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Factor investing in China: abundant opportunity, but beware of structural breaks

Creative solutions to common problems in fixed income portfolios

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Risk & Reward

Research and investment strategies

In the post-COVID world, China's role is widely expected to be far more important than ever before. We believe this is a good reason to analyze what the country has in store for factor investors.

As with all things new, factor investing in China holds a special appeal. There is abundant opportunity, but there are also notable differences compared to the investment world as we know it. In particular, given the historically rapid pace of change in China, the past may be a less reliable guide to the future than elsewhere. In this issue of Risk & Reward, three of my colleagues describe how they navigate the shifting Chinese investment landscape and show that factor strategies can be effective even when there are structural breaks in the data.

Other articles in this issue address fixed income investing in times of low market yields, real estate sector investing, the merits of estimating the covariance matrix and how to capture multi-asset class factor premia.

Given the complex dynamics of a post-COVID world, we know investors have questions. Can factor strategies help fixed income investors who are seeking higher yields? Which specialty real estate sectors still hold promise when the world as we know it has changed dramatically? Is it worthwhile to forecast covariance – or are old-fashioned return forecasts sufficient? How can retirement savers benefit from a multi-asset class factor approach? This new edition of Risk & Reward offers some answers.

Best regards,

Marty Flanagan
President and CEO of Invesco Ltd.

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In focus

Factor investing in China: abundant opportunity, but beware of structural breaks

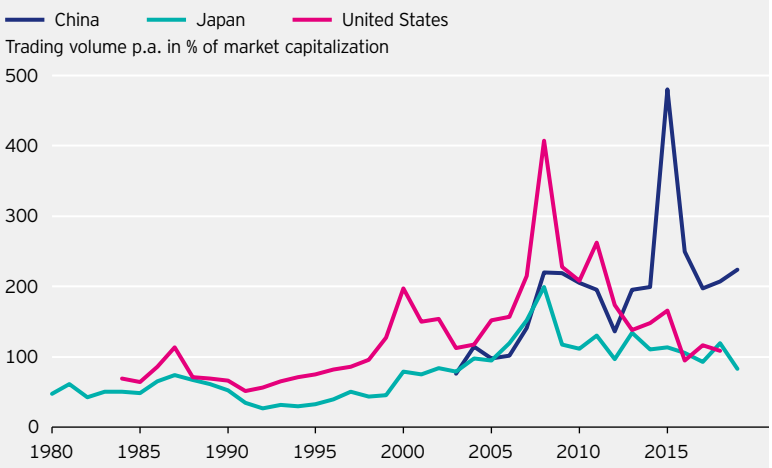
By Alexander Tavernaro and Andrew Tong

In brief
To avoid overfitting a model based on historical data, it is important to understand how policy affects market behavior. We describe important regulatory changes in the Chinese A-shares market over the past decades, analyze the impact of these changes on market efficiency and investigate the relevance of past data – and what it all means for factor investing strategies.

Factor investing has a relatively short history in China. But the abundance of alpha opportunities in the Asian powerhouse has been well noted by academics and practitioners alike. The breadth and depth of China's A-shares market, significant cross-sectional stock dispersion, high liquidity and competitive transaction costs make it an attractive universe for alpha-oriented quants. What really sets the market apart, however, is the unique development of its regulatory landscape over the past three decades, which has significantly influenced factor behavior.

China today is the second-largest economy in the world, and China's A-shares market is the world's second-largest equity market. It is very liquid, with an annual turnover ratio of more than 200%, compared to around 100% in the US and Japan (figure 1). One reason for this immense trading volume may be China's large share of retail investors, which is often cited as an important reason for the market's comparatively high volatility and inefficiency.

Figure 1
High turnover in China



Source: The World Bank. Domestic shares for China (A-shares), Japan and the US. Latest data as at 31 December 2019.

The peculiar combination of high liquidity and market inefficiency in the A-shares market has drawn the attention of quantitative investors.

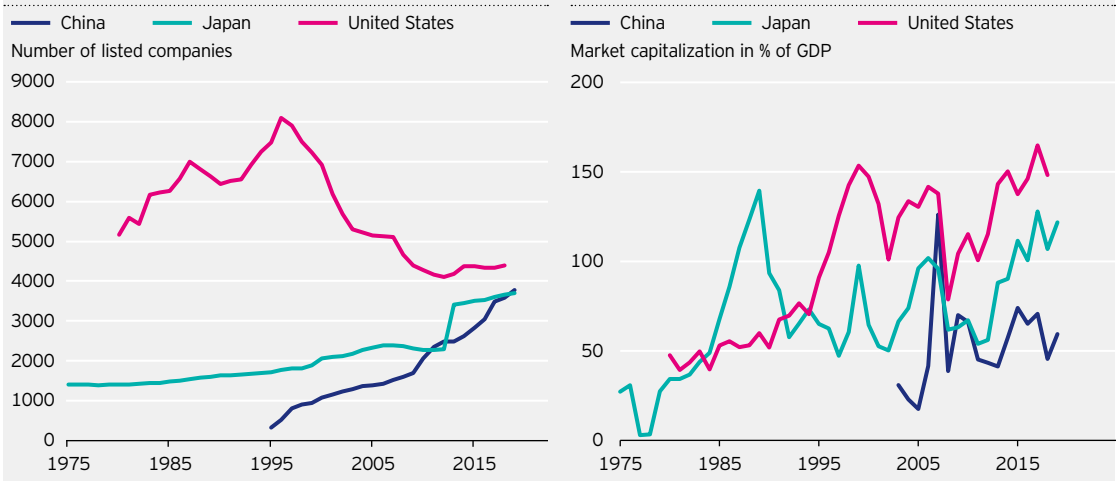
While the peculiar combination of high liquidity and market inefficiency in the A-shares market has drawn the attention of quantitative investors, avid participation by retail investors is not the only source of systematic inefficiency. Effects from top-down policies have also played an important role, albeit often only temporarily. We will now examine some notable policy events and their implications.

