



#03

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Jubilee edition

Risk & Reward celebrates 30 years of original research and investment insights.

Risk & Reward

Research and investment strategies



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It is my pleasure to acknowledge the 30th anniversary of Risk & Reward, Invesco's quarterly original research and thought leadership publication.

Since the beginning, Risk & Reward has provided our quantitative research team the forum to publish their findings. Over time, Invesco's factor-based equity expertise has expanded to include new asset classes such as fixed income and commodities, as well as new domains such as exchange-traded funds and self-indexing. The investment professionals comprising the related teams are practitioners in the best sense of the word: they have acquired their quantitative strategies knowledge through years of practical experience, continuously improving and refining their investment processes.

Risk & Reward includes perspectives from multiple investment teams covering a myriad of topics across asset classes, regions and investment styles. In this anniversary edition, however, we have chosen to celebrate Invesco's long history of factor investing research. We have included articles from each of the past three decades in an effort to show our continuous progression in the advancement of data-based investing. Our goal is to look beyond the obvious and mundane and to present perspectives that give our clients unique insights.

As a pioneer of factor-based investing, Invesco has promoted innovation in this field for 40 years and today manages over USD 119 billion in factor-based strategies as part of the more than USD 1.2 trillion

overall that we have the privilege of managing for clients across the globe. Our expertise in active investment management and factor-based investing is available in a wide variety of investment vehicles, allowing us to deliver customized investment solutions for our clients.

As part of our commitment to further developing the field of factor-based investing, we support the Consortium on Factor Investing at Cambridge University, where investment practitioners and leading academics in the field of factor investing gather to discuss the latest research and its practical applications. We also publish the annual Invesco Global Factor Investing Study, which presents the development and adoption of factor-based strategies being used by more than 180 global institutional and wholesale investors.

We trust this Jubilee Edition will illustrate new paths forward in the continually developing investment landscape. We look forward to continuing our work to help you achieve your investment goals.

Best regards,

A handwritten signature in dark ink that reads "Marty L. Flanagan". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

Marty Flanagan
President and CEO of Invesco Ltd.

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The 1990s: beginnings

The first edition of Risk & Reward was published in July 1989. At that point, the Capital Asset Pricing Model (CAPM) had been around for about 25 years, and so-called 'market anomalies' were a hot topic. A large body of empirical research already existed on the effects of size, volatility and value. Academics and practitioners alike observed that stocks with certain characteristics, such as small market capitalization, low volatility or low price/earnings ratios tended to deliver superior returns. It wasn't long before solid explanations for these observations were brought forward.

The pioneers of asset management started following quantitative approaches, and Invesco was among them. The new generation of portfolio managers was eager to make investing an exact science, based on empirical analysis and theoretical models and replacing the traditional stock picking style used by the likes of André Kostolany and Peter Lynch, which was merely led by intuition.

Stock prices had been rising since the early 1980s and continued to do so nearly unabated throughout the 1990s. When the Berlin Wall fell in autumn 1989, and socialism came to an end in all of Eastern Europe, a new optimism emerged, which even Saddam Hussein's invasion of Kuwait could not diminish. As it turned out, reforming the eastern European economies (and societies) proved more difficult than originally envisioned. Nevertheless, markets continued their bull run, fuelled by the Fed's loose monetary policies and increasing globalization, highlighted by the introduction of the euro as the common European currency on 1 January 1999. Towards the end of the decade, the sky seemed to be the limit, particularly for tech stocks. Only pessimists believed that the dotcoms were in any way out of sync with fundamentals - a phenomenon famously described by Fed Chairman Alan Greenspan as "irrational exuberance". The new Internet and the prospects of almost unlimited data exchange were driving investors into a frenzy.

For our Jubilee Edition, we have selected extracts from three articles from this era: a short section from the editorial of the first-ever Risk & Reward, extracts from an early piece on portfolio optimizers, which demonstrates our long-standing commitment to quantitative management and, finally, an abridged version of a study on a multifactor model for bond portfolios that appeared in 1998. This was one of the first studies in which the traditional duration concept was replaced with a set of factors, here defined as 'partial durations'.



1989

Invesco
AUM (31.12.1989): USD 38.6 bn

Factor Investing
Invesco's Quantitative Strategy's sixth anniversary

Economics/Politics
Revolutions in Eastern Europe, fall of the Berlin Wall
Average US Dividend Yield: 4.2%



1990

Invesco
AUM (31.12.1990): USD 49.5 bn

Economics/Politics
Iraqi invasion of Kuwait, Gulf War
Margaret Thatcher resigns as UK Prime Minister
Barrel of oil: USD 23
Gold/ounce: USD 384



1995

Invesco
AUM (31.12.1995): USD 83.6 bn

Economics/Politics
World Trade Organization (WTO) founded



1996

Invesco
AUM (31.12.1996): USD 94.5 bn

Economics/Politics
IPO records shattered:
739 firms raised USD 43 bn



1991

Invesco

AUM (31.12.1991): USD 58.5 bn

Economics/Politics

Japanese asset bubble bursts
and Lost Decade begins
Soviet Union dissolved



1992

Invesco

AUM (31.12.1992): 61.7 bn

Economics/Politics

Maastricht Treaty signed
ASEAN Free Trade Area created



1994

Invesco

AUM (31.12.1994): USD 65.3 bn

Economics/Politics

North American Free Trade Agreement
(NAFTA) goes into effect
Nelson Mandela elected President of
South Africa



1993

Invesco

AUM (31.12.1993): USD 67.0 bn

Economics/Politics

World Wide Web developed at the European
Organization for Nuclear Research



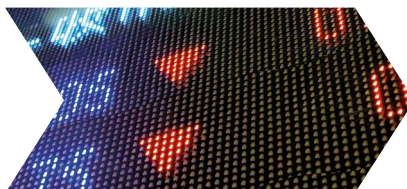
1997

Invesco

AUM (31.12.1997): USD 192.2 bn
Invesco and AIM Investments
merged creating AMVESCAP

Economics/Politics

Hong Kong becomes part of the
People's Republic of China
Tony Blair becomes prime minister
of the UK
TIPS introduced



1998

Invesco

AUM (31.12.1998): USD 275.4 bn
Acquisition of LGT Asset Management

Economics/Politics

Asian currency crisis



1999

Invesco

AUM (31.12.1999): USD 357.4 bn

Economics/Politics

Euro launched as the new single currency
of the European Monetary Union
Russian currency crisis
LTCM collapse

Stocks more attractive than bonds

(...) Risk & Reward, as its name suggests, is more interested giving our readers practical advice about the markets where they should focus their investments and the opportunities and risks they should keep an eye on than in joining the long list of journals that discuss the minute ups and downs of the economy. In other words, we will be more concerned with the future than with the past.

But, as historical trends teach us, there will always be surprises over time, which is why we strongly recommend that our readers ensure careful diversification of their portfolios at all times. Since there is no such thing as one ideal portfolio for everyone, each investor must consider and define an individual risk profile. These matters are very specific to an investor's own circumstances, which is why our experts are more than happy to offer their advice.

Although we are mainly concerned with the unknown qualities of the future, our aim is to distil our expectations as far as possible into meaningful figures. These will be presented in a clear and readily understandable form as we assume our readers are less interested in the sometimes very complicated tools we use than in the results of our work.

Risk & Reward 06/1989
Hubert Günter

The taming of portfolio optimisers

For as long as it has existed, the investment industry has been concerned with expected returns. Harry Markowitz added risk as a second point of discussion at the end of the 1950s. He introduced the concept of efficient portfolios, or portfolios with an optimal risk-return tradeoff. It was not until the early 1970s that computers were powerful enough to calculate efficient portfolios using complicated portfolio optimization programmes. Nowadays, even PCs can be used as portfolio optimizers, and an entire industry – mainly consisting of consultants – has arisen to concern itself with expected returns.

(...) A portfolio optimizer is easily purchased. However, expectations that this magic wand will make life easy are soon disappointed. Portfolio optimizers are highly complicated and sensitive instruments, and their use in an uncritical, dilettante manner soon turns them into damp squibs. The greatest sources of danger are:

1. Garbage in, garbage out syndrome: Inaccurate expected returns still lead to bad portfolios, albeit ones that are structured more consistently and under additional consideration of risk.
2. Sham optimization: Particularly high or low weightings in a portfolio are often intuitively unacceptable. This may lie in the inaccuracy of expected returns and/or risk, as well as in the consistent application of unreasonable estimates. The resulting uncertainty often leads to the imposition of arbitrary ex-post upper and lower restrictions for individual assets, leading to intuitively more acceptable weightings at the next optimization. With enough such restrictions, the resulting portfolio will be as arbitrary as if no optimizer had been used.
3. Manipulated optimization: Transaction costs are specific negative returns necessary to achieve unreliable positive returns. Portfolio optimization that takes no account of transaction costs or current portfolio structure is of limited value. It is even more questionable if the transaction costs employed are higher or lower than in reality merely in order to decrease or increase the sensitivity of the optimizer.
4. Error maximization: Extremely high or low expected returns are usually tainted by uncertainty and, in hindsight, are often shown to have been wrong. It is precisely these returns that normally lead to particularly high or low weightings in a portfolio, thus influencing performance to a great extent.
5. Misjudgement of the investor: While an entire industry has grown up around the calculation of expected risk and return, calculation of individual investors' risk aversion has been the subject of criminal neglect. This has resulted in the misjudgement of risk aversion in optimization for efficient portfolios. They may be efficient, but not at a risk level acceptable to the investor.

6. Choice of risk environment: While investors may think in terms of absolute risk, a portfolio manager is more interested in active risk, i.e. risk versus a benchmark. Any optimization that takes account of only one of these risks must, per se, neglect the interests of the other.

(...) A portfolio optimizer is no magic wand. It is a highly sensitive instrument, which may initially seem obstinate but is simply ingenious if properly used. Ingenious because it remains the only tool that enables consistent, optimal portfolios to be constructed using various benchmarks and differing investors' restrictions and levels of risk aversion. In addition to iron self-discipline, the determination of risk aversion and benchmarks in accordance with an investor's desires and the integration of absolute and active risk are all milestones on the road to the taming and application of portfolio optimizers. If the influence of particularly risky return forecasts has been limited by ex-ante restrictions, attention may be turned to the oldest and original problem of the investment industry: expected returns. This can now be done with a clear conscience because these estimates can be consistently converted to portfolios in clients' interests.

Risk & Reward Q3/1991
Wolfgang Seiler

Multifactor model for the evaluation of bond portfolios

(...) The traditional duration approach discounts all payment streams of a bond with a single interest rate (YTM) to obtain the quoted price.

We, too, use this discounting mechanism for obtaining the price. However, our approach is differentiated by the following feature: interest rates (zero-coupon rate) are allowed to differ for payments at different times (coupon and principal).

(...) To compute the change in value of a portfolio, it is important to find out how the change in the risk factors (i.e. the change of the zero-coupon rates) influences the price of the portfolio. For obtaining a market-oriented portfolio evaluation, it is advisable to calculate the sensitivities of the portfolio with regard to every individual zero-coupon rate (risk factor). These sensitivities make it possible to map interest rate changes onto price changes.

(...) We call these sensitivities "partial duration" (We use the "modified" variant, i.e. each partial duration is adjusted with the factor $(1+z_t)^{-1}$).

(...) With the help of partial duration, one can measure the risk of interest rate change in an existing portfolio more precisely than by using duration, which does not take the dynamic of the yield curve into account. For example, a bond portfolio strategy which is duration-neutral with regard to a benchmark cannot be implemented exactly (...). For each portfolio, so-called PD-profiles can be constructed (...). PD-profiles are very helpful for active portfolio management. They make active bets relating to the benchmark transparent, and make it possible to neutralize these bets, if necessary, using suitable instruments (buying/selling of futures etc.).

(...) This paper has shown that, strictly speaking, the commonly used measure duration is inadequate for estimating the risk of a portfolio. Partial duration is better suited for this purpose since it overcomes the most critical assumption of the duration concept - the assumption of a parallel shift of the yield curve - and takes the dynamic of the zero-coupon curves into account.

The PD-concept enables the portfolio management to implement various portfolio strategies more exactly, and the more precise identification of existing interest rate risks permits the tailoring of portfolio characteristics.

Risk & Reward Q3/1998
Michael Simmeth and Pascal Traccucci

The 2000s: foundations

Even though the dreaded Millennium Bug turned out to be a non-event, the first decade of the new century was nonetheless a time of disillusionment. In early 2000, the dotcom bubble finally burst, though this was at the time perceived as a temporary setback and not realised to be the end of the journey until about a year later. Then came 9/11, and when the accounting fraud at Enron, the self-proclaimed "World's Greatest Company", was discovered, investors lost confidence not only in tech stocks and the invulnerability of the US, but also in the financial statements of well-known companies.

Accordingly, stock market performance was miserable. It wasn't until late 2002 that markets began to recover, and investors had to wait until 2007 before many of the major indices had regained their all-time highs. But the downward spiral resurfaced when the subprime crisis broke out: on 15 September 2008, Lehman brothers filed for bankruptcy and, in 2009, the US economy shrunk by 3.5%. Once again, stock markets lost all previous gains; their lows in early 2009 were below even those of 2002.

Financial markets lost much of their glamour. The new buzzwords were: risk management, diversification and rationality! It is no surprise that, in the difficult 2000s, quantitative investment approaches made big advances. They perfectly fitted the prevailing mood. As the saying goes, every crisis is also an opportunity. Not surprisingly, the 2000s were also the decade when socially responsible investing left its niche and hit the mainstream. With all the exuberance over, ESG concepts finally had the room they needed to prove their ability to beat conventional approaches.

Our Jubilee Edition features six articles published between 2000 and 2007. We start with an exposition of behavioural finance, reprinted in full since we believe it summarizes the concept, which is a key foundation of factor investing today, very convincingly - as well as showing how new it still was back then. We've also included an extract from a study on style investing in the US, highlighting the importance of different stock characteristics (aka factors) in different parts of the market cycle. Next, our 2005 article on quantitative investing - described as "risk controlled" and "economically sound" - brings to life all the flavour of the years following the burst of the tech bubble. The fourth article deals with currency hedging - very appropriate at the time when investors were increasingly diversified beyond their home markets. We also analyze the 'winner's curse' phenomenon and, finally, reprint extracts from a piece on the global warming dividend, one of the first studies dealing with the consequences of climate change for investors and the opportunities afforded by renewable energies.



2000

Invesco
AUM (31.12.2000): USD 402.6 bn
Acquisition of Perpetual (UK)
Acquisition of Trimark (Canada)

Economics/Politics
Dotcom bubble bursts
Barrel of oil: USD 27
Gold/ounce: USD 279



2001

Invesco
AUM (31.12.2001): USD 397.9 bn

Economics/Politics
Attack on the World Trade Center ("9/11").
Enron accounting fraud
China joins World Trade Organization



2006

Invesco
AUM (31.12.2006): USD 462.6 bn
Acquisition of PowerShares

Economics/Politics
Ben Bernanke becomes Chair of the Federal Reserve Board of Governors
More money raised in new share issues in Hong Kong than in New York or London



2002

Invesco

AUM (31.12.2002): USD 332.6 bn

Economics/Politics

Euro notes and coins introduced



2003

Invesco

AUM (31.12.2003): USD 370.6 bn

Economics/Politics

Jean-Claude Trichet becomes ECB president

US invasion of Iraq



2005

Invesco

AUM (31.12.2005): USD 386.3 bn

Economics/Politics

Angela Merkel becomes Germany's first female Chancellor

Kyoto Protocol comes into force, committing UN member states to reduce greenhouse gas emissions



2004

Invesco

AUM (31.12.2004): USD 382.1 bn

Economics/Politics

Google IPO

Eight Eastern European countries (as well as Malta and Cyprus) join the EU



2007

Invesco

AUM (31.12.2007): USD 500.1 bn

Headquarters relocated to Atlanta

Moved listing from the London Stock Exchange to the New York Stock Exchange

Economics/Politics

Apple releases the iPhone

Treaty of Lisbon signed in order to reform and deepen the European Union



2008

Invesco

AUM (31.12.2008): USD 357.2 bn

Economics/Politics

Lehman Brothers collapses

Global Financial Crisis begins - US stocks down 50%; Balanced portfolios down 24%



2009

Invesco

AUM (31.12.2009): USD 423.1 bn

Acquisition of Van Kampen

Economics/Politics

Barack Obama becomes US president

US economy shrinks by 3.5%

Greek government debt crisis begins, marking the beginning of the eurozone crisis

Unconventional monetary policies begin to combat the fallout of the financial crisis

Behavioural finance - "irrational" investor behaviour

Every practitioner and investor is well aware of the influence of psychology on the stock market. There is almost nothing in economic life that affects the emotions (ranging from euphoria to depression) of participants more than the stock market. And these emotions can change in a flash - today in seventh heaven and tomorrow mortally aggrieved. Almost all investors have experienced this personally. How, therefore, could one argue that these emotional states have no impact on market dynamics? This article examines the importance of behavioural theories for capital markets. It presents insights from behavioural finance (BF) that might help investors to critically rethink their own decision-making behaviour and correct possible mistakes.

