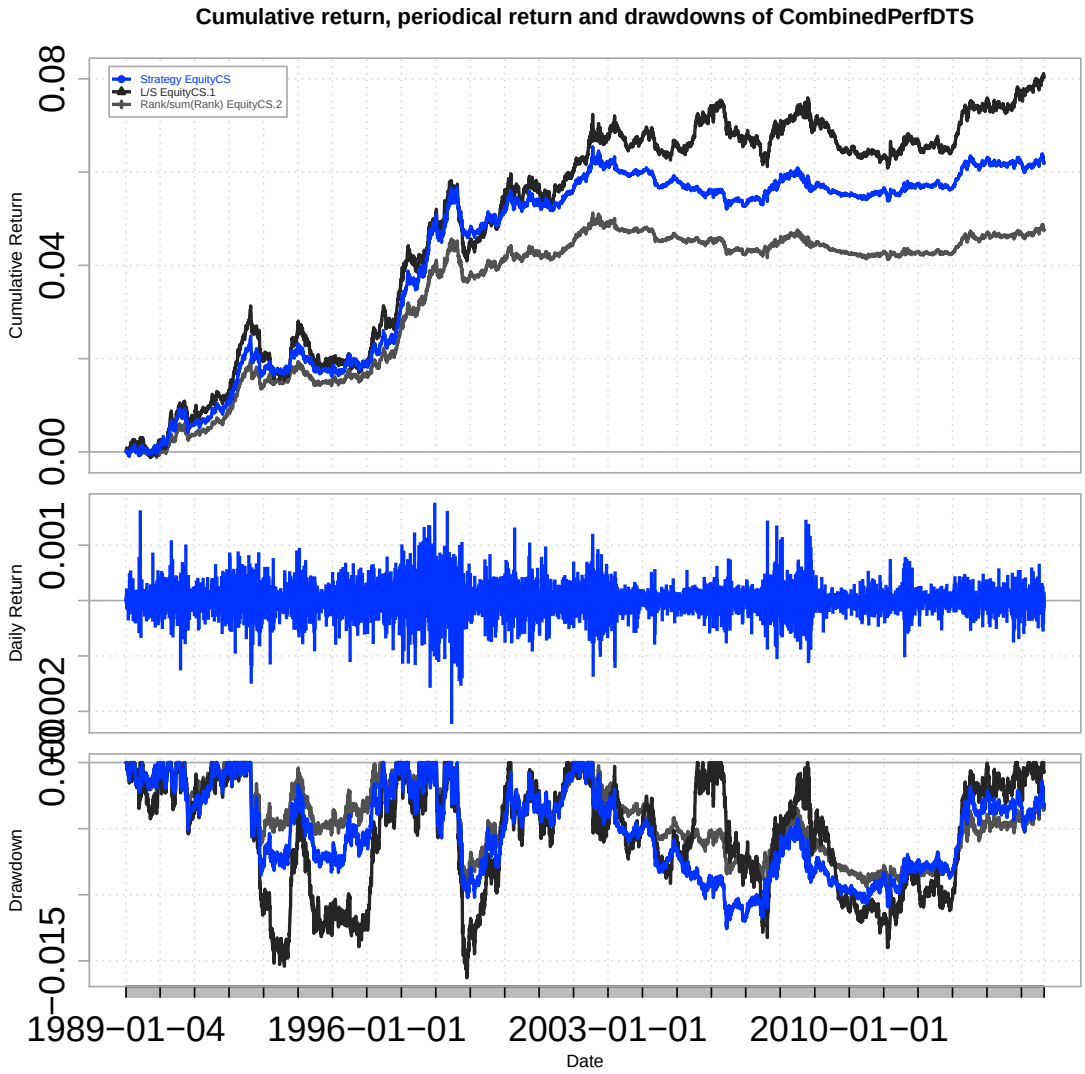


Figure 14: Performance charts of alternative signal implementations

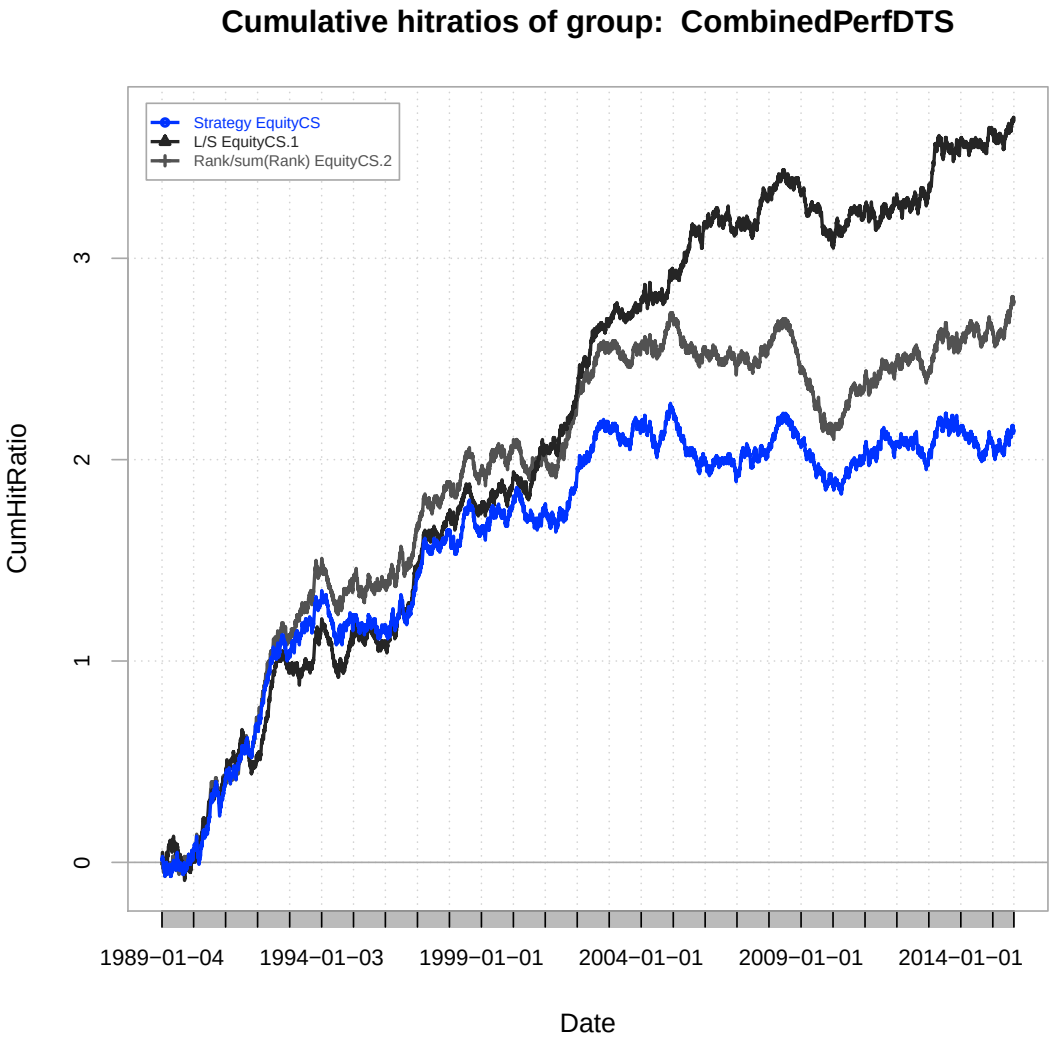