2005 – 2010: The end of Non-Tradeable Shares

The Non-Tradeable Shares (NTS) reform in 2005 was one of the most important regulatory changes in Chinese stock market history. In the early 1990s, the Shanghai and Shenzhen exchanges were established as part of China's economic reform, which introduced market-based mechanisms to its centrally planned economy. The initial privatization of State-Owned Enterprises (SOE), which had become dominant players during the strong economic growth of the 1980s, helped to dilute government ownership with new initial public offering (IPO) capital. It also created a unique split-share structure. The government's majority ownership in these companies was retained in the form of NTS held by the state or its entities, which

Growth potential

Even though the number of listed companies has increased significantly in recent years, China is still somewhat behind in terms of market capitalization as a percentage of GDP. This bodes well for the market's longer-term growth potential.



Source: The World Bank. Domestic shares for China (A-shares), Japan and the US. Latest data as at 31 December 2019.

accounted for about two-thirds of all outstanding shares by the end of 2004. These NTS afforded the same right to the holder as Tradable Shares (TS), but they could not be traded in the public market. This created a major hurdle for corporate governance: NTS holders wielded majority control of the firm but had little incentive to improve share price performance or protect minority shareholders´ rights. Large NTS ownership was a hurdle for privatization and market reforms, and led to a less attractive capital market for new entrants seeking listing.

In 2005, the China Securities Regulatory Commission (CSRC) announced a reform of NTS policy, requiring their holders to compensate TS holders in exchange for the right to trade NTS in the future. This, in effect, converted all NTS to fully tradable shares; the process was largely completed by the end of 2010 (figure 2).[1]

Implications for factor performance

The increase in market liquidity may have created downward price pressure on NTS stocks with a book value that was below the market price after adjusting for the compensation to TS holders. Furthermore, there is reason to believe that firms with previously weak governance benefited most from the alignment of shareholder interest through the reform. As a result, the NTS reform had a considerable impact on factor performance from 2005 to 2010:

First, during the announcement and implementation period, stocks of companies with a local auditor – and thus perceived as having weaker governance – performed significantly better than those with an international auditor (Beltratti and Bortolotti, 2007).

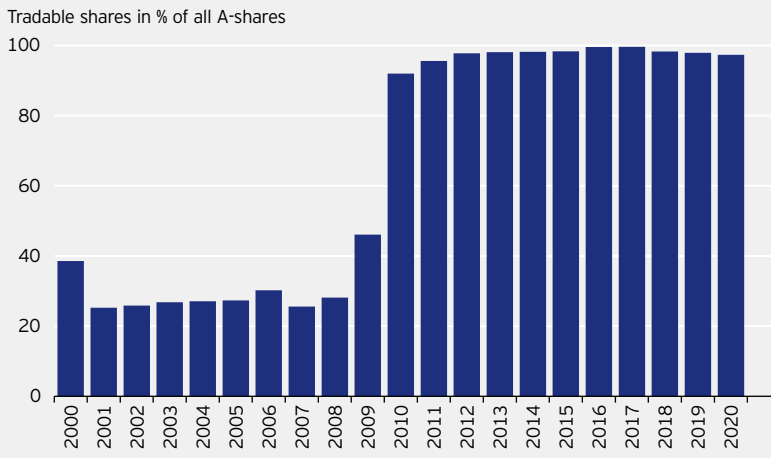
Second, 22% of the 1209 companies that implemented the reform from 2005 to 2007 promised dividends or other shareholder-friendly incentives, which may have boosted performance of the dividend yield factor in the period.

At the same time, market sentiment was much better than the possibility of share dumping by the NTS holders would have suggested. This was likely due to the selling restriction placed on the originally non-tradeable shares in the first 12 to 36 months after implementation of the reform. Although the market rose 126% (CSI300 Gross, CNY) in the following year, the onset of a liquidity rush after expiry of the lock-up period was considered to have played a role in the market crash of 2008.

2013 – 2016: Rise of reverse mergers

Initial public offerings serve an important role when it comes to bridging the supply of and demand for capital in a market economy. Historically, the IPO application process in China worked on an approval basis, with companies wishing to be listed subject to a rigorous, lengthy vetting process by the CSRC to ensure they meet all the necessary criteria in terms of profitability, governance and other factors. In 2013, the government proposed an IPO reform: the application-based process would be replaced by a registration-based one with more focus on corporate disclosures. Implementation, however, was delayed until recent years, when the newer STAR Market and ChiNext boards began adopting the more efficient process.