The catchword BF refers to a new area of research that tries to examine and describe the behaviour of financial market players in order to explain, among other things, market reactions that are not covered by traditional financial market theory, or often even contradict it. This approach is based on the findings of psychology and thus related to the literature of "bounded rationality", which is also relatively young. That literature tries to examine economic behaviour without resorting to the postulate of an optimally informed and completely rational Homo oeconomicus, and it does so from both a theoretical and an empirical perspective.

Human behaviour in traditional capital market theory

Traditional capital market theory views the investor as an informed and rational being, i.e. as Homo oeconomicus. Since all information is supposedly readily available at no cost, each investor maximizes his utility or his wealth based on the same return expected by all and an objective risk that is identical across investors. His investment decisions are then influenced by his attitude toward risk. The results are well known. The price of a security reflects all the information available at the time. Future price fluctuations are impossible to predict, and an investor can only achieve an excess return compared to the market if he is willing to accept a higher risk. Each investor holds an identical and diversified, but risky, market portfolio. Differences in individual investment policies are entirely due to different risk preferences. The latter, in turn, are reflected in a different mix of risky market portfolio and risk-free investments.

Traditional capital market theory and especially its extensions have made a major contribution to understanding how financial markets work. Yet both practical experience and numerous studies have shown that neither the underlying behavioural model nor the resulting findings stand up to empirical data. Investors are neither as (almost super-humanly) rational as assumed by the model, nor do they measure risk objectively. Rather, they consider it a subjective parameter. Moreover, information is neither free of charge nor equally available. To criticize assumptions as being too far removed from reality is not convincing per se, but when empirical results contradict the model

predictions, modifications are necessary. And the gap between empirical findings and model implications is wide.

Not only are investor portfolios different from what the theory predicts, they also are little diversified. A well-known example of the lack of diversification of investor portfolios is the so-called "home bias" effect, meaning that investors prefer domestic types of investment. An empirical study by French and Poterba (1991) shows that the share of domestic investments in total stock capital ranges from 79% in Germany to up to 95.7% in Japan¹.

Beside this certainly most important example, there are a number of other phenomena that are difficult to reconcile with traditional theory. For instance, according to capital market theory, investors should not be able to achieve a systematic outperformance versus the market index without bearing additional risk. Consequently, there should also be no reason to actively manage equity funds. In reality, however, such funds are very popular. It is also hard to explain the in some cases sharp price fluctuations in the stock market with a theory that assumes complete information.

These examples show that it pays to shed light on investor behaviour. First, through a better understanding of psychological effects, investors can recognize their own mistakes and correct them. Second, investor behaviour may lead to systematic capital market distortions that can then be exploited in one's own investment strategy.

Behavioural finance and individual investor behaviour

In the BF model, investor behaviour under uncertainty as well as the perception of risk and the way it is dealt with, take centre stage. This is because almost all decisions in financial markets depend on an assessment of risk. The individual perception of risk is an ideal subject of study since it can be examined using experimental, controlled lab trials. It has been observed that market players by no means measure risk objectively, as assumed by the above-described traditional theory. For example, the type of description - be it verbal or statistical/mathematical - already determines how market participants perceive risk. Studies have found that a verbal or diagrammatic description of the return on a security leads to an underestimation of risk over time, whereas depicting it in form of a distribution function results in an overestimation. However, it is true overall that, regardless of the type of description, investors give disproportionate weight to the possible maximum loss in assessing risk, rather than viewing risk as being distributed around an expected mean. Hence, the perception of risk involves considering a worst-case scenario.

Since the description of risk alone can directly influence the investor's assessment, it is also not surprising that investors behave differently depending on whether they see a risky investment as an opportunity or a threat to their wealth. For example, if investors had considered the stock price trend up to the late summer of 1998, the perception of risk - due to years of a bull market - would have certainly diminished, while it would have increased again as a result of the subsequent sharp decline. Such a

subjective perception of risk is also evident in the importance of an investor's income, or rather financial situation. A millionaire will be much calmer about a potential gain or loss of 10,000 euros than somebody who only has 20,000 euros. Hence, how an investor perceives a situation and makes decisions strongly depends on his or her initial situation.

This dependence on a certain starting point serves as a possible explanation for a relatively robust pattern of investor behaviour: the more frequent sale of stocks that are winners rather than losers. In other words, investors tend to prefer selling a stock for a gain rather than for a loss.² This is clearly shown by an experimental study conducted by Weber and Camerer (1998) wherein the participants sold roughly 40% of losers and about 60% of winners. If all stocks have to be automatically sold after each round, one observes the so-called "disposition effect". At the beginning of a round, each participant would have been able to exactly re-create the portfolio at the end of the previous period, but this did not happen. Hence, it does not appear attractive to buy back a loser. But if the loser is already in the portfolio, it is held. This also shows that investors are definitely able to recognize whether a given stock is a loser or not. For many investors, it seems to be difficult to sell a share for a loss, though objectively (and probably also subjectively) this would be the right decision. Thaler (1985) offers another explanation for this phenomenon. In his decision to sell, the investor looks at each stock individually rather than considering his total portfolio or total assets. When selling a loser, the investor has to accept the loss. If he continues to hold it, there is a chance that the price will rise again and he will be able to realize a gain. To exaggerate: it is difficult to admit a mistake and accept the consequences.

In addition to the above-mentioned reasons, the fact that losers are held too long is at least also due to investors' perceptions. Before purchasing a stock, investors usually examine and assess various alternatives. The decision to buy a certain stock then seems to be rational and may lead the investor to perceive future information only selectively, and thus distortedly. More weight is given to positive than to negative information because it supports the investor's own opinion and confirms his or her own analysis. In addition, investors tend to be clearly overconfident about their analytical skills and abilities. A typical example of such overconfidence is that most Germans believe that they are among the best drivers. Of course, objectively, this can only be true for a small portion of them. Subjective confirmations can be numerous and differ for each person. So, one only takes note of what supports one's own opinion. There are numerous empirical as well as experimental studies that demonstrate this overconfidence. Experimental studies, for instance, show that people regularly overestimate the probability of their statements being true. When respondents are additionally asked if they are sure (e.g., "Are you 50, 70, 90 or 100% sure?"), significantly less than 90% of answers are actually correct in the 90% interval.

Market implications of investor behaviour

The investor behaviour described so far helps explain two regularities in the stock market that are considered extremely robust: momentum and overreaction/

mispricing. A momentum in stocks, in particular, has been proven to exist in numerous countries. However, there is still a heated debate in the literature over whether the periods of overreaction are supported statistically.

The BF model explains the momentum in stocks by the fact that new information diffuses only gradually across investors. Not all investors have the same amount of information at all times to react immediately to the news.³ Moreover, it can be rational for professional stock analysts not to adjust their (erroneous) forecasts immediately to the changed conditions if, for instance, revisions might be interpreted as a sign of the quality of an analyst.⁴ Consequently, investors who base their decision on these experts' assessment are guided by insufficiently revised figures.⁵ Hence, faulty assessments are only corrected over time.

We also have to take into account that investors differ in their ability to absorb and process information. For example, existing shareholders view positive information as a confirmation of their decision. But non-shareholders may give little weight to the new information if they are neutral or negative on the stock. As a result of this behaviour, along with the tendency of investors to sell stocks too soon, the price adjusts slowly to its fair value. The situation is different with respect to negative information. Existing shareholders pay little attention to this information and – particularly when realizing losses – do not exert the necessary selling pressure. Thus, the behaviour of investors and stock analysts, coupled with the slow diffusion of information, can explain momentum in stock prices.⁶

Whereas the momentum model rests on the assumption that the market underreacts to new information, the opposite is true for overreactions. And there is ample evidence for an overreaction to new information. For example, if a company fails to realize its predicted profit, its stock price often falls sharply in the short run. This shows that new information can trigger an immediate overreaction if it is given too much weight. However, it seems equally plausible to expect a kind of delayed overreaction. If – as described above for an underreaction – important news is initially reflected in prices with a time lag, this slow adjustment can set an automatism in motion that will let prices overshoot their equilibrium. After a number of erroneous forecasts in the same direction, stock analysts can become too optimistic or pessimistic. Momentum investors can – without looking at the fundamentals – try to take advantage of the trend; or sentiment – be it euphoria or depression – may spread and lead to the frequently observed overreactions.

A number of empirical studies confirm these described reactions. These studies compile winners and losers over different formation periods. In the case of momentum strategies, the winners and losers respectively of the formation period are bought or sold (short). These portfolios are then held over a test period and the resulting outperformance relative to a market portfolio is calculated. The studies display a general pattern: momentum strategies seem to be profitable, even net of transaction costs. But, in most of them, the larger part of the outperformance is

due to the purchase of the winners and the smaller part to the sale of the losers. In this context, a formation period of 6 - 12 months and an equally long holding period have proven to be particularly successful.

In the case of a long-term strategy based on market overreaction, the past losers are bought and the winners are sold. Analogous to the momentum strategy, profits are asymmetric. It is more profitable to buy the losers than to sell the winners. Hence, the markets seem primarily to overreact to bad news about a company and less so to good news. For this strategy, a formation and test period of 3 and 5 years respectively has proven to be the most profitable. What is certainly interesting about these empirical studies is (i) the robustness of the results for different periods and countries - at least for the momentum strategy - and (ii) the different periods necessary to render both strategies successful. For example, momentum strategies are clearly short-term oriented because, for holding periods of two years and over, the outperformance relative to the market portfolio disappears again, or even becomes negative. By contrast, when pursuing a countercyclical strategy, the outperformance is negligible or even negative for holding periods of less than two years.

Summary

The findings about investor behaviour explain two regularities in the stock market - momentum and overreaction - which are hard to reconcile or do not comply at all with traditional capital market theory.

In particular, the slow diffusion and processing of information plays a key role in this respect. The investor can use both regularities in his investment decisions. When using momentum, he buys the winners of the recent past and - if possible - sells the losers. In the case of the strategy that takes advantage of overreactions, he buys the stocks neglected for a long time and sells the long-standing favourites. However, with respect to this strategy, one should always make sure that these deviations are not due to fundamentals - such as the profit trend. This is quite tricky, and hence makes the faulty assessment strategy less useful than the momentum strategy.

The BF model can also be used to improve the decision-making behaviour of investors. The limited perception and processing of information on the one hand and the strong overconfidence regarding one's abilities on the other usually have an adverse effect on decision-making behaviour. To exaggerate: stock price gains prove one's own excellent analytical skills. In the case of price losses, the market has not (yet) recognized the company's potential. These findings can explain why investors hold losers too long and sell winners too soon. There are very simple and now common rules that can help avoid this mistake, if applied consistently: remain invested as long as prices are rising and determine the maximum price decline or loss you would accept before selling.

Risk & Reward, Q1/2000
Dr. Bernd Rieger

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- 1 Tesar and Werner (1992) also find an above-average weighting of domestic investments for fixed income securities.
 - 2 An extensive study by Odean (1998) proves the asymmetric transaction behaviour by customers of an American discount broker.
 - 3 One indication may be that momentum strategies work best among stocks with low analyst coverage. They seem to be less successful among big companies with high analyst coverage.
 - 4 For example, trends in profit revisions by analysts are a frequently observed phenomenon in stock markets.
 - 5 To be fair, it must be noted that the described analyst behaviour is controversial. That analysts are rational and act in their own self-interest is an assumption of classical capital market theory. By contrast, the proponents of the BF model assume that there are limits to the rationality of analysts. The latter, for instance, may give more weight to new, and perhaps more spectacular, information than to old information. This would entail an overreaction to new information. But such an interpretation is counteracted by the already mentioned positive autocorrelation between profit revisions. Of course, both possibilities are conceivable and are also evident in empirical studies.
 - 6 The possible objection that the jump in prices prompted by new information contradicts the existing line of reasoning is not relevant if a momentum is built after this jump and the stock continues to rise or fall in the absence of new information.

Value vs. Growth: style investing in the US

(...) A key determinant of the relative performance of growth and value ... appears to be the slope of the Treasury yield curve.

The shape of the yield curve may be interpreted as an implicit forecast within the financial marketplace of future growth prospects. A steep yield curve, or one in which T-Bill rates are generally lower than T-Bond rates, signals a view of a more robust future. That view could be because the Fed has lowered short-term rates in an effort to stimulate economic growth. (...)

The absolute level of 10-year Treasury yields may also be important in determining the relative price of growth and value. The level of interest rates affects stocks in terms of their durations or interest rate sensitivities. Stocks with longer durations tend to be more interest rate sensitive than stocks with shorter durations. It should not be surprising that growth stocks tend to have relatively high durations as their valuations are dependent upon earnings growth farther into the future than value stocks' valuations. Therefore, as interest rates change, growth stocks' prices will be impacted more so than value stocks' prices. For example, as interest rates rise, future earnings are more heavily discounted and have less of an impact on current prices. Conversely, as yields fall, growth prices should be disproportionately helped as the discounted value of future earnings increases.

A third factor that may be important to the growth and value cycle is inflation. Generally speaking, inflation increases cash flows by allowing companies to simply raise prices. Value companies typically have higher fixed costs (i.e. debt, property, plant and equipment). As inflation rises, value companies' margins tend to expand more rapidly than their growth counterparts' margins. Conversely, as inflation falls, value companies' margins are adversely squeezed. (...)

Now that we have identified a core set of macroeconomic variables that should help explain the relative growth and value cycle, we are able to establish a stable long-run co-integration relationship. Table 1 summarizes the results of the long-run relationship. (...)

Table 1
The long-run relationship

	Coefficient	t-statistic
Constant	0.3950972	9.963340
Yield curve	0.2020185	9.770380
10-year T-Bond yield	0.0139446	3.912890
Inflation	0.0557677	12.784642

Estimation period: 9/1977 - 5/2000.
X variable: relative value/growth index.
DF = -5.45, ADF = -4.98; i.e. the co-integration property is confirmed at a 1%-significance level.

Risk & Reward, Q3/2000
Scott Hixon

Single stock oriented, risk controlled, economically sound - in a word: quantitative

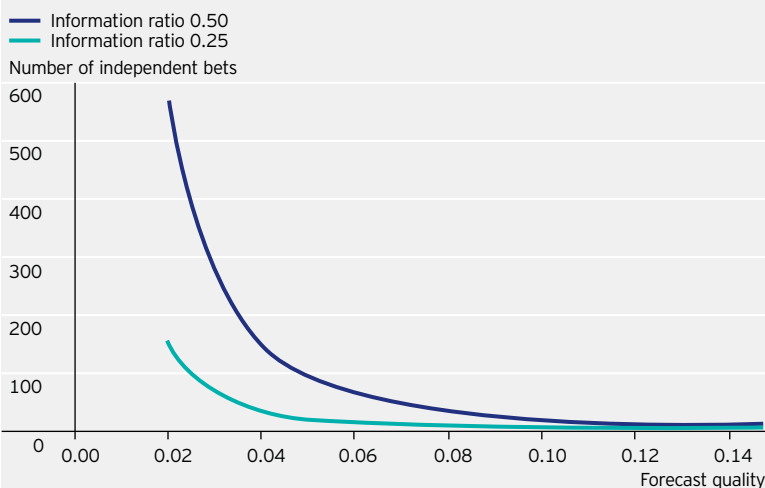
Quantitative investment strategies are frequently associated either with mindless optimisation based on historical time series which either cannot be carried over to the future, or only to a very limited extent, or with so-called "black box" models. This does not tally with reality given that successful quant managers attach great value to transparency and economic logic. According to the INVESCO Global Structured Products Group, both are indispensable if an investor is to be convinced of granting a mandate to a quantitative manager.