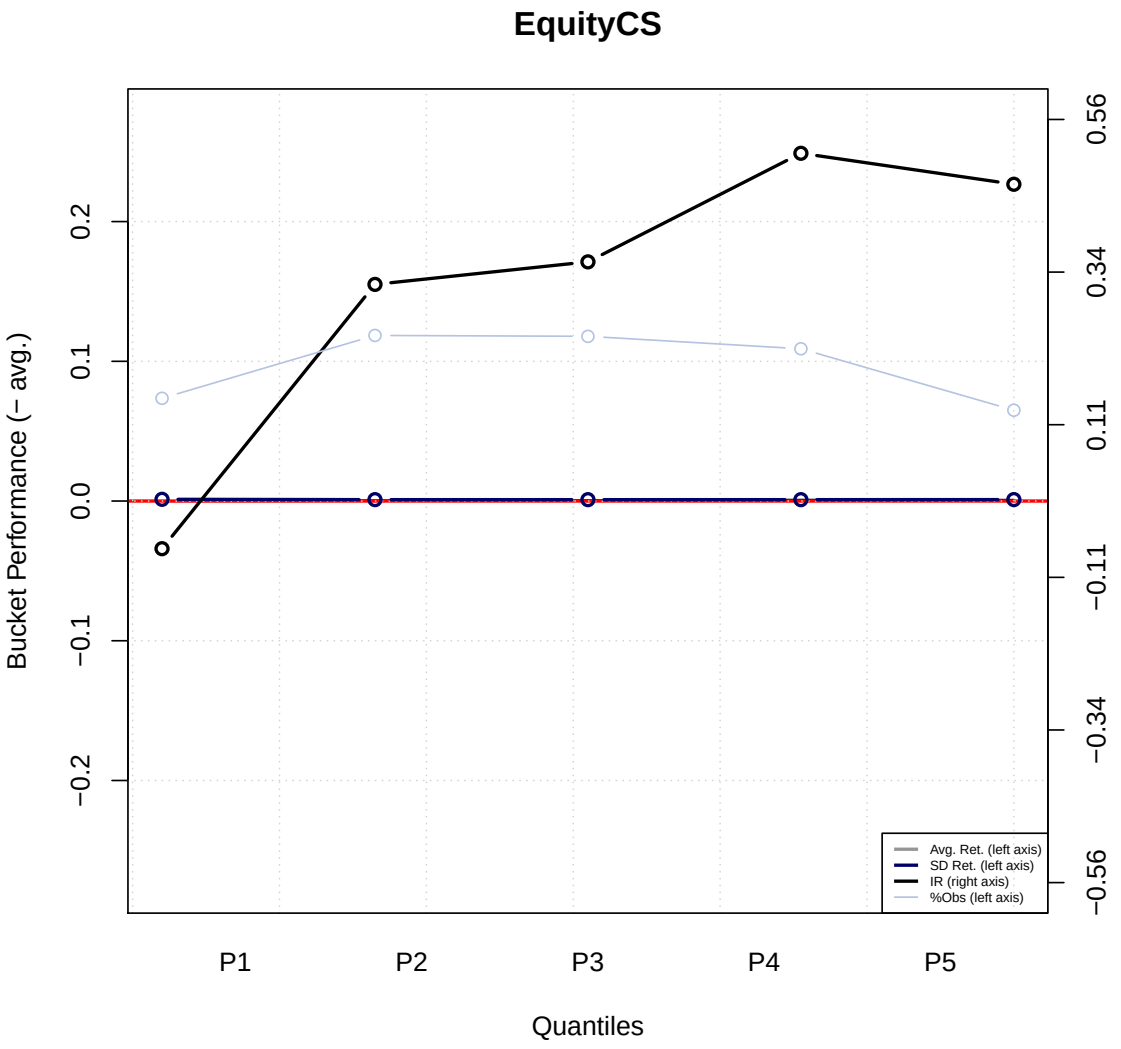


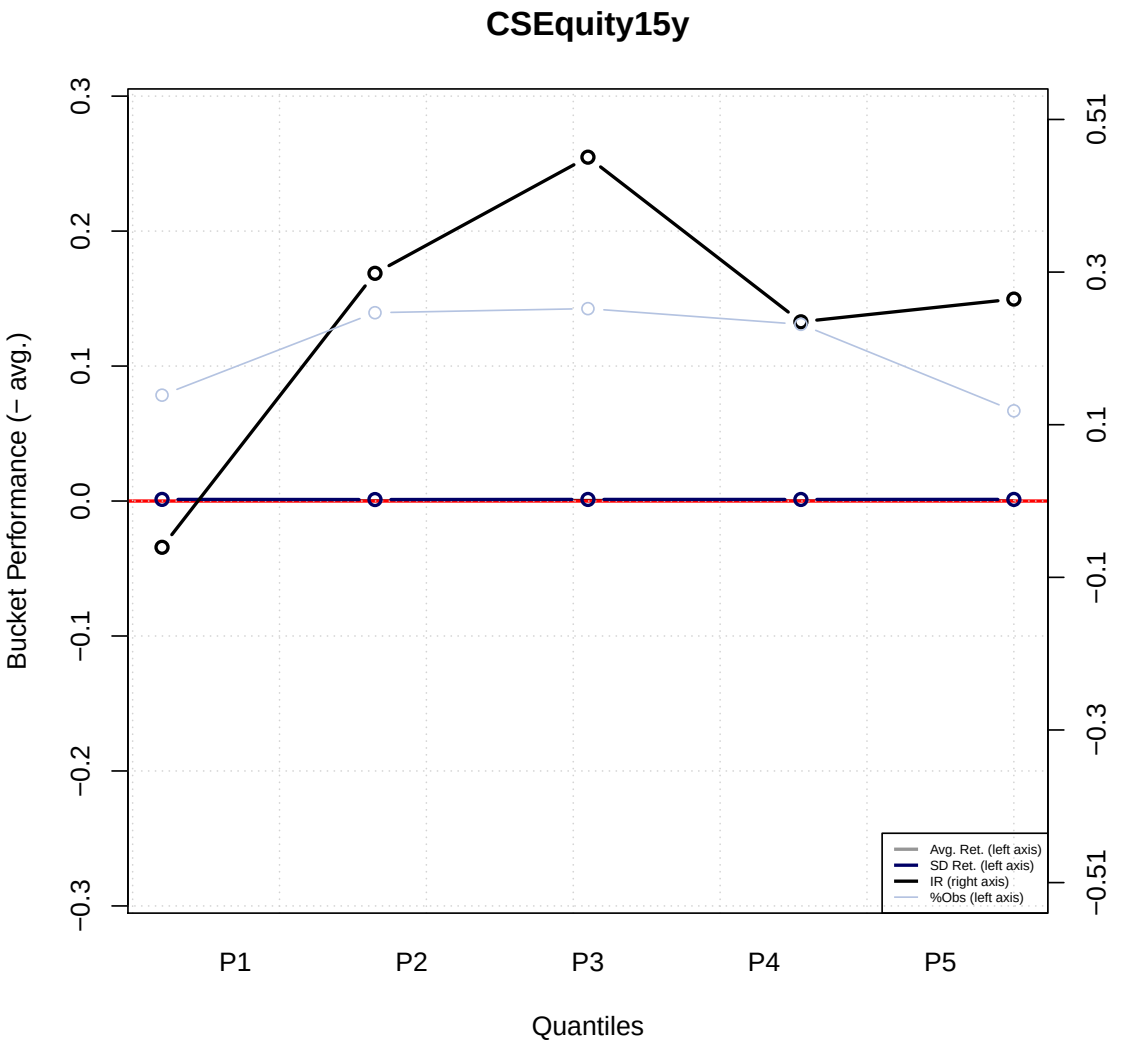
Figure 15: Cumulative hitratio of alternative signal implementations