Figure 2
Almost all shares now tradeable

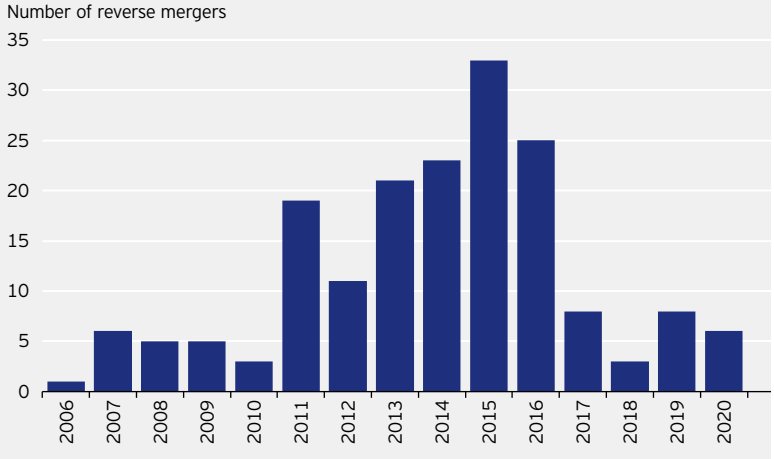


Source: Wind. Data as at 8 December 2020.

The costly wait and uncertainty associated with an IPO approval caused many private companies seeking public capital to take an alternative route: reverse mergers. A wave of backdoor listings (a private company "taking over" a, usually dormant or relatively low-valued, listed company) rose to nearly 20 per year from 2011 to 2016 (figure 3). This spurred demand for listed companies with a higher probability of becoming the target of such a reverse merger. ST stocks (listed companies that suffer losses for two consecutive years or more are labeled "ST", Special Treatment, to represent their risk of delisting), which have poor fundamental and residual value, typically fell into this category.

Ultimately, in September 2016, the CSRC issued stricter rules on stock mergers, which imposed requirements similar to those for an IPO. Coupled with an acceleration in domestic IPO approvals, the number of reverse mergers has dropped significantly in recent years. Over the last two years, the CSRC has tried to revitalize the M&A market with a more

Figure 3
More firms engaged in reverse mergers from 2013 to 2016 as IPO approvals slowed



Source: Wind. Data up to year-end 2020.

efficient examination and approval process as well as relaxed fundraising regulations. It has also renewed its pledge to convert the current approval system for mainboard listings to a registration-based system.

Implications for factor performance
Lee et al. (2017) found that, before the reform, firms characterized by small size, low profitability, high delisting risk (ST status) and low ownership concentration tended to become the targets of reverse mergers. This also explained why ST stocks outperformed the CSI800 Index by 52% p.a. from 2011 to 2016. Among ST stocks, companies with lower EV/Asset also earned a higher premium vs. CSI800 (+58.5%, IC=0.63) than those with lower EV/Asset (+45.3%, IC=0.61) ratios, suggesting that firms with lower total takeover cost compared to their assets (which may also be written off in the future) had greater appeal.

When the IPO reforms are eventually extended to the Main Boards, there is good reason to believe that some of these IPO-related anomalies will change or even disappear.

2007: Less red tape for private placements
Corporate refinancing took a hiatus after implementation of the NTS reform, and was restarted in 2006, when CSRC published the Regulation for Listed Companies. In 2007, details about private placement regulation were also unveiled, marking the beginning of vibrant growth in the private placement market (figure 4). An IPO drought between 2012 to 2014, and after the stock bubble crash in 2015, also strengthened the role of private placements as the primary capital raising channel for many companies.

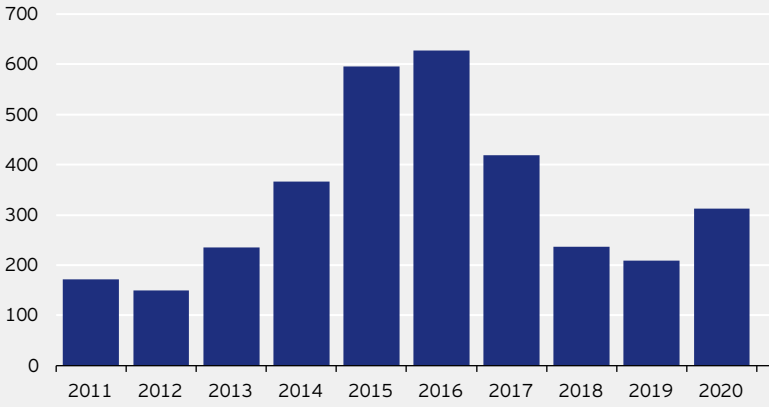
Firms typically use private placement to raise capital for acquisitions, project financing or shoring up capital. Acquisition was the primary motivation in more than half of placements since 2006 and is often viewed as a positive management signal in China. Although a portion of them were linked to reverse mergers, most were legitimate acquisitions of assets for business expansion or transformation in step with China's economic development.

Implications for factor performance
The strong performance of companies offering private placements was heavily correlated with ROE, issuance ratio, lock-up period and short-term price momentum, but may also have been influenced by market sentiment (Liu, 2016). In an efficient market, we would have expected firms that issue stock (lower investment quality) to subsequently earn weaker returns relative to other firms (Greenwood R. et al., 2010). But the unusually good performance of companies offering private placements indicates a systematic anomaly that may continue in the future.

