Academic Research Monitor
Advances in Momentum Investing

Equities

Global
Quantitative

David Jessop
Analyst
david.jessop@ubs.com
+44-20-7567 9882

Claire Jones, CFA
Analyst
claire-c.jones@ubs.com
+44-20-7568 1873

Josie Gerken, PhD
Analyst
josephine.gerken@ubs.com
+44-20-7568 3560

Desi Ivanova
Associate Analyst
desi-r.ivanova@ubs.com
+44-20-7568 1754

Paul Winter
Analyst
paul-j.winter@ubs.com
+61-2-9324 2080

Oliver Antrobus, CFA
Analyst
oliver.antrobus@ubs.com
+61-3-9242 6467

Pieter Stoltz
Analyst
pieter.stoltz@ubs.com
+61-2-9324 3779

Josh Holcroft
Analyst
josh.holcroft@ubs.com
+852-2971 7705

Shanle Wu, PhD
Analyst
shanle.wu@ubs.com
+852-2971 7513

Economics and currency momentum

Does an improving economy drive improvements in the strength of the country's currency? The authors of our first paper suggest that it does. They create an economic momentum trading strategy which buys the currencies of countries where the underlying economy (measured by, for example, changes in interest rates or CPI) is improving relative to the other countries in the study. We extend the authors' results to the current day.

Does a company's home town have information?

Creating a basket of companies with the same centre of incorporation gives us a new momentum signal in the US – one which appears to be orthogonal to existing factors.

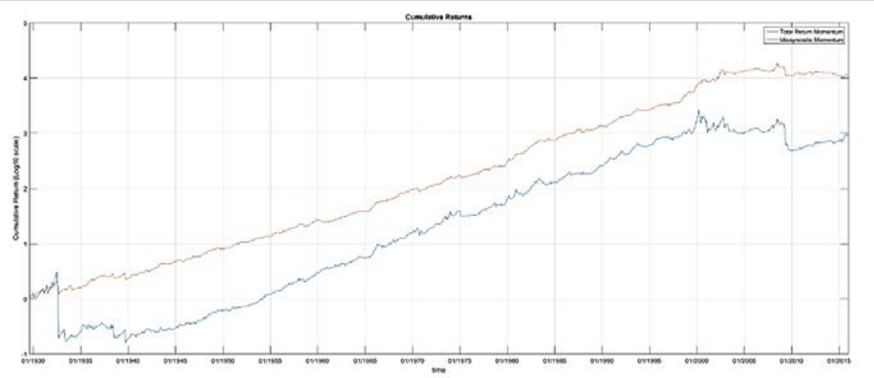
Idiosyncratic Momentum without Total Return Momentum Crashes

Constructing sorted portfolios according to idiosyncratic momentum rather than total return momentum generates anomalous returns for several global markets; Japan included! Whilst similar to conventional momentum from a factor perspective, it turns out that using idiosyncratic momentum instead as a signal results in more stable returns without the crashes momentum strategies typically suffer from.

Can you realise momentum profits after costs?

The fourth paper we review looks at the effect of costs on momentum strategies globally. Momentum is more effective in medium sized stocks than in large cap in most markets globally. However attempting to realise a momentum (or other) strategy in small companies will probably fail due to low trading volumes.

Figure 1: Idiosyncratic Momentum vs. Total Return Momentum



Source: Figure 1 from "Idiosyncratic Momentum" by Blitz, Hanauer & Vidojevic. Used by permission

Introduction

In this issue of our Academic Research Monitor, we return to the topic of momentum investing (Figure 2). We have covered momentum in previous editions of the ARM. These are available here (ARM, Jan 2015 ARM, July 2013)

The first paper takes an interesting approach to investing in currency momentum – it uses momentum in economic data as the signal rather than in the underlying price of the currency. The authors find a significantly large return to this economic momentum effect. Given the attractiveness of the strategy we extend the authors' results to the end of Feb 2018.

The second paper investigates the novel idea of geographic momentum – is there momentum driven by the location where the company is based? We attempt to replicate the signal within Europe but as we only have country of incorporation the results are not successful.

The third paper we review shows that the idiosyncratic momentum effect, as given in Gutierrez and Pirinsky (2007), offers anomalous returns, like conventional momentum but is, in itself, distinct and does not suffer from crash risk which total return momentum is prone to. The authors show that portfolios sorted according to idiosyncratic momentum offer better risk-adjusted returns than conventional momentum sorted portfolios for several global markets including Japan; a region where momentum-based strategies typically don't work. Again we replicate the results and find the idiosyncratic momentum strategy is successful in all markets except for Europe.

The final paper that we review investigates the feasibility to exploit the momentum premium in different firm size categories (*small*, *medium* and *large)* in the presence of transaction costs. Despite its high turnover, the returns to medium-sized portfolio remain statistically and economically strong, while those within the small stock universe appear to be unrealizable.

Figure 2: Papers on Momentum

"Economic Momentum and Currency Returns" *Magnus Dahlquist and Henrik Hasseltoft*	*SSRN working paper, Jan 2017*
"Geographic Momentum" *Christopher Parsons, Riccardo Sabbatucci & Sheridan Ttiman*	*SSRN working paper, June 2016*
"Idiosyncratic Momentum" *David Blitz, Matthias Hanauer & Milan Vidojevic*	*SSRN working paper, Jan 2018*
"Size and Momentum Profitability in International Stock markets" *Peter Schmidt, Urs von Arx, Andreas Schrimpf, Alexander Wagner, Andreas Ziegler*	*SSRN working paper, Feb 2017*

Source: UBS.

"Economic Momentum and Currency Returns"

by Magnus Dahlquist and Henrik Hasseltoft

Most analysis of currency momentum considers simply the momentum in the currency returns themselves – ranking on the past 12 months return and going long the currencies with the best return and shorting those with the worst (or going long those with a positive return and shorting those with a negative return) is a successful strategy. This paper analyses a different sort of momentum – that in the economic fundamentals of the underlying countries. As the authors say "a strategy that goes long currencies in countries with relatively strong economic momentum and short currencies in countries with relatively weak economic momentum exhibits an annualised Sharpe ratio close to one over the 1976-2014 period and delivers a statistically significant alpha when controlling for common currency strategies."

The authors look at eight economic variables, which are listed in Figure 3. As we detail in the table the changes are measured so an increase in the variable should be associated with higher growth[1].

Figure 3: Economic variables

Variable	Measure / direction
10 year rates	Increasing / difference
1 month rates	Increasing / difference
Yield spreads (short – long)	Flatter / difference
Consumer prices	Increasing / log change
Producer prices	Increasing / log change
Industrial production	Growth / log change
Retail sales	Growth / log change
Unemployment	Decreasing / log change

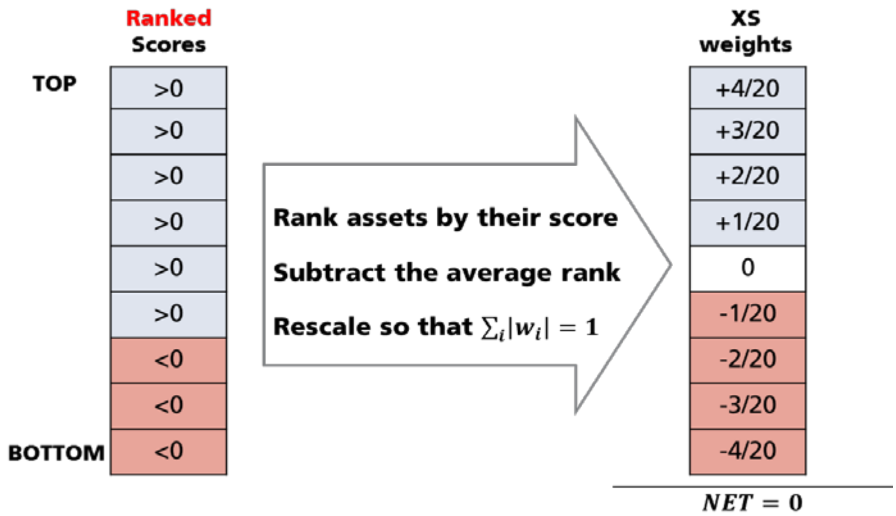
Source: Economic Momentum and Currency Returns by Dahlquist et al. Used by permission.

These variables are analysed across 19 countries, all of whose currencies are analysed against the USD. A twentieth region, the Euro, replaces a number of the currencies at the end of 1998. In our reproductions of the authors' results below we use the G10 currencies against the USD, a subset also used by the authors.

Portfolio construction

For each variable the authors consider lookback periods from 1 to 60 months. Each month they rank on the relevant change in the macroeconomic variable and then use a demeaned rank weighting, which is detailed in Figure 4, to create a dollar neutral portfolio. Given they have 8 macroeconomic variables and 60 lookback periods, this means each month they create 480 separate portfolios.

Figure 4: Cross sectional demeaned rank weighting. Example with 9 assets, 6 with positive scores, 3 with negative scores



Source: UBS Quantitative Research.

[1] The authors report the results of a number of panel regressions which confirm the direction of the relationship.

The authors use three-month-lagged data for the non-interest rate variables to guarantee data availability. They have also created portfolios using non-revised real-time macroeconomic data; they report "the results are very similar to our main results."

The economic data is lagged to ensure it is available

The returns of these portfolios are calculated using one month forward returns. In our reproduction below we use the returns of the continuous first future which is analogous to the authors' approach. When combining the individual portfolios together this is done using inverse volatility weighting where the volatility used is calculated over the previous three years. They combine the portfolios either by macro variable, grouping the trends into short-, medium- and long-term and also an overall combined portfolio covering all 480 strategies.

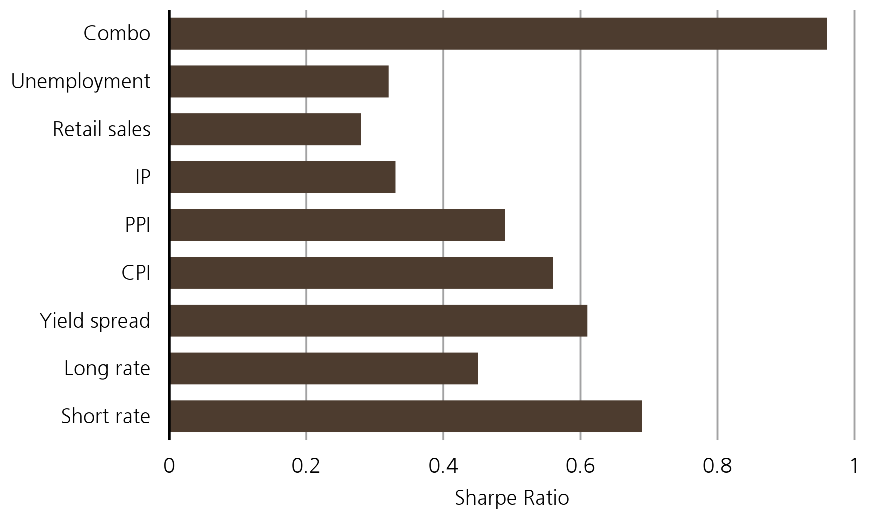
Performance

Dahlquist and Hasseltoft show that almost all their 480 portfolios have a positive Sharpe ratio over the full sample period, with only two of the industrial production, three of the retail sales and seven of the unemployment based portfolios. The highest individual Sharpe ratios are close to 0.8.

Almost all the portfolios have a positive return

Combining the individual portfolios using inverse volatility weighting gives the Sharpe ratios shown in Figure 5.