5.2 Performance Conditional upon Positioning

To examine whether performance is increasing or decreasing over the cross-sectional ranks of the variable we compute the cross-sectional rank at each point in time, assign that to a portfolio and examine the subsequent performance of the underlying instruments over the resulting 'portfolios'. The figure below depict the results for our full-sample period.


EquityCS
Bucket Performance (– avg.)
0.2
0.1
0.0
−0.1
−0.2
0.56
0.34
0.11
−0.11
−0.34
−0.56
Avg. Ret. (left axis)
SD Ret. (left axis)
IR (right axis)
%Obs (left axis)
P1
P2
P3
P4
P5
Quantiles

Alternatively, we can focus at the last 15yrs, in which case we obtain:


CSEquity15y
Bucket Performance (– avg.)
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
0.51
0.3
0.1
−0.1
−0.3
−0.51
P1
P2
P3
P4
P5
Quantiles
Avg. Ret. (left axis)
SD Ret. (left axis)
IR (right axis)
%Obs (left axis)

Next, we analyze the relationship between the performance of the strategy and the sign of our positions, as summarized in table **??**. Detailed results per individual market can be found in the Appendix.

	IR (p-value) Signal = -1	IR (p-value) Signal = 0	IR (p-value) Signal = 1
S.P500	-0.11 (60.7%)		0.51 (1.8%)
FTSE100	-0.62 (99.0%)		0.21 (30.3%)
DJESI50	-0.06 (58.2%)		0.38 (11.9%)
ASX200	-0.44 (92.8%)		0.27 (22.8%)
TSE60	-0.46 (93.7%)		-0.12 (64.6%)
OMX	0.37 (14.4%)		0.80 (0.1%)
SMI	-0.43 (91.3%)		0.85 (0.1%)
Nikkei	0.01 (48.4%)		-0.19 (70.3%)
HangSeng	-0.17 (70.2%)		0.70 (0.9%)
KOSPI200	0.26 (16.3%)		0.25 (20.3%)

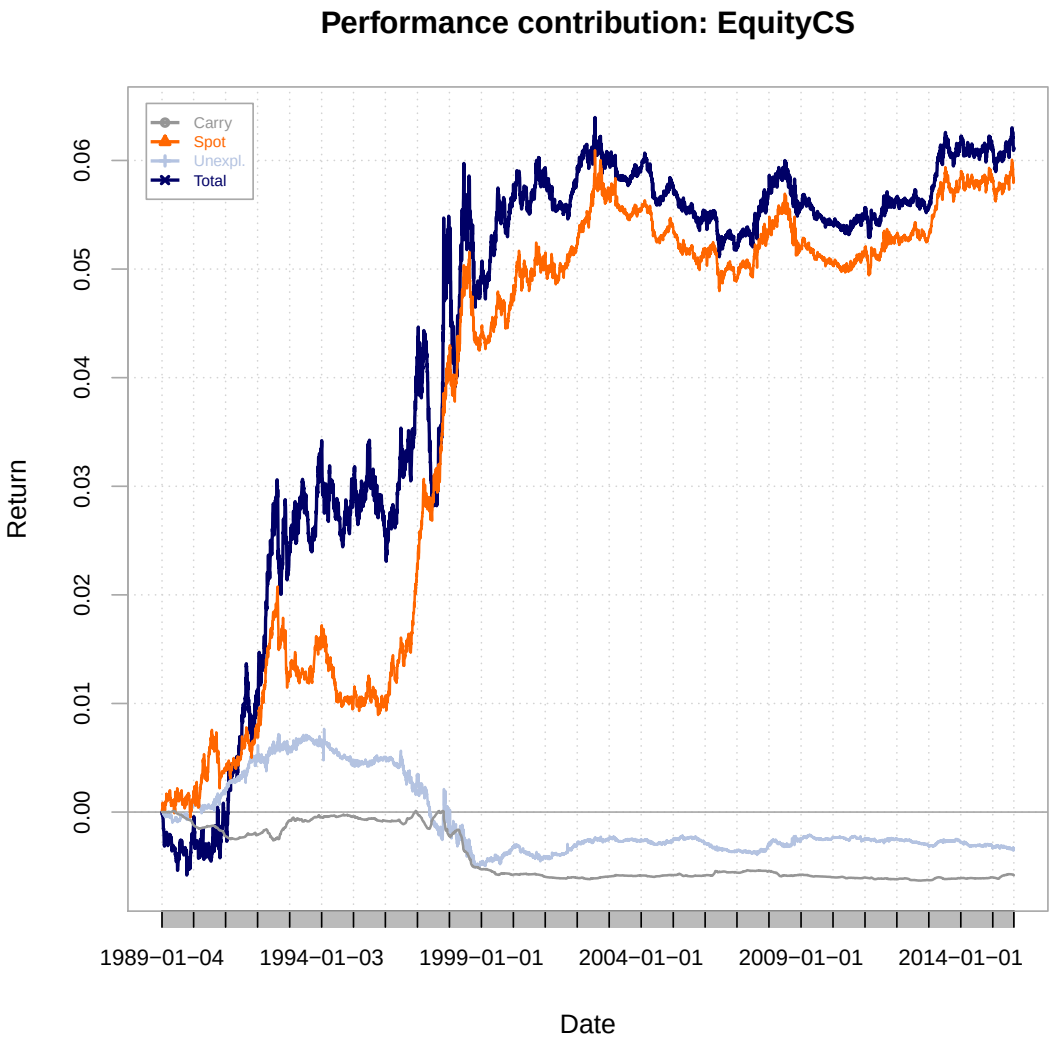
Table 17: Position analysis summary

6 Performance Attribution

In this Section we decompose the performance of the strategy into contributions coming from carry, spot changes and residual effects for the strategy aggregated over markets (the results per individual market can be found in the Appendix). The results our summarized in table **??** and the figures below.

	x
Carry ret. (%)	-0.02
Spot ret. (%)	0.21
Unexpl. ret. (%)	-0.01
Total ret. (%)	0.22
Carry contr. (%)	-9.72
Spot contr. (%)	94.89
Unexpl. contr.(%)	-5.49
Total contr. (%)	100.00

Table 18: Performance attribution


Performance contribution: EquityCS
Carry
Spot
Unexpl.
Total
Return
0.00
0.01
0.02
0.03
0.04
0.05
0.06
1989−01−04
1994−01−03
1999−01−01
2004−01−01
2009−01−01
2014−01−01
Date

7 Scenario Analysis

In this Section we analyze the conditional performance of the strategy conditional upon a market development, limits to arbitrage and other scenario's or the directional position of the strategy. The tables below summarize the results via the Information Ratio (IR) and its p-value. In the Appendix you can find the more detailed results.

