Quantitative Monographs

Are you already timing styles successfully?

Equities

Global
Quantitative

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Style timing is hard

Style timing has been called the 'Siren Song' of quantitative investment; deliciously alluring but typically disappointing. Researchers have consistently found it difficult to design a style-timing strategy that outperforms a benchmark quantitative fund.

But maybe this is because you are implicitly style timing already.

We argue that the price momentum and low volatility styles have time-varying loadings on quality, value and size. Hence if either of these styles are a constituent of a quantitative fund, the fund already implicitly incorporates a style-timing strategy.

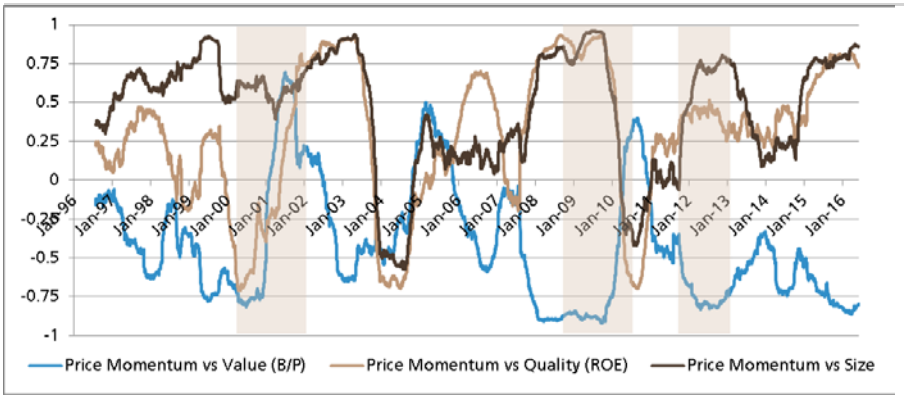
The implicit style-timing strategy can be extracted …

We use a regression approach on the cross-sectional style scores to construct a style-timing strategy from quality, value and size that mimics the performance of low volatility and price momentum.

… and shown to be an effective style-timing strategy.

We analyse the performance of these mimicking portfolios; firstly to show that they are an effective style-timing strategy, and then to show that they are intimately related to the economic cycle, tilting to quality in downturns and to value in upswings.

Figure 1: Rolling 6 month correlation of the 3 core fundamental styles with price momentum



Source: UBS Quantitative Research. The panel plots the 6 month rolling correlation of the daily returns to the 3 core fundamental style portfolios with the returns to the price momentum portfolio.

Introduction[1]

We break down investment styles into two categories: fundamental and technical. Fundamental styles use company data, such as earnings, cash flow (sometimes scaled by price), to build portfolios. Technical styles use a history of return data to construct portfolios, for example price momentum and low volatility. We first show that correlations between fundamental styles scores are remarkably stable over time; whereas the correlations of technical style scores with either other technical or fundamental scores vary over the economic cycle.

Fundamental Styles are built from accounting data, technical styles from return data.

This leads us to ask the following question; how far can the implicit style-timing within technical styles explain their performance? We show that it is possible to replicate the returns to technical styles closely using only fundamental styles by employing the implicit style rotation strategy embedded within the technical style. For example, a low volatility investment strategy loads on value during market upswings and quality in market downturns. Given that this style has earned a positive return premium over our data period, this suggests this implicit style rotation strategy is an effective style-timing strategy.

Technical styles have time-varying loadings on the fundamental styles.

These time-varying loadings implicitly embed an effective style-timing strategy.

For a quantitative investor, this is interesting for two reasons. Firstly it suggests possibly why, after many years of exhaustive backtesting, quant investors have not uncovered a successful style-timing algorithm; technical styles do it very effectively already and these implicit strategies are hard to beat. For example, in mid-2016 the price momentum portfolio was tilted towards quality stocks as the quality style has been outperforming for nearly all of 2016. Hence, as long as price momentum is part of the fund portfolio, the fund will be overweight quality relative to history. Given the economic uncertainty in 2016, this is precisely the tilt a quant investor would want from her style-timing strategy. So if an investor wishes to design an effective style-timing strategy, it must affect this tilt more efficiently than the implicit style-timing within price momentum. Not easy to do. This is why Clifford Asness refers to the 'siren song of factor timing'; style timing is a seductive idea to improve portfolio performance but more often than not disappoints.

This makes designing an explicit style-timing strategy difficult as this implicit one is effective.

Secondly, for quant investors who still wish to persevere in the search of an effective style-timing strategy despite the difficulties, this work suggests limiting your choice of styles 'to time' to the fundamental ones. This is because the relative performances of these styles are stable over time. Then as part of the timing algorithm, one can use the information embedded within the technical styles, as well as other external signals, to help time these fundamental styles. To push the metaphor above too hard, listen to the song of the technicals but don't be overawed.

There has been some important work in the academic literature on these lines. Huang (2009) investigates the relationship between cashflow volatility (a fundamental style) and low return volatility (a technical style). Huang finds that cashflow volatility can explain some of the low volatility return anomaly, but also finds clear differences between the two styles. Walkhausel (2013) builds on this and finds that the quality style (fundamental) can span some of that difference. Similarly there has been a body of research linking the price momentum style (technical) to earnings momentum (fundamental). The earlier work of Chan,

[1] The authors would like to thank Professor James Sefton of Imperial College Business School, London for the significant contribution he provided to this material.

Jegadeesh, Lakonishok (1996) found a strong correlation but differences too. The later work Chordia and Shivakumar (2006), Leippold and Lohre (2012) and Novy-Marx (2015) all found these differences to be less pronounced and went on to suggest that earnings momentum picked up all the risk premium of price momentum.

A Summary of our Key Results

In this paper, we focus on a small set of the most widely used styles. We use as our universe all stocks in the MSCI US large and mid-cap indices over the period January 1996-June 2016.

Our set of fundamental styles include a value style (constructed from the book value of equity to price ratio), a quality style (constructed from return on equity scores), a size style (constructed from the market value of equity), an earnings momentum style (constructed from the percentage change in the 12 month forward EPS forecast over the last 3 months) and a cash flow volatility style (constructed from volatility of quarterly cash flow to sales ratios over previous 4 years).

We limit our set of technical styles to a low volatility style (using the standard deviation of daily returns over the past 12 months) and a price momentum style (percentage change in prices over the past 12 months).

Our findings are:

1. Cross-sectional score correlations between fundamental styles are very stable over time – save a small 'jig' at the height of the technology boom in late 1999-2001.

2. Cross-sectional score correlations of technical styles vary with each other and with fundamental styles over time. These variations appear to be strongly related to the economic cycle. Further the time-series correlations of the strategy returns appear similar but exaggerated and lag by the length of the estimation window.

3. The performance of a low volatility portfolio can be replicated successfully by combining a cash flow volatility, quality, value and size portfolio with time-varying weights. The weights are calculated from a cross-sectional regression of the low volatility scores on the fundamental portfolio scores at the end of the month and then held constant over the following month.

    a. The replication portfolio has a roughly constant weight on both cash flow volatility and size but tilts towards quality in a downturn and value in an upswing.

    b. The performance of the low volatility strategy (as measured by the Sharpe ratio) is significantly better than the individual performance of all the replication portfolio constituents. In particular it outperforms a cash flow volatility strategy, the most highly correlated of the constituents.

    c. We show that this implies the implicit style timing strategy embedded in low volatility – tilting to quality in downturns and value in upswings – is an effective style-rotation strategy.

4. The performance of a price momentum portfolio can be replicated successfully by combining an earnings momentum, value, quality and size portfolios with time-varying weights. However the replication can be improved by including a low volatility portfolio as well.

    a. In the full replication portfolio (which includes low volatility) the weights tilt towards the low volatility during, and for a period after, an economic downturn. In the replication portfolio without low volatility this timing strategy is reproduced by tilting towards quality in downturns and towards value in upswings (as would be expected from the results in 3).

    b. Though our replication portfolio mimics the behaviour of price momentum more closely, the performance of an earnings momentum strategy is superior.

    c. The implicit timing strategy within price momentum therefore seems to add little value over and above earnings momentum.

Our results are consistent with the recent academic literature relating – in our terminology – fundamental styles to technical styles. We find technical styles embed a style rotation strategy of tilting toward quality in downturns and gently to value in upswings. However the strategy appears to be more successfully 'implemented' within low volatility. We hypothesise that this is because the signal expresses itself, or can be recognised, earlier in the volatility of equity returns than in the rolling mean of equity returns.

The rest of the paper provides the details behind these results. Section 2 defines the styles and looks at their properties – in particular their cross correlations – over time. Section 3 builds a replication portfolio from fundamentals of the low volatility portfolio. It shows that the embedded style rotation strategy within low volatility is an effective style timing strategy. Section 4 examines price momentum. It shows there is a similar embedded style rotation strategy, but it is far less effective. The final section concludes.

2. Fundamental and Technical Styles

Data Preliminaries

Throughout this note we limit ourselves to a few basic styles[2]. This is partly pragmatic as otherwise the combinations balloon quickly. However we believe it is valuable to develop some clear conclusions using 'basic' styles before undertaking a more exhaustive search.

Fundamental Styles are built from accounting data, technical styles from return data.