Figure 5: Sharpe ratios of the separate macro factor based portfolios



Source: Economic Momentum and Currency Returns by Dahlquist et al. Used by permission.

The average correlation between the eight strategies is 0.16 which means the combination portfolio of all 480 has a Sharpe ratio of 0.96, a skewness of -0.2 and a high excess kurtosis of 7.42.

Interestingly combining the strategies into short- (look back periods of 1-12 months), medium- (13-36 months) and long-term (37-60 months) shows that the highest Sharpe ratio, 0.95, is generated by the long term momentum signals, with the medium term giving 0.85 and the short term 0.63. In our reproduction of the analysis below we find a lower overall Sharpe ratio over a more recent period. The authors go on to show that the aggregate portfolio weights forecast future currency returns.

The long look back periods give the best performance

The obvious question to ask is whether these results are simply a repackaging of the standard carry, momentum and value strategies. The authors construct three cross sectional portfolios (using the same demeaned rank weighting approach described above in Figure 4) to represent these factors. They use the forward premium (one month forwards divided by the spot exchange rate), twelve month returns, and the negative of the log change of the real exchange rate over the past 60 months respectively.

Is this just carry, momentum and value?

Regressing the returns of the combo portfolio on these three factors leaves a significantly positive annualised alpha of 1.23%. The only beta which is significant is that to carry, which the authors interpret as "a portion of the [economic] trend returns reflects cross-sectional differences in interest rates". A regression on changes in FX volatility, the TED spread and changes in the VIX has a marginally significant negative coefficient to FX volatility, suggesting the trend portfolio does badly when FX volatility is rising.

No – there's a significant positive alpha after adjusting for these factors

Reversing the analysis and regressing the returns to the carry strategy on momentum, value and the various groupings of the economic trend portfolios (either by factor type or look back period) has the result in every case that the alpha to carry is no longer significant at the 5% level. In the authors words "economic momentum subsumes the alpha of carry trades".

The return to carry is subsumed by the economic momentum returns

Another way of considering the importance of a strategy is to introduce it into a mean-variance efficient portfolio. A portfolio containing just carry, momentum and value has weights of 29%, 27% and 44% respectively. Adding the economic trend portfolio changes these to 3%, 14% and 21% with the remaining 62% in the economic momentum portfolio. The Sharpe ratio rises from 0.89 to 1.10.

There are some further results in the paper which we briefly summarise here.

- Volatility targeting the combo portfolio showed "modest improvements" in the Sharpe ratio.
- Adding transaction costs of 10 basis points reduces the Sharpe ratio by a modest 0.08.
- Reducing the universe to just the G10 currencies produces similar results albeit with a somewhat reduced Sharpe ratio (0.81 from 0.96).
- Splitting the sample period in two gives a better performance in the first half, but the second half remains significant.

Reproducing the results

Given the positive nature of these results, which stop in May 2014, the question has to be asked as to whether the success of the strategy continues out of sample. To investigate this we chose to just analyse the currencies of the G10 countries (Australia, Canada, Eurozone, Japan, New Zealand, Norway, Sweden, Switzerland and the UK) against the USD from May 2002 to Feb 18. We start at May 2002 as this is when we have future available on all 9 currencies against the US dollar[2]. We have only analysed seven of the variables the authors considered as we struggled to find some of the industrial production data.

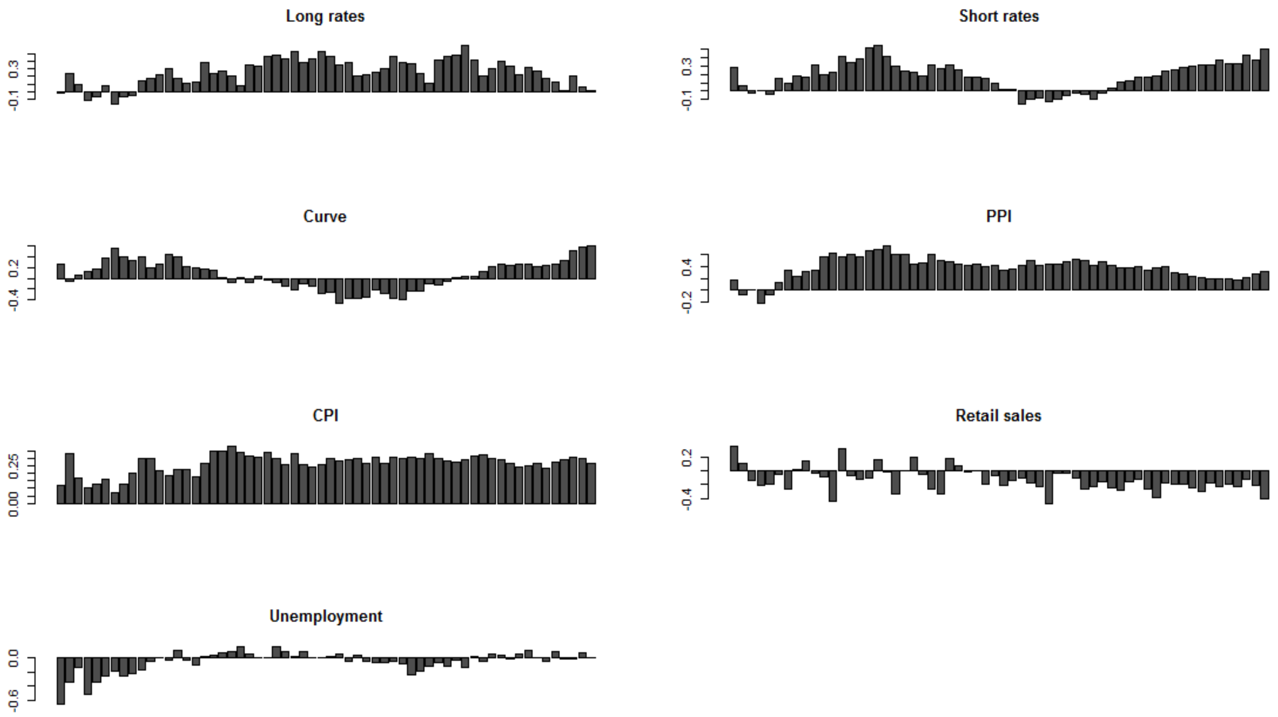
[2] - The currency returns are retrieved as continuous first futures from Bloomberg.

Over this period we find the results are less impressive than those shown in the paper. The Sharpe ratios of the individual portfolios are shown in Figure 6 below. As can be seen the long rate, CPI and PPI based strategies remain successful, but the retail sales and unemployment strategies have very subdued returns.

The short rate and curve (short – long rates) strategy performances are mixed.

Note the data starts in 2005 to be comparable with the combined strategies where we use the first three years of data to calculate the volatility of the individual sub-portfolios.

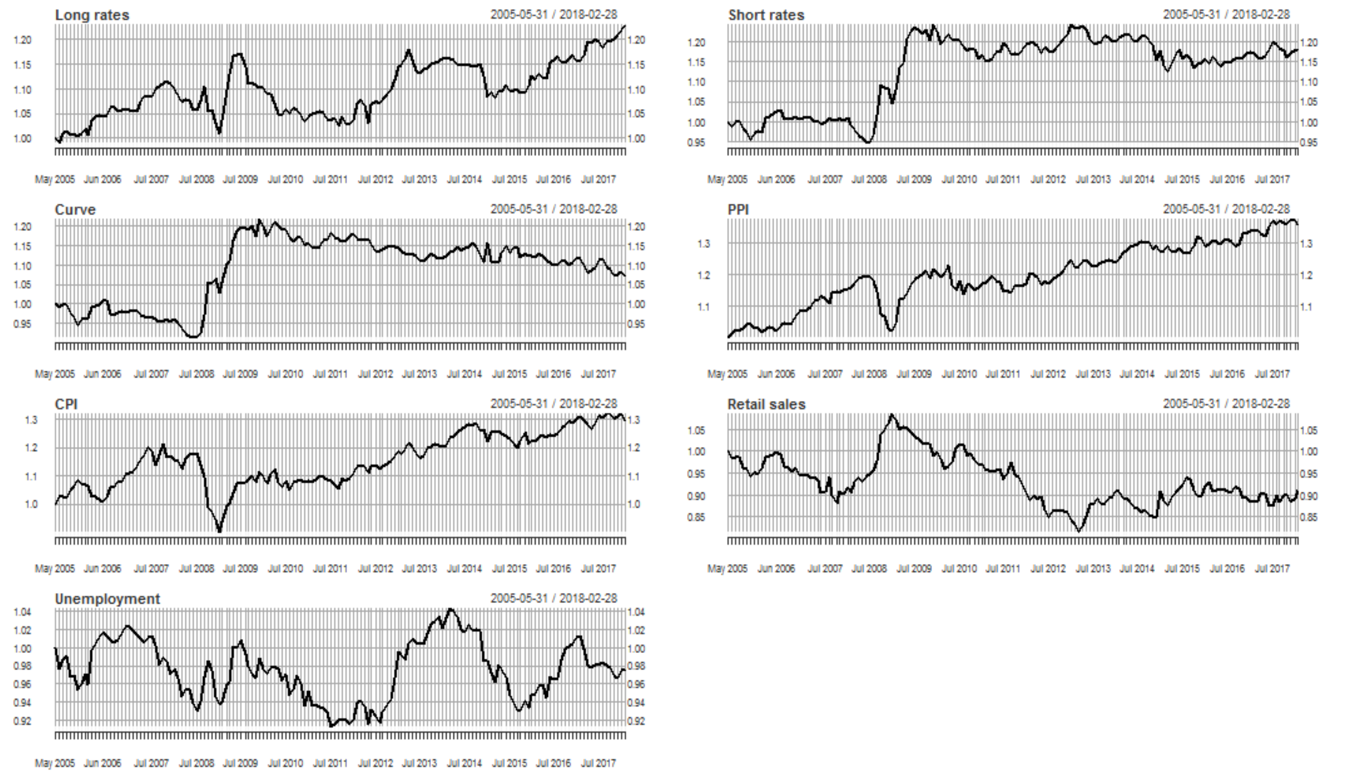
Figure 6: Sharpe ratios of the individual portfolios



Source: UBS Quantitative Research. Data from May 2005 to Feb 2018. The lags are from 1 to 60 months. The non-interest rate data is lagged by 3 months.

Combining the individual sub-portfolios into seven strategies we show the time series returns in Figure 7 below. These results confirm those seen in the bar charts above.

Figure 7: Time series returns for the portfolios combined by macroeconomic variable



Source: UBS Quantitative Research. Data from May 2005 to Feb 2018. Subportfolios are combined using 1 / volatility weighting.

The overall portfolio – combining all 420 sub-portfolios – has a Sharpe ratio of 0.38 – somewhat down on the performance reported in the paper (although better than the returns to a simple price momentum strategy run over the same time period). The details of the performance for this portfolio are shown below.

Figure 8: Performance statistics of the Overall portfolio

Annualized Return (Geometric %)	1.09%
Annualized Return (Arithmetic %)	1.13%
Volatility (%)	2.85%
Skewness	0.87
Kurtosis	3.97
Max Drawdown (%)	-6.33%
Annualized Sharpe Ratio	0.38
Calmar Ratio	0.17

Source: UBS Quantitative Research. The figure reports various performance statistics using monthly excess returns for the overall combined portfolio, where the individual portfolios are weighted using 1/vol weighting. The Calmar ratio is defined as the annualised geometric mean return over the maximum drawdown. The sample period is May 2005 to Feb 2017.