Quantitative investment processes are free of subjective and emotional decisions and feature a high degree of objectivity. A consistent investment process, human logic and modern technology are the key factors for success. Quantitative analysts and portfolio managers develop and test econometric models and compile a portfolio on this basis in line with the client's demands. Particular significance is attached to keeping transaction costs as low as possible. A precondition for this is a modern IT infrastructure able to reliably and efficiently process the huge volume of data accumulating daily.

Quantitative means single stock oriented

In broad principle, there are two ways in which an active manager can achieve a better performance than the market index: (1) by making high-quality individual bets and (2) by the number of these bets. If the forecast quality is equally high, a greater number of individual bets will allow a higher information ratio (figure 1). The information ratio is the ratio of excess return versus the benchmark relative to the risk taken. The higher the ratio, the more the portfolio manager will succeed in generating excess return for the clients by deviating from the benchmark.

Figure 1
Dependence of the information ratio on forecast quality and the number of independent bets



Notes: The information ratio is the ratio of excess return versus the benchmark and risk taken. The forecast quality is measured using information coefficients (= correlation of return forecasts with actual results) For illustrative purposes only.
Source: INVESCO.

While qualitative managers frequently take a few large-scale bets, quantitative managers tend to back a higher number of smaller bets. According to the fundamental law of active management, at an equally high probability of excess return the risk of deviating from the benchmark is all the smaller the more individual bets the portfolio manager independently takes. For this reason, many quantitative managers focus exclusively on selecting single stocks and orient themselves closely on the overall market when it comes to the portfolio's sector, country and currency allocations. The reason for this is that the number of possible forecasts on the sector, country or currency level is far lower than the number of potential single stock forecasts in a universe of hundreds, or even thousands, of stocks.

Quantitative means objective

If the attractiveness of single stocks is determined on the basis of quantitative criteria, a large number of single stocks can be monitored daily with few resources as there is no need for time-consuming company visits, talks with CFOs and reading Annual Reports. In a quantitative approach, the single-stock analysis is carried out by a small team, no matter the size of the investment universe. The team ensures that the investment decisions are made on a uniform basis and not influenced by subjective factors. The implementation of findings gained by quantitative methods with respect to the attractiveness of individual stocks gives the portfolio manager no discretionary scope whatsoever when transferring the results of the analysis into the portfolio. This is one of the main points distinguishing quantitative portfolio managers from traditional portfolio managers, who may allow their own personal view to influence decisions.

Quantitative means risk-controlled

A higher number of stocks can lead to broader diversification and thus reduces the risk of clearly missing a pre-defined benchmark. In this way, risk management becomes an integral component of the entire quantitative process.

The portfolio optimisation focuses not merely on the return but also on limiting the risk of deviating from the benchmark. This allows the optimum risk-return ratio to be implemented for a given tracking error and takes additional conditions (such as limiting transaction costs and client-specific restrictions) into account. This, in turn, means that the performance of the portfolio does not diverge too greatly from the performance of the market index and that the portfolio has a risk-return profile similar to the corresponding reference index.

Another advantage of a quantitative model is that, thanks to the swift and efficient evaluation of information using mathematical methods, market inefficiencies can be exploited immediately and without any time lags. This, too, contributes toward reducing portfolio risk.

Quantitative means cost-conscious. An analysis of the transaction costs establishes whether a regrouping in the portfolio will still add value when broker fees and any direct influence on the market price are taken into account. Not every transaction that appears attractive before costs is still advisable

after costs. Here, too, mathematical processes provide the necessary objective estimates.

Quantitative means economically sound

Developing a quantitative investment strategy doesn't just end with the analysis of data from the past. In our view, a simple technical model is not suited to creating lasting added value for the investor if it otherwise lacks any fundamental economic logic.

It is not only important that a model explains past performance, it must also provide a logical, fundamental explanation for the correlation evident between several variables in the past. Only then can this correlation be expected to continue in the future. Only quantitative indicators that can be fundamentally explained will make a long-term contribution toward success.

An important point when considering multiple indicators is making sure that the individual concepts overlap as little as possible and that different aspects of a stock are taken into account. For example, the return forecast of the Global Structured Products Group of Invesco is based on four concepts which provide results that are practically uncorrelated. To generate an active return, we adopt a single stock approach and calculate a measure for the attractiveness of each stock in the universe on the basis of the indicators. These indicators are based on the four concepts: earnings revisions, management action, valuation & price trend and volume. When distinguishing between attractive and unattractive stocks, we concentrate on the forecast of expected returns relative to the investment universe. Our in-house developed stock selection model has been successfully deployed in the US for a total of 20 years. Since 1999, our European and euro area products, and since 2001 our global products, have been managed on the basis of the same model.

Each of our four concepts determines the attractiveness of single stocks relative to the universe. The approach has proved its worth in the past and we are convinced that this will continue in the future, not least owing to the fact that each concept is fundamentally and analytically based. In other words: all the concepts in our model involve indicators selected according to economically meaningful methods and should therefore not be confused with the results of unmotivated data mining. (...)

Risk & Reward, Q3/2005

Thorsten Paarmann and Alexander Tavernaro

Global diversification and currency hedging

(...) Plan sponsors around the world can reduce the expected risk of their equity allocation through international diversification, i.e. allocation away from their home markets. Assuming that the long-term return expectations for the major developed markets are at least similar, the risk associated with concentrating on only one of them has a significantly lower probability of being rewarded in the long run. Hence, one may seek to minimize risk through international diversification.

Due to globalisation, the benefits of diversification between countries may have become smaller in recent years, but they have not vanished entirely. When diversifying internationally, we believe hedging foreign currency exposure is essential for risk reduction and significantly increases the optimal share of non-domestic exposure. (...)

Risk & Reward, Q1/2007
Michael Fraikin

The global warming dividend

(...) Global warming and the associated demands on politics, industry and business are leading to interesting investment opportunities. In the years to come, companies from the renewable energies sector should benefit particularly from the trend toward climate protection. It is, however, important to make a disciplined and intelligent selection of individual stocks. This is especially relevant because the overall risks of this sector are not to be underestimated. Many companies, such as those in the solar power industry, are currently regarded as overvalued. Moreover, political decisions for or against the promotion of renewable energies and the associated discussions also have a strong impact on share prices. In general, renewable energies should form only a smaller part of a portfolio because they are highly sensitive to fluctuations.

Risk & Reward, Q3/2007
Manuela von Ditfurth

Winner's Curse in markets

(...) First, beware of IPOs. It should not be forgotten that when one is wrong in one's assessment as regards the attractions of an IPO, one can be allocated a disproportionate amount of it ("If I can have a lot - I do not want any", anonymous, 2000).

Second, if we take the above to mean that acquisitions are bad for the shareholders of the company that is doing the acquiring, it is natural that one would seek to underweight, or even short, such companies. This poses several issues. On the one hand, one needs to identify the companies that are the acquirers and, on the other hand, one needs to establish how important an acquisition is to the company that made it. It is very typical for acquiring companies to either issue shares or increase outstanding debt for important acquisitions, whereas companies that are buying back stock or paying back debt are generally not suspect. If we couple this with the fact that it will take time for the Winner's Curse to take its toll, one way of identifying unattractive companies is to look for companies that have seen considerable increases in the number of shares or the amount of debt outstanding compared to periods of more than one year ago.

Risk & Reward, Q2/2007
Michael Fraikin

The 2010s: modern factor investing

Over the past decade, factor investing has really taken off. The difficult 2000s proved to be a fertile ground for advances. And when, in the early 2010s, the subprime crisis gave way to the Greek and euro crises, the concept became even more popular by meeting investor demand for risk-controlled rationality.

In all, however, the 2010s were a good time for investors, marked by recovery, with extraordinarily expansionary and unconventional monetary policies pushing the markets forward. The European Central Bank did all it could to prevent an escalation of the euro crisis, and we all remember Mario Draghi's famous "Whatever it Takes" speech in July 2012, when he vowed to save the euro: "And believe me, it will be enough".

Towards the end of the decade, however, new fears erupted - sparked mainly by the anti-globalization policies of the US administration, leading to a trade war with China. It remains to be seen whether the decades-long process of globalization will finally come to end or the current policies are merely a temporary setback.

It comes as no surprise that most of the articles we have chosen for our Jubilee Edition - 14 out of 23 - were written within the last ten years. All of them are abridged, and the aim is to give you a good impression of how factor investing at Invesco has progressed.

The 14 selected pieces range from "Risk modelling in turbulent times" (which indeed they were back in 2010) and an analysis of sustainable investment performance, to various analyses of factor investing approaches. We outline in detail the low volatility anomaly, develop an investment concept for volatile asset classes and show what the old active-passive debate means for factor strategies. More recent articles provide a systematic overview of all the different possible factors, discuss factor completion portfolios, macro factors, multi-asset multi-factor investing, currency factors, the suitability of factor strategies for specific investment needs and present methods to apply the factor concept to specific asset classes such as commodities and bonds.

As we enter into another new decade, factor investing has firmly entered the mainstream. It is no longer a niche concept for stocks, but a promising approach for nearly all asset classes. Invesco is proud to have been at the forefront of this development and looks forward to what comes next.



2010

Invesco

AUM (31.12.2010): USD 616.5 bn

Economics/Politics

Revival of General Motors after a near-bankruptcy the year before

Arab spring begins in Tunisia

Barrel of oil: USD 71
Gold/ounce: USD 1,225



2011

Invesco

AUM (31.12.2011): USD 625.3 bn

Economics/Politics

Mario Draghi becomes President of the ECB

Eurozone Crisis

China overtakes Japan as world's 2nd largest economy



2016

Invesco

AUM (31.12.2016): USD 812.9 bn

Acquisition of Religare

Economics/Politics

Brexit referendum passes

Donald Trump elected US President

CETA free trade treaty between EU and Canada signed; a similar treaty between the EU and the US (TTIP) fails after opposition on both sides of the Atlantic



2012

Invesco

AUM (31.12.2012): USD 687.7 bn

Economics/Politics

Facebook goes public

Shinzō Abe Prime Minister of Japan, marking the beginning of 'Abenomics'

Mario Draghi's famous "Whatever it Takes" speech



2013

Invesco

AUM (31.12.2013): USD 778.7 bn

Factor Investing

Factor AUM reaches USD 59 bn

Economics/Politics

US government shutdown, "Taper Tantrum"



2015

Invesco

AUM (31.12.2015): USD 775.6 bn

Factor Investing

Factor AUM increases 28% US (USD 70 bn to USD 90 bn)

Economics/Politics

First Fed interest rate hike since Global Financial Crisis



2014

Invesco

AUM (31.12.2014): USD 792.4 bn

Economics/Politics

Janet Yellen becomes first female chair of the Federal Reserve Board of Governors

Narendra Modi Prime Minister of India, marking the beginning of economic reforms



2017

Invesco

AUM (31.12.2017): USD 937.6 bn

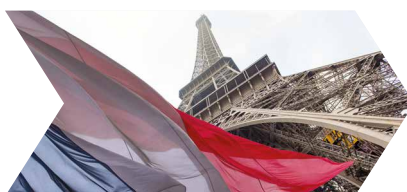
Acquisition of Source

Economics/Politics

US tax reform legislation is passed

US Administration launches trade wars

Populism on the rise in Europe



2018

Invesco

AUM (31.12.2018): USD 882.2 bn

Acquisition of Guggenheim Investment's ETF

Factor Investing

Factor AUM reaches USD 110 bn

Economics/Politics

Jay Powell becomes Chair of the Federal Reserve Board of Governors

'Yellow vests' protests in France

Jair Bolsonaro President of Brasil



2019

Invesco

AUM (30.09.2019): USD 1,184.4 bn

Acquisition of Oppenheimer Funds

Economics/Politics

First Fed interest rate cut since Global Financial Crisis

New UK Prime Minister Boris Johnson grapples with Brexit

Risk modelling in turbulent times

(...) The most recent financial market turbulence represented the first real test for the effectiveness of our new copula-GARCH¹ risk model. There has been considerable volatility in European equity markets since the spring of this year, due not least to the Greek debt crisis. (...)

The risk measures based on the normal distribution assumption did not adequately capture this change in volatility. They remained nearly unchanged over the course of the simulation period at around 4% (VaR) and 4.6% (ES). The copula-GARCH ES indicator, on the other hand, reacted quickly to the jump. At the beginning, in the phase of low volatility, our risk measure was lower than those determined on the basis of normal distribution. Over time, it then rose continuously, allowing for early reduction of portfolio risks. When volatility then decreased at the end of May, copula-GARCH ES came down as well - though it still remains higher than the risk measures determined on the basis of normal distribution. In other words, the new model continues to suggest a more conservative positioning.

Unlike in times of low volatility: then, the copula-GARCH model indicated larger risk positions than the other risk measures. In this case, the assumption of normal distribution resulted in an overly conservative approach.

Thus, the copula-GARCH model and the Expected Shortfall derived from it definitely satisfy demands for a rapid-reaction indicator. The comparison showed that copula-GARCH ES was superior to the risk measures derived assuming normal distribution.

Risk & Reward, Q3/2010
Dr. Bernhard Pfaff

Sustainability: investing with foresight

(...) Institutional investors like public-sector pension funds, foundations or churches are increasingly demanding that the managers of their portfolios focus not only on the traditional aims of profitability, liquidity and safety, but also on extra-financial factors - so-called sustainability or ESG factors.

At the same time, however, many investors are still reluctant to engage in sustainable investing. They fear that they will have to sacrifice performance in order to pursue an ESG strategy. The restriction of an investment universe, so the argument goes, must necessarily mean a diminishing of returns.

But, the idea behind sustainable investing is precisely that competing companies will generate above-average profits and increase shareholder value over the long term if they take advantage of the value-adding potential of environmental and social factors in their corporate strategy. Companies that prepare now for future social and environmental challenges are able to identify risks earlier and seize on opportunities before others. (...)

There are various ways to integrate ESG factors into the investment process, and Invesco offers a number of concepts for equities and for bonds. This is in addition to "engagement" programmes, in the context of which we exercise influence on companies on behalf of our clients. We also make use of external providers to analyse and value companies or countries based on a broad range of ESG criteria. (...)

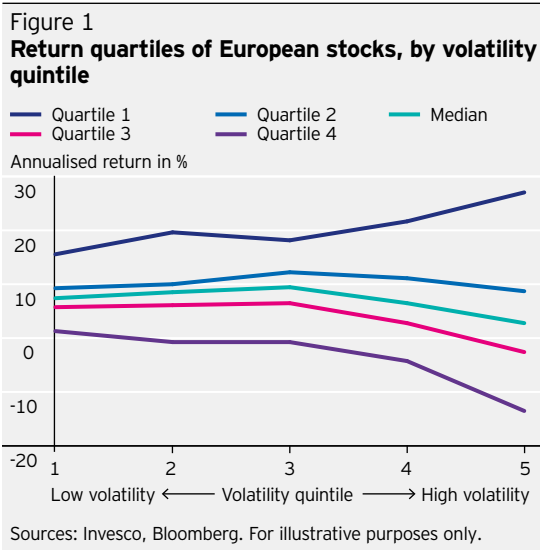
Risk & Reward, Q3/2010
Manuela von Dittfurth

¹ GARCH = Generalized AutoRegressive Conditional Heteroscedasticity

More risk = More return: fact or fiction?

(...) Traditionally, financial market theory holds that, in equilibrium, the expected return of a risky asset (for instance a stock) equals the “risk-free” interest rate plus a premium based on the risk (beta) of the security. The higher the volatility of the asset, the higher its expected return – and vice versa. This also means that investors are only willing to hold a higher risk security if the level of risk is matched by an appropriate return. (...)

In order to get to the bottom of the relationship between these two factors, we looked at the risk and return of 507 European stocks in the period from July 2002 to June 2010. (...) One can see (figure 1, ...) that stocks with a higher volatility tend to perform below average (return quartiles 3 and 4), and practically no different than those with a lower volatility. (...)