7.1 Markets

In this Subsection we analyze the relationship between the performance of the strategy and the performance (over the past 1 year and past 3 years, including the month of the strategy return) of the market, as summarized in tables **??** and **??**.

	EquityCS
IR (p-value) MSCI World = -1	0.13 (36.5%)
IR (p-value) MSCI World = 1	0.68 (0.1%)
IR (p-value) MSCI EM = -1	0.07 (41.1%)
IR (p-value) MSCI EM = 1	0.78 (0.1%)
IR (p-value) Barc. US Aggr. = -1	0.28 (17.8%)
IR (p-value) Barc. US Aggr. = 1	0.66 (0.5%)
IR (p-value) DJ UBS = -1	0.69 (1.7%)
IR (p-value) DJ UBS = 0	1.08 (13.2%)
IR (p-value) DJ UBS = 1	0.36 (7.5%)
IR (p-value) HFRX = -1	-0.40 (75.5%)
IR (p-value) HFRX = 0	0.83 (0.1%)
IR (p-value) HFRX = 1	0.19 (27.9%)

Table 19: Market analysis (1yr) summary

	EquityCS
IR (p-value) MSCI World = -1	0.19 (31.3%)
IR (p-value) MSCI World = 1	0.56 (0.9%)
IR (p-value) MSCI EM = -1	0.48 (7.4%)
IR (p-value) MSCI EM = 1	0.46 (3.5%)
IR (p-value) Barc. US Aggr. = -1	0.52 (3.5%)
IR (p-value) Barc. US Aggr. = 1	0.42 (7.3%)
IR (p-value) DJ UBS = -1	0.45 (9.3%)
IR (p-value) DJ UBS = 1	0.47 (3.0%)
IR (p-value) HFRX = -1	-0.13 (59.7%)
IR (p-value) HFRX = 0	0.79 (0.3%)
IR (p-value) HFRX = 1	0.07 (42.1%)

Table 20: Market analysis (3yr) summary

Tables ?? and ?? show the results of similar analysis, but now conditioned on beginning of period (ex ante) measures.

	EquityCS
IR (p-value) MSCI World = -1	0.00 (49.4%)
IR (p-value) MSCI World = 1	0.79 (0.0%)
IR (p-value) MSCI EM = -1	0.09 (11.6%)
IR (p-value) MSCI EM = 1	0.80 (0.0%)
IR (p-value) Barc. US Aggr. = -1	0.50 (0.0%)
IR (p-value) Barc. US Aggr. = 1	0.60 (0.0%)
IR (p-value) DJ UBS = -1	0.56 (0.0%)
IR (p-value) DJ UBS = 0	0.85 (0.0%)
IR (p-value) DJ UBS = 1	0.54 (0.0%)
IR (p-value) HFRX = -1	-0.61 (100.0%)
IR (p-value) HFRX = 0	0.83 (0.0%)
IR (p-value) HFRX = 1	0.24 (0.0%)

Table 21: Market analysis (1yr) summary: predictive

	EquityCS
IR (p-value) MSCI World = -1	0.07 (19.6%)
IR (p-value) MSCI World = 1	0.67 (0.0%)
IR (p-value) MSCI EM = -1	0.59 (0.0%)
IR (p-value) MSCI EM = 1	0.48 (0.0%)
IR (p-value) Barc. US Aggr. = -1	0.62 (0.0%)
IR (p-value) Barc. US Aggr. = 1	0.44 (0.0%)
IR (p-value) DJ UBS = -1	0.54 (0.0%)
IR (p-value) DJ UBS = 1	0.51 (0.0%)
IR (p-value) HFRX = -1	0.14 (11.5%)
IR (p-value) HFRX = 0	0.80 (0.0%)
IR (p-value) HFRX = 1	0.05 (22.5%)

Table 22: Market analysis (3yr) summary

7.2 Scenarios and Limits to Arbitrage

In this Subsection we analyze the relationship between the performance of the strategy and various market and limits to arbitrage and other scenarios. The scenarios and the idea behind them are:

Economic Environment in economic downturns (expansion) investors tend to have lower (higher) risk appetite, and hence risk premia may be higher (lower). Moreover, during economic downturns, investors tend to be more pessimistic (and less prone to some behavioral biases) and market liquidity issues tends to be bigger for arbitrageurs.

Sentiment in optimistic periods the reliance on certain 'behavioral pitfalls' tend to be stronger, causing a possible stronger performance of mispricing-based behavioral strategies.

Liquidity and costs during liquidity crunches (as measured by the TED spread) margin capital of arbitrageurs in relation to their borrowing cost tend to be more expensive, implying less demand for borrowing or leverage, and hence mispricing may be stronger.

Share of arbitrageurs in scenarios where arbitrageurs are less active in markets, or otherwise put noise traders are more active (as reflected in the (detrended) short rate since that signals whether margin requirements are more expensive and capital for borrowing is scarce or expensive), mispricing may be larger.

Volatility in scenarios of higher volatility (as reflected in VIX being high, medium or low) arbitrageurs run greater risk and tend to devote less capital to arbitrage trades, causing mispricings to possibly remain stronger.

Risk Appetite in highly risk averse periods (as reflected in a high RAI) investors tend to have higher lower appetite, and hence risk premia may be higher.

Uncertainty in scenarios of high uncertainty investors tend to rely more on heuristics and other 'bias'-phrone decision rules, making behavioral biases and mispricings possibly stronger.

Past 1yr or 3yr strategy return in scenarios in which mispricing-based strategies underperform, performance-based arbitrageurs may face poor performance and as a consequence outflows of investors who judge based on recent performance, causing liquididations of positions and less arbitrage activity.

In tables **??**, **??**, and **??**, we summarize the contemparenous performance of the strategy across various economic scenarios or past performance of the strategy.