"Geographic Momentum"

by Christopher Parsons, Riccardo Sabbatucci and Sheridan Titman

In this paper, the authors contrast the effect of sector momentum to the much less well documented geographic momentum. They find strong evidence to support both, but note that sector momentum has greater explanatory power. However, they also find that the effect of sector momentum declines amongst stocks with high analyst coverage, while the effect of geographic momentum remains constant. This is important for investors because it means that geographic momentum remains a plausible investment strategy within the large-cap, highly liquid universe.

Results

Parsons et al have data on US stocks from 1970 to 2013. They use 12 sector classifications and identify each stock's geography by the location of its headquarters. There are twenty different geographies, each representing a large urban centre e.g. Denver or New York.

Evidence for both sector and geographic momentum, but sector momentum has a bigger impact

They regress the excess returns of a stock onto the excess returns of a portfolio consisting of all its non-local sector peers and the excess returns of a portfolio consisting of the firms which share its city but not its sector.

$$r_{i,c,s,t+1} = \alpha + \beta_{city} r_{c,\notin s,t} + \beta_{sector} r_{s,\notin c,t} + \varepsilon_{i,c,s,t+1}$$

They find that both betas are significant, but that the beta to the industry (0.20) is approximately three times larger than the beta to the city (0.07). This suggests that, while both geographic and sector momentum are significant, the impact of sector shocks is considerably larger than the impact of geographic shocks.

Strategy based on geographic momentum would have outperformed

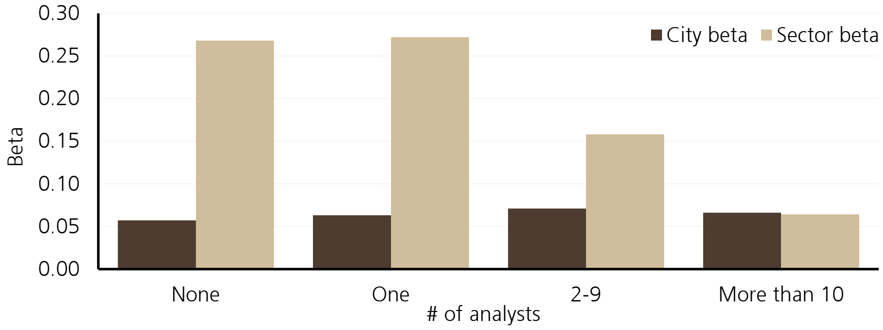
The authors simulated the performance of a trading strategy based on geographic momentum. Each month, they created quintile of stocks based on the average lagged return amongst firms headquartered in the same geography but from different sectors. These quintile portfolios were then rebalanced monthly. The highest quintile had a Fama-French alpha of 21 basis points per month, compared to -24 basis points in the lowest quintile.

It is also notable that the Fama-French alphas are almost identical to the CAPM alphas, suggesting that geographic momentum is orthogonal to the classic quantitative signals.

Sector momentum effect declines for more highly covered stocks, but geographic momentum remains constant

The authors extend this analysis by examining how their results change if they examine parts of the universe with low analyst coverage vs high analyst coverage. They find that the sector beta declines as the number of analysts covering a stock increases, but that the city beta remains roughly constant.

Figure 9: Effect of city and sector momentum by number of covering analysts



Source: Panel A of Table 5, "Predictive regressions with cross-sectional cuts (Fama-MacBeth)", taken from "Geographic Momentum" by Parsons, Sabbatucci & Titman, June 2016 Used with permission

This suggests that a sector momentum strategy will be less effective amongst highly scrutinised stocks, but that a geographic momentum strategy will remain equally effective.

This is important because it allows investors who are constrained to the more liquid parts of the market to use geographic momentum as an alpha signal and also because it suggests that a geographic momentum portfolio could remain profitable even with a large AUM.

Theoretical explanation

Because analysts typically work in sector teams, not geographic teams, information diffuses more rapidly across sectors than geographies

The authors' explanation for their result hinges on one (plausible) assumption: when two firms are covered by the same analyst, then information gleaned from one firm is rapidly incorporated into the price of another firm. For example, if a firm issues a profit warning, then the analysts who cover it adjust their beliefs about the profitability of the other firms they cover accordingly, and this is then priced in by the market. In contrast, when two firms do not have any overlapping coverage, the information may be much slower to be priced in.

The authors note that the great majority of analysts work on sector teams rather than geographic teams e.g. there are many utilities specialists but fewer Ireland specialists. As a consequence, information may diffuse more rapidly across sectors than across geographies. Investors can take advantage of the slow incorporation of information into prices by buying momentum portfolios. This allows geographic momentum to be a successful strategy, even if sector shocks have a bigger impact on asset prices than geographic stocks.

This allows geographic momentum to keep working even amongst stocks with high analyst coverage.

The structure of the investment analyst business has another important consequence. As the number of analysts increases, the probability that any pair of stocks from the same sector have at least one overlapping analyst rises to nearly one. In contrast, increasing the number of analysts does not greatly change the probability that two stocks from the same geography but different sectors are covered by the same analyst. It will remain close to zero, because very few analysts cover multiple sectors.

That means that highly covered stocks rapidly incorporate information from other stocks in the same sector (via the overlapping analysts), so sector momentum is less effective. However, information from other stocks in the same geography does not diffuse rapidly even to highly covered stocks (as there aren't any overlapping analysts) so geographical momentum can still be a useful signal amongst these names.

Our replication

We have attempted to replicate this work in Europe. Unfortunately, we do not have a dataset giving companies' location down to the city level. Instead, we define the geographies as countries rather than urban centres. We use the ten ICB sectors.

At each month end and for each stock, we compute the excess returns over the previous month of an equal weighted portfolio of stocks from the same country but a different sector and an equal weighted portfolio of stocks from the sector, but from different countries. All returns were total returns and were computed in USD.

We find geographic reversal effect, not momentum

We then run a panel regression, regressing the excess returns to the stocks onto the returns to these two portfolios. Figure 10 shows the results. We did not replicate the authors' findings. We find evidence of a positive sector momentum effect, but a negative geographic momentum effect i.e. geographic reversal.

Over the one-month horizon, the beta between past returns of the stock's country (ex its own sector) portfolio and future returns to the stock appears to be negative. This suggests the presence of geographic reversal rather than momentum.

Figure 10: Panel regression of excess returns onto country and sector portfolio returns from the previous month

	Value	T-statistic	P-value
Intercept	0.00	-0.04	97%
Country beta	-0.05	-8.74	0%
Sector beta	0.18	26.11	0%

Source: UBS Quantitative Research

There are a wide variety of explanations for this difference. One key difference is that countries are much bigger geographic sub-groups than urban centres. This may make information about other stocks in the same geography less relevant, and hence reduce the effect of momentum.

"Idiosyncratic Momentum"

by David Blitz, Matthias X. Hanauer and Milan Vidojevic

Portfolios formed by sorting stocks on total return momentum, typically defined by the return over the past 6 or 12 months, have shown to deliver above-average returns in the subsequent period[3]. In this paper, Blitz, Hanauer and Vidojevic (2018) show that the idiosyncratic momentum effect (to be defined shortly) as given in Gutierrez and Pirinsky (2007) offers positive returns in a similar vein to conventional momentum but is, in itself, distinct and does not suffer from crash risk which total return momentum is prone to.

Total return momentum has proved successful but it has drawbacks…

As we showed in "Are you already timing styles successfully?", price momentum has time-varying loadings on quality, value and size, a result corroborated elsewhere in the literature (see e.g., Kothari and Shanken, 1992). A negative consequence of the existence of these style exposures is when those styles reverse; during such periods, the total return momentum factor is known to experience large losses.

…its time-varying loadings on other styles have negative consequences when those style reverse.

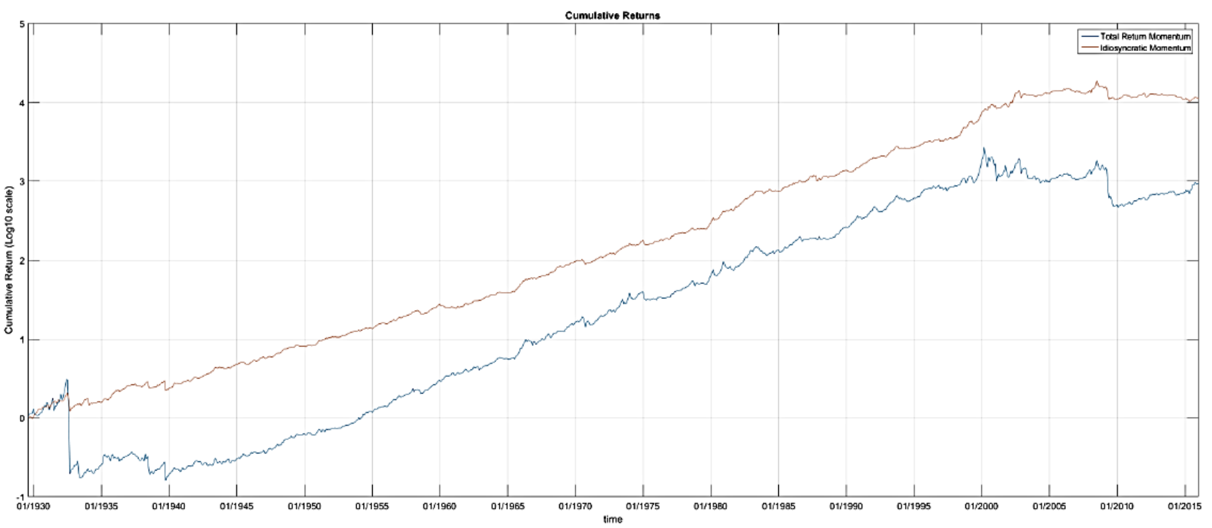
In summary, the findings of the paper are as follows:

- The idiosyncratic momentum anomaly is a phenomenon distinct from conventional momentum and cannot be explained by standard asset-pricing models;
- Neither the overreaction hypothesis, investor overconfidence nor risk-based reasons offer an explanation for idiosyncratic momentum;
- Profits to idiosyncratic momentum strategies are consistent with investor underreaction to news;
- Idiosyncratic momentum based portfolios in international equity markets also perform favourably, Japan included.

Idiosyncratic momentum is distinct from conventional momentum and does not suffer the same shortcomings.

It even works in Japan!

Figure 11: Cumulative Returns



Source: Figure 1 from "Idiosyncratic Momentum" by Blitz, Hanauer & Vidojevic. Used by permission. The plot shows cumulative performance of the top over bottom TR MOM and iMOM portfolios, equal-weighted and rebalanced monthly, over the period July 1963 – December 2015

[3] Jegadeesh and Titman (1993, 2001)

Motivation

The motivation for investing according to traditional momentum is associated with the empirically observed anomaly that stocks with strong past performance continue to outperform over the subsequent period. Whilst a strategy of buying past winners and selling past losers has proven effective, its success often does not persist beyond a couple of months and it has not demonstrated success in the Japanese equity market. It is also prone to crash risk which can be explained by its option-like behaviour. That is, in down-turning markets, a conventional momentum strategy is effectively a short call option on the market with bounded gains as the market further declines yet unbounded losses when the market rises. Broadly speaking, therefore, momentum performs better when market conditions persist than when the market transitions to another state.

Total return momentum has option-like behaviour. Hence, it is highly exposed to crash risk.