2004 – 2016: More dividends, please!
Information economics theorizes that companies pay dividends to signal sound prospects and good corporate governance, thus reducing agency risk (Jensen, 1986). Considering China's concentrated ownership structure, dividends could help enhance minority shareholders' rights and prevent the inefficient deployment of companies' free cash flows.

Figure 4
A private placement boom

Annual number of private placements for China A-shares



Source: Wind. Data as at 31 December 2020.

In 2004, CSRC provided its earliest guidance, stating that listed companies should implement proactive profit distribution. Two years later, in 2006, it reiterated that shareholders of listed companies are entitled to obtain dividends and other forms of interest distribution.[2] In 2008, the CSRC further specified the rules by requiring total cash dividend payouts to be no less than 30% of the average annual distributable profits in previous the three years.

Implications for factor performance
The regulator's support for dividends may have had some impact on the performance of stocks with a high dividend yield, which outperformed the market from 2005 to 2009 and again from 2013 to 2016, closely mirroring the periods after policy enactment (figure 5). In these two periods, the "dividend yield factor" proved particularly successful.

Figure 5
Outperformance of dividend yield factor from 2005 to 2009 and 2013 to 2016

Dividend yield, percentage points, 31 December 2014 = 0

Source: MSCI. A-shares, cumulative daily factor return for dividend yield from 31 December 2004 to 14 December 2020. Factor returns are based on multivariate cross sectional regression of market, industry and risk indices factor exposures on China A-shares stock universe. Dividend factor exposure is calculated using the stock's historical dividend yield in the previous 12 months and forecast dividend yield in the next 12 months. **Past performance is not a guide to future returns.**

2009 – 2019: Institutionalization
There is a common perception that retail investors in China lack the ability to price and time their investments efficiently. Their substantial share in trading volume has thus contributed to the historically high volatility of the China market, as well as to factor premia such as reversal and liquidity.

However, there are early signs pointing to a potential shift in the investor base. Both markets for higher growth companies (the new STAR Market, introduced in 2019, and Chinext, which started in 2009) require a higher level of capital and experience from investors. Retail investors who cannot meet such requirements can only participate via mutual funds or ETFs. This has boosted the growth of mutual funds as they become a popular means for retail investors to participate in the bull run this year. According to Wind, more than 1,100 new funds were launched in 2020, raising a total of USD 373bn.

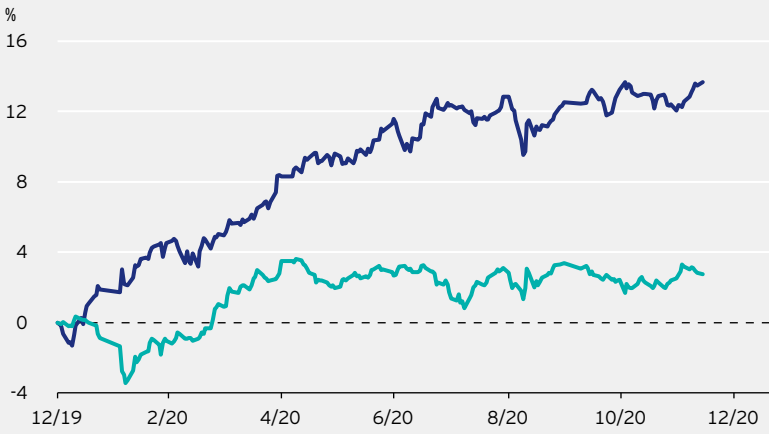
Furthermore, CSRC has also consolidated the Qualified Foreign Institutional Investors (QFII) and RMB Qualified Foreign Institutional Investor (RQFII) schemes for foreign investors, scrapped their quotas and enhanced their appeal in various aspects.

Implications for factor performance
As the investor mix changes, past factor anomalies may be replaced by other factor premia that exist in more efficient markets. For instance, in 2020, the reversal effect, which is strongly associated with retail investor behavior, has weakened significantly relative to price momentum (figure 6).

Conclusion
We have examined several important reforms related to historical ownership structure, primary market operation and corporate governance in China. Their effects on the market often reveal themselves in the behavior of factors. Therefore, as factor investors, we must treat past data with caution. The challenge for factor investors in China is not so much the length of time series or the availability of data, but the relevance of past data for today, given how rules and conditions have changed over the years. In this regard, in-depth examination of the causal effects of quantitative factors and an ongoing challenge of assumptions in the face of changing regulatory and economic landscape will be essential for maneuvring the upcoming bends and curves in the road.

The challenge for factor investors in China is the relevance of past data for today.

Figure 6
More momentum, less short-term reversal



Source: MSCI. A-shares, cumulative daily factor returns from 31 December 2019 to 14 December 2020. Factor returns are based on multivariate cross sectional regression of market, industry and risk indices factor exposures on China A-shares. Momentum factor exposure is calculated using the stock return in the previous 12 months with a lag of 1 month. Short-term reversal factor exposure is calculated using the stock return in the previous 1 month multiplied by -1. **Past performance is not a guide to future returns.**

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About the authors

Alexander Tavernaro, CFA, CAIA
Senior Portfolio Manager
Invesco Quantitative Strategies
Alexander is a Senior Portfolio Manager for Invesco´s Quantitative Strategies team. In this function, he is responsible for multiple global and regional equity portfolios.