	EquityCS
IR(p) Expan sion = -1	0.40 (6.8%)
IR(p) Expan sion = 1	0.63 (1.2%)
IR(p) Senti ment = -1	0.46 (5.1%)
IR(p) Senti ment = 1	0.56 (1.8%)
IR(p) (Il)liqui dity = -1	0.40 (15.3%)
IR(p) (Il)liqui dity = 1	0.58 (0.5%)
IR(p) Share arb. low = -1	0.32 (11.8%)
IR(p) Share arb. low = 1	0.72 (0.4%)
IR(p) Vola tility = 1	0.19 (30.4%)
IR(p) Vola tility = 2	0.96 (0.0%)
IR(p) Vola tility = 3	0.11 (38.9%)
IR(p) Risk Appetite = -1	-0.07 (59.1%)
IR(p) Risk Appetite = 1	0.77 (0.1%)

Table 23: Scenario analysis summary

	EquityCS
IR (p-value) Past strat. return(1yr) = 1	0.79 (0.0%)
IR (p-value) Past strat. return(1yr) = 2	0.45 (0.0%)
IR (p-value) Past strat. return(1yr) = 3	0.66 (0.0%)
IR (p-value) Past strat. return(1yr) = 4	0.94 (0.0%)
IR (p-value) Past strat. return(1yr) = 5	0.43 (6.3%)

Table 24: Past strat. perf. analysis summary 1yr

	EquityCS
IR (p-value) Past strat. return(3yr) = 1	0.38 (0.0%)
IR (p-value) Past strat. return(3yr) = 2	0.47 (0.0%)
IR (p-value) Past strat. return(3yr) = 3	1.09 (0.0%)
IR (p-value) Past strat. return(3yr) = 4	0.68 (0.0%)
IR (p-value) Past strat. return(3yr) = 5	-0.09 (65.1%)

Table 25: Past strat. perf. analysis summary 3yr

In table **??** we summarize the predictive performance of the strategy across various economic scenarios or past performance of the strategy.

	EquityCS
IR(p) Expan sion = -1	0.34 (10.4%)
IR(p) Expan sion = 1	0.68 (0.7%)
IR(p) Senti ment = -1	0.21 (22.8%)
IR(p) Senti ment = 1	0.75 (0.3%)
IR(p) (Il)liqui dity = -1	0.29 (23.0%)
IR(p) (Il)liqui dity = 1	0.62 (0.3%)
IR(p) Share arb. low = -1	0.42 (6.2%)
IR(p) Share arb. low = 1	0.61 (1.3%)
IR(p) Vola tility = 1	0.02 (47.7%)
IR(p) Vola tility = 2	1.08 (0.0%)
IR(p) Vola tility = 3	-0.04 (54.3%)
IR(p) Risk Appetite = -1	0.18 (29.1%)
IR(p) Risk Appetite = 1	0.65 (0.4%)

Table 26: Scenario analysis summary

8 45 years of data

Next, we build a dataset of long-term returns and test whether Momentum systematically predict returns for this long-term sample (as we would expect). The markets for which we can analyse performance over the long-term sample are summarized in the column "Markets" of table **??**, together with the weights used to aggregate results across the markets that we consider and the date at which long-term data on CSMomComb is available.[3]

	Markets	Main 10	Major 4 overw.	StartDate
1	USD	0.10	0.14	1971-02-26
2	GBP	0.10	0.14	1971-02-26
3	EMU	0.10	0.14	1989-02-28
4	AUD	0.10	0.07	1971-02-26
5	CAD	0.10	0.07	1971-02-26
6	SEK	0.10	0.07	1971-02-26
7	CHF	0.10	0.07	1971-02-26
8	JPY	0.10	0.14	1971-02-26
9	HKD	0.10	0.07	1971-02-26
10	KRW	0.10	0.07	1989-02-28

Table 27: Series in the long-term sample

[3]The start dates of the aggregated series are the first dates that data on its components are available.

The direction of the signals over time is depicted in the next figure.

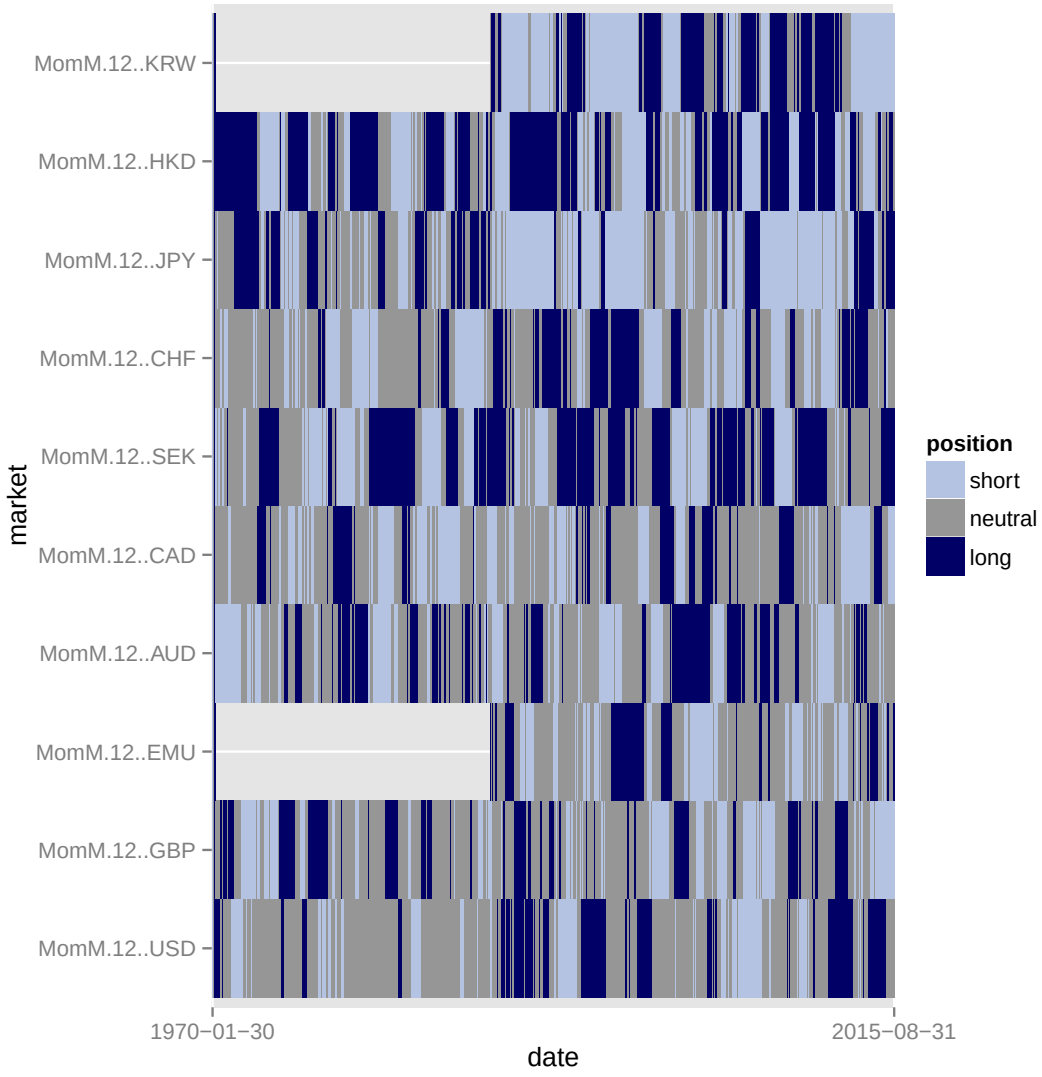

MomM.12..KRW
MomM.12..HKD
MomM.12..JPY
MomM.12..CHF
MomM.12..SEK
MomM.12..CAD
MomM.12..AUD
MomM.12..EMU
MomM.12..GBP
MomM.12..USD
market
1970−01−30
2015−08−31
date
position
short
neutral
long

Table **??** summarizes the main risk and performance metrics over the long-term sample.