We make a distinction between what we call fundamental styles and technical styles[3]. Fundamental styles are those constructed from fundamental or accounting data of the firm (though we allow this data to be scaled by prices). Fundamental styles therefore focus exclusively on the cash flows and assets of the firm. In contrast, technical styles are constructed using past return data. They thus focus on how the market is pricing these cash flows and assets, as well as the perception of the underlying risks. One might therefore suspect that the constituent turnover of technical style portfolios to be greater, as they are based return information which varies more dynamically. Indeed, we show that this is the case and the distinction between fundamental and technical is a powerful way to classify styles.

Our universe is the MSCI USA index, and our data sample is Jan 1996 to June 2016

Our universe of stocks is the constituents of the MSCI USA index, and our data sample runs from January 1996 to June 2016. This index covers the large and mid-cap sectors of the US market with the explicit aim of accounting for just over 80% of the total market cap.

We limit ourselves to 5 fundamental styles; Value, Quality, Size, Cash Flow Volatility and Earnings Momentum.

The following is a list of fundamental styles with a description of how the styles scores are calculated:

1. Value: constructed from the firm's book to price ratio.
2. Quality: constructed from the firm's return on equity (ROE).
3. Size: using the firm's total market value of equity
4. Cash Flow Volatility: constructed using minus the standard deviation of the quarterly cash flow from operations to sales ratio over the previous 4 years.
5. Earnings Momentum: a weighted average of the percentage changes in the 12 months forward EPS forecast relative to 1, 2 and 3 months ago.

We limit ourselves to 2 technical styles; low volatility and price momentum.

A similar list of the technical styles is:

1. Low volatility: constructed using minus the standard deviation of daily returns over the past 12 months.
2. Price momentum: constructed from the percentage return to the equity of the past 12 months.

The first three fundamental styles are the bedrock of any quantitative portfolio strategy. Similarly the two technical styles are probably the most highly researched styles. We also included cash flow volatility because of the recent research, for example Huang (2009) and Walkhausel (2013), linking it to the low volatility

[2] There has been an enormous industry in looking for new factors of returns; Harvey, Liu and Zhu (2015) document the 'discovery' of 313 since 1967.
[3] We shall use the terms styles and factor of returns interchangeably.

factor; similarly we select earnings momentum because of the literature, see for example Chordia and Shivakumar (2006), Novy-Marx (2015), linking it to the price momentum factor. We use the negative of a volatility measure, either cash flow or return volatility, so that a high number denotes a desirable property. The styles – except cash flow volatility[4] – are described and discussed every month in the UBS Global Style Watch publication.

We use a standard methodology to build our portfolios.

The portfolios are all built in a standard manner. At the end of the each month, the stocks are sorted according to relevant scores and then split into quintiles. The long only style portfolio is an equally weighted portfolio of the stocks in the top quintile, and the long-short portfolio is the long portfolio minus an equally weighted portfolio of the stocks in the lowest quintile.

During the report, we also investigate the performance of sector-neutral style portfolios too. These portfolios are built in a similar way to our non-sector neutral portfolios, except now each of the 10 GICS sectors[5] is sorted into quintiles independently. The long portfolio and the short portfolio are an equally weighted portfolio of the top and bottom quintiles of each sector.

Throughout this report, we shall refer to the data used to build the style portfolios at the end of each month as the scores; and the return to these portfolios over time as the strategy returns.

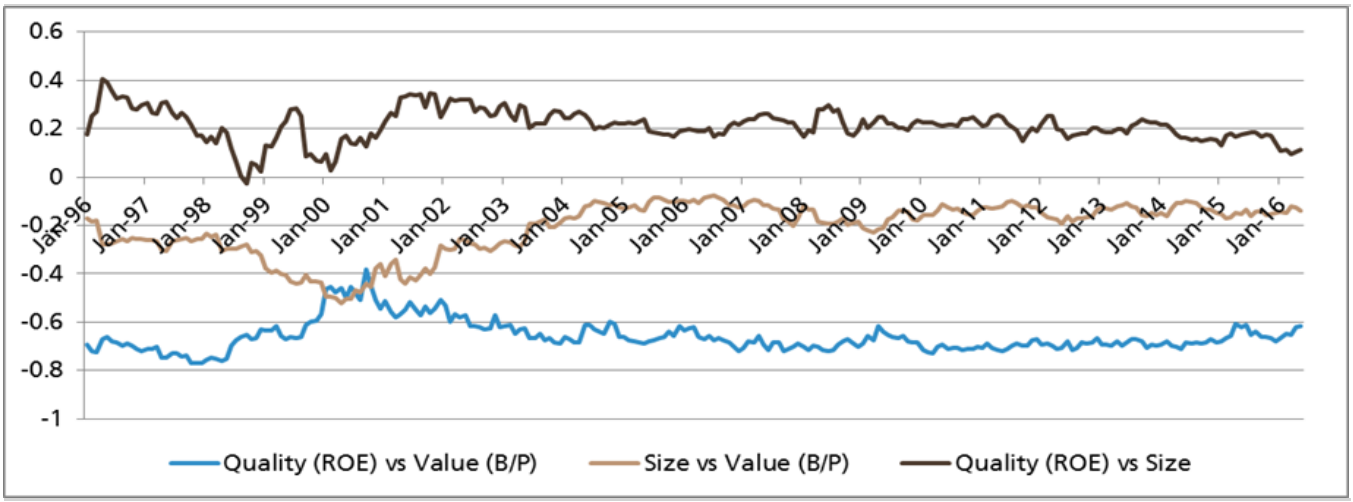
The remarkable stability of correlations across fundamental styles

Fundamental styles are built using the firm's accounting data. One might expect the relative properties of this accounting data across firms to be stable over time: it is in fact remarkably stable.

The cross-correlations between value, quality and size style scores are remarkably stable …

The cross-sectional correlation between two styles at the end of every month is the Spearman rank correlation of the two styles scores. In Figure 2, we plot the time variation in these over time for our three core fundamental styles.

Figure 2: Cross-sectional correlation of style scores



Source: UBS Quantitative Research. The cross-sectional correlation between two styles at the end of every month is the Spearman rank correlation of the two styles scores. The figure plots the value of these correlations over time

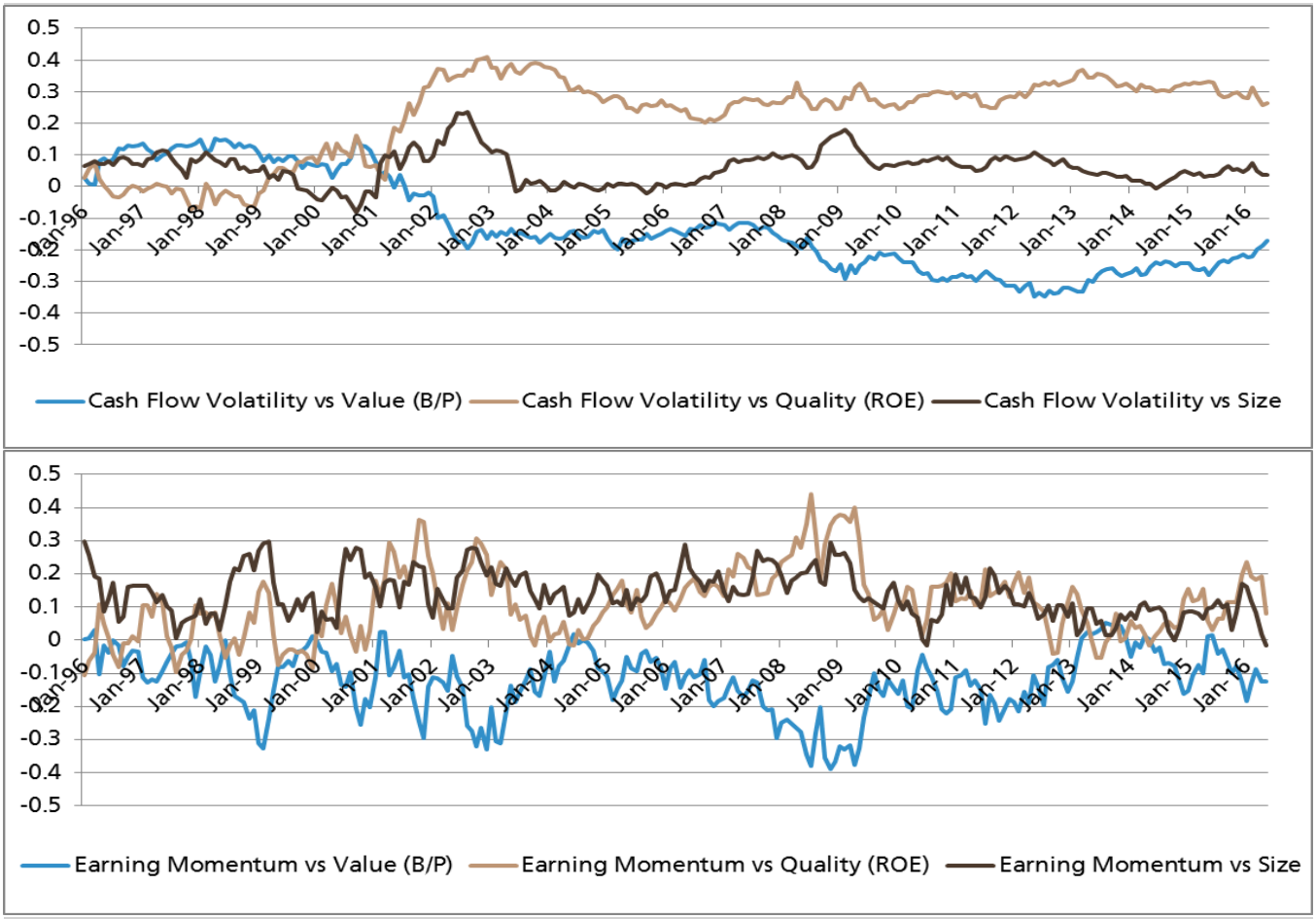
[4] For the cash flow volatility style we mimic the approach used in Huang (2009) to build a cash flow volatility score for each stock in the our universe.
[5] The analysis was carried out prior to the recent change of GICS into 11 sectors.