Related to this, the sign of momentum returns typically follows those of the market; a pattern associated with the overreaction hypothesis, investor overconfidence and self-attribution bias. The authors of this paper show that idiosyncratic momentum (henceforth iMOM) is less exposed to crashes as well as credit market factors[4]. Furthermore, the premium realised by this alternative definition of momentum cannot be explained by investor overreaction or over confidence.

Idiosyncratic momentum is less exposed to crash risk and cannot be explained by those reasons often posited for conventional momentum.

Data and Definitions

The calculation process of iMOM is achieved in three stages:

iMOM is defined as the past 12-month vol-adjusted mean idiosyncratic return (excluding the latest month)

(1) Using a return history of 36 months, the following model is estimated each month for all stocks in the universe:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{mkt,i} \cdot (R_{mkt,t} - R_{f,t}) + \beta_{hml,i} \cdot R_{hml,t} + \beta_{smb,i} \cdot R_{smb,t} + \epsilon_{i,t}$$

(2) Idiosyncratic momentum returns are calculated using the estimated betas from stage (1):

$$\epsilon_{i,t} = R_{i,t} - R_{f,t} - \alpha_i - \beta_{mkt,i} \cdot (R_{mkt,t} - R_{f,t}) - \beta_{hml,i} \cdot R_{hml,t} - \beta_{smb,i} \cdot R_{smb,t}$$

(3) The iMOM score is then computed as the last 12-2 month volatility-adjusted mean idiosyncratic return:

$$Idiosyncratic\ Momentum_{i,t} = \frac{\sum_{t-12}^{t-2} \epsilon_{i,t}}{\sqrt{\sum_{2-12}^{t-2} \left(\epsilon_{i,t} - \overline{\epsilon_i}\right)^2}}$$

For the U.S. case, security-level data is sourced from CRSP[5] over the period December 1925 – December 2015 where the universe consists of common shares traded on NYSE/AMEX and NASDAQ exchanges with the usual selection criteria. Balance sheet and income statement data is obtained from Compustat annual files. The one-month U.S. Treasury bill is used to represent the risk-free rate. Finally, Fama-French factor returns are sourced from the website of Professor Kenneth French.

[4] The authors cite a few papers which suggest that positive returns to momentum depend on the credit market during the holding period. This bias to the credit market, referred to as the "spillover effect", however, is not substantial for idiosyncratic momentum as it is for conventional momentum.
[5] Center for Research in Security Prices.

Empirical Results

In their empirical analysis, equal-weighted portfolios are constructed and, for the purpose of validation, an iMOM factor is formed following the same methodology Fama and French employ for building their (WML) momentum factor. More specifically, the iMOM factor is the zero-investment, value-weighted portfolio which is long small and big (idiosyncratic) winners and short small and big (idiosyncratic) losers, rebalanced monthly and held for one month:

The relative benefits of using iMOM rather than TR MOM as an investment signal.

iMOM factor definition.

$$iMOM_t = \frac{1}{2}(Big_{idio}Winners_t + Small_{idio}Winners_t) - \frac{1}{2}(Big_{idio}Losers_t + Small_{idio}Losers_t)$$

In the first instance, iMOM decile portfolios are constructed, the performance of which is compared to the performance of equivalent portfolios formed according to total return momentum (henceforth TR MOM) and is summarised in Figure 12 and Figure 13 .

Figure 12: Performance of Idiosyncratic Momentum Decile Portfolios

Decile	Excess Return	Vol	Sharpe Ratio	Alpha CAPM	tstat	Alpha 3FM	tstat	Alpha 5FM	tstat
D1	0.22	5.92	0.04	-0.38	(-3.48)	-0.53	(-5.81)	-0.47	(-5.04)
D2	0.43	5.54	0.08	-0.13	(-1.47)	-0.3	(-4.26)	-0.32	(-4.43)
D3	0.52	5.29	0.1	-0.03	(-0.41)	-0.2	(-3.58)	-0.24	(-4.17)
D4	0.64	5.2	0.12	0.1	-1.28	-0.08	(-1.62)	-0.11	(-2.14)
D5	0.73	5.12	0.14	0.2	-2.66	0.02	-0.39	-0.03	(-0.72)
D6	0.77	5.1	0.15	0.24	-3.21	0.07	-1.69	0.02	-0.42
D7	0.82	5.09	0.16	0.28	-3.97	0.12	-2.8	0.06	-1.49
D8	0.87	5.09	0.17	0.34	-4.46	0.18	-3.94	0.14	-2.99
D9	1.01	5.26	0.19	0.46	-5.74	0.31	-5.66	0.27	-4.74
D10	1.19	5.57	0.21	0.63	-6.7	0.52	-7.32	0.51	-6.86
D10-D1	0.98	3.33	0.29	1	-7.51	1.05	-7.78	0.98	-7.02

Source: Table 1 from "Idiosyncratic Momentum" by Blitz, Hanauer & Vidojevic. Used by permission. The table reports descriptive statistics to decile portfolios formed according to idiosyncratic momentum scores for U.S. stocks over the period July 1963 – December 2015.

Figure 13: Performance of Total Return Momentum Decile Portfolios

Decile	Excess Return	Vol	Sharpe Ratio	Alpha CAPM	tstat	Alpha 3FM	tstat	Alpha 5FM	tstat
D1	0.13	7.74	0.02	-0.58	(-3.29)	-0.81	(-5.12)	-0.59	(-3.72)
D2	0.48	5.97	0.08	-0.11	(-0.92)	-0.32	(-3.17)	-0.3	(-2.89)
D3	0.63	5.26	0.12	0.1	-1.03	-0.12	(-1.59)	-0.18	(-2.33)
D4	0.64	4.86	0.13	0.15	-1.85	-0.06	(-1.01)	-0.13	(-2.32)
D5	0.67	4.71	0.14	0.18	-2.47	-0.01	(-0.21)	-0.1	(-1.96)
D6	0.73	4.65	0.16	0.24	-3.58	0.06	-1.28	-0.05	(-1.19)
D7	0.83	4.69	0.18	0.34	-4.97	0.18	-3.76	0.07	-1.58
D8	0.86	4.94	0.17	0.35	-4.53	0.21	-3.77	0.1	-1.85
D9	1.04	5.6	0.19	0.48	-4.58	0.41	-5.19	0.37	-4.57
D10	1.2	7.09	0.17	0.55	-3.33	0.57	-4.6	0.64	-5.07
D10-D1	1.07	6.42	0.17	1.14	-4.42	1.37	-5.47	1.23	-4.77

Source: Table 1 from "Idiosyncratic Momentum" by Blitz, Hanauer & Vidojevic. Used by permission. The table reports descriptive statistics to decile portfolios formed according to convention total return momentum scores for U.S. stocks over the period July 1963 – December 2015.

If we first consult Figure 12, the second and fourth columns report monotonically increasing excess and risk-adjusted returns, respectively, going from low to high iMOM decile portfolio. This remains true even after adjusting for the standard factors, as is shown in the fifth, seventh and ninth columns. Furthermore, the self-financing $D10 - D1$ iMOM portfolio delivers a monthly return of 0.98% which, although lower than the equivalent portfolio based on TR MOM (see the bottom row of Figure 13), offers a much lower monthly volatility of 3.3% (compared to 6.42%) resulting in a 77% improvement in Sharpe ratio (0.29 vs. 0.17). In general, Figure 12 and Figure 13 point to the conclusion that idiosyncratic momentum generates more stable alphas than its traditional counterpart. Note, as well, that the conclusions do not materially differ when the same statistics are computed for large cap decile portfolios[6].

Sharpe ratios for iMOM decile portfolios generally exceed those of their conventional counterpart.

Is Idiosyncratic Momentum distinct?

Beyond investigating the performance advantages of a newly defined factor, a necessary exercise is to show that those results thus documented are robust. The authors achieve this and examine whether iMOM is a "separate factor that expands the efficient frontier" via three sets of tests:

Is iMOM superior to TR MOM according to time-series and cross-sectional factor tests?

1. **Time-series: GRS** – quantifies whether the iMOM decile portfolios have a joint alpha of zero.

2. **Cross-section: Fama and MacBeth (1973)** – regresses the iMOM returns on a set of characteristics; the estimated coefficients of which represent premia associated with a unit of exposure to a factor (characteristic) holding all other factors constant.

3. **Factor Spanning** – time-series regressions on various sets of factors including conventional momentum and iMOM factors.

Regarding the first test, Figure 14 shows GRS statistics for the same asset-pricing models used for measuring the decile portfolio alphas in Figure 12 and Figure 13. The first thing to note is that neither of these models can explain the returns to either definition of momentum. Secondly, GRS statistics relating to iMOM are consistently higher that those relating to TR MOM.

Figure 14: GRS Test for joint alpha

	iMOM	TR MOM
Alpha CAPM	7.72 (0)	5.14 (0)
Alpha 3FM	7.12 (0)	4.6 (0)
Alpha 5FM	5.7 (0)	3.66 (0)

Source: "Idiosyncratic Momentum" by Blitz, Hanauer & Vidojevic. Used by permission.

The overall conclusion stemming from the Fama-French regressions is that, whilst both momentum strategies are highly economically and statistically significant, when both are jointly considered, the estimated coefficients associated with iMOM are stronger in magnitude with higher t-stats. We can interpret this as follows: "there is information about average returns in idiosyncratic momentum that is not considered in total return momentum."

Finally, the factor spanning tests show that TR MOM is subsumed by iMOM; the alpha to TR MOM becomes insignificant when we control for iMOM. On the other hand, iMOM is not subsumed by TR MOM. The same story emerges when the same computations are made for small and large caps.

According to factor spanning tests, TR MOM is subsumed by iMOM but iMOM is not subsumed by TR MOM.

In light of the above, whilst both definitions of momentum cannot be explained by any of the standard asset-pricing models; iMOM "seems to pose an even bigger challenge".

[6] See the appendix for the performance statistics for the large cap case.

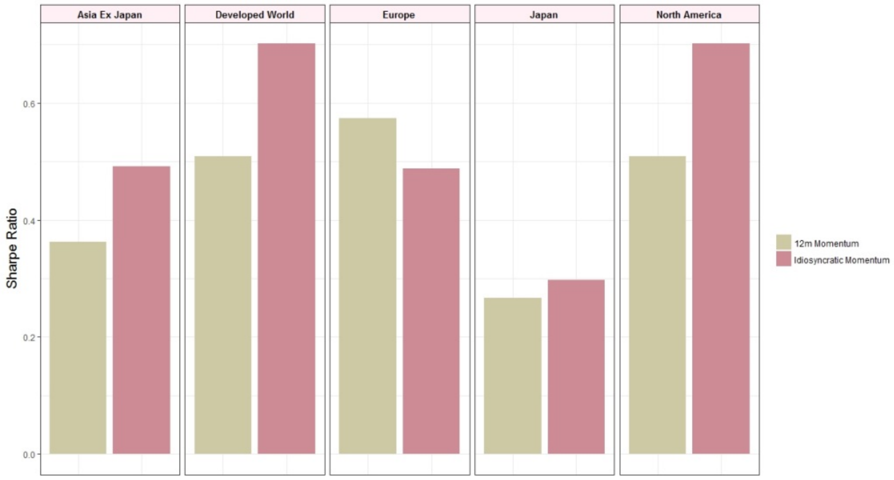
As a final exercise, the authors test the robustness of their results in four global regions including Europe, Japan, Asia Pacific ex Japan and the emerging markets. Again, portfolios are equal-weighted but, since they apply country neutrality, they sort constituents into quintiles instead of deciles.