	USD	GBP	EMU	AUD	CAD	SEK	CHF	JPY	HKD	KRW	Main 10	Major 4 overw.
N.obs	535.00	535.00	319.00	535.00	535.00	535.00	535.00	535.00	535.00	319.00	535.00	535.00
Annualized Return (geometric)	0.07	-0.07	-0.06	-0.03	-0.51	1.22	0.26	0.02	0.67	0.56	0.23	0.17
Annualized Return (arithmetic)	0.07	-0.06	-0.05	-0.02	-0.50	1.24	0.27	0.04	0.73	0.60	0.23	0.17
Median Return	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.07
Annualized Volatility	0.86	1.40	1.44	1.44	1.24	1.99	1.28	1.74	3.39	2.94	0.56	0.51
Skewness	-1.10	-2.83	-0.06	-2.52	-1.15	0.13	0.42	0.20	0.84	-0.97	0.39	0.03
Kurtosis	11.78	31.91	4.56	25.63	7.85	4.36	7.45	3.43	11.47	9.95	4.58	4.93
Information Ratio	0.08	-0.05	-0.04	-0.02	-0.41	0.61	0.20	0.01	0.20	0.19	0.41	0.33
p-value Information Ratio	0.30	0.63	0.58	0.55	1.00	0.00	0.09	0.47	0.09	0.17	0.00	0.01
Downside Risk	0.62	1.11	1.04	1.14	1.04	1.18	0.83	1.21	2.18	2.08	0.35	0.31
Sortino	0.11	-0.06	-0.06	-0.03	-0.49	1.03	0.31	0.02	0.31	0.27	0.67	0.54
VolofVol	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.03	0.02	0.00	0.00
MaxDD	-8.57	-12.29	-8.74	-15.17	-21.29	-3.43	-8.28	-14.01	-16.25	-7.63	-1.74	-1.59
P_Loss	0.19	0.23	0.24	0.24	0.26	0.25	0.24	0.33	0.36	0.37	0.47	0.47
HitRatio	0.52	0.51	0.48	0.52	0.41	0.61	0.52	0.50	0.53	0.53	0.52	0.52
p-value HitRatio	0.17	0.39	0.73	0.17	1.00	0.00	0.22	0.53	0.10	0.12	0.15	0.17
Stability: R2Time	45.03	18.92	19.59	30.51	90.82	95.64	74.56	23.48	63.27	66.91	92.37	88.07

Table 28: Table with a summary of performance measures for the aggregation over markets: LT sample

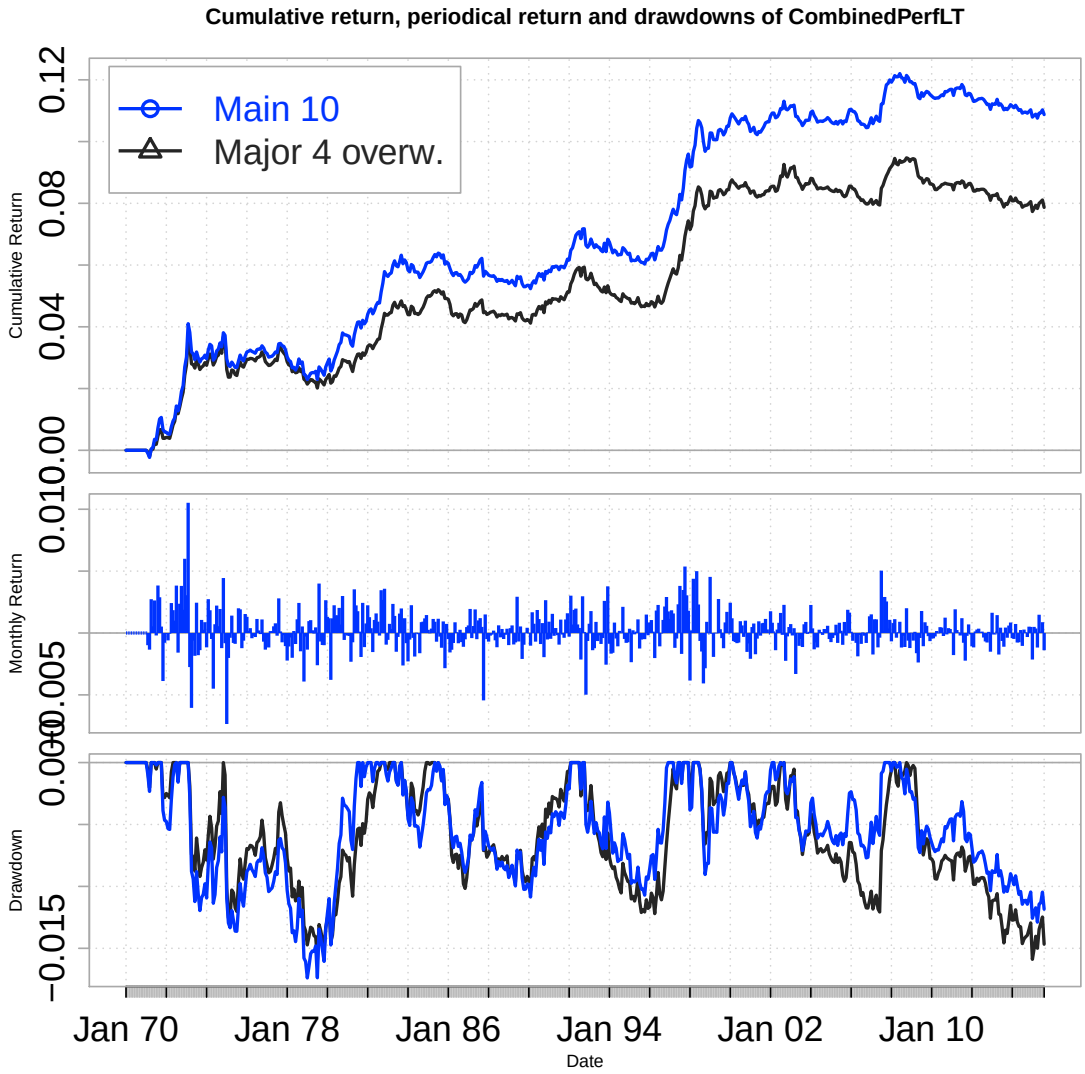


Figure 16: Performance charts of the aggregated strategy: LT sample

The two figures below depict performance of the strategy over time in terms of performance and hitratios.