Apart from the smallest 'jig' around the end of the tech boom, the cross-sectional correlations are very stable over time. Quality and value are strongly negatively correlated; quality is positively correlated with size, whereas value is only slightly negatively correlated with it.

In Figure 3, we plot the cross-sectional correlations of our three core fundamental styles with cash flow volatility and earnings momentum.

… as are those with cash flow volatility and earnings momentum.

Figure 3: Cross-sectional correlation of core fundamental styles with cash flow volatility and earnings momentum



Source: UBS Quantitative Research. The cross-sectional correlation between two styles at the end of every month is the Spearman rank correlation of the two styles scores. The figure plots the variation in these correlations over time.

Though not as stable as the correlations in Figure 2, there is only a small amount variation in these numbers over time. The correlations are all intuitive, with quality and size being associated with low cash flow volatility and high earnings momentum, and value with high volatility and low earnings momentum. The correlations with cash flow volatility are weaker prior to 2000.

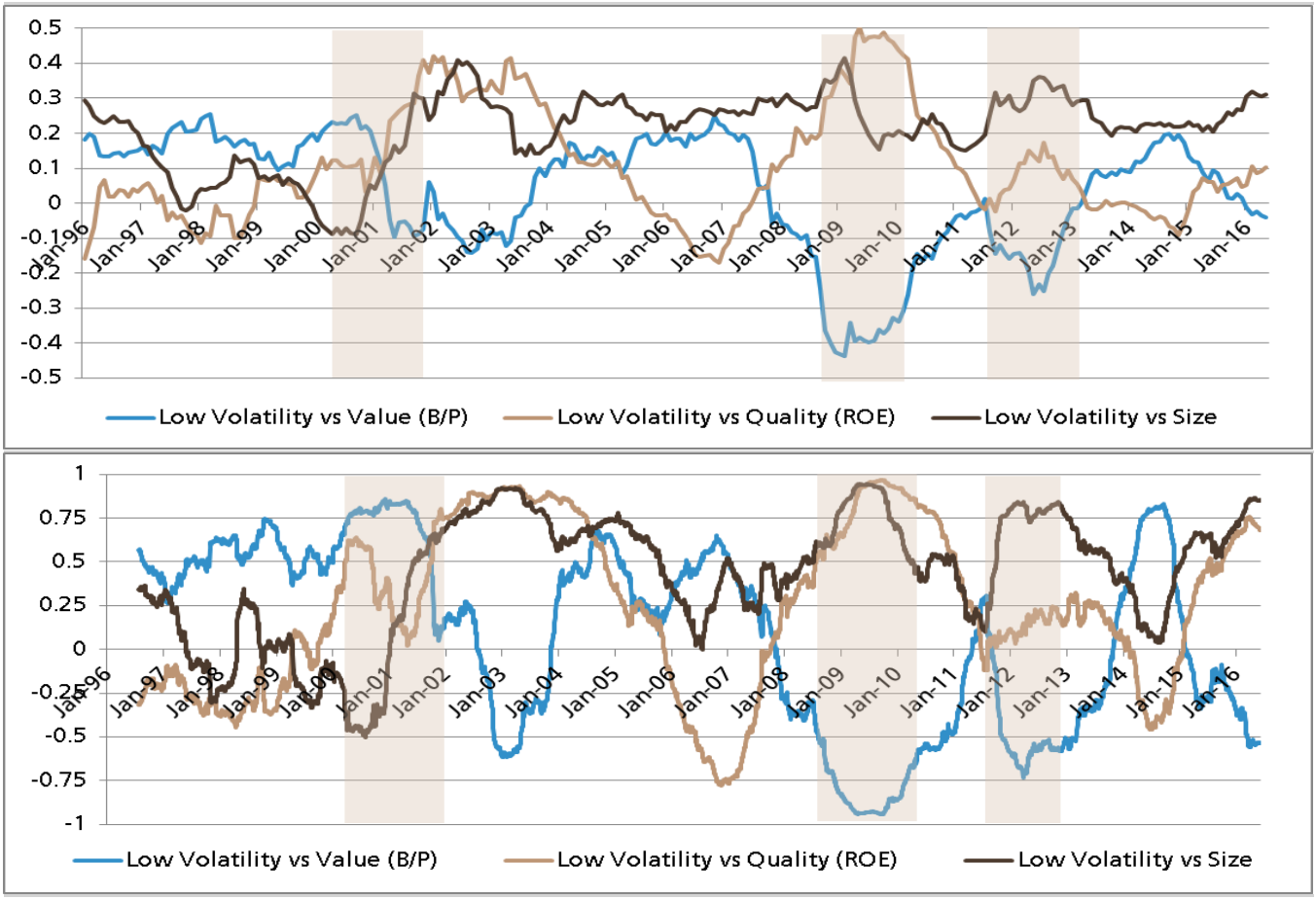
Style-timing is based on the premise that as the economic cycle varies the market price of the various portfolio characteristics vary too. If the relative correlation of these characteristics remains constant, it is more likely that the relative price of these portfolios will change in a predictable fashion. Though this argument would need formalising, it suggests that designing a style-timing strategy on only fundamental styles might be an easier task than a more general set that includes technical styles.

The instability of correlations of technical styles with other styles

We now contrast the stability of the cross-correlations of fundamental styles scores with each other with the instability of the cross-correlations involving technical styles. Figure 4 plots the both the correlation of the monthly scores and the time series correlation of the strategy returns of our three fundamental core styles with the low volatility style.

The score cross-correlations of low volatility with the fundamental styles are time-varying …

Figure 4: Cross-sectional (top) and time-series (bottom) correlations of our core fundamental styles with low volatility



Source: UBS Quantitative Research. The top panel plots the cross-sectional correlation of our 3 core fundamental style scores with the low volatility score at each month end. The bottom panel plots the 6 month rolling correlation of the daily returns to the 3 core fundamental style portfolios with the returns to the low volatility portfolio.

We have also shaded periods of economic uncertainty in the figure following the crash of the technology boom, the great recession and the start of the Euro debt crisis. These periods are indicative only, and have not been formally dated.

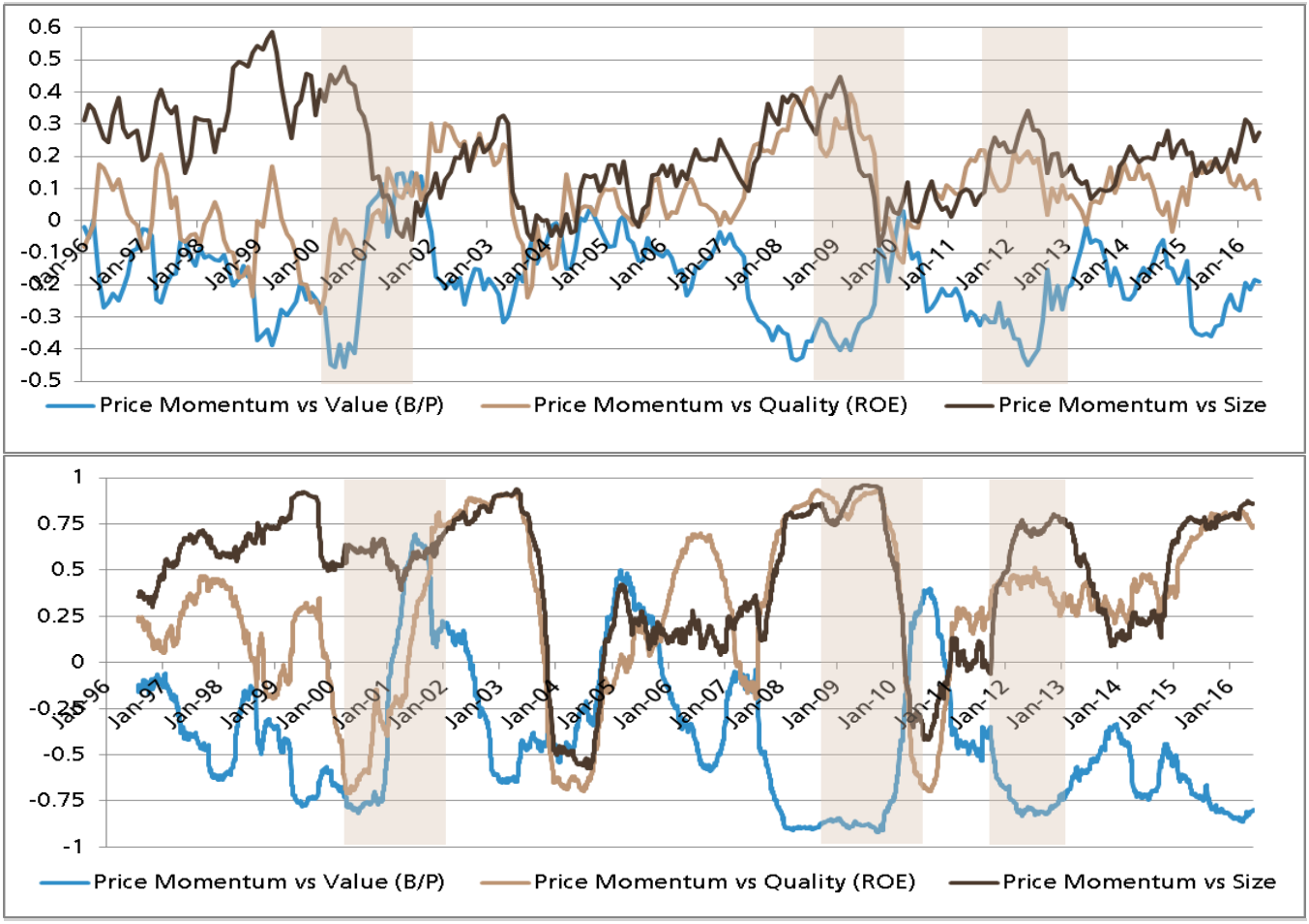
During periods of high economic uncertainty, the correlation of the low volatility scores with quality style scores rises and with the value style scores falls. These correlations then slowly reverse. The correlation with size also varies over time, but its synchronisation with market swings is less marked. The lower panel in Figure 3 plots the rolling six month correlation of the low volatility style returns with those of our core fundamental styles. These time series correlations show a similar cyclicality to the portfolio score correlations but lag by roughly the estimation window of six months. The swings are also more pronounced, varying between a correlation of -0.75 to 1 as opposed to -0.4 to 0.5 for the score correlations.