As Figure 15 illustrates, iMOM generates superior risk-adjusted returns for top-minus-bottom quintile portfolios across the regions tested. The same general conclusion was reported for t-statistics relating to CAPM and three-factor alphas. The most interesting finding here is for Japan; a region where momentum typically doesn't work as well. For this region, iMOM "generates a return on 0.44% per month which is statistically significant at the most conservative levels."

Replication

In light of the positive conclusions documented for idiosyncratic momentum in this paper, we were keen to investigate whether the results remained true when applying the same methodology to global investible universes. In a similar vein to the analysis carried out in their paper, we computed and compared the performance of iMOM and past 12-month momentum (excluding the latest month) decile portfolios for global regions including Europe, North America, Japan, Asia ex Japan and World. In each case, we took the constituents from the universe[7] at the end of every month and grouped them into deciles according to both definitions of momentum.

Figure 16: Sharpe Ratios of Global Momentum-based Strategies

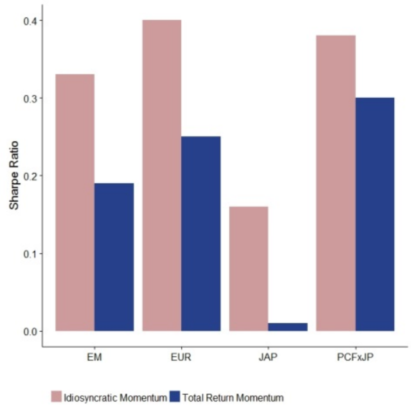


Source: UBS Quantitative Research: The bar charts show Sharpe ratios of global developed momentum-based portfolios (top and bottom decile) over the period Feb 1997 – Jan 2018.

Our dataset is slightly shorter in length than the period covered in the paper; our period of analysis starts in March 1994 but the strategies start 3 years later to allow for the 36 months of data we need to compute the idiosyncratic momentum values.

In general, our results mostly agree with the paper; iMOM portfolios typically generate higher risk-adjusted returns compared to their conventional equivalent. As Figure 16 shows, the difference in Sharpe ratios for Japan isn't as large in magnitude but is still greater for iMOM. Also, we didn't see the same outperformance in Europe. This is most likely due to the different period over

Figure 15: International Results

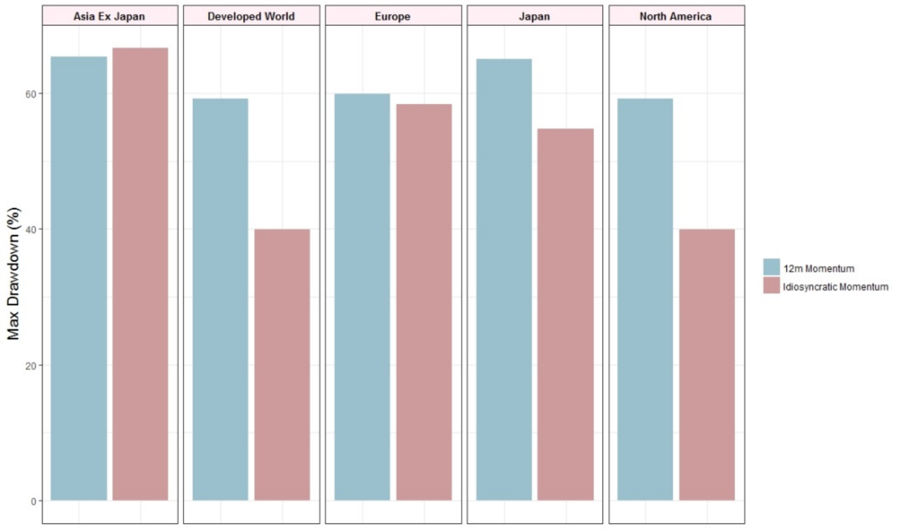


Source: Results are taken from Table 10 of "Idiosyncratic Momentum" by Blitz, Hanauer & Vidojevic. Used by permission. The table reports Sharpe ratios for the top-minus-bottom Q5-Q1 iMOM and TR MOM global portfolios relating to the period Dec 1989 – December 2015.

[7] We start, in all cases, with the constituents from an MSCI universe for all regions.

which we could run our backtests. In addition, the performance of conventional momentum strategies since December 2015 (when the momentum strategy performance ends in the paper) may have been highly positive to the extent that iMOM portfolios would have had to achieve phenomenal returns to significantly outperform it.

Figure 17: Maximum Drawdown for Global Momentum-based Strategies



Source: UBS Quantitative Research: The bar charts show the maximum drawdown of global developed momentum-based portfolios (top and bottom decile) over the period Feb 1997 – Jan 2018.

On a final note, excluding Asia ex Japan, Figure 17 shows that iMOM portfolios also typically experience lower drawdowns that the same portfolios formed on total return momentum.

"Size and Momentum Profitability in International Stock Markets"

by Peter Schmidt, Urs von Arx, Andreas Schrimpf, Alexander Wagner, Andreas Ziegler

The strong performance of momentum strategies across time and markets is widely documented in the academic literature. When it comes to practical implementation, however, two major concerns emerge: (1) momentum is much stronger among small-cap stocks (2) momentum premium vanishes after accounting for trading costs.

In their paper Schmidt *et al* study the feasibility to implement investment strategies based on size and momentum in 14 countries by considering three aspects of trading costs:

- **Portfolio turnover with fixed trading costs.** Assume 30 basis points (bp) for small stocks before 2001 and 40bp after 2001 (numbers taken from Frazzini et al (2012)), and 15bp for large stocks for the whole period. The portfolio return with trading costs, r_t^{tc}, is calculated as:

  $$r_t^{tc} = r_t - tc^l \cdot to_t^l - tc^s \cdot to_t^s,$$

  Where tc^l and to^l denote the trading cost and the turnover of the long portfolio, respectively, while tc^s and to^s refer to the short portfolio.

- **Critical trading cost.** This is defined to be the maximum trading costs that an investor could bear and still obtain significant returns:

  $$tc_{crit} = \frac{\frac{1}{T}\sum_{t=1}^{T} sp_t - t_{crit}\sqrt{\frac{1}{T}\sum_{t=1}^{T}(sp_t - \mu)^2}}{\frac{1}{T}\sum_{t=1}^{T} to_t},$$

  where sp_t is the return to a long-short spread portfolio with mean μ at time t, t_{crit} is the critical value of the assumed t-test and to_t is portfolio turnover.

- **Trading volume** of the portfolios to assess the capacity of such strategies.

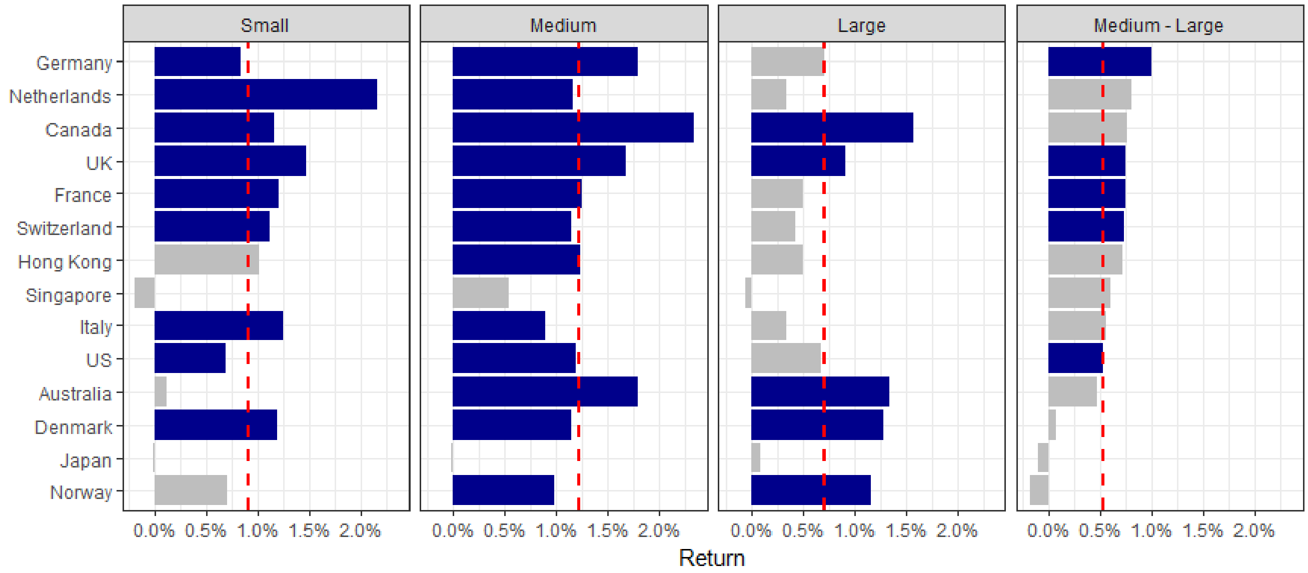
Methodology

The data is sourced from Thomson Reuters Datastream, Thomson Reuters Worldscope and Kenneth French's website for the sample period 1991 through 2012. The portfolios under consideration are long-short, formed on the basis of a three-by-three independent double sort on size and momentum. The momentum signal is constructed using the past 12 months, excluding the most recent one.

Relationship between size and momentum – no transaction costs

Figure 18 shows the monthly returns to the long-short portfolios for each size group. Interestingly, the relationship between size and momentum profitability generally does not appear monotonic – the medium sized portfolios achieve higher absolute return than both large and small-cap portfolios (average over all countries is at 1.2%, 0.9% and 0.7% for medium, small and large, respectively). The difference between the returns to the medium and large size stocks is positive for 12 out of the 14 countries under consideration, with the difference being statistically significant at the 5% level for 5 of them (Germany, UK, France, Switzerland and US).

Figure 18: Momentum returns relative to size



Source: *"Size and Momentum Profitability in International Stock Markets"* by P. Schmidt, U. Arx, A. Schrimpf, A. Wagner and A. Ziegler, based on the results in Table 2. Reproduced with permission. Dark-blue indicates that the monthly returns are significant at the 5% level; the dashed red line shows the average across all countries.

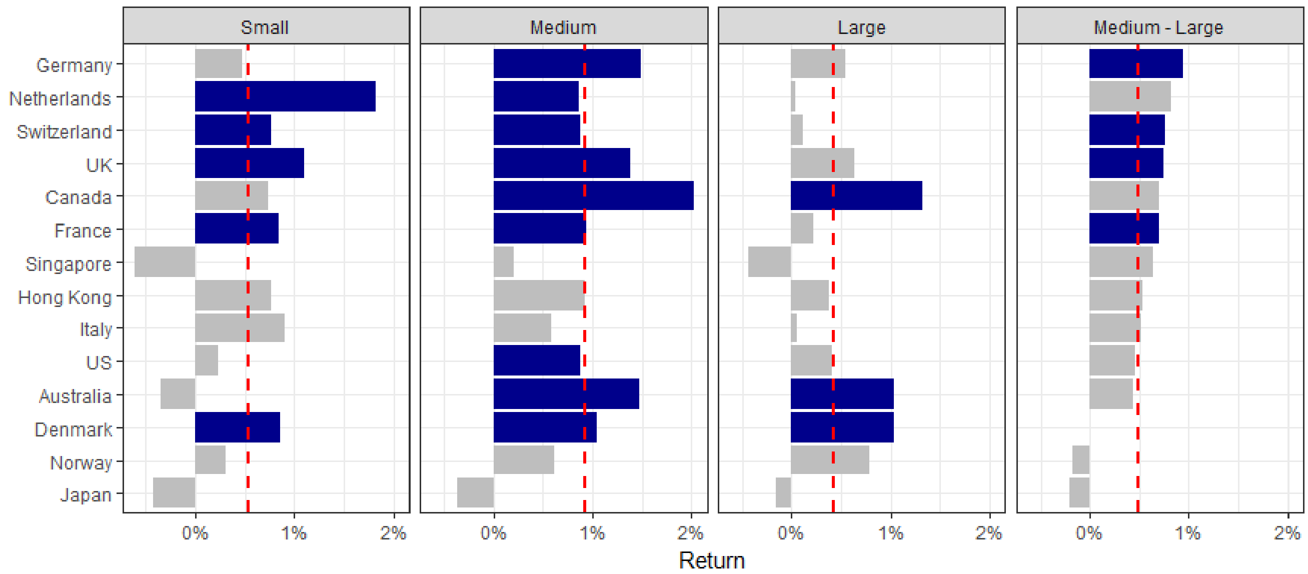
Mixed results on the role of shorting

Another common criticism of momentum strategies is that its performance is driven by the short side. The authors examine the role of shorting by evaluating the performance of winners and losers separately and find that both sides contribute to the raw return of the momentum strategy. However, after accounting for the Fama and French 3 factors (market, size and value), the role of shorting becomes more prominent, particularly for the medium and large stocks.