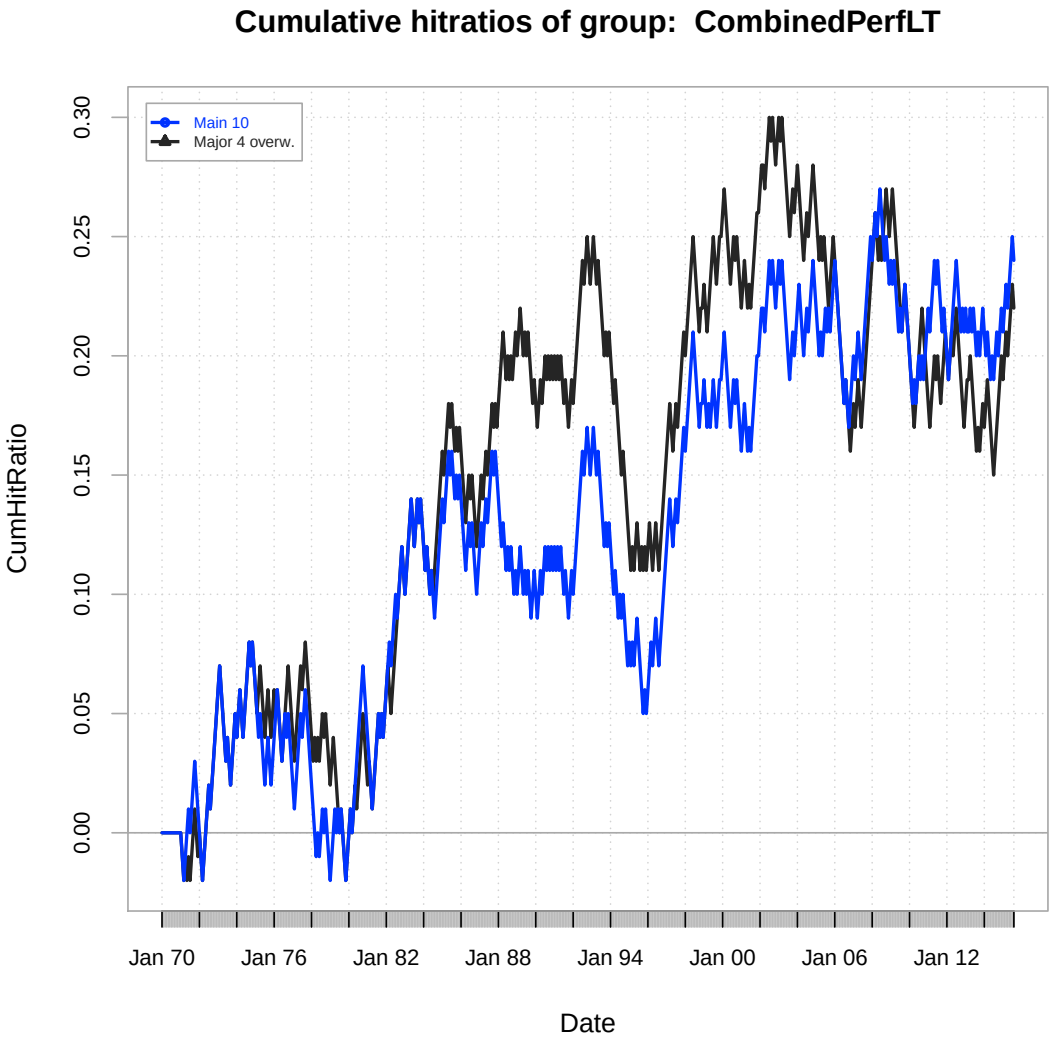
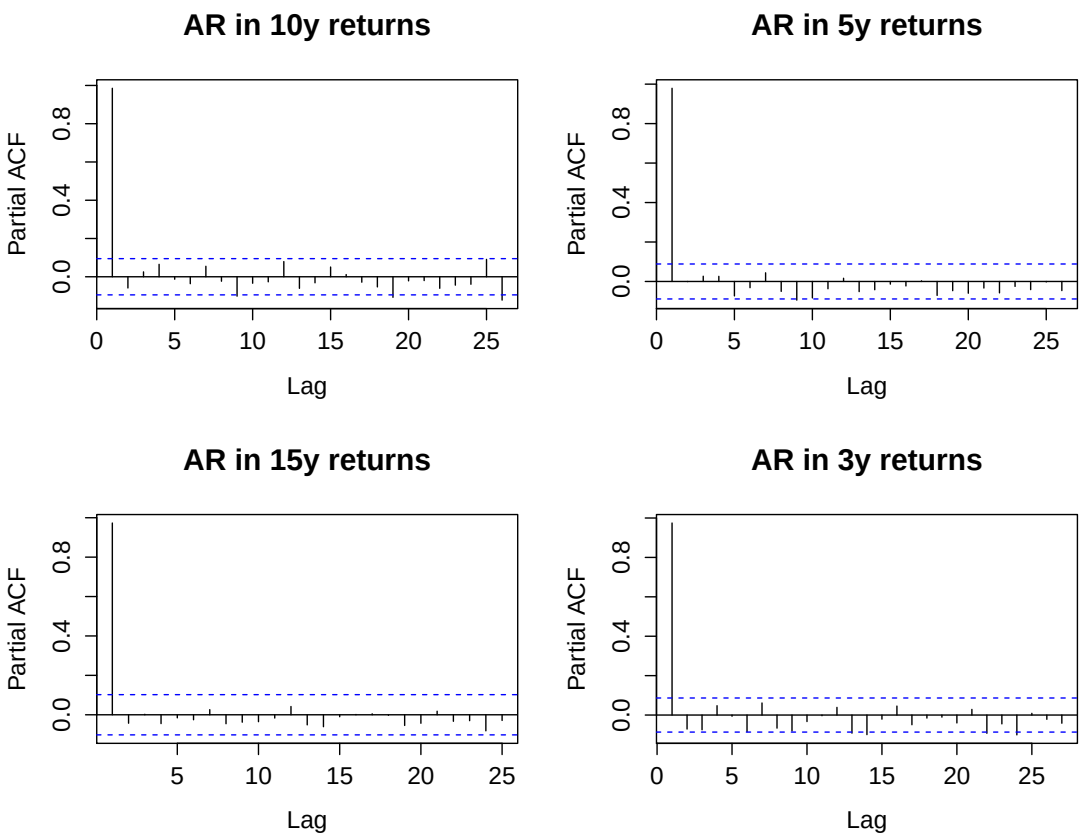
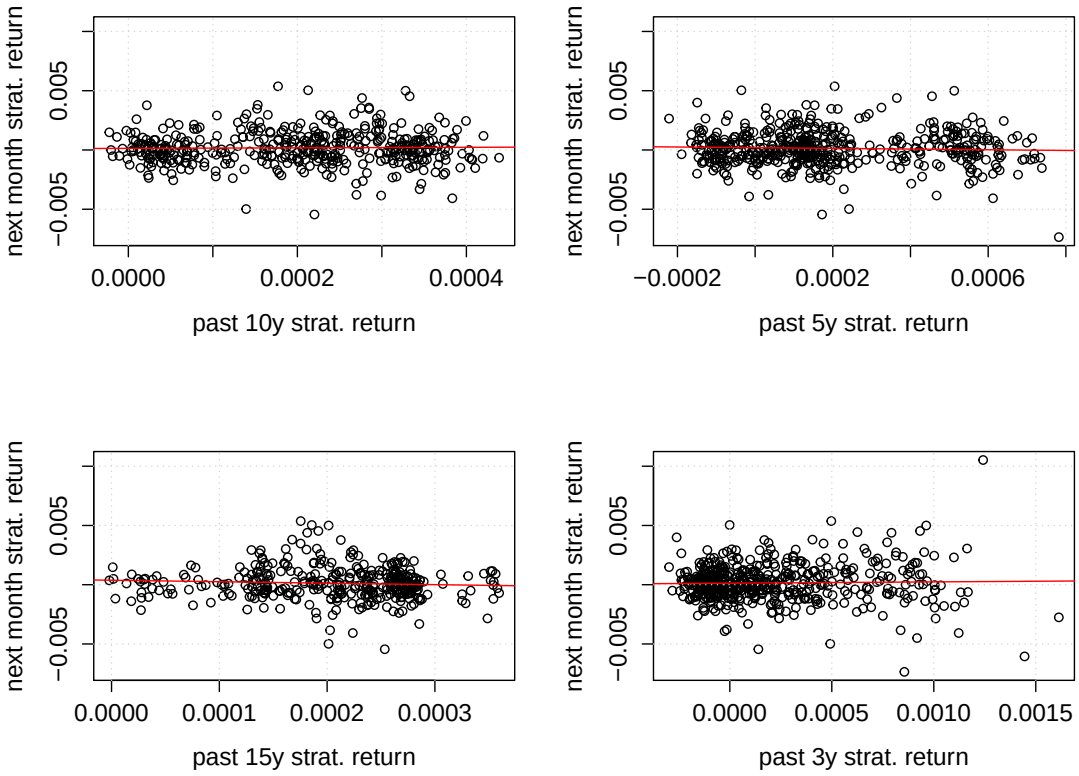