Andrew Tong
Senior Portfolio Manager
Invesco China A Investments, Invesco Quantitative Strategies
Andrew Tong is the co-manager of Invesco's China A-Shares Quant strategies and has long-standing experience in factor modeling and portfolio construction.

Notes

1 To ensure an equitable outcome, the exact compensation terms were to be negotiated between the shareholders of each firm, requiring a resolution approved by at least two-thirds of the TS holders and two-thirds of all shareholders. The premium paid to the TS holders eventually averaged to about 30%.
2 CSRC (2204, CSRC (2006)).

"Quant strategies may become more mainstream."

Interview with Chin Ping Chia, Alexander Tavernaro and Andrew Tong

Chin Ping Chia

Alexander Tavernaro

Andrew Tong

Risk & Reward spoke to Chin Ping Chia, Head of China A Investment, Business Strategy & Development, Alexander Tavernaro and Andrew Tong about the Chinese A-shares market and factor investing in China.

Risk & Reward
In light of the extraordinary events in 2020, what has changed about the China investment landscape?

Chin Ping Chia
In a year characterized by the global pandemic and US-China trade tensions, the A-shares market was among the best performing equity markets, supported by strong domestic investor sentiment and global capital flows. While traditionally, investment decisions have been driven mainly by index inclusion, China's economic rebound and policy reforms have begun to take center stage in terms of allocation signals in recent years.

The most recent Invesco Global Sovereign Asset Management Study confirms the growing interest in Chinese stocks. Global sovereign wealth funds singled out China as the one market where their allocations were clearly increasing. Over 90% of large sovereigns, with more than USD 100 billion assets under management, indicated an exposure in China. Interestingly, close to four-fifths of allocations to China were cited as active decisions rather than benchmark driven.[1] And about 85% of these active allocations were long-term and strategic.

Alexander Tavernaro
Unlike Europe, China is still in a mid to high-growth stage of economic development. Its higher return potential is attractive for European asset owners, who need to optimize their allocations to meet increasing pension liabilities.

But, even though China is the world's second-largest economy, its weight in global equity portfolios remains limited. As China is projected to overtake the US over the next ten years, more investors may opt for a stand-alone allocation to China to better reflect its idiosyncrasies. Many investment consultants even now advocate a greater allocation to China, not least because rapid deregulation of the A-shares market in recent years has greatly enhanced its accessibility.

Andrew Tong
2020 marked the 30th anniversary of the A-shares market, which traces its beginnings to the establishment of the current Shanghai Stock Exchange in 1990. The impact of the pandemic, as well as a wave of trade protectionism and political tensions, may have accelerated market reforms. As China embarks on economic transformation under the "dual circulation" model – strengthening consumption and the domestic economy – we expect the market to evolve even more quickly over the next ten years. Moreover, as experience from the US and Japan shows, capital market development and stability are often key drivers of mutual funds growth.

The current 14th 5-year plan spells out the importance of strengthening wealth management – don't forget that China's population is aging too. Together with the opening of China's market to global investors, we believe this will drive steady market growth.

Risk & Reward
How does all this affect quant investing in China? Are you seeing more opportunities or risks?

Chin Ping Chia
Quantitative investing in China has only started to gain a foothold in the last ten years, since enhanced index strategies based on systematic factor premia were introduced. Today, there are more than 300 mutual funds using quantitative techniques. Active quant or enhanced index products have more than USD 250 billion in assets under management. But that's only a small fraction of the overall mutual fund market in China. There is clearly significant growth potential, particularly compared to other countries.

Andrew Tong
In my opinion, quant strategies could become more mainstream for a number of reasons. They are cost efficient and scalable, which makes them well-suited for a large and diverse universe like the A-shares market. Their natural advantage in handling large

datasets can provide an edge in more quickly and effectively processing digitized information. And, as the market grows and matures, we expect investors will increasingly look for alpha rather than pure beta. Quantitative strategies that can deliver pure alpha or smart beta are likely to be in greater demand as time goes on.

Risk & Reward
We often hear about the dominance of retail investors in the A-shares market. What is your view?

Alexander Tavernaro
Chinese investors have a strong domestic bias, often leading to a low correlation of Chinese stocks with the markets in the US and Europe. This creates diversification opportunities for global investors, more than many other emerging markets. But a large proportion of retail investors can also lead to overheating risk. Last year, however, activity was more subdued, which greatly alleviated investors' fears of a new bubble.

Chin Ping Chia
Chinese retail investor behavior is well studied. We think that, with the right expertise and skill, the A-shares market can be one of the best alpha hunting grounds investors can find. Over the years, active managers in China have been able to generate outsized returns. From 31 December 2007 to 31 December 2019, even the median manager outperformed the benchmark (the CSI 300 Index) by more than 4 percentage points annually. Top quartile managers outperformed by over 12 percentage points per year.[2]

Risk & Reward
What about traditional quant factors?