… being positive with quality during downturns and positive with value in upswings.

Figure 5 plots the correlations of the core fundamental styles but this time with the price momentum style. Again the correlations vary over time, though the relationship to our identified periods of economic uncertainty is less clear.

Similarly correlations with price momentum are time-varying.

Figure 5: Cross-sectional (top) and time-series (bottom) correlations of the fundamental styles with Price momentum



Source: UBS Quantitative Research. The top panel plots the cross-sectional correlation of our 3 core fundamental style scores with the price momentum score at each month end. The bottom panel plots the 6 month rolling correlation of the daily returns to the 3 core fundamental style portfolios with the returns to the price momentum portfolio.

In this section, we have tried to show that the relationships – as measured by the correlations of style scores – between fundamental styles is more stable over time than those between technical styles. Though this is perhaps unsurprising, it does suggest merit in differentiating between fundamental and technical styles.

3. Replicating Returns to Low Volatility

Ang, Hodrick, Xing and Zhang (2006, 2009), Baker, Bradley and Wurgler (2011), Frazzini and Pedersen (2014) all document a low volatility effect; stocks with low idiosyncratic return volatility tend to earn a higher risk adjusted return. Huang (2009) argued that a low cash flow volatility factor was able to capture a proportion of this low volatility effect.

We argue that low volatility embeds a style rotation strategy.

In this section we shall show that cash flow volatility in conjunction with an embedded style rotation strategy within low volatility can capture the majority of the excess return to low volatility. We thus will show that the low volatility strategy implicitly incorporates a style timing strategy over quality, value and size.

We extract the embedded strategy using monthly cross-sectional regressions on the scores.

Our approach to replicating the low volatility strategy is a straightforward regression based approach. At the end of each month, denoted t, we regress the normalised[6] fundamental style scores on the normalised low volatility scores

$$LV_t = \gamma_1 (B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 CFV_t + \varepsilon_t$$

where the notation is hopefully self-evident. The coefficients, γ_i, are the estimated implicit style weights within low volatility. We then use as our low volatility replicating score for that month the fitted score $\gamma_1 (B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 CFV_t$. The regression is repeated for each month end. These replicating scores can then be used to construct a long-short portfolios and replicating strategy returns in the usual manner[7].

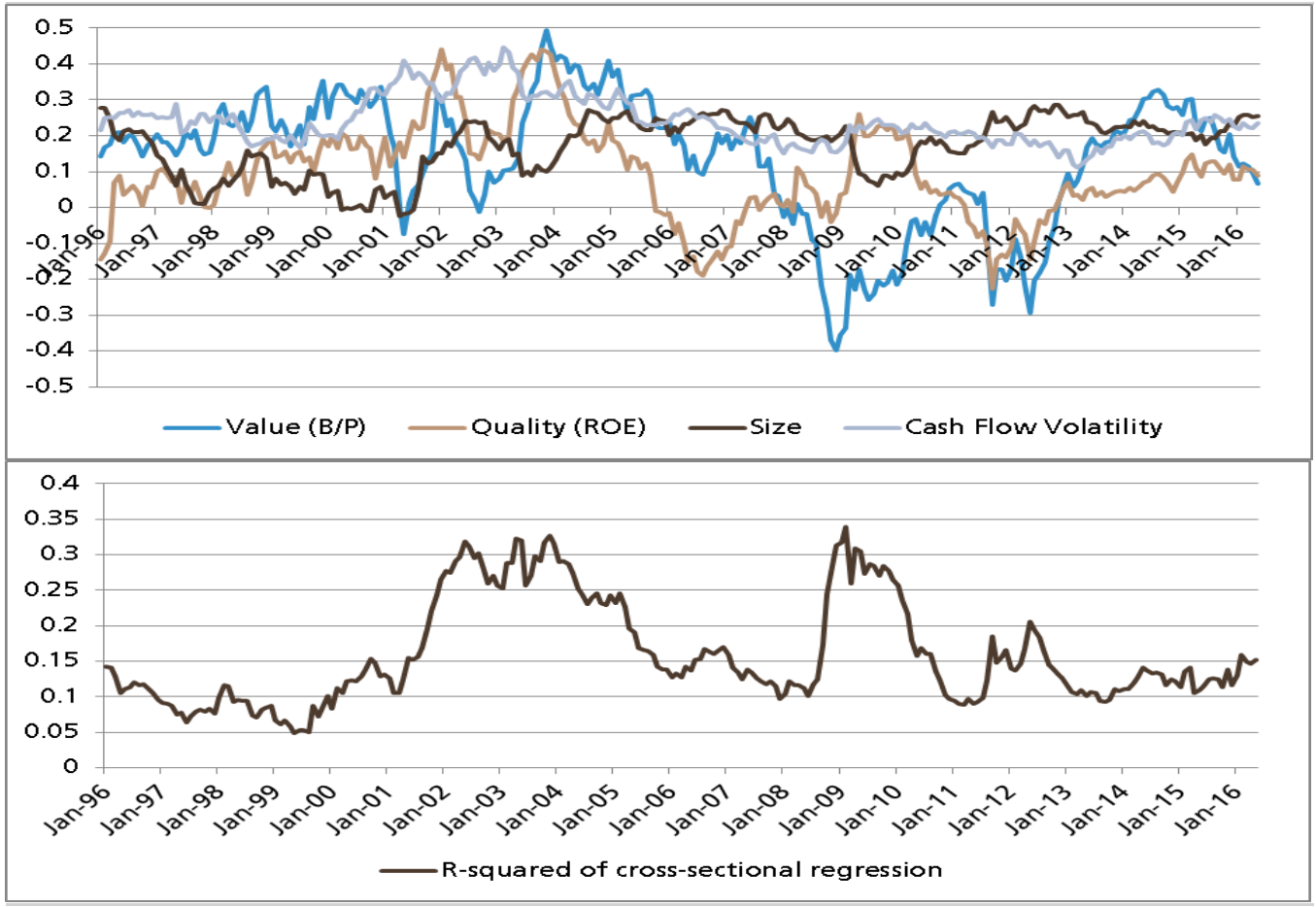
The upper panel in Figure 5 plots the estimated weights, γ_i, over time. The weight on the cash flow volatility is large, positive and relatively stable over time. The weights on both value and quality vary over time. During the value run in the mid-2000s, the weight on value is positive, but since the financial crisis the weight has been negative. The weight on quality is large and positive roughly during periods of identified economic instability.

The lower panel in Figure 6 plots the time variation in R^2 statistic of the regressions. The statistic can be understood as the square of the cross-sectional correlation between low volatility fitted scores and the actual low volatility scores. Thus an R^2 statistic of 0.1 corresponds to a correlation of 0.31 between the replicating and actual scores and one of 0.3 to a correlation of 0.54. Therefore, even when the regression fit is low, there is a correlation between scores as large as those chronicled in Figure 4 and Figure 5.

[6] To normalise a style score, we demean the score and divide by the medium absolute deviation (MAD). The scaled scores are then winsorized by setting a score greater than 3 is set to 3 and a score less than -3 is set to -3. The scaling alone does not affect the regression fit. The purpose of the winsorizing is to make the linear regression less sensitive to score outliers; an alternative but similar approach would be to perform a robust regression rather than a linear one on the unwinsorized data.

[7] The manner is described in section 1.

Figure 6: A plot of the estimated low volatility replicating portfolio weights, γ_i, over time and the achieved fit



Source: UBS Quantitative Research. The top panel plots the history of weights, γ_i on each of the fundamental styles that are used to replicate the performance of the low volatility long-short portfolio. The weights are estimated at the end of each month as the coefficients in the regression in the regression of the fundamental style scores on the low volatility scores: $LV_t = \gamma_1(B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 CFV_t + \varepsilon_t$. The bottom panel is the plot of the goodness-of-fit R^2 statistic of the regressions in each month.