■ **The desire for excess return:** As a rule, investors strive to beat a defined benchmark or reference index. In order to enhance their participation in market performance, investors who are counting on rising prices will therefore often decide for a portfolio with a high beta. Those awaiting falling prices should then logically invest in stocks with a low beta. But this usually does not happen, as these stocks also lose value. Instead, the proportion of stocks held in the portfolio is often reduced. Another factor is that asset allocation and investment decisions within an asset class are often strictly separated. The investor first decides, for instance, between stocks and bonds. Upon reaching a decision in favour of stocks, the individual assets are selected. At this point, however, defensive stocks are generally not selected since this does not fit with the overarching asset allocation model. Both of these things mean that stocks with a low beta or low volatility tend to be avoided, and therefore – measured in terms of dividend yield – undervalued.

■ **Lottery effect:** People are fascinated by games of chance and are always on the lookout for a chance to earn a lot of money with a small investment. This is true for lottery players as well as for investors who buy highly volatile stocks. (...) The prospect of high returns causes many investors to ignore the fact that there are considerably fewer good stocks with high volatility than there are good stocks with a lower volatility. In other words: it takes some effort of will to forego the chance of very high returns and opt instead for lower but steady performance. (...)

*Risk & Reward, Q4/2010
Dr. Martin Kolrep*

There are some explanations for the described anomaly (...):

■ **Investment restrictions:** There is an asymmetry to the beta desired by the investor. An investor interested in a low beta can either buy stocks with a low beta or construct his or her portfolio partly to feature stocks with a higher beta and cash. For example, if a beta of 0.7 is desired, then the portfolio could contain 100% stocks with a beta of 0.7. Alternatively, it would also be possible to invest 50% in a stock portfolio with a beta of 1.4 and hold 50% cash. Investors interested in a high beta – for example, 1.4 – can create a portfolio with a beta of 1.4 or leverage a portfolio of stocks with a low beta. In a portfolio with a beta of 0.7, the factor necessary for this is 2. In many cases, however, this degree of leverage is not allowed. This asymmetry tends to overvalue high-beta stocks – measured in terms of dividend yield.

Making volatile asset classes investable

(...) Every asset class has its own particular risk – that's the view generally held. And anyone unwilling to accept the high risk of equities should steer well clear of them. In this article, we present a concept for constructing an equity portfolio for virtually any risk preference. The goal is a portfolio that correlates very strongly with the equity market but is less risky. Risk can be defined as volatility or as the potential maximum shortfall. (...) Owing to their construction, portfolios that track capitalization weighted equity indices generally do not pursue the goal of optimizing return per unit of risk. Instead, their main concern is to more or less replicate a market or a region, with the size of the companies being the key weighting criterion. This might be an efficient method, but it might not be optimal for investors (...). For this reason, (...) we compare various so-called "alternative beta" strategies, which can be ideally used for a predefined risk budget. (...) But, for more conservative investors, this might not be enough. The next step is therefore (1) to keep the target volatility constant or (2) to limit the maximum shortfall of the portfolio as a whole.

Keeping the target volatility constant...

(...) To achieve this, the equity exposure is lowered for high risk forecasts and raised again for lower risk forecasts. If, for example, the target volatility is 5% and the expected equity market volatility is 15%, the equity allocation is fixed at 33%, i.e. one-third – since one-third of 15% is 5%. But if the expected volatility falls from 15% to 10%, the equity allocation rises from 33% to 50%. With this procedure, the target equity exposure is regularly adjusted to the expected market volatility – the frequency and extent of the adjustments depending on the precise specifications for maintaining the volatility goal. In the long run, a degree of added value can be achieved with this strategy because equity market returns are lower when volatility is high. (...)

... or limiting the maximum shortfall

An alternative goal is to limit the maximum shortfall, for example to 15%. (...) The gap between the total portfolio value and minimum portfolio value can be used as a risk buffer – the risk budget lies at a maximum of 15% and is at least 0% of the portfolio's total value. (...) If the risk forecast lies within the risk budget, the equity allocation is set at around 100%. Theoretically, however, the equity allocation could also be raised to above 100% with very low risk forecasts, but the example used here does not permit this.

If the risk forecast lies above the risk budget, the current market risk for an equity allocation of 100% is too high. The portfolio's shortfall risk must be reduced by lowering the equity allocation. (...) The effective risk position is then the product of the new equity exposure and the current risk forecast, thereby returning it to within the risk budget. (...)

*Risk & Reward, Q3/2015
Dr. Martin Kolrep*

Factor investing: passive or active?

(...) In recent years, MSCI has launched a series of factor indices for equities. Criteria for equities to be included in these indices are measurable features – for example, above-average dividend yield, low market capitalization or high return on equity. (...) MSCI has two index families. The main objective of high exposure indices is to model factors, with investability playing a secondary role. (...)

Should several factors be combined?

For diversification purposes, it would have paid off to invest not just in one factor index but in a combination. But what weighting is optimal?

As the starting point for the first portfolio, we chose the high exposure MSCI World Momentum Index, the factor index with the best historical performance. Then, for the next five portfolios, we added positions, one at a time, in the five other high-exposure factor indices, beginning with the MSCI World Quality Index as the second-best and ending with the MSCI World High Dividend Index as the weakest. In all six portfolios, the indices are equally-weighted throughout. (...) The best risk-return ratio would have been delivered by an equal-weighted combination of the factors momentum, quality and value (portfolio 3), with an information ratio of 0.75.

Can alternative weighting methods help?

Alternatively, the factor indices could be weighted on the basis of their historical volatility. In this case, the (defensive) MSCI World Minimum Volatility Index would have a higher share than an equal-weighted portfolio, and the same applies in the case of the MSCI Quality Index. The other four factor indices would, by contrast, be more weakly represented. In all, this leads to an information ratio of 0.5 – even less than with the simple equal-weighted portfolio. (...) The results would therefore appear to be unsatisfactory.

Is active management a possible solution?

To forecast the returns of individual stocks, Invesco Quantitative Strategies has already been using a multi-factor model for more than 30 years. We consider four concepts to be of particular relevance: earnings expectations, market sentiment, management & quality and valuation. But rather than following a static approach, the factor specifications are being continuously fine-tuned and adjusted to new developments. As a result, both the weightings of the indicators as well as the indicators themselves can vary. In this way, we aim to overcome the weaknesses of the passive approaches (...) – notably the fact they are static and do not react appropriately to structural changes.

The factor-based return forecast is the most important element of portfolio construction, alongside the risk forecast and the transaction cost forecast as well as portfolio-specific restrictions. The aim of such an active factor strategy is excess return over the MSCI World as well as the MSCI Factor Indices or an index combination – and that at low risk. (...)

*Risk & Reward, Q4/2015
Alexander Tavernaro*

Factor investing: an introduction

(...) At the most fundamental level, “factors” can be described as quantifiable characteristics of assets. They include: value, size, momentum, volatility and quality. Some researchers distinguish between risk and return factors, with return factors explaining long-term returns and risk factors explaining their variability. However, we prefer to view risk-return on a continuum. Consequently, we refer to both risk and return factors as “style factors” (figure 1).

While style factors are often discussed in the context of equity portfolios, they can also be used for other asset classes. For example, value corresponds to assets trading attractively relative to intrinsic value as measured by price to book in equities and term premium (the current yield versus future expected yield) in bonds.

In addition, there are “macro factors”, such as growth and inflation. These are especially well-suited for spanning asset classes, as different asset classes have different macro factor sensitivities. For example, investors often associate lower average returns with bonds as compared to equities. But that is not necessarily true. A factor investor would say that bonds have a lower exposure to the growth factor, which often drives equity returns. (...)

Essentially, factor investing means allocating a portfolio to style and macro factors in an effort to achieve particular investment objectives. Similar to more traditional investment processes, factor investing involves taking positions in individual

assets. But, unlike more traditional approaches focusing on security selection, a factor approach makes use of tradable securities, such as stocks and bonds, to achieve broad and diversified exposure to specific investment themes. (...)

Factors vs. fundamentals

The factor-based approach is often set in contrast to a “fundamental” approach, which implies that factor investing is not fundamentally based – something of a misconception. Many, if not most, widely used factors, such as: value, momentum or quality, rely on the same fundamental investment themes used by more traditional asset managers. Some would argue that these drivers take advantage of behavioural anomalies, creating exploitable market inefficiencies. Others would counter that factor returns reflect premia for additional risk over the broad market. In either case, similar to most traditional asset management concepts, factor models require a strong investment rationale. So, the real difference between a factor-based approach and a more traditional one is not the nature of the investment themes, but the way they are implemented in a portfolio. Whereas traditional or “fundamental” managers typically rely on bottom-up selection and careful investigation into the current state of each company, factor investing delivers transparent, structured and disciplined operationalization of traditional investment themes. (...)

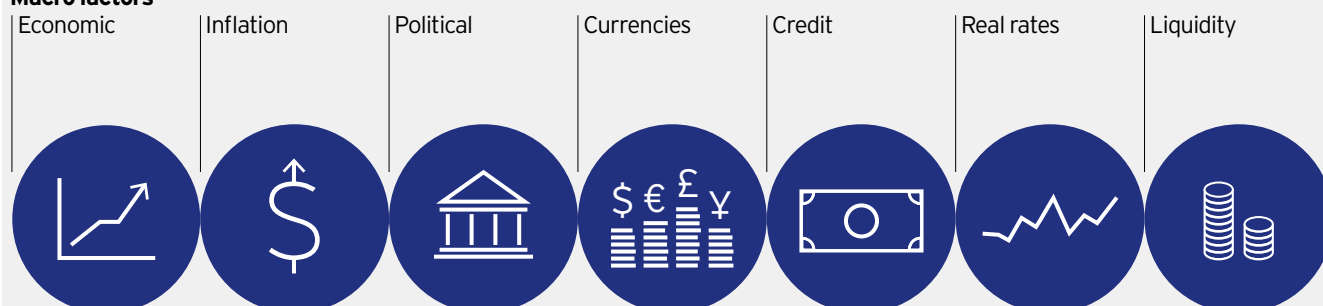
A few examples

To better understand how this works, let us consider specific examples of style and macro factors. “Momentum” is a common style factor: it refers to the phenomenon that assets with positive (negative) returns in the past, tend to also have positive

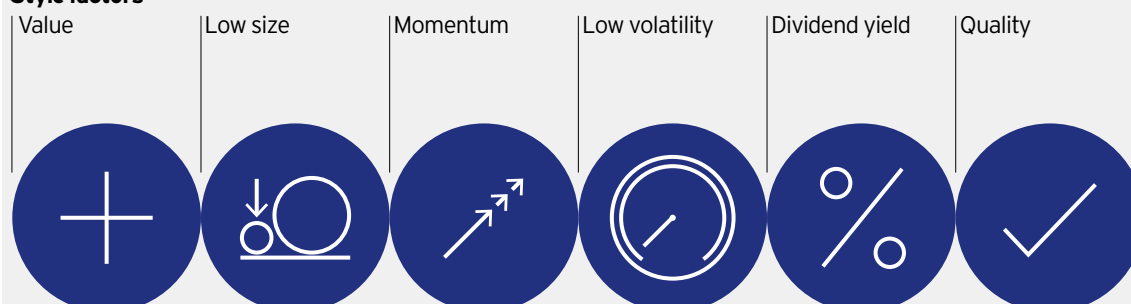
Figure 1

What is a factor? Macro and style factors

Macro factors



Style factors



Source: Invesco. For illustrative purposes only.

(negative) returns in the future. There is a very good reason for this: Peter Lynch, the legendary “fundamental” manager of Fidelity’s Magellan Fund, has said that investors tend to “trim the flowers and water the weeds”. In other words, they sell winners too early and hold onto losers for too long. Such behaviour leads to incomplete price discovery and - ultimately - price trends, i.e. “momentum”.

“Growth”, on the other hand, is an important macro factor: since World War II, in periods with increasing GDP growth, stocks have had a significantly higher Sharpe ratio than bonds. Therefore, a portfolio with a large equity allocation relative to bonds is significantly exposed to growth factor risk, and has typically been rewarded with higher returns in these periods. (...)

Factors are investments, and, as with other investments, holding a diversified, well-balanced portfolio of factors can reduce risk and deliver a smoother, positive return stream. (...)

*Risk & Reward, Q4/2016,
Jay Raol, Jason Stoneberg and Andrew Waisburd*

Factor investing: complementing portfolios with customized factor solutions

When a portfolio has unwanted factor biases, there are several ways to deal with this. One possibility is a factor-based completion portfolio. (...)

To construct a portfolio with balanced factor exposure, it is therefore important to understand the factor tilts implicit in an initial portfolio. Once these tilts have been measured, a completion portfolio can be constructed. Taken together, the two portfolios should exhibit the desired factor exposures (figure 1).

Figure 1

How the completion portfolio works

1: Scanning initial portfolio



2: Choice of completion



3: Balanced portfolio



Source: Invesco. For illustrative purposes only.

(...) By complementing existing portfolios with bespoke factor completion portfolios that account for certain gaps in terms of (factor-based) diversification, we find that risk-return profiles can be improved. The possibilities range from highly liquid low-cost solutions using the broad set of available factor ETFs, all the way through to developing actively managed, highly customized solutions that best reflect a client's desired risk-return targets. Our analysis shows that both ways have the potential to meaningfully improve a wide range of portfolio statistics, including the information ratio.

*Risk & Reward, Q2/2017
Michael Abata, Georg Elsaesser, Brad Smith and
Jason Stoneberg*

How macro factors can aid asset allocation

Often, portfolios are built around the correlations between asset classes. But such an approach is not without its shortcomings – especially since the familiar correlations of the past changed during the financial crisis. (We) present an alternative approach to portfolio construction, one that is based on correlations: but here the focus is on co-movements of asset classes with various macro factors. (...)

The analysis indicates that asset class (bond and equity) correlations are driven by macro factors (growth and inflation). For example, in periods when inflation is on the rise, intuition would suggest that a fixed return asset (such as a bond) would have an inferior return relative to a flexible return asset (such as a stock). (...)

(This) analysis can be used to examine the portfolio allocation problem through a macroeconomic lens. For instance, to answer the question of how an investor should consider allocating between stocks and bonds, we first develop a forward-looking view of growth and inflation. These forecasts allow us to construct a “macro factor framework” to predict how various asset classes will likely behave in each environment.

(...) It is possible to see that the diversification benefits of holding stocks and bonds is highly dependent upon the correlation between growth and inflation. For example, during the 1973-1998 regime, there was essentially no benefit to owning both stocks and bonds – the optimized portfolio performed no better than either asset class. During this period, stocks and bonds were highly correlated, which we would expect since growth and inflation were negatively correlated. In contrast, during the 1998-2016 regime, when growth and inflation were positively correlated, diversification produced tremendous benefit – the optimized portfolio outperformed each asset class. (...)

An important outcome of our analysis was the identification of a third factor, distinct from the widely accepted factors of growth and inflation. This third factor seemed to be correlated with several proxies for financial conditions. We believe that this “financial conditions” factor, or this “policy factor”, corresponds to the effect of monetary and fiscal policy on asset prices. Because financial conditions affect the discount rate that investors use to determine the net present value of any asset, any tightening of financial conditions should theoretically prove negative for all asset classes. We believe this factor provides the missing link in the post-2008 world, where equity and bond returns have been positive despite anaemic growth and inflation. It would seem that unconventional monetary policy (loose financial conditions) can be considered the primary driver of returns. (...)

Risk & Reward, Q2/2017
Jay Raol, PhD

Investing in a multi-asset multi-factor world

(...) The systematic search for reasonable and uncorrelated building blocks to complement traditional asset allocation suggests turning to factor strategies. (...)

A common feature of traditional asset classes is their directional nature; that is, an investment in a traditional asset class is exposed to market risk. When markets appreciate or depreciate broadly, traditional asset classes generally follow suit. Conversely, factors often perform differently, particularly if we control for market movement. (...) Figure 1 gives a quick overview of the most salient style factors – carry, value, momentum, quality and defensive. Interestingly, investigation shows these general factors apply across asset classes. Thus, one could think of these factors as likely approximations of latent risk factors in an asset pricing context. Managing relevant factors in conjunction with multiple asset classes therefore both expands the opportunity set and improves risk controls. (...)

Figure 1
Major style factors



- **Carry:** High yield assets tend to outperform low yield assets – provided all else is equal
- **Momentum:** Recent relative price winners tend to outperform recent relative price losers
- **Market:** Asset classes tend to exhibit time series predictability that can be exploited systematically
- **Defensive:** Low risk assets tend to have higher risk-adjusted returns than high risk assets
- **Quality:** High quality assets tend to have higher risk-adjusted returns than low quality assets
- **Value:** Cheaper assets (according to a given valuation metric) tend to outperform expensive ones

Source: Invesco. For illustrative purposes only.