Andrew Tong
Interest is growing in quantitative investing in China, perhaps because institutional investors – both onshore and offshore – are becoming more sophisticated. Adjusted for differences in market structure, traditional factors such as Value and Size may be at least as effective in China as in the US, if not more so. In addition to the retail investor bias, there are significant regulatory effects. We've analyzed the Non-Tradable Shares (NTS) reform and phenomena like reverse mergers, and what they have meant for market behavior and factor performance. Some of the results are included in our article in this edition of Risk & Reward.

Alexander Tavernaro
Challenges arise when traditional factors don't work as accustomed. This has been the case for the Value factor over the past decade, especially in developed markets. China may still be different, but that could change when its economy advances. Our recent innovations in natural language programming and artificial intelligence may then help to improve diversification of factor alphas.

Risk & Reward
How do you deal with factors that are specific to the Chinese market?

Andrew Tong
Since we use structural growth as well as alpha opportunities, we have to distinguish between systematic and idiosyncratic risks. Our research in China was built from the ground up to avoid the pitfalls of over-extrapolating from the behavior of other emerging markets. For instance, even though a longer data history is generally good, data from before the NTS reform, which began in 2005, bear little relevance in today's vastly different market.

Instead, we study various factors' efficacy in different market segments – e.g. large caps vs. small caps. We examine factor rationales with the help of additional macro and market microstructure data. Especially in China, investors should not be afraid to challenge conventional wisdom.

Risk & Reward
Thank you for your insight.

Notes
1 Invesco (2020): Figure quoted is based on a sample of respondents to the study. Some 139 chief investment officers, heads of asset classes and senior portfolio strategists (68 sovereign funds and 71 central banks) were interviewed between January and March 2019 for the study. These investors are responsible for managing over US$20 trillion in assets (as of March 2019).
2 Source: Wind, data from 31 December 2007 to 31 December 2019. "Active Equity Funds" refer to all onshore China A active funds with over 60% in equity but excluding passive and quant funds, with more than 12 months performance history. Median and top quartile managers refer to managers who outperformed the 50th and top 25th percentile fund performance sample respectively. Past performance is not a guide to future returns.

About risk
The value of investments and any income will fluctuate (this may partly be the result of exchange rate fluctuations) and investors may not get back the full amount invested. When investing in less developed countries, you should be prepared to accept significantly large fluctuations in value. Investment in certain securities listed in China can involve significant regulatory constraints that may affect liquidity and/or investment performance.

Creative solutions to common problems in fixed income portfolios

By Ward Bortz and Paisley Nardini

In brief

In three case studies, we show how one might analyze and then adjust fixed income allocations to address common challenges in fixed income portfolios. Case study 1 deals with improving returns of a core allocation in times of low interest rates. Case study 2 highlights techniques to improve high yield exposure. Case study 3 addresses how one might adjust credit exposure without changing the duration or yield profile of the portfolio. In all three studies, we use novel analytical techniques to analyze and modify baseline allocations.

Due to a lack of tools, many investors may not be equipped to adequately assess the risks in their bond portfolios. Providing investors with risk analytics, similar to familiar equity risk measurement tools, is part of our approach to multi-asset investment solutions. And we've developed proprietary tools to support this next generation of fixed income analytics. In three case studies, we show how they may be applied to solve common problems in fixed income portfolios.

Though portfolio allocation has a strong influence on future returns, there are important distinctions among asset class exposures. Understanding the risk and factor exposures of a portfolio is key to pinpointing desired market exposures, which is ultimately what allows investors to meet their objectives.

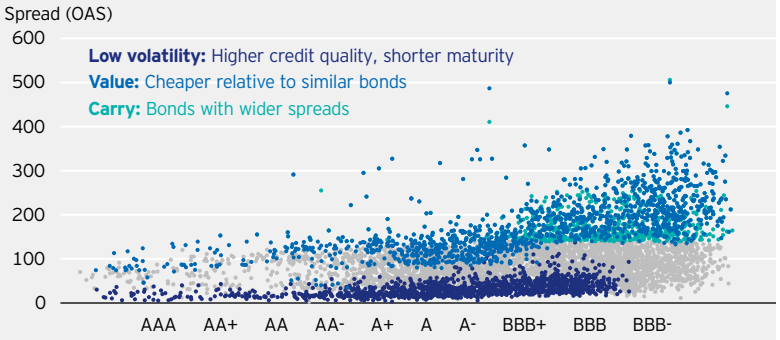
Three types of concerns fixed income investors often have include: increasing total returns in a low yield environment, obtaining efficient high yield market exposure and adjusting credit exposure without sacrificing yield. In three case studies, we illustrate how these needs may be addressed using an analytical, factor-based approach to understanding and adjusting return drivers in fixed income portfolios.

Fixed income factors
When assessing the risk exposures of fixed income portfolios, we find that three key factors tend to drive returns, in addition to traditional return drivers like duration and credit:

- The **low volatility factor** explains the higher risk-adjusted excess return potential of bonds with the most stable prices in the investment universe. These bonds typically have shorter maturities and lower default risk, as measured by their ratings. They tend to be good stores of value in times of market stress.
- The **carry factor** explains the higher excess return potential of bonds with wider spreads relative to the broad market. These bonds typically have longer maturities, lower ratings and are in sectors with the widest spreads. They tend to be the riskiest bonds in the universe.
- The **value factor** explains the higher excess return potential of bonds priced at the largest discounts relative to their historical default rates. The value factor groups bonds with similar ratings and identifies the cheapest (or widest-spread) bonds within those groups.