So as to identify the embedded style rotation more accurately, we also report in the tables below the ability of value, quality and size styles on their own to replicate low volatility. We call this the 'Embedded Style Rotation' Strategy. The replicating scores for this strategy are calculated in an almost identical way using the regression

$$LV_t = \gamma_1(B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \varepsilon_t$$

Thus we have dropped cash flow volatility from the regression to focus on the embedded style rotation within low volatility. Though this portfolio is less able to replicate the low volatility style, we can use it to measure the effectiveness of the embedded style rotation strategy.

We show that the extracted style rotations strategy both mimics the low volatility strategy …

We now test the ability of these replicating portfolios to mimic the returns to low volatility. Figure 7 records the results of regressing the various replicating strategy returns on the low volatility strategy returns. The low volatility replication strategy can reproduce the returns to a non-sector neutral low volatility strategy with an R^2 of 0.82 and to a sector neutral one with R^2 of 0.71. The embedded style rotation portfolio does slightly less well but is still more effective than the cash flow volatility style alone. On a sector-neutral basis, the fit of all three alternatives is only a slightly weaker.

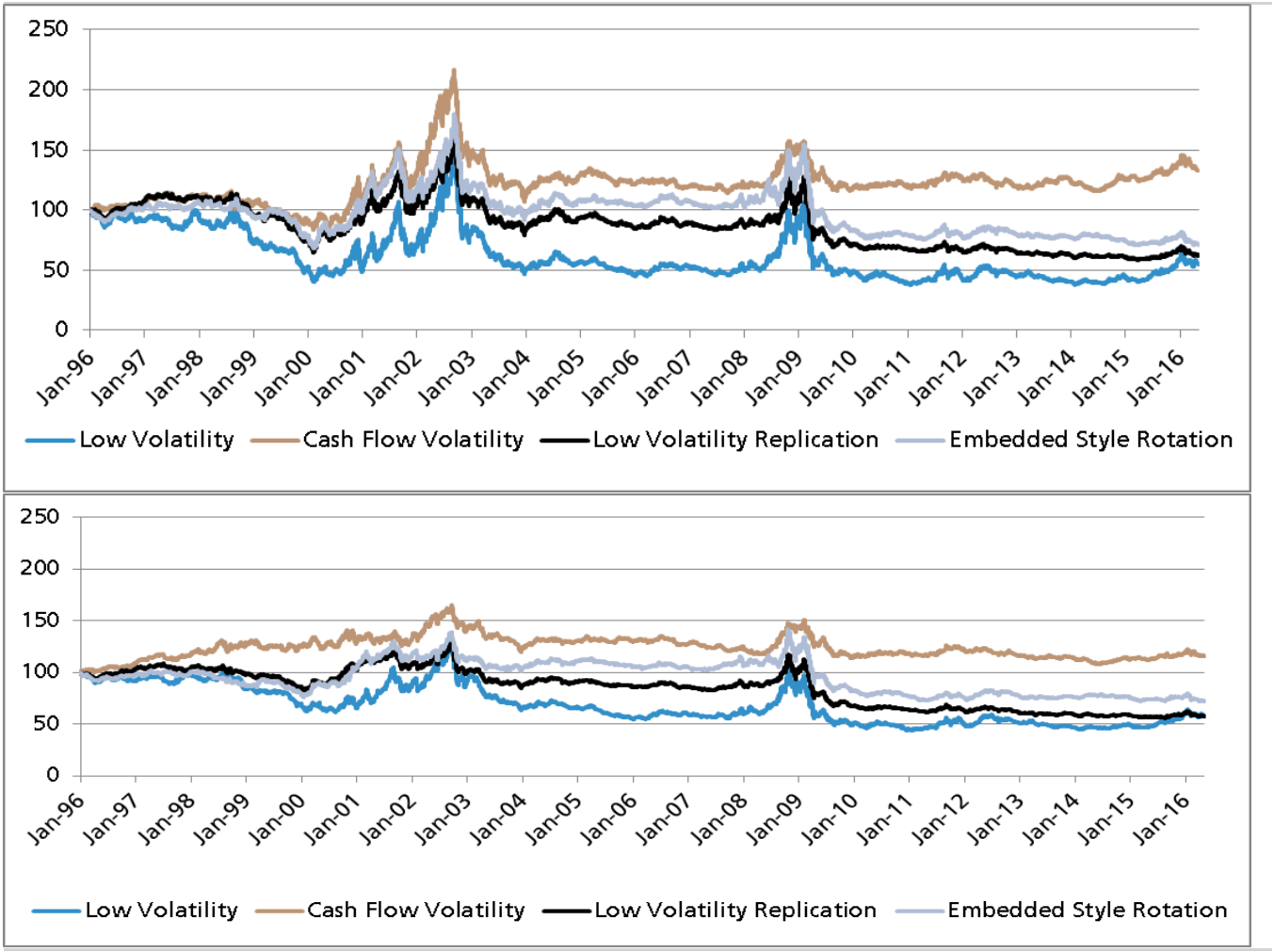
Figure 7: Regression and Fit of the Low Volatility Replicating Portfolios

	Non Sector Neutral Portfolios							Sector Neutral Portfolios					
	Estimate	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Low Volatility Replication		1.26	115.33					0.98	75.55				
Embedded Style Rotation				1.17	95.04					0.93	66.17		
Cash Flow Volatility						1.23	81.57					0.93	49.85
MSCI US Index	-0.82	-0.36	-41.99	-0.40	-40.42	-0.51	-49.13	-0.35	-54.32	-0.35	-49.57	-0.44	-60.05
Intercept (*252)	0.082	0.026	2.25	0.023	1.75	0.012	0.84	0.023	1.75	0.014	1.45	0.009	0.82
R^2	0.38	0.82		0.77		0.73		0.71		0.67		0.59	

Source: UBS Quantitative Research. The returns to various replicating portfolios and the MSCI US Index are regressed on the returns to the low volatility strategy. The table records the regression coefficients and their respective t-statistics as well as the R^2. The intercept term is multiplied by 252 to express it on annualised basis. The first column records a regression on the market alone; the next 6 columns record the statistics when the portfolios are non-sector neutral and the last 6 when they are.

The table also records the coefficient on the market index returns; this is average difference in the beta of the strategies. This difference averages around -0.35 for the various replicating strategies which can be compared to the average beta of the low volatility strategy of -0.82 (first column). Thus the replicating strategies have a significant negative beta (approx. -0.45); though it is less than the beta of the low volatility strategy. We can see the impact of this negative net beta in Figure 8. The replicating strategies mimic closely the performance of the low volatility long-short strategy, but there is a visible wedge between the two which can be accounted for by the difference in beta exposures.

Figure 8: Comparison of the performance Low Volatility Strategy Index against the Replicating Strategy Indices



Source: UBS Quantitative Research. The figure plots the performance of the low volatility strategy index against the various replicating strategy indices. The upper panel is non-sector neutral strategies; the lower panel is sector neutral ones.

... and can be used to construct an effective style-timing strategy.

One of the most documented pricing anomalies is that a low volatility portfolio earns positive risk adjusted returns; see for example Ang et al. (2006, 2009). Frazzini and Pedersen (2014) coined the phrase 'Betting against Beta' (BAB) for a long-short strategy that captures this 'alpha'. We now investigate whether our replicating portfolios are as successful in capturing this alpha too.

We build our BAB strategy in three stages; closely following the approach of Frazzini and Pedersen (2014).

1. Build a long only low volatility strategy: portfolios are built at the end of each month by equally weighting all stocks in the top quintile of the relevant score (this maybe the actual low volatility score or one of the replicating scores).

2. Build a beta neutral long-short portfolio: At the end of each month, estimate the beta to the long only strategy over the previous six months. Construct a long-short beta neutral portfolio by going long this portfolio and short beta times the market portfolio.

3. Dynamically adjust the leverage of the long-short portfolio to target 9% volatility: At the end of each month, estimate the volatility of the beta-neutral long short portfolio over the previous 6 months. Scale the

leverage of the long-short portfolio by the inverse of this estimated volatility so as to target a 9% annualised volatility.

Statistics on the performance of the BAB strategies are recorded in Figure 9 and the index performance plotted in Figure 10. All the low volatility strategies have delivered a steady out-performance since March 2000. Low volatility does outperform all the replication strategies. However until early 2015, the performance of the strategies was very similar.