Mean-variance spanning of style factors vis-à-vis traditional asset classes

To help gauge the contribution of the investment factors, it is instructive to examine the corresponding factor returns and volatilities with a mean-variance diagram alongside traditional asset classes. Figure 2 charts all factors and asset classes in terms of their mean and standard deviation, pertaining to the sample period from 2001 to 2016. To visualize the investment opportunity set of a classical multi-asset investor, we compute the efficient frontier, based on the above international bond and equity indices labelled MA (multi-asset).¹ Then, we consecutively add factor sets by asset class – first, we include equity factors, which significantly boost the return perspective and testify to favourable equity factor performance. Next, we additionally include the four FX factors, shifting the efficient frontier further to the northwest. The same can be observed when including commodity factors. Finally, we add the four rates factors to the mix. Note that these factors have historically shown sub-par return performance. Still, they help shift the frontier to the left by offering diversification benefits. (...)

Maximum diversification in a multi-asset multi-factor world

Having selected a viable set of assets and factors, the final challenge is optimally combining them into one coherent portfolio. While the classical mean variance paradigm of Markowitz (1952), shown in figure 2, is a classic method for optimally balancing the trade-off of expected portfolio return and risk, it often suggests highly concentrated portfolio weights that – experience tells us – are likely to

disappoint ex-post. Obviously, these observations are rather unsettling given that diversification is at the heart of mean-variance portfolio theory. (...)

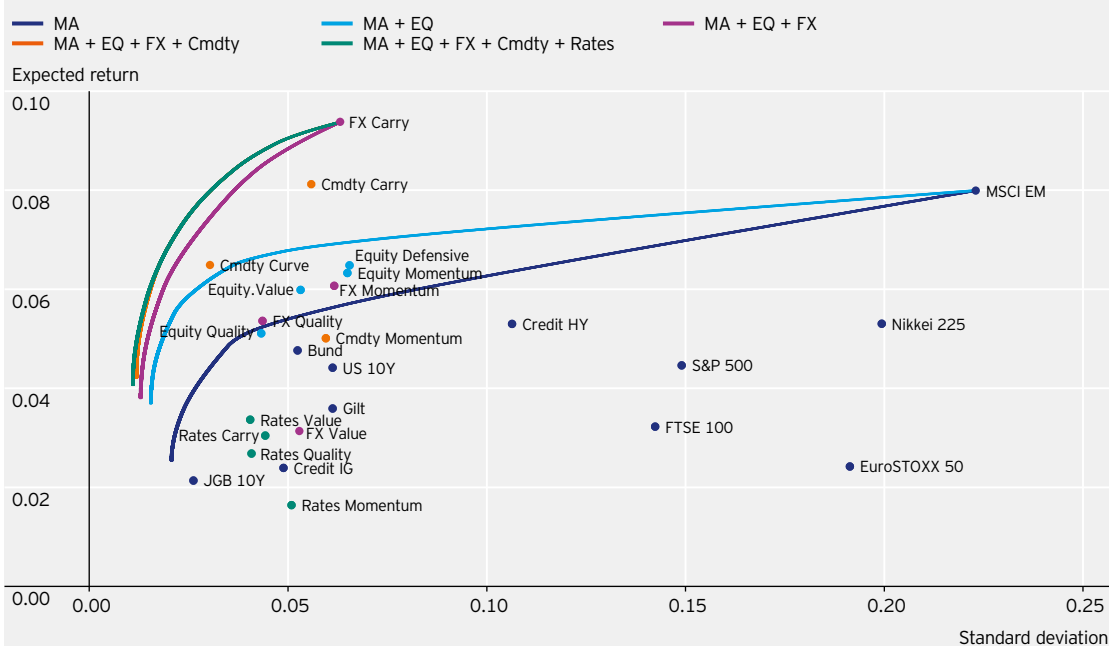
In the framework of Markowitz, diversification benefits are usually considered as increases in expected portfolio return at a given level of risk and/or decreases in expected portfolio risk at a given level of return. However, diversification as such is not explicitly defined. Notably, Meucci (2009) has advanced a framework to manage the degree of portfolio diversification, which happens to resonate well with the general intuition that “a portfolio is well-diversified if it is not heavily exposed to individual shocks.” To this end, Meucci suggests extracting uncorrelated risk sources from the underlying assets. Maximum diversification obtains for a risk parity strategy along these uncorrelated risk sources. That is, the portfolio is allocated in such a way that each uncorrelated risk source contributes equally to overall portfolio risk. We dub this approach “diversified risk parity” (DRP). (...)

The diversification rationale naturally extends to the case of multi-asset multi-factor investing. At the heart of a maximum diversification strategy is the choice of risk model and the corresponding factors along which to diversify. In general, there are three viable options:

1. “Kitchen sink”: Consider every asset class and factor as a unique source of risk. This operationally simple approach does not rely on clustering asset classes or factors, and can therefore become unstable because of dimensionality concerns.

Figure 2

Mean-variance spanning of asset classes and factors



Sources: Bloomberg, Invesco, Goldman Sachs.

2. Cluster factors by asset class: This approach would resonate with the organizational structure of a typical asset management organization. However, it fails to account for factor risks that cross asset classes.
3. Cluster factors across asset classes: Clustering in this way is a natural choice when considering the world from a pure factor investing view as it more closely ties the return and risk objectives to the diversification process.

Therefore, we will focus on option 3. Naturally, a complete risk model should jointly consider major traditional asset classes and aggregate style factors. (...)

Maximum diversification benefits

To accord with the diversification framework of Meucci (2009), the set of seven asset classes and style factors must be transformed into one of uncorrelated risk sources. However, to achieve our ultimate objective, we must manage each of the seven components such that they remain true to their definition while interacting with the other components in a predictable way. A traditional academic route would consider a “principal component analysis” (PCA). (...) A more useful route is an approach similar to PCA, but one that defines diversification in a way more closely tied to our asset classes and factors. In that regard, Deguest, Meucci and Santangelo (2015) suggest a more appropriate alternative to decompose the investment opportunity set. In particular, their methodology can be used to de-correlate the original factors at minimum tracking error. As a consequence, the corresponding portfolio is more stable than that derived from a PCA, and better positioned to harvest factor premia when and if they occur; see Bernardi, Leippold and Lohre (2017) for an application in the realm of commodity investing.

Applying this methodology to the case of multi-asset multi-factor investing, we demonstrate that the findings indeed translate to a stable and investable portfolio. (...)

Risk & Reward, Q3/2017

*Alexandar Cherkezov, Dr. Harald Lohre,
Sergey Protchenko and Jay Raol, PhD*

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¹ The efficient frontier collects the risk and return combinations to be achieved in the optimum of a standard mean-variance portfolio optimization. That is: the efficient frontier depicts the highest attainable return at a given level of risk or (vice versa) the lowest attainable variance at a given level of return.

Currency management with style

There are good reasons to believe that the optimal currency hedge lies between the two extremes of a full hedge and no hedge at all. We believe that it pays to have a closer look at currency style factors for determining a beneficial currency allocation.

(...) Figure 1 depicts a mean-variance diagram of the three FX style factors carry, value and momentum, as well as five traditional asset classes as given by US equity, US Treasuries, US corporate bonds (investment grade and high yield) and commodities.¹

First, we inspect the investment opportunity set of traditional multi-asset investors based solely on the latter five asset classes. In particular, we take the perspective of a EUR investor who is fully hedging USD/EUR exposure. The left chart in figure 2 shows the ensuing mean-variance allocations along the efficient frontier for the five multi-assets only. Going from left to right, we learn that a more defensive investor would have allocated toward government bonds, whereas the latter allocation for less risk-averse investors gives way to investment grade and high yield credit positions.

Second, adding the three FX style factors to the mix would significantly expand investors' opportunity set. The ensuing efficient frontier including FX styles shifts considerably to the northwest compared to the multi-asset-only allocation.² Obviously, the inclusion of the FX carry and value factors expands the portfolio return perspective. Still, judging from the corresponding mean-variance allocations, we learn that all three FX style factors crucially enhance the

tail-hedging capabilities of any multi-asset investor, as demonstrated by their large portfolio weights in the minimum-variance portfolio.

While FX momentum does play a role, especially for very defensive allocations, we see that FX value is beneficial across the whole spectrum of risk profiles. Likewise, allocation to the FX carry trade replaces some of the high yield allocation, reflecting its close association with genuine equity and credit risk.

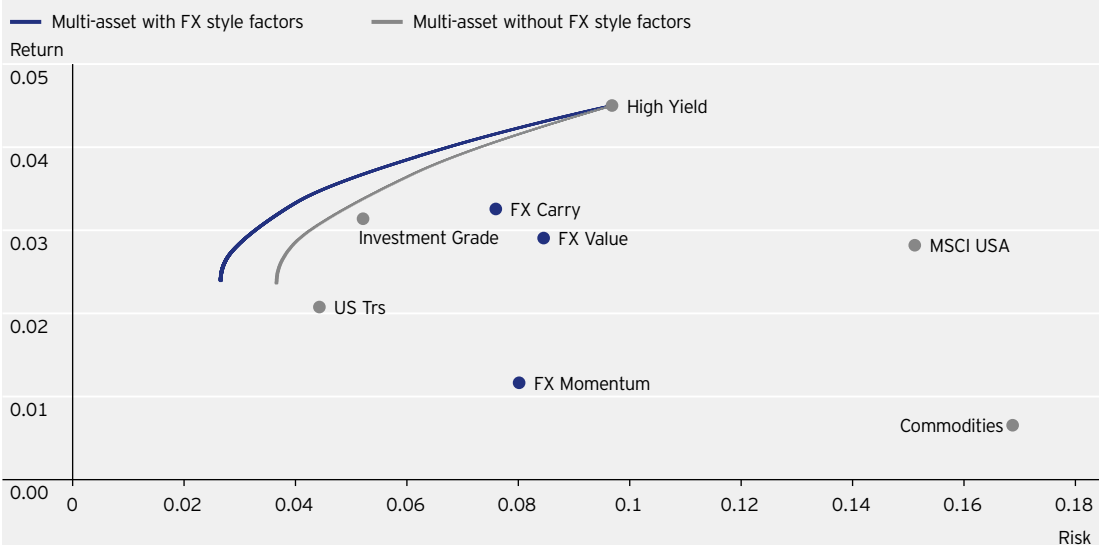
FX style factor investing for a multi-asset portfolio

Note that the above mean-variance spanning analysis for the FX style factors should be taken with a grain of salt. The corresponding allocations all represent stylized optimal mean-variance allocations that result from knowing the full return history. To investigate the potential out-of-sample benefits of FX style factor investing, we need to build allocations based on the information available at the time of each rebalancing. As we want to focus on FX factors, we fix the five multi-asset weights according to a standard risk parity scheme. Taking the perspective of a euro investor, we first fully hedge the USD exposure and then consider further allocating towards FX style factors. In particular, two approaches are investigated:

1. Tail-hedging as given by a minimum-variance hedge consisting of FX style factors
2. Return-seeking based on mean-variance investing using historical average FX style returns as return estimates

In both cases, we restrict the FX style factor weights to 100% (on top of the traditional asset allocation that is fixed to the 100% risk parity strategy). These

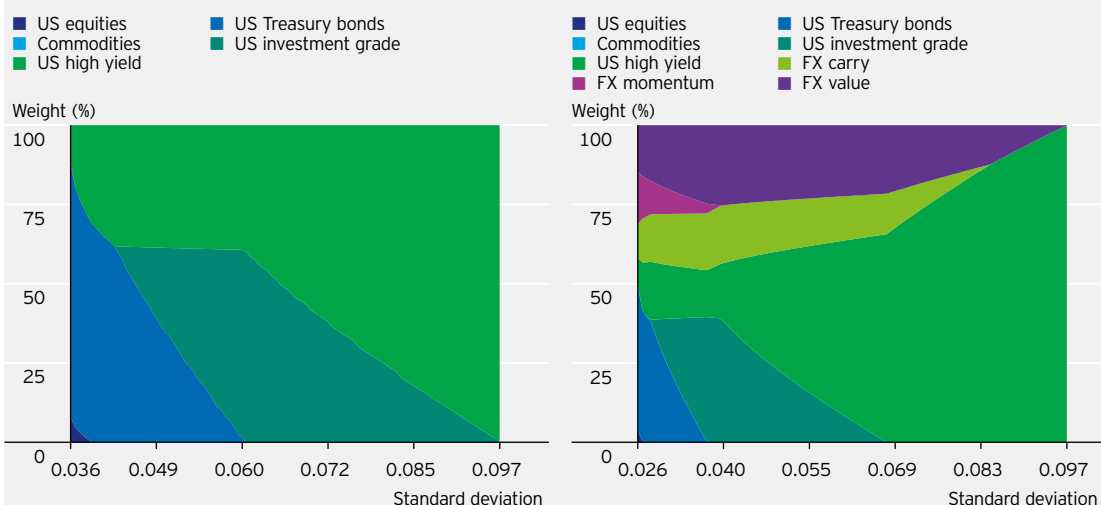
Figure 1
Mean-variance spanning of FX style factors and asset classes



Simulated past performance is not a guide to future returns. The figure depicts two efficient frontiers based on different sets of underlying asset classes or FX style factors. Based on the traditional asset classes equity (MSCI USA), government bonds (US Treasuries), US corporate bonds (High Yield and Investment Grade) and commodities, all of which denoted with grey dots, we compute the multi-asset efficient frontier (grey line), see footnote 1 for a description of the relevant indices for the traditional asset classes. Next, we add FX style factors to compute the efficient frontier (blue line) based on FX style factors (blue dots) and asset classes. The underlying mean-variance optimizations are subject to full investment and short-sale constraints. Mean-variance inputs are derived from monthly excess return data over the sample period from 29 January 1999 to 31 December 2016. Both risk and return figures are annualized. Asset class returns are fully hedged from the perspective of a EUR investor.
Sources: Bloomberg, Invesco.

Figure 2

Efficient frontier allocations: FX style factors and asset classes



The figure depicts the two spectrums of efficient frontier allocations based on two different sets of underlying asset classes or FX style factors. The left chart is based on the efficient frontier for traditional asset classes: equity (MSCI USA), government bonds (US Treasuries), US corporate bonds (High Yield and Investment Grade) and commodities, see footnote 1 for a description of the relevant indices for the traditional asset classes. The right chart is based on the efficient frontier that additionally considers the three FX style factors carry, value, and momentum. Data inputs are derived from monthly excess return data over the sample period from 29 January 1999 to 31 December 2016. Sources: Bloomberg, Invesco.

constraints allow the overall strategy to stay within risk limits. While this objective could also be couched in a more elaborate risk budgeting framework, this approach is straightforward in carving out the stylized facts of adding a factor-based currency overlay to a multi-asset portfolio. The out-of-sample period is 31 January 2002 to 31 December 2016, reflecting the use of 36 months to calibrate the inputs of the first mean-variance optimization. Subsequently, we estimate parameters based on an expanding window over time.

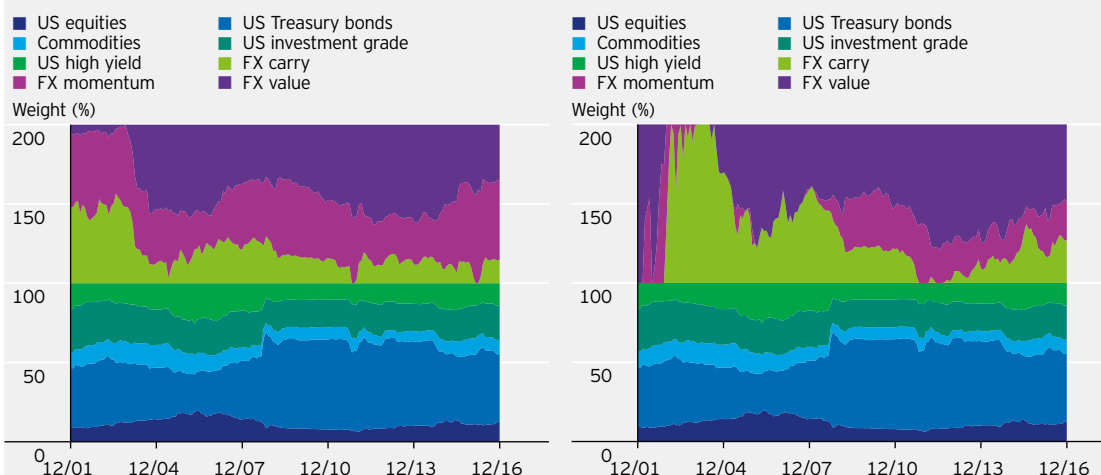
The left chart in figure 3 depicts the allocation weights over time for the tail-hedging strategy based on a minimum-variance optimization with FX style

factors. Naturally, the fixed underlying asset allocation exhibits quite a conservative risk profile resonating with the risk parity paradigm. Unhedged, a euro investor would see annualized volatility of 8.8%. (...) Equipped with the three FX style factors, the same investor could bring this figure down to 6.0%. (...)