Figure 1 depicts these factors and places them in the context of credit quality and spread. Each dot represents a bond from the Bloomberg Barclays US Corporate Bond Index. Low volatility bonds (dark blue), which tend to be shorter in duration and higher in credit quality, are clustered toward the bottom of the chart. Carry bonds (green), which have wider spreads and tend to be lower in credit quality, are clustered toward the right. Finally, value bonds (blue), which represent the highest-spread securities in each rating category, span the top of the range. The remaining bonds (grey) do not fall into any of the three categories.

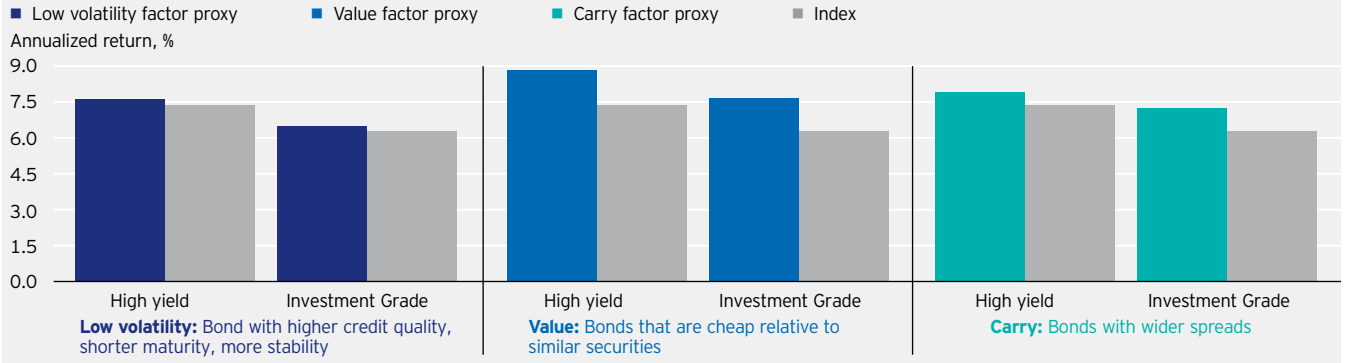
Figure 1
Visualizing factors in the US investment grade bond universe



Source: Bloomberg, Invesco calculations. Data as at 31 December 2020.

Figure 2 shows that all three clusters – the three factor proxies – had higher historical returns than the broad market in both high yield and investment grade. Of course, these factors are not the only drivers of return in fixed income. Weighting portfolio allocations along the lines of interest rates, foreign exchange, regions and credit, and implementing asset class and credit quality tilts also impacts returns.

Figure 2
Factor returns in US investment grade and high yield bonds



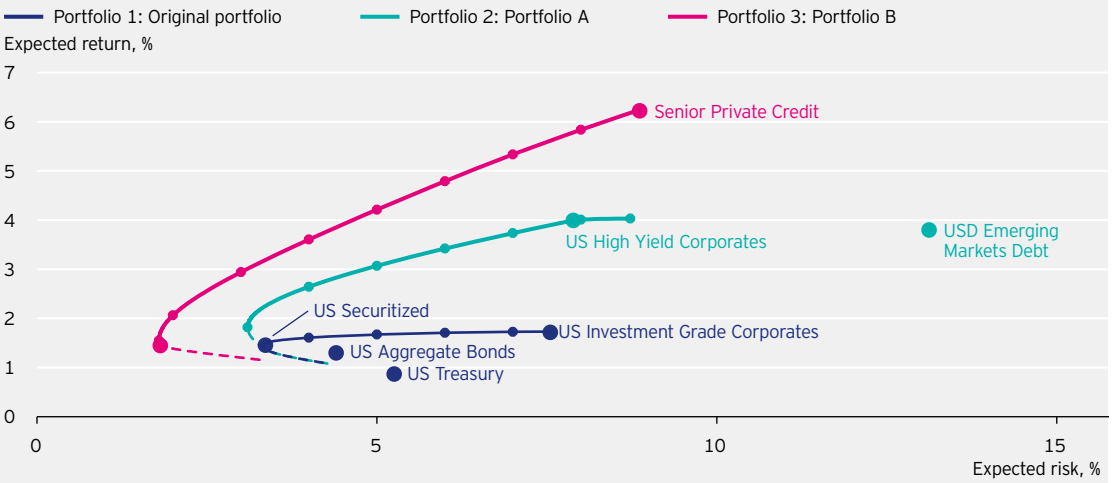
Source: Bloomberg Barclays US Credit Index for US investment grade bonds; Bloomberg Barclays US Corporate High Yield Index for US high yield bonds. Based on data from 1 December 2000 to 31 December 2020. Please see appendix for more information on the mathematical process underlying the value, carry and low volatility factor proxies.

Case study 1:
Improved returns from core fixed income
In this example (figure 3), the portfolio includes standard US bonds, as reflected in the Bloomberg Barclays US Aggregate Bond Index. To potentially enhance returns, we add US high yield and US dollar-denominated emerging market (EM) sovereign debt to portfolio A. To portfolio B, we also add US senior private credit.