Figure 17: Cumulative hitratio of the aggregated strategy: LT sample

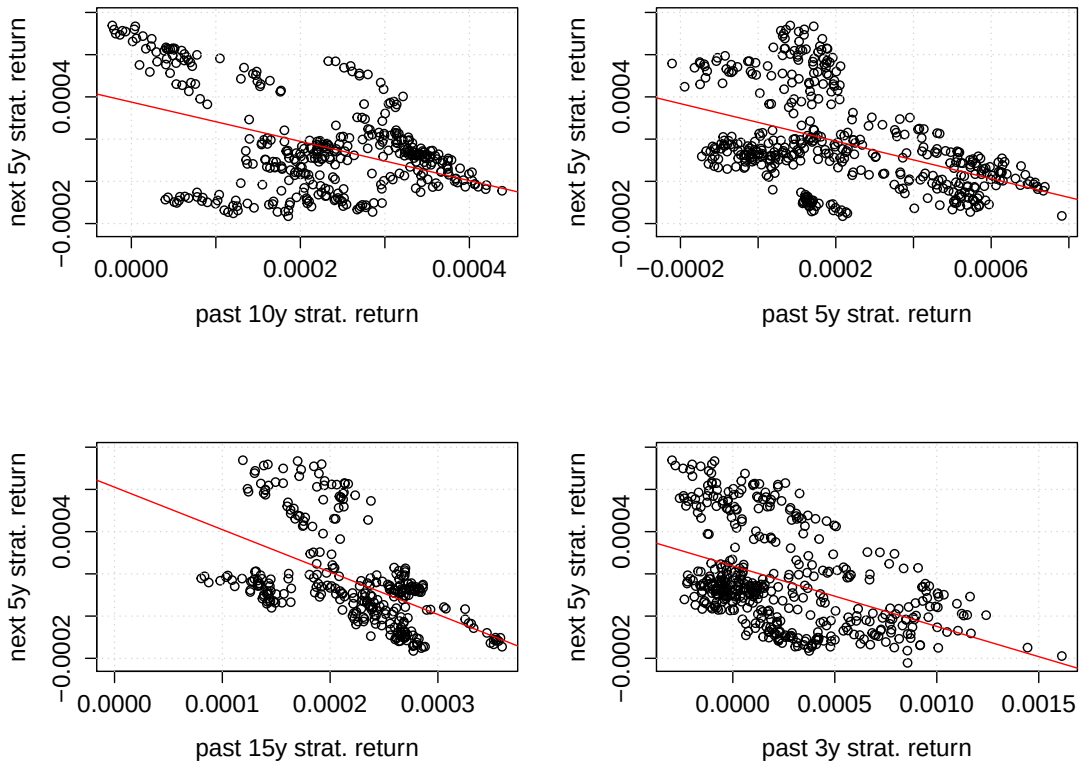
Next, we may wonder how predictive past strategy returns are for future returns on the strategy. This question is especially relevant since performance since 2000 (especially between 200 and 2010) has been rather weak. To this end, we take 3 approaches.
First, we compute rolling 10, 5, 15 and 3y strategy returns and examine if there is positive (partial) auto-correlation in them (as you would expect in case past performance positively predicts future performance). The figure below shows the results.


AR in 10y returns
AR in 5y returns
AR in 15y returns
AR in 3y returns
Partial ACF
0.0
0.4
0.8
0
5
10
15
20
25
Lag

Second, we compute rolling 10, 5, 15 and 3y strategy returns and regress them on next month's strategy returns:


next month strat. return
0.005
−0.005
0.0000
0.0002
0.0004
past 10y strat. return
next month strat. return
0.005
−0.005
−0.0002
0.0002
0.0006
past 5y strat. return
next month strat. return
0.005
−0.005
0.0000
0.0001
0.0002
0.0003
past 15y strat. return
next month strat. return
0.005
−0.005
0.0000
0.0005
0.0010
0.0015
past 3y strat. return

In general, our investment horizon for a strategy is longer than one month, and more likely to be close to a couple of years. So, third, we compute rolling 10, 5, 15 and 3y strategy returns and regress them on next 5 years' strategy returns:


next 5y strat. return
−0.0002
0.0004
0.0000
0.0002
0.0004
past 10y strat. return
next 5y strat. return
−0.0002
0.0004
−0.0002
0.0002
0.0006
past 5y strat. return
next 5y strat. return
−0.0002
0.0004
0.0000
0.0001
0.0002
0.0003
past 15y strat. return
next 5y strat. return
−0.0002
0.0004
0.0000
0.0005
0.0010
0.0015
past 3y strat. return