To investigate whether a risk-affine investor would have been able to capture more of the performance upside through FX style factors, we have designed a return-seeking FX style allocation. In particular, we ran a mean-variance optimization based on a more offensive risk aversion, where the expected return inputs for the FX style factors derive simply from

Figure 3

Tail-hedging and return-seeking with FX style factors: allocations



The left chart depicts the asset and FX style factor allocation for the tail-hedging strategy based on FX style factors over time; the right chart depicts the asset and FX style factor allocation for the return-seeking strategy based on FX style factors. See footnote 1 for a description of the relevant indices for the traditional asset classes underlying the risk parity asset allocation. Sources: Bloomberg, Invesco. Data as at 31 December 2016.

their historical average. The latter is estimated using an expanding window to allow for a true out-of-sample experience. (...)

While these two illustrative use cases document the diversification benefits of adding FX style factors to a traditional asset allocation, one has to acknowledge that our analysis relies on the ability to implement an outright long-short currency overlay. It is an open question whether these benefits continue to be relevant for a global investor who is incapable of following these allocations but merely intends to hedge existing direct investments. (...)

Risk & Reward, Q1/2018

Dr. Martin Kolrep and Dr. Harald Lohre

1 To represent the traditional asset classes, we build on broad market indices. In particular, we use MSCI USA for US equities, Barclays US Aggregate Government Treasury for US Treasury bonds, Barclays US Aggregate Credit for US investment grade corporate bonds, Barclays US Aggregate Credit Corporate High Yield for US high yield and the Bloomberg Commodity Index for commodities.

2 In fact, in unreported mean-variance spanning tests based on Kan and Zhou (2012), we document this shift in the efficient frontier to be statistically significant. This finding applies to the joint use of the three FX style factors, but also to any single FX style factor when added to the five multi-assets in isolation.

Factor investing: the third pillar of investing alongside active and passive

(...) Each of the three pillars of investing – market cap weighted indexing, factor investing and alpha strategies – offer distinct advantages and disadvantages. Each plays a valuable role in the investment ecosystem, and each can therefore be an attractive option given the right set of circumstances. Equipped with this framework to focus on what is possible to control and a proper perspective on what it means to be active and passive, investors can make better decisions and improve their overall investment outcomes. (...)

Passive investing

(...) In passive investing, key decisions are made not by individuals, but by aggregate market participants using, and benefitting from, competitive buying and selling forces. Most passive investors have decided, whether implicitly or explicitly, that the market portfolio is good enough. Perhaps market returns suffice to help them meet their investment goals, or maybe the investors don't have the appetite to risk underperforming the market. So, they opt to accept what the market dictates.

(...) Passive investors allow the market to set their allocation for them and employ no active management. What's left? Fees. For passive investors, fees are the only thing left within their control. This is why fee levels are such a particular focus for them. Warren Buffet famously advised his wife to invest in low-cost passive funds in the event of his death. So why would one of the world's most accomplished active investors say this? Even after committing the vast majority of his multi-billion US dollar fortune to charity, Buffet's wife is at no risk of running out of money unless she makes foolish decisions. Market returns seem good enough, with any deviation simply adding risk.

But, for everyone who has less than an extreme overabundance of resources, making the decision to invest passively might not be so straightforward. A little extra gain over time could make the difference between a pension fulfilling its promises or telling workers that it cannot hold up its end of the bargain. Due to the power of compounding, seemingly small differences add up over time. Consider, a 1% difference in return (from 5% to 6%) over an investment lifetime of 25 years ultimately leads to 33% more wealth. Of course, this cuts both ways, so fees matter and risk control is critical as well. (...)

Active investing

Moving on from the asset allocation discussion, we now address the next item within our control: active management. Active management is the opposite of passive. Rather than passively accepting market returns or a market-dictated asset allocation, investors can actively pursue their own unique strategies. Historically, this is what was expected from professional money managers: to use skill, experience, knowledge or some sort of advantage to produce a better outcome. (...)

The term alpha is used to describe excess return generated versus a benchmark. It simply refers to the positive performance not explained by the other three elements of returns: market returns, asset allocation and fees. Alpha could come in the form of higher returns, lower risk or some combination of the two.¹

A key reality of alpha-seeking active managers is that, if there are winners, there must also be losers. If one manager produces a return stream that demonstrates positive alpha, someone else must have inferior returns, because the market incorporates all investors. This is what is meant when people say active management is a zero-sum game. All above-benchmark returns must, by definition, be balanced by below-benchmark returns somewhere else. And this is before accounting for any fees. With that in mind, it should not be surprising to anyone that capturing alpha is difficult – though that has not stopped investors from trying. (...)

Factor investing

We are now ready to address factor investing. A brief definition is warranted to ensure a common understanding. Factor investing is a systematic, evidence-based approach that targets certain characteristics of an asset, called factors, which tell us something useful about the security's expected return or risk.

We can specifically structure a portfolio around an investment factor. Some of the most common investment factors are value, momentum, quality and size. Meanwhile, macroeconomic factors, like unemployment and inflation, enable investors to assess how exposed their portfolios are to different stages of the economic cycle, similar to a doctor collecting information to diagnose a patient's condition.

Factor investing unlocks an improved understanding of markets and asset allocation, and might thus be considered a third pillar of investing. Previously, we looked primarily at asset classes – like stocks, bonds, cash – and also at sectors and other characteristics to understand the expected risk and return sources of the portfolio. Rigorous academic research has pushed the understanding further, illustrating how factor exposures help explain more of historically observed security returns. Factors, at least the ones that we have confidence are worth monitoring and pursuing in a portfolio, also have a solid economic rationale. Because factor investing is based on improved understanding, its increasing adoption throughout the world likely marks a permanent change in how assets are managed. (...)

Providing advantages through flexibility

With these distinctions, we can make informed choices: to be active or passive in asset allocation and/or portfolio management? And at what cost? Once we decide whether to actively or passively allocate across factors, we can decide whether to actively or passively manage the allocation. Most smart beta strategies are passive exchange traded fund (ETF) applications relating to a single or multi-factor index. Remember, the index construction is making active factor bets that should be understood, as these bets are likely to be a driver of performance.

These ETF applications might be attractive because of transparency. The index construction methodology is usually available and straightforward. A more active application allows for unique factors, differentiated definitions of factors, ongoing trade-offs between factor exposures and/or evolution of the process as new techniques are developed. We know the world is constantly changing, so there might be real advantages to having flexibility available to achieve active implementations.

Last, but certainly not least, are fees. There is no question that fees directly impact performance in a negative way. But, do not be fooled into thinking cheaper is always better. (...) True alpha is a relatively scarce resource and, as mentioned above, requires some sort of advantage. We should not expect this valuable benefit to be given away. There should be a balance between alpha and the cost to capture it. Factor strategies can potentially add returns and/or control risk in ways pure indexing cannot. Therefore, the optimum should be somewhere between pure alpha and indexing. Traditional passive indexing involves no added value, so it is mostly about low cost. (...)

*Risk & Reward, Q2/2018,
Stephen Quance*

¹ These examples are intended to be illustrative and are not an exhaustive list of objectives.

Advancing the frontiers of factor investing

(...) The first day of the conference was rounded off by awarding the best paper with the Invesco Factor Investing Prize, which came with a cash prize of GBP 2,000. After careful consideration, the jury awarded Andrea Tamoni (London School of Economics) and his co-authors Fahiz Baba Yara and Martijn Boons from Nova School of Business and Economics for their academically rigorous but accessible work on "Value Timing: Risk and Return Across Asset Classes". As part of the ceremony, Dr. Harald Lohre from Invesco Quantitative Strategies cited from the scientific committee's appraisal that the "paper is simple but interesting to both academics and practitioners. Moreover, it is very well-written and has an extensive analysis." The authors demonstrate that value strategies in equities, bonds, commodities and currencies are predictable via value spreads. Returns to value strategies are found to be substantial in all asset classes when the value spread is comparably wide, and this predictability is economically and statistically significant. (...)

Risk & Reward, Q3/2018

by Marie Brière, Michael Fraikin, Raman Uppal and Daniel Giamouridis

Implementing a multi-factor commodity strategy: a practitioner's approach

Factor investing has become mainstream, but most approaches still focus on equities. We have developed a factor-based commodity strategy that takes note of the particular features of this asset class. (...)

Since 1992, when Fama and French proposed size and value as powerful descriptors of cross-sectional equity returns, factor investing research has generated increasing interest among both academics and practitioners. Over the past twenty-five years, there have been so many anomaly papers published that it is almost impossible for anyone to keep up with the entire scope of the research. Harvey, Liu and Zhu (2013) identify 316 different factors in 313 articles, representing just a sample of the universe of papers. Whether described as smart beta, factor investing or enhanced indexing, these strategies are all derived from the same idea: go long (overweight) assets with high values in a particular metric and short (underweight) assets with low values in the same metric. However, most of these studies and strategies have one thing in common - they refer to equities.

Commodities have a much shorter history as a mainstream asset class. Institutional investors had invested only USD 18 billion in commodities in 2003 according to a Barclays Capital survey. But due to the growth in multi-asset strategies and the inflation hedging property of commodities, institutional investors have become increasingly interested in the asset class. Therefore, we believe that the time has come to look at commodities from a factor perspective.

Four commodity factors

To start with, commodity factors should satisfy the same three properties as equity (or indeed currency or bond) factors: first, their definitions should be intuitive and driven by a fundamental understanding of commodity markets instead of empirical results in order to minimize the risk of mere data mining. Second, they should offer positive returns over time, though achieving the highest in-sample return is never the goal. Third, factors used in a multi-factor commodity strategy should be differentiated in terms of their information content. In other words, there should be no strong positive correlations among them.

With these properties in mind, we constructed three cross-sectional factors - momentum, value and carry - using 20 commodity futures. We also constructed a fourth factor, which we identify as defensive, with a somewhat different structure. (see figures 1 - 4) (...)

From commodity factors to a factor portfolio

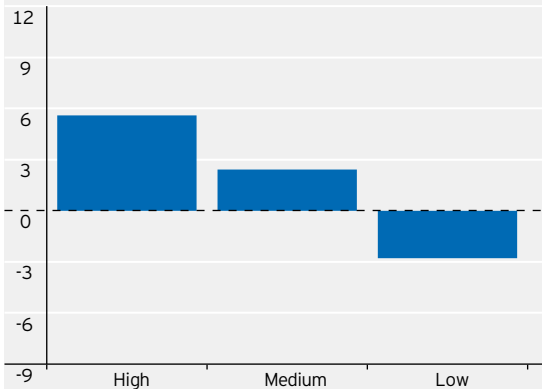
For each of the three cross-sectional factors, we apply a risk parity framework to create a factor strategy. Both the long and short side of each factor strategy are weighted according to each asset's volatility and correlation characteristics. In this case, more volatile, highly correlated assets will tend to receive smaller weights than less volatile, uncorrelated assets. In our experience, a risk parity approach helps to improve portfolio diversification versus a simple 1/N allocation approach, particularly when there are wide variations

Figure 1

The momentum factor

- The tendency for assets that have risen in value to continue to rise
- Adjust for differences in asset volatilities
- Representative academic research: "Momentum Strategies in Commodity Futures Markets"

Simulated annualized excess return by factor rank, in %
(30 June 1998 - 30 June 2018)



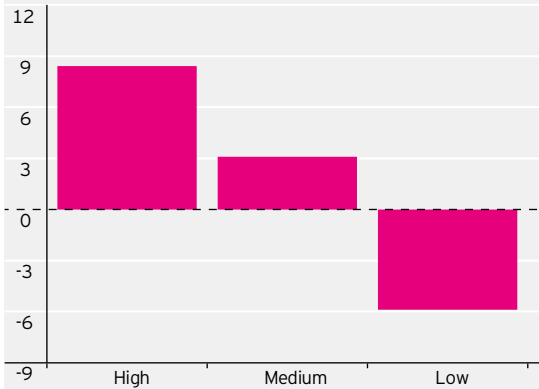
Sources: Bloomberg, Datastream, Invesco analysis. Joëlle Miffre, and Georgios Rallis, "Momentum Strategies in Commodity Futures Markets", (5 August 2006). Journal of Banking and Finance, Vol. 31, No. 9, 2007. Available at SSRN: <https://ssrn.com/abstract=702281> or <http://dx.doi.org/10.2139/ssrn.702281>. Returns based on changes in prices for future contracts which are by nature excess returns above cash. **Figures refer to simulated past performance and past performance is not a reliable indicator of future performance.**

Figure 3

The value factor

- Assets that have fallen in value over an extended period of time will tend to outperform other assets
- Adjust for bias to have negative carry
- Representative research: "Combining Momentum with Reversal in Commodity Futures"

Simulated annualized excess return by factor rank, in %
(30 June 1998 - 30 June 2018)



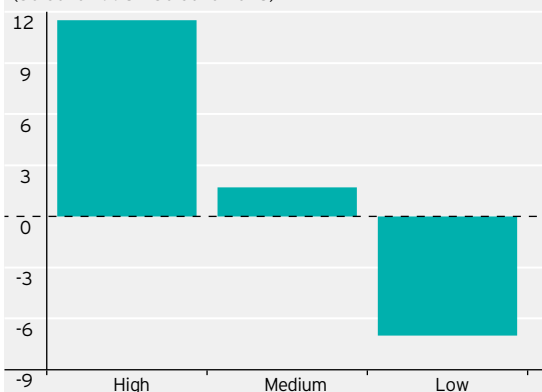
Sources: Bloomberg, Datastream, Invesco analysis. R. Bianchi, M. Drew and J. Fan (2015). "Combining momentum with reversal in commodity futures". Journal of Banking & Finance, 59, 423-444. Returns based on changes in prices for future contracts which are by nature excess returns above cash. **Figures refer to simulated past performance and past performance is not a reliable indicator of future performance.**

Figure 2

The carry factor

- The tendency for assets that have high implied roll yields to produce higher total returns than other assets
- Representative academic research: "The Strategic and Tactical Value of Commodity Futures"

Simulated annualized excess return by factor rank, in %
(30 June 1998 - 30 June 2018)



Sources: Bloomberg, Datastream, Invesco analysis. Claude B. Erb and Campbell R. Harvey, 2005. "The Strategic and Tactical Value of Commodity Futures", NBER Working Papers 11222, National Bureau of Economic Research, Inc. Returns based on changes in prices for future contracts which are by nature excess returns above cash. **Figures refer to simulated past performance and past performance is not a reliable indicator of future performance.**

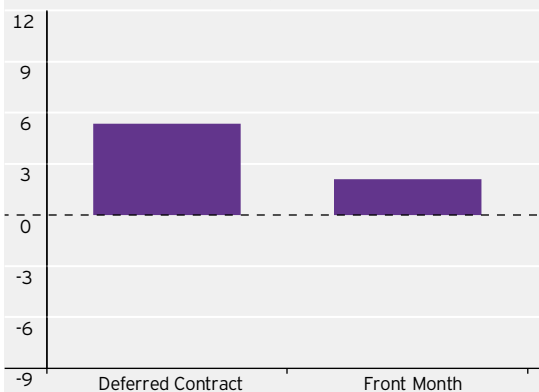
in the characteristics of the asset universe. In addition to the allocation framework, we have also included a risk target (10%) for both the long and short side of each factor strategy.