Fixed transaction costs

The results follow a similar pattern after adjusting for trading costs (Figure 19). In particular, the returns to medium size portfolios are positive for all countries (except Japan) and significant for the majority of them.

Figure 19: Momentum returns relative to size with transaction costs



Source: *"Size and Momentum Profitability in International Stock Markets"* by P. Schmidt, U. Arx, A. Schrimpf, A. Wagner and A. Ziegler, based on the results in Table 6. Reproduced with permission. Dark-blue indicates that the monthly returns are significant at the 5% level; the dashed red line shows the average across all countries.

With the exception of Japan and Singapore, the critical trading costs are positive in every country for at least one size group. In addition, 10 out of 14 countries in the middle group have maximum trading costs thresholds substantially exceeding the costs implied by the analysis based on portfolio turnover; the respective number is 6 for small and 3 for large caps.

Positive critical trading cost for all countries except Japan and Singapore

As a final step the authors estimate *maximum fund size* for each country by combining portfolio turnover and trading volume as:

$$\text{max fund size} = \min\left(\frac{\textit{trading volume, long side}}{\textit{turnover, long side}}, \frac{\textit{trading volume, short side}}{\textit{turnover, short side}}\right)$$

Using the data for the US as an example, Figure 20 calculates the maximum fund size using the formula above. Following Frazzini *et al* (2012), the authors assume that a fund should have a size of at least $1.5b in order to be created.

Given an implied maximum fund size of ~0.7b for small stocks, it transpires that the momentum premium for small caps is likely infeasible (even if one assumes that the hypothetical fund is equally split between small and large caps). On the other hand, the authors find that for medium stocks an investor will have to move about 10% of the market each month (given maximum fund size of $15b), meaning that the momentum premium would remain significant if trading costs are below 50bp (on average). Finally, for big stocks, the maximum fund size is ~300b, meaning that rebalancing (the hypothetical fund) is unlikely to have a big impact.

The authors conclude "when accounting for trading costs we find that all strategies involving small size stocks are probably not realizable because the US dollar trading volume of the small size stocks needed for implementation is too low and because actually trading these stocks with appropriate quantities would presumably increase stock prices and decrease the profitability of these strategies significantly. For the momentum strategies, which involve medium size and big stocks this problem is not that severe."

Figure 20: Max fund size, US

		Small	Med	Large
Volume	Long	527	11,570	787,836
	Short	735	7,700	193,841
Turnover	Long	76%	48%	37%
	Short	56%	51%	65%
Ratio	Long	693	24,104	2,129,286
	Short	1,305	15,098	298,999
Max fund size		**693**	**15,098**	**298,999**

Source: *"Size and Momentum Profitability in International Stock Markets"* by P. Schmidt, U. Arx, A. Schrimpf, A. Wagner and A. Ziegler, based on the results in Table 9 and Table 10. Reproduced with permission.

References

Blitz, D., Hanauer, M.X., and M. Vidojevic (2018) Idiosyncratic momentum. Available at SSRN.

Dahlquist, M. and H. Hasseltoft, (2017) Economic Momentum and Currency Returns. Swedish House of Finance Research Paper No. 16-14. Available at SSRN

Frazzini, A., R. Israel and T.J. Moskowitz, (2012). Trading Costs of Asset Pricing Anomalies. Working Paper, University of Chicago

Gutierrez, R. and C.A. Pirinsky (2007) Momentum, Reversal, and the Trading Behaviors of Institutions. *Journal of Financial Markets 10, pp. 48-75.*

Jegadeesh, N. and S. Titman (1993) Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency. *The Journal of Finance 48(1), pp. 65-91*

Jegadeesh, N. and S. Titman (2001) Profitability of Momentum Strategies: An Evaluation of Alternative Explanations. *The Journal of Finance 56(2), pp 699-720.*

Kothari, S.P. and J. Shanken (1992) Stock return variation and expected dividends: A time-series and cross-sectional analysis. *Journal of Financial Economics 31(2), pp 177-210.*

Parsons, C. A. R. Sabbatucci, and S. Titman, (2016) Geographic Momentum Available at SSRN

Schmidt, P., Arx U., Schrimpf A., Wagner A. and Ziegler A. (2017) Size and Momentum Profitability in International Stock Markets. Available at SSRN.

UBS Equity Quantitative Research publications

Monographs, Keys and Q-Series

Title	Date
Where to next for volatility and what to do?	Feb-18
How does deployed human capital relate to future returns?	Feb-18
Exploiting predictable forecast errors	Jan-18
Are China mutual fund managers skilful?	Jan-18
Why is increasing volatility likely to benefit active managers in 2018?	Jan-18
Exploring ESG Investing	Dec-17
What works in the Southbound universe?	Nov-17
The seasonality in factor returns	Nov-17
At which participation rate should you trade?	Nov-17
Introduction to Deep Learning	Oct-17
What is your fund's capacity?	Sep-17
Lower turnover and smart beta factors	Sep-17
Timing style rotations in China's domestic market	Jul-17
Should smart beta factors be orthogonalised?	Jul-17
How to pick stocks in the MSCI China A-Share Market	Jun-17
Active vs Passive: What is the Future of Active Management?	Jun-17
The hidden value in fund holdings	Jun-17
Can social network analysis enhance strategies following trading by corporate insiders?	Jun-17
Using Trend & Carry to time Global Bond Markets	May-17
What you need to know about Japanese equities	Apr-17
What times the bond market?	Mar-17
Passive Opportunities for Active Managers	Feb-17
Active vs Passive: How Will the World of Investing Evolve?	Jan-17
What will demographics mean for growth and stock market returns?	Jan-17
How to pick stocks in China's domestic market	Jan-17
Systematic Strategies for Single-Stock Futures	Oct-16
Irrational asset management	Oct-16
China domestic market – alpha for quantitative investors	Oct-16
Are you already timing styles successfully?	Sep-16
Do low-volatility stocks have interest-rate risk?	Sep-16
What does splitting the financials sector change?	Aug-16
Harvesting Yield from Cross-Asset Carry	Aug-16
When is the stock market likely to correct?	Aug-16
Is it easier to be a quant in small cap?	Aug-16
Follow the smart money	Jul-16
How can supply chains improve earnings visibility?	Jul-16
Where are the attractive dividend paying stocks?	Mar-16
Why does increasing volatility matter?	Feb-16
What crowded positions are bubbling up in equity markets	Feb-16

Academic Research Monitor

Topic	Date
Cross Asset Skewness and Risk Models	Feb-18
Asia Pacific Quant Conference 2017 proceedings	Nov-17
Factor investing: Allocation and Implementation	Nov-17
Explaining factor returns	Oct-17
Low-Risk, Low-Volatility, Low-Correlation patterns	Jul-17
Stories about Active Management	Jun-17
UBS UK Quantitative Conference 2017 Highlights	Apr-17
Recession and Tail Risk?	Mar-17
Where does Volatility Targeting Work?	Jan-17
ESG Quant Investing	Dec-16
Quality, Low-Risk and Momentum Investing	Nov-16
Combining Smart Beta Factors	Sep-16
Portfolio Construction and Overfitting	Jul-16
UBS Equity Markets Conference	May-16
European Quantitative Conference 2016 Highlights	Apr-16
Does Oil matter for Equity Markets?	Mar-16
Low Risk Investing	Feb-16
Value Investing	Dec-15
Analyst Forecasts and Measuring Distance	Nov-15
UBS Market Microstructure Conference	Oct-15
Equity Risk Premium Forecasting and Market Timing	Sep-15
Behavioural Investing Patterns	Jul-15
Quality and Size Investing	May-15
European Quantitative Conference 2015 Highlights	Apr-15
Smart Beta, Factors and Style Investing	Feb-15
Momentum-Investing	Jan-15
Investment Strategies & Textual Analysis Signals	Dec-14
Commodity Risk & Institutional Investing Habits	Nov-14
Index Membership, Investor (in)attention to News & Spurious Correlations	Sep-14
Forecasting the Equity Risk Premium	Aug-14
Implied Cost of Capital & Shorting Premium	Jun-14
Trend Following	Mar-14

PAS User Guides

PAS Macros	Feb-16	Reports	Apr-14
Quick Reference Guide	Nov-15	Risk Parity	Feb-13
Risk Parity and Composite Assets	Jan-15	Advanced Analysis	Oct-12
Introduction to the UBS Portfolio Analysis System	Jan-15	Risk Models	Nov-11
Long-Short Analysis	Jan-15	UBS Hybrid Risk Model	Dec-10
Installation	May-14	Quick Portfolio Analysis	Jul-10

R Advice

Getting started with deep learning in TensorFlow	Jan-18	data.table, the best package in the world?	Mar-17
A quick tutorial in 'nowcasting'	Oct-17	R and Excel	Dec-16
Conventional active returns can be misleading	Sep-17	Rolling window calculations – which package to use	Sep-16
Predictive modelling with caret	Jul-17	Getting started with random forests	Aug-16
Tidy data science with the tidyverse	May-17	Optimising in Rs	Jun-16
Bayesian regressions with stan	Mar-17	Speeding up R / Plotting correlation matrices	Jun-16

Team

UK – London

Maylan Cheung	+44-20-7568 4477
Ian Francis	+44-20-7568 1872
Josie Gerken	+44-20-7568 3560
Simon Iley	+44-20-7568 6327
Desi Ivanova	+44-20-7568-1754
David Jessop	+44-20-7567 9882
Claire Jones	+44-20-7568 1873
Manoj Kothari	+44-20-7568 1997
Simon Stoye	+44-20-7568 1876
Christine Vargas	+44-20-7568 2409

Hong Kong

Cathy Fang (Shanghai)	+86-021-3866 8891
Josh Holcroft	+852-2971 7705
Shanle Wu	+852-2971 7513

Australia– Sydney

Oliver Antrobus	+61-3-9242 6467
Luke Brown	+61-2-9324 3620
Pieter Stoltz	+61-2-9324 3779
Paul Winter	+61-2-9324 2080
Nathan Luk	+61-2-9324 2247

Required Disclosures

This report has been prepared by UBS Limited, an affiliate of UBS AG. UBS AG, its subsidiaries, branches and affiliates are referred to herein as UBS.