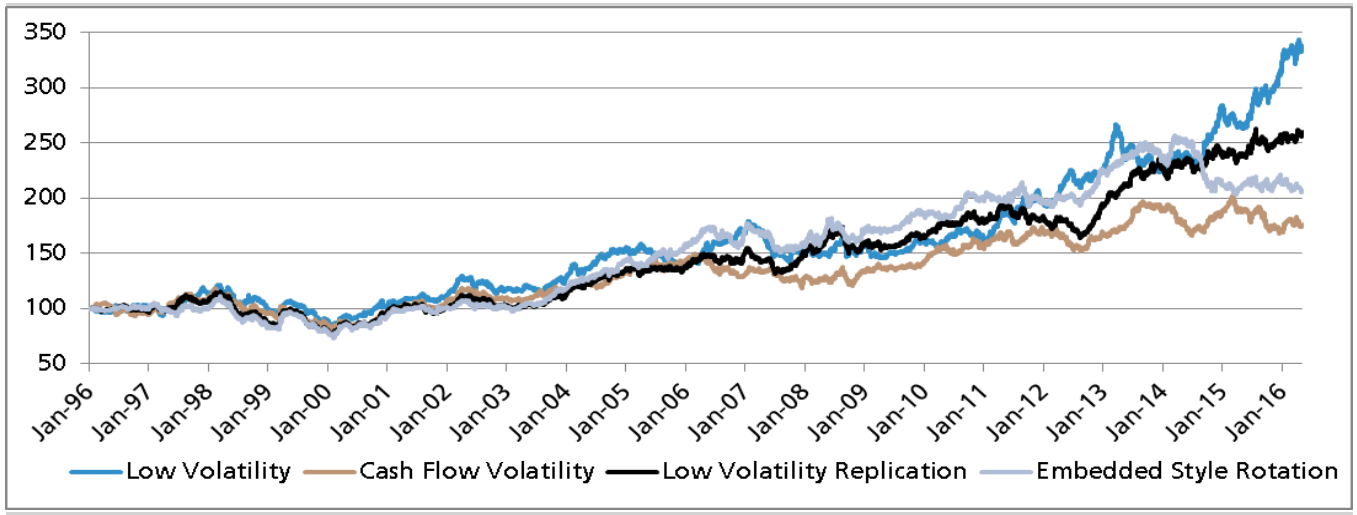
Figure 9: Performance Statistics of the Betting Against Beta Strategies based on different style scores

	Correlation with Low Volatility	Mean Return (annualised)	Std. Dev. (annualised)	Sharpe Ratio
Low Volatility	1.00	6.2%	9.2%	0.67
Low Volatility Replication	0.88	5.0%	8.9%	0.55
Embedded Style Rotation	0.84	3.1%	8.9%	0.43
Cash Flow Volatility	0.78	3.1%	8.9%	0.35
Quality	0.59	2.0%	9.0%	0.22
Value	-0.15	0.3%	9.2%	0.03
Size	0.57	-0.3%	8.8%	-0.04

Source: UBS Quantitative Research. The table records the scores of BAB strategies based on different style scores. The statistics are calculated on daily data over the complete sample of January 1996 to end of June 2016.

Of the replication strategies, the low volatility replication (which includes cash flow volatility scores) has a respectable Sharpe of 0.55. Of more interest to our discussion is that embedded style rotation strategy has a Sharpe of 0.43, far in excess of any of its constituent portfolios (quality, value and size).

Figure 10: Index Performance of the Low Volatility Betting Against Beta Strategies



Source: UBS Quantitative Research

The aim of this section has been to explain the performance of a low volatility BAB strategy in terms of the performance to a low cash flow volatility strategy and an embedded style rotation strategy. The analysis suggest that the low volatility strategy performance derives from both components in almost equal measure; the Sharpe of the respective strategies is 0.35 and 0.43 which combined delivers a Sharpe of 0.55.

4. Replicating Returns to Price Momentum

In this section we investigate whether price momentum embeds a momentum based style rotation strategy. The intuition is straightforward; if a style is performing well then its constituents are more likely to be included within a price momentum portfolio. Hence the price momentum portfolio will be naturally tilted towards this style. As in the previous section, we can use cross-sectional regressions to extract these tilts so as estimate the embedded style rotation strategy.

We investigate whether price momentum embeds a momentum based style rotation strategy.

We do indeed find a strong embedded style rotation strategy in price momentum. It is most clearly expressed in a tilt to or away from the low volatility style. The direction of the tilt appears to be related to the economic cycle; being positive in times of economic downturns and negative in upswings. However there is very little evidence that this rotation strategy adds any value. In fact, a strategy based on the fundamental earnings momentum style outperforms both price momentum as well as the embedded momentum style rotation strategy.

We find that it does …

This work connects consistently with two strands of work in the academic literature. Firstly a number of papers - Lewellen (2002), Teo and Woo (2004), Chen and DeBondt (2004), Aarts and Lehnert (2005), Clare, Sapuric, and Todorovic (2010) - have investigated whether a momentum based style rotation strategy can add value. The results are mixed, though some papers find weak evidence that it can add value. We find little support for this idea.

… but (in contrast to low volatility) it adds little value.

The other body of work connects the price momentum style to earnings momentum. Chan, Jegadeesh, Lakonishok (1996) found a strong correlation between the two styles but argued that neither subsumed the other. The later work of Chordia and Shivakumar (2006), Leippold and Lohre (2012) and Novy-Marx (2015) all found differences between the styles to be less pronounced and argued that earnings momentum dominated price momentum. Our results are consistent with this literature.

Building a replicating Price Momentum Strategy

We proceed using the same regression based approach. We regress at the end of each month, t, the fundamental style scores on the price momentum scores for that month,

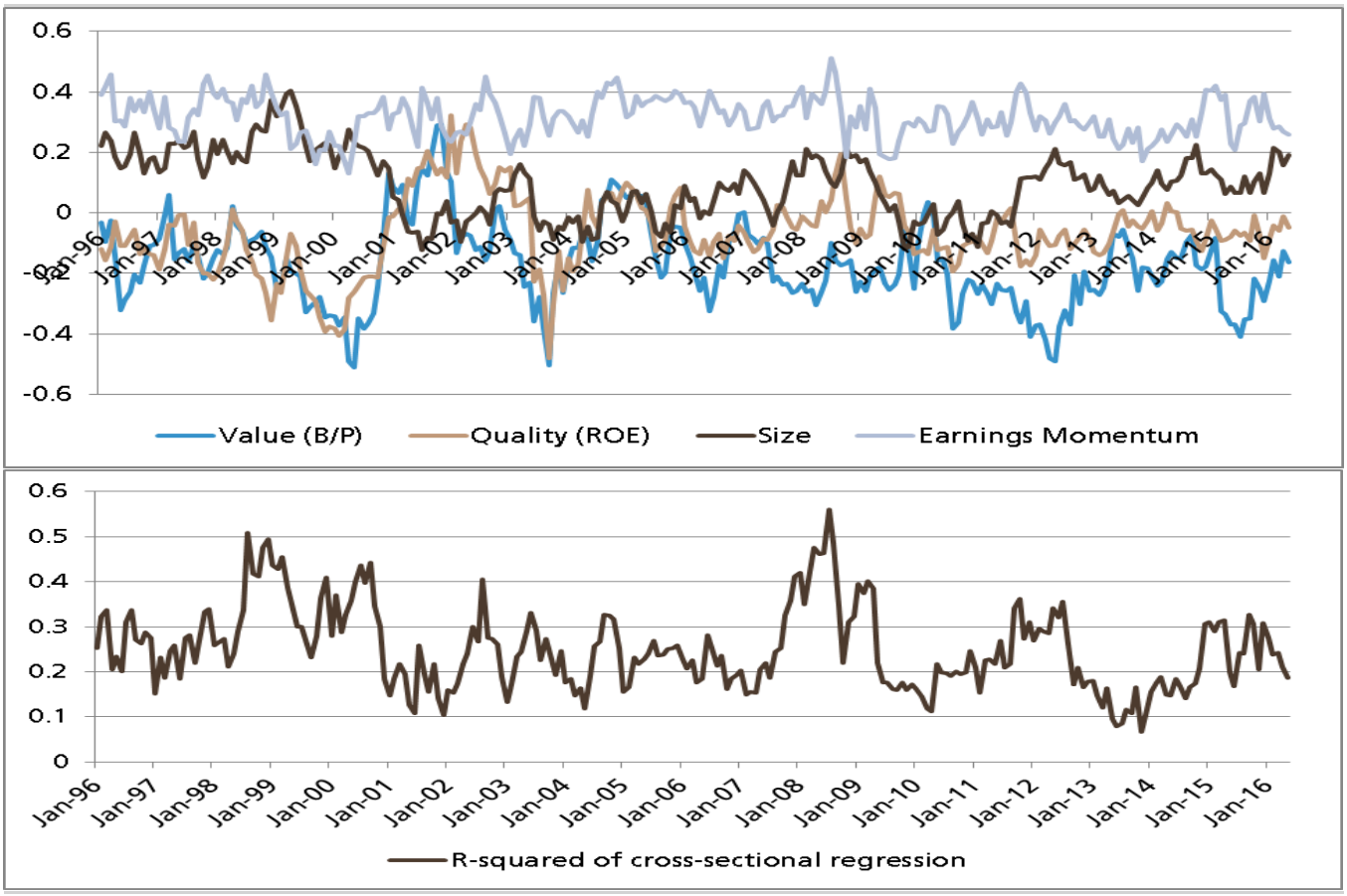
We extract the embedded style rotation using a regression based approach …

$$(PM)_t = \gamma_1 (B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 \left(EM\right)_t + \varepsilon_t$$

where PM and EM denote the price and earnings momentum scores respectively (the other notation remains the same). We then call the best fit weighted combination of the fundamental scores, that is $\gamma_1 (B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 \left(EM\right)_t$, the price momentum replicating scores and use these scores to construct both the replicating portfolios and strategy returns as before.