Figure 4

The defensive factor

The tendency for lower volatility assets - in the case of commodities, deferred contracts - to outperform higher volatility ones

Simulated annualized return by factor rank, in %
(30 June 1998 - 30 June 2018)



Sources: Bloomberg, Datastream, Invesco analysis. **Figures refer to simulated past performance and past performance is not a reliable indicator of future performance.**

For the defensive factor, trading two futures contracts in the same asset tends to lead to a strategy with relatively low volatility. In order to maintain low leverage, we have chosen to implement the strategy only on the assets where we have a long position based on the three preceding factors rather than as a fully independent factor. Despite this more limited exposure to the factor, the annualized return of the multi-factor portfolio improved by approximately 2% without increasing portfolio risk. (...)

Portfolio allocation on factors

The next phase focuses on constructing a multi-factor portfolio using three cross-sectional factors: momentum, value and carry. We again apply a risk parity approach to achieve this goal. (...) By combining three diversified factors, the multi-factor portfolio can offer much better performance than any of the factors individually. The return profile is also very attractive due to low correlation to traditional commodity, equity and bond returns. (...)

Conclusion

Factor investing research to date has generally focused on equities. However, commodities are a natural next frontier given the deep roots of research into pricing anomalies. Based on the results of this research, factor investing in commodities appears to offer the potential to extend the asset class from a reliable inflation hedge to a consistent return generator, irrespective of the economic environment. As we have found in virtually all of our research, the inputs – underlying factors in this case – are important, but require a sound portfolio construction process to achieve the desired results: in this case, attractive prospective returns and low expected correlation to traditional financial markets.

Risk & Reward, Q4/2018

Scott Hixon, Hua Tao and Scott Wolle

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How can fixed income factors help investors with allocation decisions?

How can fixed income factors enhance the more traditional credit rating, industry or duration view of portfolio construction? Can adding a factor element improve the risk-return profile of a multi credit portfolio? Do fixed income factors make sense in a balanced equity-fixed income allocation? How can investors complement an existing allocation without significantly disrupting the existing portfolio? (We) address these four questions often faced by investors. (...)

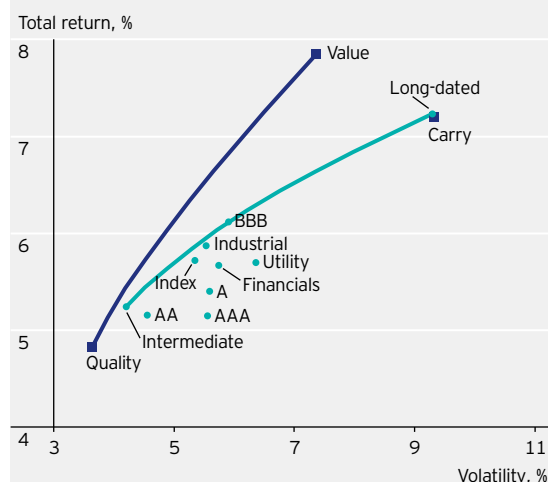
1. How do fixed income factors fit with the more traditional credit rating, industry or duration view of portfolio construction?

To answer this question, we narrow complex fixed income portfolio construction to a simple analysis of how to use factors within US investment grade credit. An investment grade credit portfolio must balance the wide ranges of risk and return across the bond universe. In order to represent different investment choices, we divide subsets of the universe into sectors according to rating, maturity and industry using the following market value weighted indices (figure 1). (...)

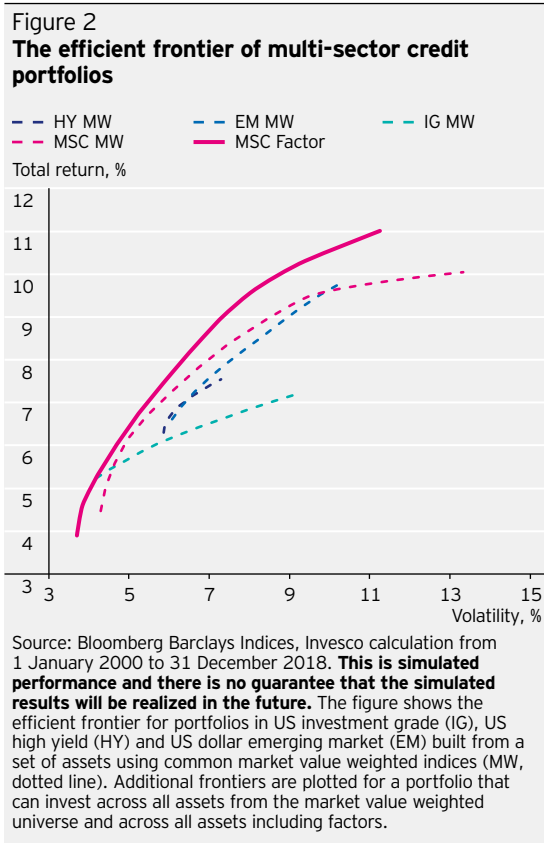
2. Can adding a factor element improve the risk-return profile of a multi-credit portfolio?

We now increase the level of complexity and consider multi-sector credit portfolios. Figure 2 shows the

Figure 1
How factors can improve the risk-return profile of US investment grade portfolios



Source: Bloomberg Barclays Indices, Invesco calculation from 1 January 2000 to 31 December 2018. **This is simulated performance and there is no guarantee that the simulated results will be realized in the future.** The figure shows the efficient frontier from constructing a long-only portfolio without leverage from a universe of investment grade quality, value and carry factors along with common market value weighted indices, including US investment grade, represented by the Bloomberg Barclays US Corporate index, Intermediate Corporate Index, Long US Corporate Index, US Corporate Industrial Index, US Corporate Utility Index, US Corporate Finance Index, US Corporate AAA Index, US Corporate AA Index, US Corporate A Index and US Corporate BBB Index. The efficient frontier is constructed by solving for the weights of different assets that maximize the Sharpe ratio of a portfolio for a given level of risk. The highest Sharpe ratio portfolios are shown for portfolios built with market value weighted indices only (green) and those including factors (blue).



efficient frontier that can be achieved by looking across credit sectors using the traditional asset class breakdowns found in typical multi-sector credit (MSC) portfolios.

Even in a multi-sector context, we can see that including factors can meaningfully improve performance. This shows that factor portfolios are more than just a “reshuffling” of traditional risk buckets (i.e. adding the investment grade value factor is not equivalent to adding high yield beta); they represent a separate and complementary asset allocation decision.

3. Do fixed income factors make sense in a balanced equity and fixed income allocation?

Finally, we look at how credit factors can complement a balanced portfolio of equities and bonds even when equities already benefit from a factor-based approach. We construct the equity portfolio from MSCI USA factor indices that include value, quality, size, momentum and minimum volatility. We then construct the efficient frontier and plot the associated weights for each asset, aggregating the fixed income factors, the traditional fixed income sectors (US Treasuries, US investment grade corporates and US high yield corporates) and the MSCI equity factor weights (figure 3).

At almost all levels of risk, the most efficient portfolio includes a significant allocation to fixed income factors. It is important to understand that fixed income factors are not subsumed by equity factors. While fixed income and equity factors have some correlation to each other, they are more often diversifying. In addition, it is not surprising that fixed income factors have their highest allocation around

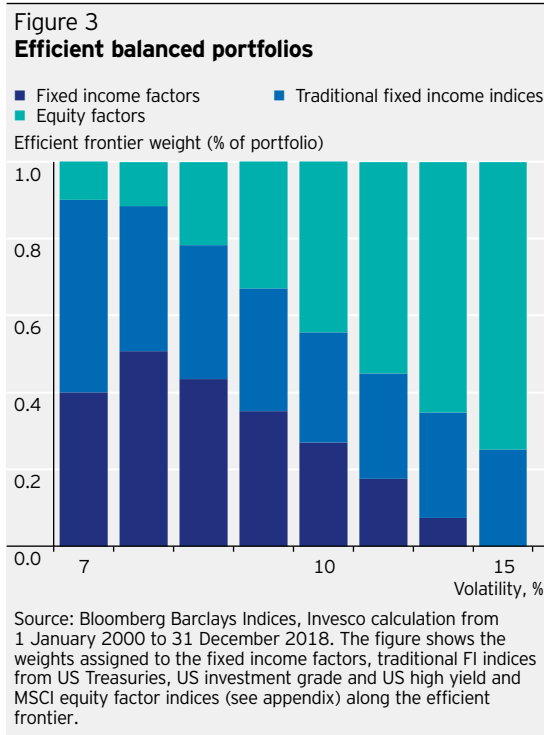
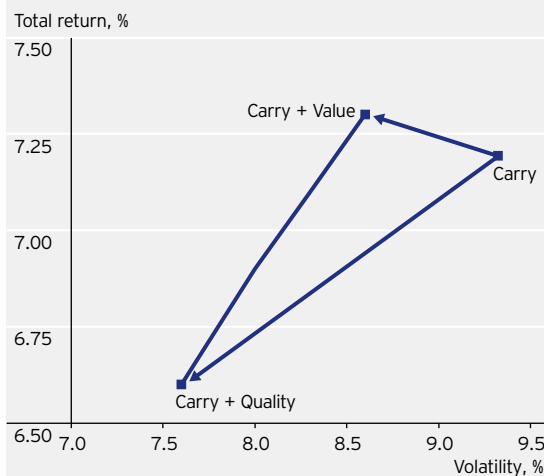


Figure 4
The efficient frontier of a portfolio with 75% allocation to carry factor



the 7% volatility level. This represents the level of risk at which factors can be harvested most efficiently across rating and geography since multiple credit sectors overlap at this risk level. This is another powerful data point suggesting the advantages of a multi-sector and multi-factor portfolio.

4. How can factors complement an existing portfolio without significantly disrupting the existing portfolio?

We consider the case of an investor seeking to improve risk-adjusted returns without major disruption to an existing carry portfolio. As a proxy for a typical investor, we consider the portfolio of the median active bond manager whose active returns have been shown to be primarily driven by carry,¹ (this proxy should reasonably approximate a true portfolio). We compute the efficient frontier given an existing, static 75% allocation to investment grade carry. Figure 4 shows that the pure carry portfolio can be improved by allocating along the spectrum to either quality or value with the overall risk varying between the minimum risk portfolio (carry + quality), with an allocation of 25% to quality, and the maximum return portfolio (carry + value), with an allocation of 25% to value. (...)

Risk & Reward, Q2/2019
Jay Raol, PhD

¹ Raol, J. and Quance, S. (2019): "Active bond funds - powered by factors", Risk & Reward #1/2019, pp. 4-7.

The next 30 years



Dr. Henning Stein
Global Head of Thought Leadership, Invesco
Fellow, Cambridge Judge Business School

30 years of Risk & Reward! We are proud of this achievement – not least because we've gotten so much positive feedback from our clients over the years. We hope you enjoyed our journey back in time and the extracts we put together for this Jubilee Edition.

We think our selection offers a good overview of how far we have come over the past 30 years, particularly when it comes to quantitative portfolio management and factor investing – where we consider ourselves to be among the leading experts.

Invesco intends to remain at the forefront of quantitative portfolio management and factor investing, which is why we put so much emphasis on research, both within Invesco and in collaboration with academia.

In keeping with this, we have established an alliance with the University of Cambridge Judge Business School, whose reputation for research excellence is world-renowned. One output of this was the 2019 Consortium on Factor Investing, organized jointly by the business school's Centre for Endowment Asset Management (CEAM) and the Financial Management Association (FMA) and supported by Invesco and the Centre for Financial Econometrics, Asset Markets and Macroeconomic Policy (EMP) at Lancaster University. Building on this success, we have teamed up again with the centres at both Cambridge and Lancaster University (CEAM and EMP) to organize a 'Frontiers of Factor Investing Conference' to be held at Lancaster University in April 2020.

Such engagements provide an ideal platform for us to maintain contact with the academic world and to encourage close links between theory and practice. In our view, this is the best way to ensure that factor investing research stays relevant and continues to bring about cutting-edge results.

Enjoy reading about the 2019 Consortium on Factor Investing in the following pages.

A handwritten signature in blue ink, appearing to read 'H. Stein'.

Dr. Henning Stein
Global Head of Thought Leadership, Invesco
Fellow, Cambridge Judge Business School

Consortium on Factor Investing in Cambridge

By Dr. Harald Lohre and Joshua Kothe



Invesco Quantitative Strategies regularly engages with the academic community to promote research into factor investing. In February, we supported the 2019 Consortium on Factor Investing at the University of Cambridge, with the best paper contribution being awarded the Invesco Factor Investing Prize.

Co-hosted by Cambridge Judge Business School's Centre for Endowment Asset Management (CEAM) and the Financial Management Association (FMA), with support from the Centre for Financial Econometrics, Asset Markets and Macroeconomic Policy (EMP) at Lancaster University and Invesco Quantitative Strategies, the consortium put out a call for high-quality submissions in the field of factor investing and asset pricing. Alongside keynote speaker Ludovic Phalippou from the University of Oxford, who elaborated on the role of factors in the private equity domain, the conference featured six contributed papers that were discussed by senior faculty members and practitioners with respect to their academic and practical relevance. In this summary, we synthesize the main insights from the academic talks and explain how they can inform the current practice of factor investing.

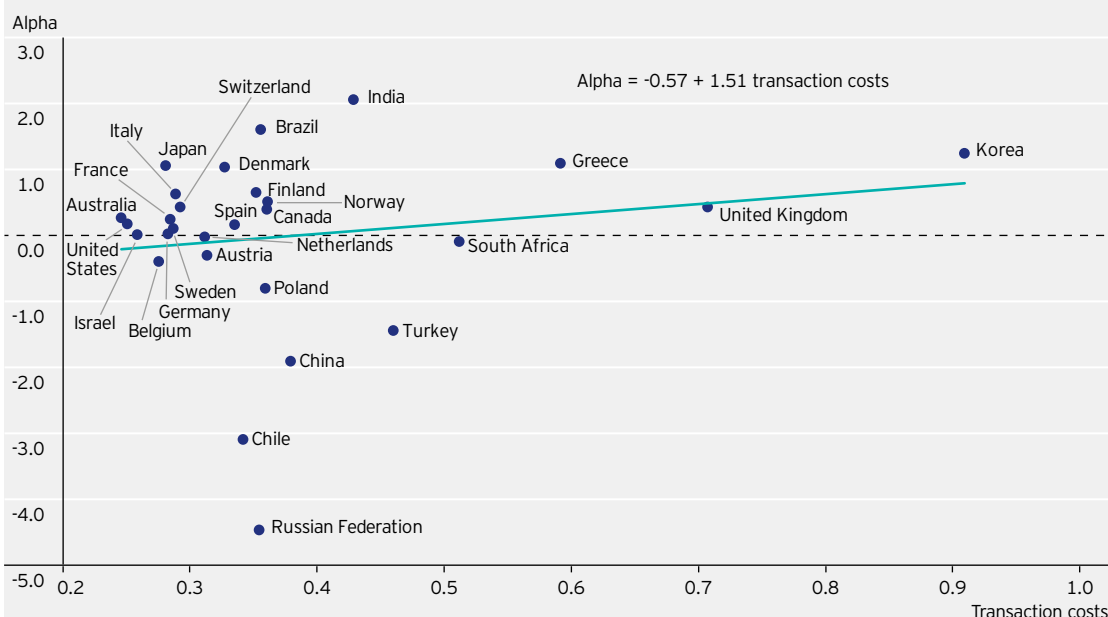
Are equities efficiently priced?

Söhnke Bartram from the University of Warwick and his co-author Mark Grinblatt (University of California) investigate the efficiency of global equity markets by analyzing how accurately market prices reflect the fair value of companies. For this purpose, the authors study an exhaustive global sample of 25,000 stocks from 36 countries based on a new measure of mispricing: fundamental point-in-time accounting information is used to come up with a fair company value. He and Grinblatt design a trading strategy that exploits the mispricing by investing in equities whose market value deviates from the fair value. This strategy earns significant excess returns in most regions but performs particularly well in emerging markets and Asia Pacific, resonating well with the idea of these markets being less efficient than developed markets (figure 1).

Bartram also elaborated on the characteristics that determine the degree of efficiency of equity markets. They find that a country's gross mispricing alpha is positively related to the prevailing level of transaction costs. This finding is economically intuitive: an arbitrageur only exploits mispricing if the alpha after transaction costs remains substantial. Thus, measuring efficiency absent transaction costs, markets with relatively high transaction costs will appear less efficient. At the same time, this suggests that the level of alpha, or excess returns, is related to the friction of capturing it in the respective countries.