For information on the ways in which UBS manages conflicts and maintains independence of its research product; historical performance information; and certain additional disclosures concerning UBS research recommendations, please visit www.ubs.com/disclosures. The figures contained in performance charts refer to the past; past performance is not a reliable indicator of future results. Additional information will be made available upon request. UBS Securities Co. Limited is licensed to conduct securities investment consultancy businesses by the China Securities Regulatory Commission. UBS acts or may act as principal in the debt securities (or in related derivatives) that may be the subject of this report. This recommendation was finalized on: 06 March 2018 02:04 PM GMT. UBS has designated certain Research department members as Derivatives Research Analysts where those department members publish research principally on the analysis of the price or market for a derivative, and provide information reasonably sufficient upon which to base a decision to enter into a derivatives transaction. Where Derivatives Research Analysts co-author research reports with Equity Research Analysts or Economists, the Derivatives Research Analyst is responsible for the derivatives investment views, forecasts, and/or recommendations.

Analyst Certification: Each research analyst primarily responsible for the content of this research report, in whole or in part, certifies that with respect to each security or issuer that the analyst covered in this report: (1) all of the views expressed accurately reflect his or her personal views about those securities or issuers and were prepared in an independent manner, including with respect to UBS, and (2) no part of his or her compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views expressed by that research analyst in the research report.

UBS Investment Research: Global Equity Rating Definitions

12-Month Rating	Definition	Coverage[1]	IB Services[2]
Buy	FSR is > 6% above the MRA.	46%	27%
Neutral	FSR is between -6% and 6% of the MRA.	39%	24%
Sell	FSR is > 6% below the MRA.	16%	13%
Short-Term Rating	**Definition**	**Coverage[3]**	**IB Services[4]**
Buy	Stock price expected to rise within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%
Sell	Stock price expected to fall within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%

Source: UBS. Rating allocations are as of 31 December 2017.
1:Percentage of companies under coverage globally within the 12-month rating category.
2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months.
3:Percentage of companies under coverage globally within the Short-Term rating category.
4:Percentage of companies within the Short-Term rating category for which investment banking (IB) services were provided within the past 12 months.

KEY DEFINITIONS:Forecast Stock Return (FSR) is defined as expected percentage price appreciation plus gross dividend yield over the next 12 months. **Market Return Assumption (MRA)** is defined as the one-year local market interest rate plus 5% (a proxy for, and not a forecast of, the equity risk premium). **Under Review (UR)** Stocks may be flagged as UR by the analyst, indicating that the stock's price target and/or rating are subject to possible change in the near term, usually in response to an event that may affect the investment case or valuation. **Short-Term Ratings** reflect the expected near-term (up to three months) performance of the stock and do not reflect any change in the fundamental view or investment case. **Equity Price Targets** have an investment horizon of 12 months.

UBS Limited: David Jessop; Claire Jones, CFA; Josie Gerken, PhD; Desi Ivanova. **UBS Securities Australia Ltd:** Paul Winter; Oliver Antrobus, CFA; Pieter Stoltz. **UBS AG Hong Kong Branch:** Josh Holcroft; Shanle Wu, PhD.

Global Disclaimer

This document has been prepared by UBS Limited, an affiliate of UBS AG. UBS AG, its subsidiaries, branches and affiliates are referred to herein as UBS.

Global Research is provided to our clients through UBS Neo, in certain instances, UBS.com and any other system, or distribution method specifically identified in one or more communications distributed through UBS Neo or UBS.com as an approved means for distributing Global Research (each a "System"). It may also be made available through third party vendors and distributed by UBS and/or third parties via e-mail or alternative electronic means. The level and types of services provided by Global Research to a client may vary depending upon various factors such as a client's individual preferences as to the frequency and manner of receiving communications, a client's risk profile and investment focus and perspective (e.g., market wide, sector specific, long-term, short-term, etc.), the size and scope of the overall client relationship with UBS and legal and regulatory constraints.

All Global Research is available on UBS Neo. Please contact your UBS sales representative if you wish to discuss your access to UBS Neo.

When you receive Global Research through a System, your access and/or use of such Global Research is subject to this Global Research Disclaimer and to the terms of use governing the applicable System.

When you receive Global Research via a third party vendor, e-mail or other electronic means, you agree that use shall be subject to this Global Research Disclaimer, where applicable the UBS Investment Bank terms of business (https://www.ubs.com/global/en/investment-bank/regulatory.html) and to UBS's Terms of Use/Disclaimer (http://www.ubs.com/global/en/legalinfo2/disclaimer.html). In addition, you consent to UBS processing your personal data and using cookies in accordance with our Privacy Statement (http://www.ubs.com/global/en/legalinfo2/privacy.html) and cookie notice (http://www.ubs.com/global/en/homepage/cookies/cookie-management.html).

If you receive Global Research, whether through a System or by any other means, you agree that you shall not copy, revise, amend, create a derivative work, provide to any third party, or in any way commercially exploit any UBS research provided via Global Research or otherwise, and that you shall not extract data from any research or estimates provided to you via Global Research or otherwise, without the prior written consent of UBS.

This document is for distribution only as may be permitted by law. It is not directed to, or intended for distribution to or use by, any person or entity who is a citizen or resident of or located in any locality, state, country or other jurisdiction where such distribution, publication, availability or use would be contrary to law or regulation or would subject UBS to any registration or licensing requirement within such jurisdiction.

This document is a general communication and is educational in nature; it is not an advertisement nor is it a solicitation or an offer to buy or sell any financial instruments or to participate in any particular trading strategy. Nothing in this document constitutes a representation that any investment strategy or recommendation is suitable or appropriate to an investor's individual circumstances or otherwise constitutes a personal recommendation. By providing this document, none of UBS or its representatives has any responsibility or authority to provide or have provided investment advice in a fiduciary capacity or otherwise. Investments involve risks, and investors should exercise prudence and their own judgment in making their investment decisions. None of UBS or its representatives is suggesting that the recipient or any other person take a specific course of action or any action at all. By receiving this document, the recipient acknowledges and agrees with the intended purpose described above and further disclaims any expectation or belief that the information constitutes investment advice to the recipient or otherwise purports to meet the investment objectives of the recipient. The financial instruments described in the document may not be eligible for sale in all jurisdictions or to certain categories of investors. Options, derivative products and futures are not suitable for all investors, and trading in these instruments is considered risky. Mortgage and asset-backed securities may involve a high degree of risk and may be highly volatile in response to fluctuations in interest rates or other market conditions. Foreign currency rates of exchange may adversely affect the value, price or income of any security or related instrument referred to in the document. For investment advice, trade execution or other enquiries, clients should contact their local sales representative.

The value of any investment or income may go down as well as up, and investors may not get back the full (or any) amount invested. Past performance is not necessarily a guide to future performance. Neither UBS nor any of its directors, employees or agents accepts any liability for any loss (including investment loss) or damage arising out of the use of all or any of the Information.

Prior to making any investment or financial decisions, any recipient of this document or the information should seek individualized advice from his or her personal financial, legal, tax and other professional advisors that takes into account all the particular facts and circumstances of his or her investment objectives.

Any prices stated in this document are for information purposes only and do not represent valuations for individual securities or other financial instruments. There is no representation that any transaction can or could have been effected at those prices, and any prices do not necessarily reflect UBS's internal books and records or theoretical model-based valuations and may be based on certain assumptions. Different assumptions by UBS or any other source may yield substantially different results.

No representation or warranty, either expressed or implied, is provided in relation to the accuracy, completeness or reliability of the information contained in any materials to which this document relates (the "Information"), except with respect to Information concerning UBS. The Information is not intended to be a complete statement or summary of the securities, markets or developments referred to in the document. UBS does not undertake to update or keep current the Information. Any opinions expressed in this document may change without notice and may differ or be contrary to opinions expressed by other business areas or groups, personnel or other representative of UBS. Any statements contained in this report attributed to a third party represent UBS's interpretation of the data, information and/or opinions provided by that third party either publicly or through a subscription service, and such use and interpretation have not been reviewed by the third party. In no circumstances may this document or any of the Information (including any forecast, value, index or other calculated amount ("Values")) be used for any of the following purposes:

(i) valuation or accounting purposes;

(ii) to determine the amounts due or payable, the price or the value of any financial instrument or financial contract; or

(iii) to measure the performance of any financial instrument including, without limitation, for the purpose of tracking the return or performance of any Value or of defining the asset allocation of portfolio or of computing performance fees.

By receiving this document and the Information you will be deemed to represent and warrant to UBS that you will not use this document or any of the Information for any of the above purposes or otherwise rely upon this document or any of the Information.

UBS has policies and procedures, which include, without limitation, independence policies and permanent information barriers, that are intended, and upon which UBS relies, to manage potential conflicts of interest and control the flow of information within divisions of UBS and among its subsidiaries, branches and affiliates. For further information on the ways in which UBS manages conflicts and maintains independence of its research products, historical performance information and certain additional disclosures concerning UBS research recommendations, please visit www.ubs.com/disclosures.

Research will initiate, update and cease coverage solely at the discretion of UBS Research Management, which will also have sole discretion on the timing and frequency of any published research product. The analysis contained in this document is based on numerous assumptions. All material information in relation to published research reports, such as valuation methodology, risk statements, underlying assumptions (including sensitivity analysis of those assumptions), ratings history etc. as required by the Market Abuse Regulation, can be found on UBS Neo. Different assumptions could result in materially different results.

The analyst(s) responsible for the preparation of this document may interact with trading desk personnel, sales personnel and other parties for the purpose of gathering, applying and interpreting market information. UBS relies on information barriers to control the flow of information contained in one or more areas within UBS into other areas, units, groups or affiliates of UBS. The compensation of the analyst who prepared this document is determined exclusively by research management and senior management (not including investment banking). Analyst compensation is not based on investment banking revenues; however, compensation may relate to the revenues of UBS and/or its divisions as a whole, of which investment banking, sales and trading are a part, and UBS's subsidiaries, branches and affiliates as a whole.

For financial instruments admitted to trading on an EU regulated market: UBS AG, its affiliates or subsidiaries (excluding UBS Securities LLC) acts as a market maker or liquidity provider (in accordance with the interpretation of these terms in the UK) in the financial instruments of the issuer save that where the activity of liquidity provider is carried out in accordance with the definition given to it by the laws and regulations of any other EU jurisdictions, such information is separately disclosed in this document. For financial instruments admitted to trading on a non-EU regulated market: UBS may act as a market maker save that where this activity is carried out in the US in accordance with the definition given to it by the relevant laws and regulations, such activity will be specifically disclosed in this document. UBS may have issued a warrant the value of which is based on one or more of the financial instruments referred to in the document. UBS and its affiliates and employees may have long or short positions, trade as principal and buy and sell in instruments or derivatives identified herein; such transactions or positions may be inconsistent with the opinions expressed in this document.