Figure 11 plots the estimated score weights γ_i, over time. The coefficient on earnings momentum is large, positive and stable over the sample period. There is some evidence of tilting in and out of quality and value over the period too. However, the rotation is not as marked as in low volatility case. The R^2 fit of the regression averages at 0.25 over the sample, consistent with an average cross-sectional correlation of 0.5 (=$\sqrt{0.25}$) between the replicating and price momentum scores.

Figure 11: A plot of the estimated price momentum replicating portfolio weights, γ_i, over time and the achieved fit



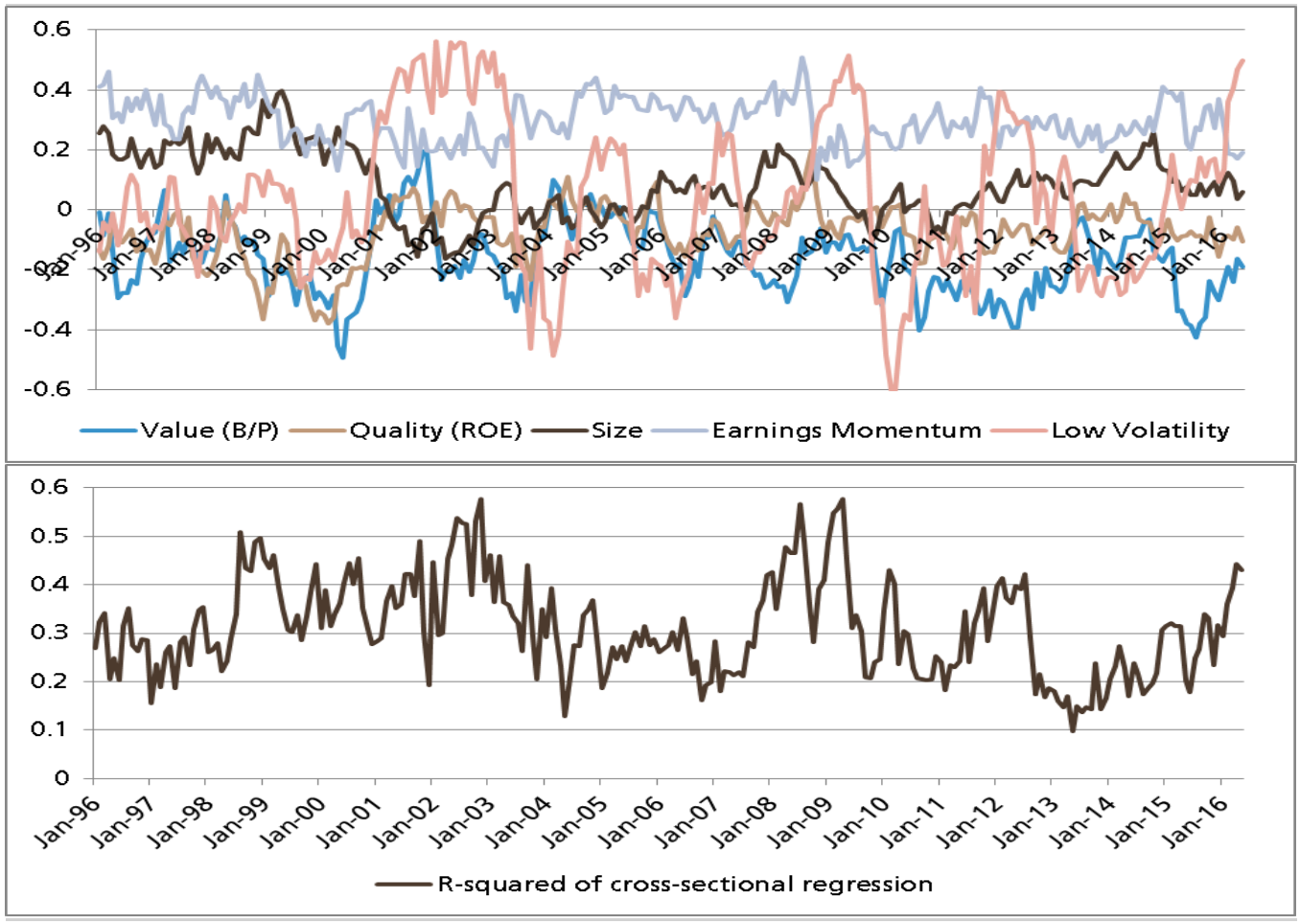
Source: UBS Quantitative Research. The top panel plots the history of weights γ_i, for each of the fundamental styles that are used to replicate the performance of the 12 month price momentum long-short portfolio. The weights are estimated at the end of each month as the coefficients in the regression in the regression of the fundamental style scores on the price momentum scores: $(PM)_t = \gamma_1(B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 (EM)_t + \varepsilon_t$. The bottom panel is the plot of the goodness-of-fit R^2 statistic for each of these regressions.

We repeat the exercise using a slightly different specification that includes the low volatility scores within the replicating portfolio scores:

$$(PM)_t = \gamma_1(B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4 (EM)_t + \gamma_5 (LV)_t + \varepsilon_t$$

Figure 12 plots the estimated score weights for this specification. The evidence of an embedded style rotation is far stronger in this case. Price momentum implicitly tilts towards low volatility during periods of economic uncertainty. The average R^2 fit of the regression also improves to 0.31.

Figure 12: A plot of the estimated price momentum replicating portfolio weights, γ_i, over time and the achieved fit



Source: UBS Quantitative Research. The top panel plots the history of weights γ_i, for each of the fundamental styles that are used to replicate the performance of the 12 month price momentum long-short portfolio. The weights are estimated at the end of each month as the coefficients in the regression in the regression of the fundamental style scores on the price momentum scores: $(PM)_t = \gamma_1(B/P)_t + \gamma_2 ROE_t + \gamma_3 Size_t + \gamma_4(EM)_t + \gamma_5(LV)_t + \varepsilon_t$. The bottom panel is the plot of the goodness-of-fit R^2 statistic for each of these regressions.

… and show that it can replicate the performance to price momentum.

Figure 13 investigates the ability of the price momentum replicating strategies to reproduce the returns to a price momentum strategy. Either at the non-sector neutral or sector neutral levels, the replicating strategies can reproduce the returns to price momentum; the coefficient on the market index and the intercept term are insignificant in all regressions at all normal confidence levels.

Both our replicating portfolios – with or without low volatility – achieve a better R^2 fit than the earnings momentum style. However the intercept term is similar suggesting that they do not improve the performance of the strategy.

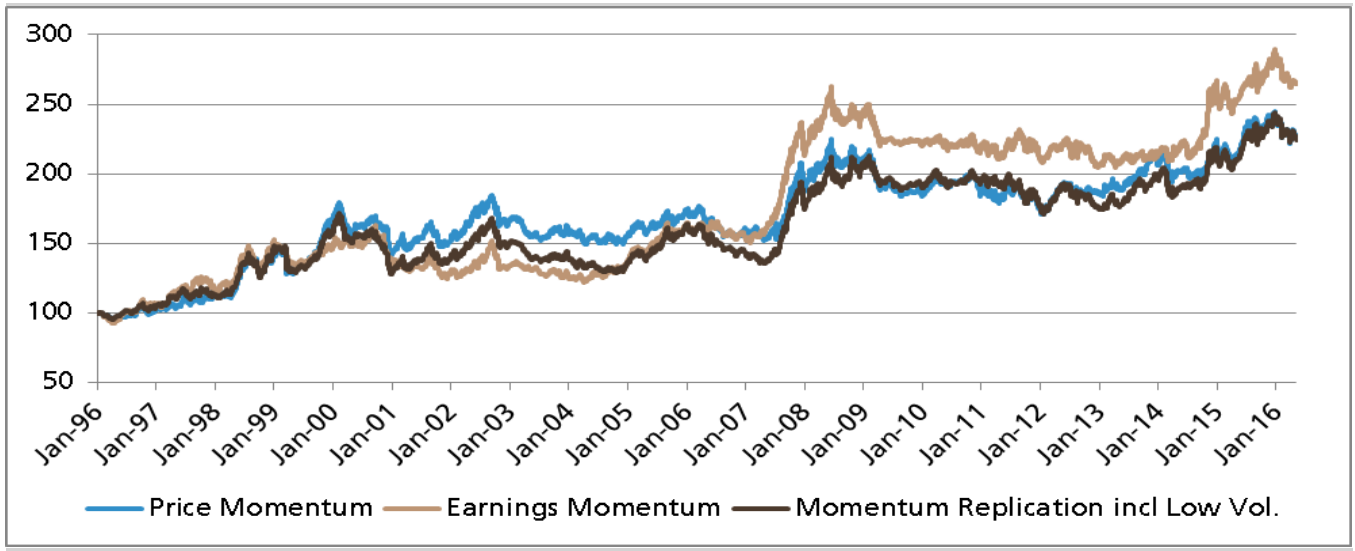
Figure 13: The ability of the replicating portfolios to mimic the returns to a price momentum strategy

Non- Sector Neutral Portfolios								
	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Momentum Replication Basic	1.12	146.35						
Momentum Replication with Low Vol			0.93	191.97			0.84	94.14
Momentum Earnings					1.16	104.81	0.02	1.13
Net Earnings Upgrades							0.21	12.55
MSCI US Index	-0.02	-3.38	0.04	6.92	-0.02	-2.74	0.03	5.83
Intercept (*252)	0.018	0.86	0.007	0.41	0.018	0.68	0.015	1.06
R^2	0.81		0.88		0.69		0.89	
Sector Neutral Portfolios								
	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Momentum Replication Basic	1.13	116.64						
Momentum Replication with Low Vol			0.96	138.73			0.78	65.64
Momentum Earnings					1.17	92.82	0.16	8.84
Net Earnings Upgrades							0.22	12.63
MSCI US Index	-0.03	-6.11	0.01	2.17	-0.03	-5.12	0.00	0.66
Intercept (*252)	0.019	1.12	0.007	1.13	0.013	0.68	0.015	1.06
R^2	0.73		0.79		0.64		0.81	

Source: UBS Quantitative Research. The replicating portfolio returns are regressed on the returns to a price momentum strategy. The table records both the coefficients and the t-statistics in the regressions, and the R^2 of the regressions. The top panel records the results when the portfolios are not constructed to be sector neutral, the bottom panel when they are. The final column also includes a Net Earnings Upgrade strategy within the regressions. The style scores for this strategy are constructed using the IBES analyst forecast database and are equal to the number of analyst earnings upgrades on FY1 minus the number of downgrades in the previous 3 months.