Figure 1

Alpha and transaction costs: positive relationship between mispricing and transaction costs



Source: Bartram and Grinblatt (2018).

Overall, the strategy's alpha exceeds country-specific institutional transaction costs.

In a similar vein, the paper "Arbitrage Portfolios" presented by Andreas Neuhierl from the University of Notre Dame and his co-authors Soohun Kim (Georgia Tech) and Robert Korajczyk (Northwestern University) disentangles the relationship between characteristics and returns, and whether these characteristics represent factor loadings or possible

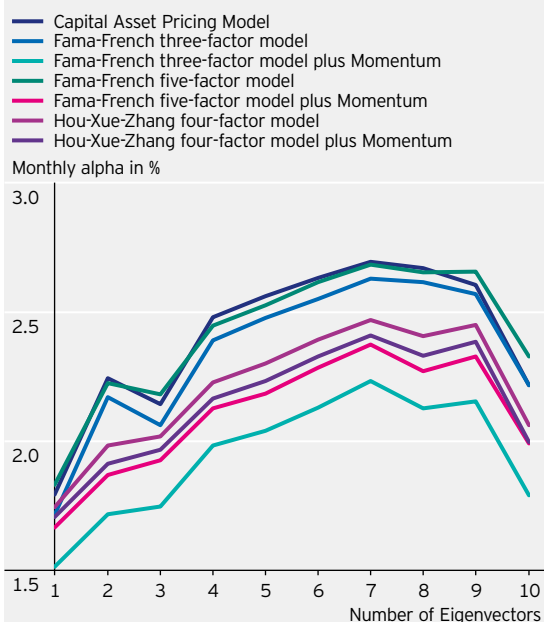
mispricing. They use the projected principal component analyses of Fan, Liao and Wang (2016) and apply this technique to a large panel of US stock returns from 1965 to 2014 in order to isolate possible mispricing from risk. The authors demonstrate that these projected principal components are certainly proxies for equity factor loadings, but not exclusively so. In fact, these components also contain information beyond that, hinting at a sizeable mispricing component. To exploit this relationship between characteristics and possible mispricing, the authors construct corresponding arbitrage portfolios. Empirically, these arbitrage portfolios generate Sharpe ratios in the order of 0.67 to 1.12, with an alpha against popular factor models of 1% to 2% per month. Moreover, these abnormal returns do not decrease significantly over time (figure 2).

The paper mainly constitutes a methodological contribution that will help estimate factors in a better way and gauge whether portfolios have attractive return properties above and beyond the premia associated with these factors. Yet, Andreas Neuhierl stresses that we can use their methodology to construct portfolios with attractive risk and return characteristics which are also largely orthogonal to known equity factors, thus separating risk from return and ultimately leaving investors with genuine excess returns.

Obviously, a common concern in such mispricing and factor strategies is that arbitrage activity leads to vanishing anomalies and declining excess returns. In his paper, "Understanding Alpha Decay", Julien Pénasse from the University of Luxembourg clarifies this very relationship between anomaly returns and alpha, ultimately endeavouring to answer the question as to whether past returns can be trusted and used as a proxy for expected returns. Financial textbooks often suggest that, if the excess returns associated with an anomaly continue after the anomaly has

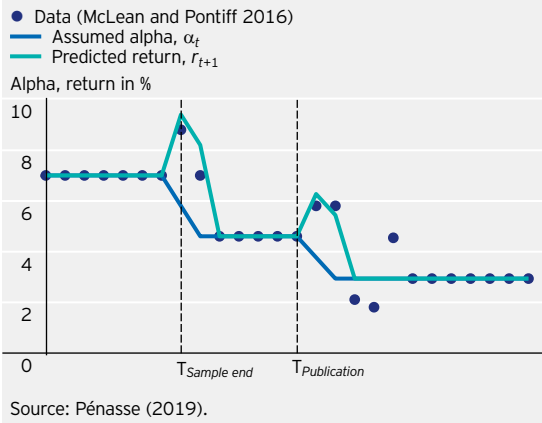
Figure 2

Monthly alpha of arbitrage portfolios for one to ten eigenvectors



Source: Neuhierl et al. (2019).

Figure 3
Anomaly versus mispricing: returns around publication of an anomaly



been published, it is a true factor. But, if it declines, excess returns may simply be the result of a spurious discovery or temporary mispricing.

However, when people learn of a discovered anomaly, they start to trade against it, thus arbitraging the anomaly away. Yet, the anomaly initially experiences more positive excess returns as prices adjust in reaction to arbitrage activity (figure 3). This insight challenges the common perception of alpha decay and empirical analyses that study only post-publication returns and may arrive at misleading conclusions. Acknowledging this insight, Pénasse emphasizes

Ludovic Phalippou: "Private Equity Laid Bare"

The keynote presentation at the consortium was held by Ludovic Phalippou from the University of Oxford's Saïd Business School, who elaborated on the question: "How Alternative are Private Equity Markets?". Phalippou stressed the importance of private equity, which has seen large inflows in recent years and controls companies in virtually every industry. Still, it remains a largely opaque industry. Phalippou addressed the question as to whether private markets should be categorized as alternative markets and investigates the overlap between private and public factors. He finds that four key dimensions split private markets, and these private factors are highly correlated to public factors, especially to "Quality-Minus-Junk" and "Betting-Against-Beta".



Source: Courtesy of Lyrique Private Equity

the importance of incorporating the possibility of alpha decay when making investment decisions, rather than relying on a long-term constant excess return.

What makes one stock riskier than others?

In his paper, "Turning Alphas into Betas: Arbitrage and Endogenous Risk", Thummim Cho from the London School of Economics & Political Science investigates characteristics that make some stocks riskier than others. It is common sense that stocks of companies with higher operational risks are also deemed riskier than stocks of companies with perceived safe business activities. However, Cho uncovers another important channel: if institutional traders are exposed to certain risks, they potentially transmit these risks to the stocks they hold. For example, levered hedge funds are exposed to funding risks – thus, the stocks traded by these investors also load on this type of risk. This observation translates into factor models, ultimately explaining why some stocks carry higher factor betas. This insight contributes to the practice of asset management as it stresses the importance of understanding the structure of the covariance matrix instead of only focusing on stocks with higher expected returns.

Combining and utilizing factors

Most researchers and practitioners agree that there has been an explosion in the number of factors, and it is not entirely clear how, if at all, investors can utilize this "zoo of factors" to build an optimal factor portfolio. For example, some factors may be redundant and explained by other factors. They may be data-mined or may already have been exploited by market participants. Thus, investors face significant uncertainty when combining and incorporating factors in their investment process. Francisco Barillas from the University of New South Wales and his co-author Jay Shanken discuss these "Real-time Portfolio Choice Implications of Asset Pricing Models" and conceive a procedure that optimally combines factors, taking the above described challenges into account.

The authors consider ten classic equity factors, including the factors of the Fama and French (2015)



Prof. Barillas presenting at Jesus College in Cambridge.

five-factor model, the momentum factor of Carhart (1997), the Hou, Xue and Zhang (2015) versions of the size, investment and profitability factors as well as the value factor from Asness and Frazzini (2013). While Hou, Xue and Zhang (2015) deem value and momentum to be redundant, Barillas and Shanken find both factors to be relevant when a more up-to-date definition of value is considered. They propose a Bayesian model averaging framework to obtain optimal factor allocations, while also taking model and parameter uncertainty into account. This asset allocation methodology can be performed with a given set of factors and implies a certain degree of shrinkage. It is advantageous in situations where factors may be the result of data mining or subsumed by other factors.

Invesco Factor Investing Prize

Based on the paper rankings by the consortium participants, the Invesco Factor Investing Prize was awarded to Daniele Bianchi (Queen Mary University of London), Matthias Büchner (Warwick Business School) and Andrea Tamoni (London School of Economics) for their paper, "Bond Risk Premia with Machine Learning". The authors investigated several supervised machine learning methods, like regression trees and neural networks, to forecast Treasury bond excess returns for different periods and maturities. Despite the growing interest in machine learning, these techniques remain a black box for many people. Against this backdrop, the authors thoroughly investigate the driving factors of predictability through the lens of neural networks and assess their relevance in financial markets applications.

They find that non-linear combinations of macroeconomic variables contain information about future interest rates that is not already included in the current term structure. Moreover, a neural network with a structure that is economically motivated by the clustering of different macroeconomic variables demonstrates strong out-of-sample predictability of bond excess returns. Given the emergent status of machine learning in financial markets applications, the findings of the paper are relevant to a broad audience; from market participants seeking different sources of returns predictability, to academics searching for new insights into the role of non-linearities in bond returns forecasting. In addition, the results in the paper are important considering that the authors' analysis is not based on big data and operates in a low signal-to-noise environment. As part of the award ceremony, Dr. Harald Lohre from Invesco Quantitative Strategies praised the authors' demanding and innovative work and conferred the prize, which came with a cash award of GBP 1000, to Daniele Bianchi.

Conclusion

Factor investing and asset pricing are highly promising areas of academic research that utilize state-of-the-art techniques and stretch across asset classes. The Consortium on Factor Investing in Cambridge brought together a select group of researchers to discuss the most recent advances in the theory and practice of factor-based asset management. Given the growing interest among investors in factor investing, which promotes allocating across factors rather than single securities, it is imperative for quantitative investment managers to remain at the forefront of academic research.



Prize winner Dr. Daniele Bianchi with Dr. Harald Lohre from Invesco Quantitative Strategies.

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About the speakers



Francisco Barillas

Francisco Barillas is an Associate Professor in the School of Banking and Finance at the University of New South Wales in Sydney, Australia. Prior to this, he was an Assistant Professor of Finance at Emory's Goizueta Business School and worked as an economist for the Bank of Canada. Francisco obtained his PhD from New York University in 2010. His research encompasses theoretical and empirical asset pricing, in particular portfolio choice, asset pricing tests and macrofinance.



Andreas Neuhierl

Andreas Neuhierl is an Assistant Professor at the University of Notre Dame and currently a Visiting Assistant Professor in the Booth School of Business at the University of Chicago. Neuhierl earned a PhD and MS in finance from the Kellogg School of Management at Northwestern University. His research focuses on asset pricing, financial econometrics and macroeconomics. His research has been published in leading journals in finance and economics.



Söhnke Bartram

Söhnke M. Bartram is a Professor of Finance at the University of Warwick. His immediate research activities center around issues in international finance and financial markets. Dr. Bartram's work has been presented at conferences organized by the NBER, CEPR, the American Finance Association, the Western Finance Association and the American Economic Association, published in the Journal of Finance, the Journal of Financial Economics and the Review of Financial Studies, and included in testimony before the US Congress House Financial Services Committee.



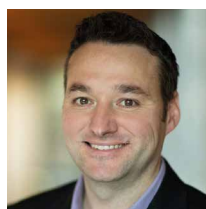
Julien Pénasse

Julien Pénasse, Ph.D., is research associate at the University of Luxembourg and scientific advisor at Unigestion. A former student of Ecole Normale Supérieure de Cachan, Julien Pénasse received a joint Ph.D. in Economics and Finance from ESSEC Business School and Tilburg University. Before enrolling for his thesis, he spent nearly six years in the trading room as a financial analyst and trader at Natixis. Julien's research includes asset pricing, macro-finance and the economics of art.



Daniele Bianchi

Daniele Bianchi is an Associate Professor in the School of Economics and Finance at Queen Mary University of London. His research interests span Bayesian methods, empirical asset pricing, financial econometrics and machine learning. His research has been presented at conferences organized by the American Economic Association (AEA), the National Bureau of Economic Research (NBER), the Econometric Society and the European Finance Association (EFA), among others. His publications include the Journal of Econometrics, the Journal of Business and Economic Statistics and the Journal of Financial Econometrics.



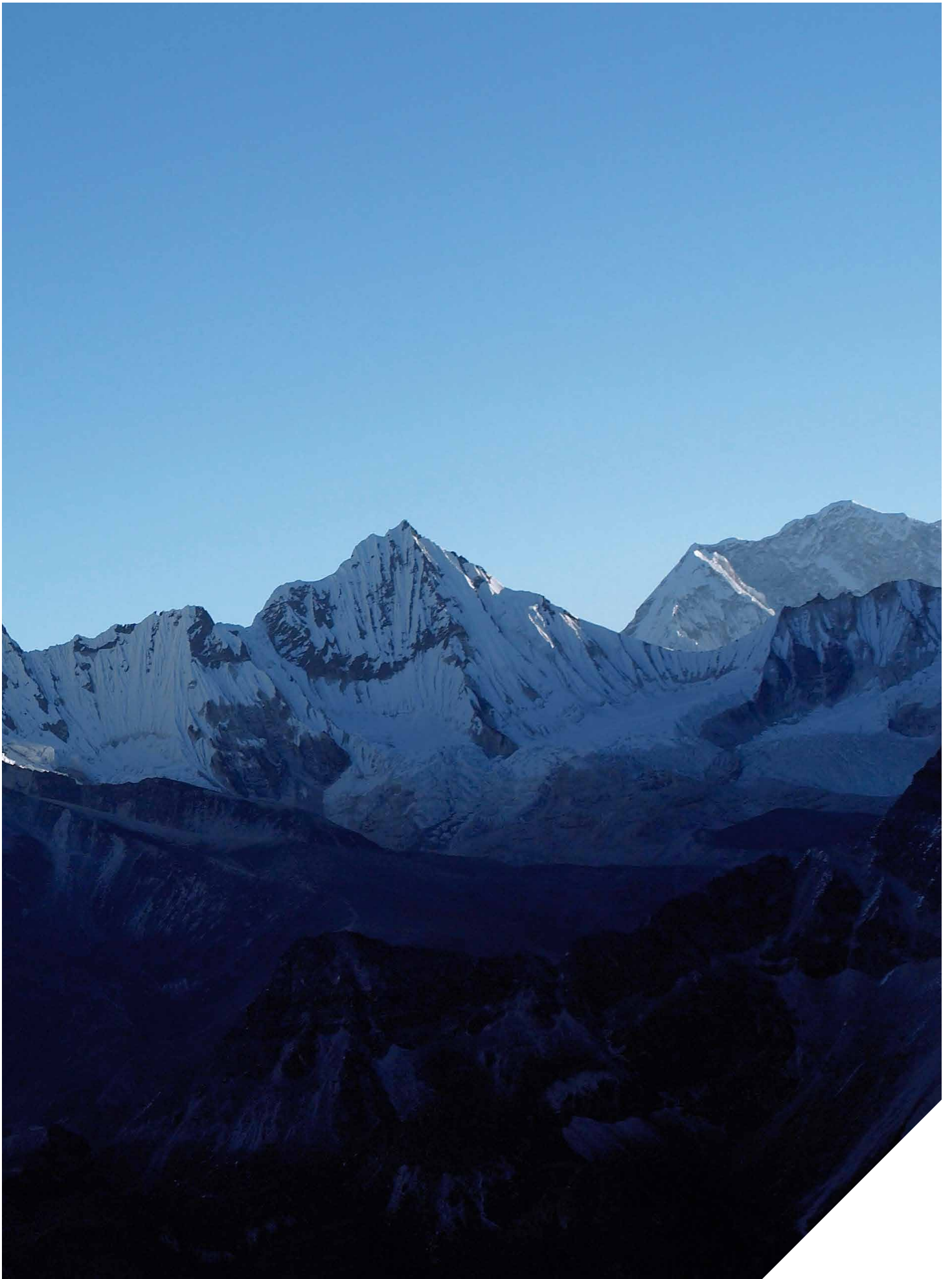
Ludovic Phalippou

Ludovic Phalippou is Professor of Financial Economics and Head of the Finance, Accounting & Management Economics group at the University of Oxford Saïd Business School. He specializes in the areas of private equity that are of interest to investors, such as fee tracking, interest alignment, and return benchmarking. Ludovic has strong links with the industry, routinely speaks at practitioner conferences and appears in the media. Ludovic's research papers have been widely cited in academia, in the press and in regulatory circles.



Thummim Cho

Thummim Cho is an Assistant Professor of Finance at the London School of Economics & Political Science. He received a PhD in economics from Harvard University in 2017 and a BA in mathematics from Cornell University in 2007. Prior to obtaining his PhD, he worked in consulting and was an army officer in South Korea. His main research area is asset pricing and his PhD thesis "Turning Alphas into Betas: Arbitrage and Endogenous Risk" is scheduled to be published at the Journal of Financial Economics.



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