United Kingdom and the rest of Europe: Except as otherwise specified herein, this material is distributed by UBS Limited to persons who are eligible counterparties or professional clients. UBS Limited is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority. **France:** Prepared by UBS Limited and distributed by UBS Limited and UBS Securities France S.A. UBS Securities France S.A. is regulated by the ACPR (Autorité de Contrôle Prudentiel et de Résolution) and the Autorité des Marchés Financiers (AMF). Where an analyst of UBS Securities France S.A. has contributed to this document, the document is also deemed to have been prepared by UBS Securities France S.A. **Germany:** Prepared by UBS Limited and distributed by UBS Limited and UBS Europe SE. UBS Europe SE is regulated by the Bundesanstalt fur Finanzdienstleistungsaufsicht (BaFin). **Spain:** Prepared by UBS Limited and distributed by UBS Limited and UBS Securities España SV, SA. UBS Securities España SV, SA is regulated by the Comisión Nacional del Mercado de Valores (CNMV). **Turkey:** Distributed by UBS Limited. No information in this document is provided for the purpose of offering, marketing and sale by any means of any capital market instruments and services in the Republic of Turkey. Therefore, this document may not be considered as an offer made or to be made to residents of the Republic of Turkey. UBS Limited is not licensed by the Turkish Capital Market Board under the provisions of the Capital Market Law (Law No. 6362). Accordingly, neither this document nor any other offering material related to the instruments/services may be utilized in connection with providing any capital market services to persons within the Republic of Turkey without the prior approval of the Capital Market Board. However, according to article 15 (d) (ii) of the Decree No. 32, there is no restriction on the purchase or sale of the securities abroad by residents of the Republic of Turkey. **Poland:** Distributed by UBS Limited (spolka z ograniczona odpowiedzialnoscia) Oddzial w Polsce regulated by the Polish Financial Supervision Authority. Where an analyst of UBS Limited (spolka z ograniczona odpowiedzialnoscia) Oddzial w Polsce has contributed to this document, the document is also deemed to have been prepared by UBS Limited (spolka z ograniczona odpowiedzialnoscia) Oddzial w Polsce. **Russia:** Prepared and distributed by UBS Bank (OOO). **Switzerland:** Distributed by UBS AG to persons who are institutional investors only. UBS AG is regulated by the Swiss Financial Market Supervisory Authority (FINMA). **Italy:** Prepared by UBS Limited and distributed by UBS Limited and UBS Limited, Italy Branch. Where an analyst of UBS Limited, Italy Branch has contributed to this document, the document is also deemed to have been prepared by UBS Limited, Italy Branch. **South Africa:** Distributed by UBS South Africa (Pty) Limited (Registration No. 1995/011140/07), an authorised user of the JSE and an authorised Financial Services Provider (FSP 7328). **Israel:** This material is distributed by UBS Limited. UBS Limited is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority. UBS Securities Israel Ltd is a licensed Investment Marketer that is supervised by the Israel Securities Authority (ISA). UBS Limited and its affiliates incorporated outside Israel are not licensed under the Israeli Advisory Law. UBS Limited is not covered by insurance as required from a licensee under the Israeli Advisory Law. UBS may engage among others in issuance of Financial Assets or in distribution of Financial Assets of other issuers for fees or other benefits. UBS Limited and its affiliates may prefer various Financial Assets to which they have or may have Affiliation (as such term is defined under the Israeli Advisory Law). Nothing in this Material should be considered as investment advice under the Israeli Advisory Law. This Material is being issued only to and/or is directed only at persons who are Eligible Clients within the meaning of the Israeli Advisory Law, and this material must not be relied on or acted upon by any other persons. **Saudi Arabia:** This document has been issued by UBS AG (and/or any of its subsidiaries, branches or affiliates), a public company limited by shares, incorporated in Switzerland with its registered offices at Aeschenvorstadt 1, CH-4051 Basel and Bahnhofstrasse 45, CH-8001 Zurich. This publication has been approved by UBS Saudi Arabia (a subsidiary of UBS AG), a Saudi closed joint stock company incorporated in the Kingdom of Saudi Arabia under commercial register number 1010257812 having its registered office at Tatweer Towers, P.O. Box 75724, Riyadh 11588, Kingdom of Saudi Arabia. UBS Saudi Arabia is authorized and regulated by the Capital Market Authority to conduct securities business under license number 08113-37. **UAE / Dubai:** The information distributed by UBS AG Dubai Branch is only intended for Professional Clients and/or Market Counterparties, as classified under the DFSA rulebook. No other person should act upon this material/communication. The information is not for further distribution within the United Arab Emirates. UBS AG Dubai Branch is regulated by the DFSA in the DIFC. UBS is not licensed to provide banking services in the UAE by the Central Bank of the UAE, nor is it licensed by the UAE Securities and Commodities Authority. **United States:** Distributed to US persons by either UBS Securities LLC or by UBS Financial Services Inc., subsidiaries of UBS AG; or by a group, subsidiary or affiliate of UBS AG that is not registered as a US broker-dealer (a **'non-US affiliate'**) to major US institutional investors only. UBS Securities LLC or UBS Financial Services Inc. accepts responsibility for the content of a document prepared by another non-US affiliate when distributed to US persons by UBS Securities LLC or UBS Financial Services Inc. All transactions by a US person in the securities mentioned in this document must be effected through UBS Securities LLC or UBS Financial Services Inc., and not through a non-US affiliate. UBS Securities LLC is not acting as a municipal advisor to any municipal entity or obligated person within the meaning of Section 15B of the Securities Exchange Act (the "Municipal Advisor Rule"), and the opinions or views contained herein are not intended to be, and do not constitute, advice within the meaning of the Municipal Advisor Rule. **Canada:** Distributed by UBS Securities Canada Inc., a registered investment dealer in Canada and a Member-Canadian Investor Protection Fund, or by another affiliate of UBS AG that is registered to conduct business in Canada or is otherwise exempt from registration. **Mexico:** This report has been distributed and prepared by UBS Casa de Bolsa, S.A. de C.V., UBS Grupo Financiero, an entity that is part of UBS Grupo Financiero, S.A. de C.V. and is a subsidiary of UBS AG. This document is intended for distribution to institutional or sophisticated investors only. Research reports only reflect the views of the analysts responsible for the reports. Analysts do not receive any compensation from persons or entities different from UBS Casa de Bolsa, S.A. de C.V., UBS Grupo Financiero, or different from entities belonging to the same financial group or business group of such. For Spanish translations of applicable disclosures, please go to www.ubs.com/disclosures. **Brazil:** Except as otherwise specified herein, this material is prepared by UBS Brasil CCTVM S.A. to persons who are eligible investors residing in Brazil, which are considered to be: (i) financial institutions, (ii) insurance firms and investment capital companies, (iii) supplementary pension entities, (iv) entities that hold financial investments higher than R$300,000.00 and that confirm the status of qualified investors in written, (v) investment funds, (vi) securities portfolio managers and securities consultants duly authorized by Comissão de Valores Mobiliários (CVM), regarding their own investments, and (vii) social security systems created by the Federal Government, States, and Municipalities. **Hong Kong:** Distributed by UBS Securities Asia Limited and/or UBS AG, Hong Kong Branch. Please contact local licensed/registered representatives of UBS Securities Asia Limited and/or UBS AG, Hong Kong Branch in respect of any matters arising from, or in connection with, the analysis or document. **Singapore:** Distributed by UBS Securities Pte. Ltd. [MCI (P) 008/09/2017 and Co. Reg. No.: 198500648C] or UBS AG, Singapore Branch. Please contact UBS Securities Pte. Ltd., an exempt financial adviser under the Singapore Financial Advisers Act (Cap. 110); or UBS AG, Singapore Branch, an exempt financial adviser under the Singapore Financial Advisers Act (Cap. 110) and a wholesale bank licensed under the Singapore Banking Act (Cap. 19) regulated by the Monetary Authority of Singapore, in respect of any matters arising from, or in connection with, the analysis or document. The recipients of this document represent and warrant that they are accredited and institutional investors as defined in the Securities and Futures Act (Cap. 289). **Japan:** Distributed by UBS Securities Japan Co., Ltd. to professional investors (except as otherwise permitted). Where this document has been prepared by UBS Securities Japan Co., Ltd., UBS Securities Japan Co., Ltd. is the author, publisher and distributor of the document. Distributed by UBS AG, Tokyo Branch to Professional Investors (except as otherwise permitted) in relation to foreign exchange and other banking businesses when relevant. **Australia:** Clients of UBS AG: Distributed by UBS AG (ABN 47 088 129 613 and holder of Australian Financial Services License No. 231087). Clients of UBS Securities Australia Ltd: Distributed by UBS Securities Australia Ltd (ABN 62 008 586 481 and holder of Australian Financial Services License No. 231098). This Document contains general information and/or general advice only and does not constitute personal financial product advice. As such, the Information in this document has been prepared without taking into account any investor's objectives, financial situation or needs, and investors should, before acting on the Information, consider the appropriateness of the Information, having regard to their objectives, financial situation and needs. If the Information contained in this document relates to the acquisition, or potential acquisition of a particular financial product by a 'Retail' client as defined by section 761G of the Corporations Act 2001 where a Product Disclosure Statement would be required, the retail client should obtain and consider the Product Disclosure Statement relating to the product before making any decision about whether to acquire the product. The UBS Securities Australia Limited Financial Services Guide is available at: www.ubs.com/ecs-research-fsg. **New Zealand:** Distributed by UBS New Zealand Ltd. UBS New Zealand Ltd is not a registered bank in New Zealand. You are being provided with this UBS publication or material because you have indicated to UBS that you are a "wholesale client" within the meaning of section 5C of the Financial Advisers Act 2008 of New Zealand (Permitted Client). This publication or material is not intended for clients who are not Permitted Clients (non-permitted Clients). If you are a non-permitted Client you must not rely on this publication or material. If despite this warning you nevertheless rely on this publication or material, you hereby (i) acknowledge that you may not rely on the content of this publication or material and that any recommendations or opinions in such this publication or material are not made or provided to you, and (ii) to the maximum extent permitted by law (a) indemnify UBS and its associates or related entities (and their respective Directors, officers, agents and Advisors) (each a 'Relevant Person') for any loss, damage, liability or claim any of them may incur or suffer as a result of, or in connection with, your unauthorised reliance on this publication or material and (b) waive any rights or remedies you may have against any Relevant Person for (or in respect of) any loss, damage, liability or claim you may incur or suffer as a result of, or in connection with, your unauthorised reliance on this publication or material. **Korea:** Distributed in Korea by UBS Securities Pte. Ltd., Seoul Branch. This document may have been edited or contributed to from time to time by affiliates of UBS Securities Pte. Ltd., Seoul Branch. This material is intended for professional/institutional clients only and not for distribution to any retail clients. **Malaysia:** This material is authorized to be distributed in Malaysia by UBS Securities Malaysia Sdn. Bhd (Capital Markets Services License No.: CMSL/A0063/2007). This material is intended for professional/institutional clients only and not for distribution to any retail clients. **India:** Distributed by UBS Securities India Private Ltd. (Corporate Identity Number U67120MH1996PTC097299) 2/F, 2 North Avenue, Maker Maxity, Bandra Kurla Complex, Bandra (East), Mumbai (India) 400051. Phone: +912261556000. It provides brokerage services bearing SEBI Registration Numbers: NSE (Capital Market Segment): INB230951431, NSE (F&O Segment) INF230951431, NSE (Currency Derivatives Segment) INE230951431, BSE (Capital Market Segment) INB010951437; merchant banking services bearing SEBI Registration Number: INM000010809 and Research Analyst services bearing SEBI Registration Number: INH000001204. UBS AG, its affiliates or subsidiaries may have debt holdings or positions in the subject Indian company/companies. Within the past 12 months, UBS AG, its affiliates or subsidiaries may have received compensation for non-investment banking securities-related services and/or non-securities services from the subject Indian company/companies. The subject company/companies may have been a client/clients of UBS AG, its affiliates or subsidiaries during the 12 months preceding the date of distribution of the research report with respect to investment banking and/or non-investment banking securities-related services and/or non-securities services. With regard to information on associates, please refer to the Annual Report at:

UBS