This observation is borne out by the comparison of the performance of these strategies in Figure 14. As is well-known – Barroso and Santa-Clara (2015) – adjusting the leverage of a momentum portfolio to target a given volatility improves its Sharpe ratio significantly. All the strategies plotted in Figure 14 have their leverage controlled to target an annualised volatility of 9%.

Figure 14: Index performance of price momentum, earnings momentum and the replicating strategy



Source: UBS Quantitative Research. The graph plots the performance of the three non-sector neutral price momentum strategies. All strategies are leveraged at each month-end rebalance to target 9% annualised volatility. This is affected by dividing the portfolio weights by the daily volatility of the unscaled strategy over the previous 6 months.

Of the three strategies, earnings momentum has the best performance. The style rotation embedded in the momentum replication strategy improves the fit of the strategy but does little for the performance.

However this momentum based style rotation add no value over an earnings momentum strategy.

This summary is backed up by the statistics in Figure 15. In this table we compare the performance of price momentum to the replication strategies. The best performing strategy is earnings momentum with a Sharpe of 0.54. The price momentum replication strategies have an almost identical performance to price momentum of a Sharpe ratio close to 0.50. This suggests the embedded style rotations strategies add little value. We test this explicitly by including two further replication strategies in the table; Embedded Style Rotation and Embedded Style Rotation including Low Volatility. These styles are built in an identical manner to, respectively, the Momentum Replication and Momentum Replication including Low Volatility strategies except now the earnings momentum scores are omitted from replicating regressions. Both these strategies – which now capture just the embedded style rotation in price momentum – perform dismally over our sample.

Figure 15: Performance Statistics of Price Momentum and associated Replication Strategies

	Correlation with Low Momentum	Mean Return (annualised)	Std. Dev. (annualised)	Sharpe Ratio
12 Price Momentum	1.00	4.3%	9.3%	0.47
Earnings Momentum	0.83	5.1%	9.3%	0.54
Momentum Replication	0.90	4.6%	9.3%	0.50
Momentum Replication incl. Low Vol.	0.94	4.3%	9.2%	0.47
Embedded Style Rotation	0.82	1.5%	9.1%	0.16
Embedded Style Rotation incl. Low Vol.	0.89	1.4%	9.1%	0.16
Low Volatility	0.56	0.5%	9.0%	0.06
Value	-0.52	-1.2%	9.0%	-0.13
Quality	0.57	1.6%	9.0%	0.18
Size	0.72	0.0%	9.1%	0.01

Source: UBS Quantitative Research. The table records the performance statistics for price momentum and associated replication strategies. The leverage of all strategies is rebalanced every month to target 9% volatility. The 'Momentum Replication' Strategy weights earnings momentum, value, quality and size scores to replicate price momentum; 'Momentum Replication incl. Low Vol' includes Low volatility scores as well; 'Embedded Style Rotation' weights Quality, Value and Size scores; 'Embedded Style Rotation incl. Low Vol.' weights Low Volatility as well as Quality, Value and Size scores The statistics are calculated on daily data over the complete sample of January 1996 to end of June 2016.

5. Conclusions

In this monograph, we argued that its useful to distinguish between fundamental styles – styles built using fundamental accounting information – and technical styles – style built on the basis of past return data. This is because the cross-sectional correlations between fundamental styles are remarkably stable over time whereas those involving technical styles are time-varying.

These time-varying relationships are intimately related to the economic cycle; in periods of economic stability both low volatility and price momentum tilt towards quality and away from value. We use this observation to extract the style rotation strategy embedded both within the low volatility and the price momentum strategy using a regression based approach.

We are able to successfully replicate the performance of low volatility using a cash flow volatility style – a fundamental style highlighted by Huang (2009) to be intimately related to low volatility – and the embedded style rotation strategy. We show that the embedded style rotation strategy performs well over our sample and can explain most of the difference in performance between the cash flow volatility and low volatility styles.

This result has clear implications for quantitative portfolio managers. Firstly it suggests that the low volatility already embeds a successful style rotation strategy. This style rotation strategy tilts towards quality in downturns and towards value in upswings, effectively using stock volatility as a signal. The manager therefore has a choice; either to use a low volatility strategy and adopt implicitly the embedded style rotation strategy, or devise a style rotation strategy to outperform this implicit one. The former approach is easy, effective and a difficult benchmark to beat. The latter approach is far from straightforward. It must take account, and add value to, the style rotation strategy implicitly embedded within low volatility. It must do this by either using the information more efficiently, or incorporating additional information from elsewhere.

We also successfully replicate the performance to price momentum. We use earnings momentum – again there is a literature arguing that this fundamental style is intimately related to price momentum – and an embedded style rotation strategy over low volatility, quality, value and size. This embedded style rotation strategy can be summarised as rotation into and out of low volatility (though this can be mimicked reasonably well using only quality and value). Again the rotation is linked to the economic cycle. However in contrast to the low volatility case, this rotation adds little value over and above earnings momentum.

We offer a more equivocal interpretation for our portfolio manager of these results. Possibly it suggests that it would be possible to design an effective momentum- based style rotation strategy, as the implicit one embedded within price momentum adds little value. Or maybe it explains why research into style momentum strategies have had very limited success.

References

Aarts, F. and Lehnert, T. "On style momentum strategies", Applied Economics Letters, Vol. 12, (2005), 795-799.

Ang, Andrew, Robert J. Hodrick, Yuhang Xing, and Xiaoyan Zhang. "The cross - section of volatility and expected returns." The Journal of Finance 61, no. 1 (2006): 259-299.

Ang, Andrew, Robert J. Hodrick, Yuhang Xing, and Xiaoyan Zhang. "High idiosyncratic volatility and low returns: International and further US evidence." Journal of Financial Economics 91, no. 1 (2009): 1-23.

Asness, Clifford. "The Siren Song of Factor Timing, Journal of Portfolio Management", special Issue #1 (2016)

Baker, Malcolm, Brendan Bradley, and Jeffrey Wurgler. "Benchmarks as limits to arbitrage: Understanding the low-volatility anomaly." Financial Analysts Journal 67, no. 1 (2011): 40-54.

Barroso, Pedro, and Pedro Santa-Clara. "Momentum has its moments." Journal of Financial Economics 116, no. 1 (2015): 111-120.

Chordia, Tarun, and Lakshmanan Shivakumar. "Earnings and price momentum." Journal of financial economics 80, no. 3 (2006): 627-656.

Clare, Andrew, Svetlana Sapuric, and Natasa Todorovic. "Quantitative or momentum-based multi-style rotation? UK experience." Journal of Asset Management 10, no. 6 (2010): 370-381.

Chan, Louis, Narasimhan Jegadeesh, and Josef Lakonishok. "Momentum strategies." Journal of Finance 51 (1996), pp. 1681–1713.

Chen, H. and De Bondt, W. "Style momentum within the S&P-500 index", Journal of Empirical Finance, Vol. 11, (2004), pp. 483-507.

Frazzini, Andrea, and Lasse Heje Pedersen. "Betting against Beta." Journal of Financial Economics 111, no. 1 (2014): 1-25.

Leippold, Markus, and Harald Lohre. "International price and earnings momentum." The European Journal of Finance 18, no. 6 (2012): 535-573.

Lewellen, J., "Momentum and autocorrelation in stock returns", Review of Financial Studies, Vol. 15, (2002), pp. 533-563.

Kim, Daehwan. "Cross - asset Style Momentum." Asia - Pacific Journal of Financial Studies 41, no. 5 (2012): 610-636.

Harvey, Campbell R., Yan Liu, and Heqing Zhu. "... And the cross-section of expected returns." Review of Financial Studies (2015): hhv059.

Huang, Alan Guoming. "The cross section of cashflow volatility and expected stock returns." Journal of Empirical Finance 16, no. 3 (2009): 409-429.

Novy-Marx, Robert. Fundamentally, momentum is fundamental momentum. National Bureau of Economic Research, No. w20984 (2015).

Teo, M. and Woo, S. "Style effects in the cross-section of stock returns", Journal of Financial Economics, Vol. 74, (2004), pp. 367-398.

Walkshäusl, Christian. "The high returns to low volatility stocks are actually a premium on high quality firms." Review of Financial Economics 22, no. 4 (2013): 180-186.

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