Despite adding US high yield corporate bonds and US dollar-denominated emerging market debt, which carry higher risk on a standalone basis, the low (and even negative) correlations of those assets to US core bond sectors (figure 4) enable the portfolio to achieve higher returns for a given level of overall risk. For investors who may invest in private credit markets, expected returns can be further increased while maintaining a level of risk similar to that of public credit assets.

As figure 5 demonstrates, the overall expected risk of high yield (7.7%) is only slightly lower than that of senior private credit (7.9%), but the individual

Figure 3
Diversifying beyond core bonds



Source: Original portfolio = Bloomberg Barclays US Aggregate Bond Index; Portfolio A = original portfolio + US high yield and US dollar-denominated emerging market (EM) sovereign debt; Portfolio B = Portfolio A + US senior private credit. Invesco Investment Solutions Capital Market Assumptions, MSCI BarraOne Forward-Looking Risk Model. Return and risk assumptions are forward-looking in nature, annualized, reflecting a 10-year investment horizon. See appendix for asset class proxies. Data as of 30 September 2020.

Figure 4
Expected correlations

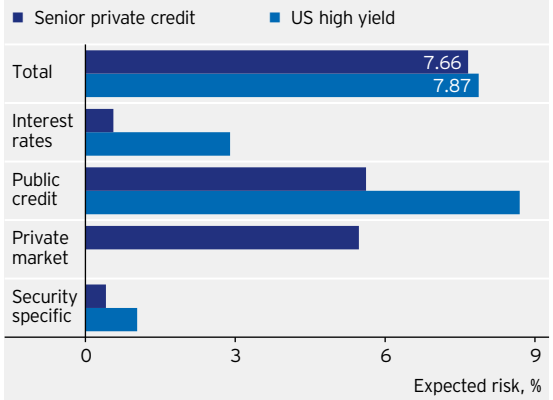
	US Aggregate	US Treasuries	US IG Corporates	US Securitized	US High Yield	USD EM Debt	Senior Private Credit
US Aggregate	1.00						
US Treasuries	0.87	1.00					
US IG Corporates	0.86	0.57	1.00				
US Securitized	0.69	0.55	0.40	1.00			
US High Yield	0.30	-0.13	0.67	0.06	1.00		
USD EM Debt	0.42	0.09	0.62	0.20	0.71	1.00	
Senior Private Credit	0.03	-0.26	0.34	-0.10	0.66	0.44	1.00

Source: Invesco Investment Solutions Capital Market Assumptions, MSCI BarraOne Forward-Looking Risk Model. See appendix for asset class proxies. Data as of 30 September 2020.

macro factor exposures are quite different. This explains why replacing part of the high yield allocation with senior private credit can lead to much better diversification and a much better risk-return profile.

Replacing part of the high yield allocation with senior private credit can lead to a much better risk-return profile.

Figure 5
Decomposition of macro factor risk exposures of US high yield and US senior private credit



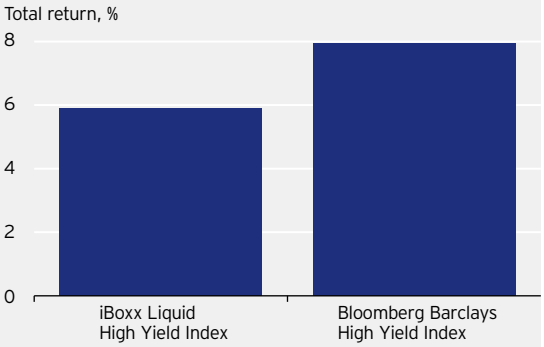
Source: Invesco Investment Solutions Capital Market Assumptions, MSCI BarraOne Forward-Looking Risk Model. Risk assumptions are forward-looking in nature, annualized, reflecting a 10-year investment horizon. See appendix for asset class proxies and details on risk modelling for private market assets. Data as of 30 September 2020.

Case Study 2:
Efficient high yield exposure

Factor exposures may also be used to address another common problem in fixed income – persistent underperformance of high yield indices relative to the broad market. In general, the low interest rate environment has caused investors to consider adding higher yielding, lower credit quality investments to their fixed income allocations, to drive income higher. This can be problematic, however, since there can be significant performance dispersion within the high yield market, driving performance differences between different passive high yield indices. The Bloomberg Barclays High Yield Index is the most common benchmark for active portfolios and a proxy for the broad high yield market. The iBoxx Liquid High Yield Index is another common high yield bond index. In the period starting January 2002, the Bloomberg Barclays Index beat the iBoxx Index by two percentage points (figure 6, gross of fees).

The iBoxx Index tilts away from factors we have found to deliver positive benchmark-relative returns over time, perhaps explaining some of its underperformance. Therefore, introducing factor exposure via an allocation to a factor-based high yield proxy that explicitly tilts toward value, low volatility and carry bonds may lead to higher returns relative to the broader market, assuming factors continue to deliver the way they have in the past.

Figure 6
Performance of common high yield indices since 2002



Source: Bloomberg L.P., 1 January 2002 to 7 December 2020. **Past performance is not a guide to future returns.**

The iBoxx Index tilts away from factors we have found to deliver positive benchmark-relative returns.

In this example, the original portfolio has a simple allocation to two passive fixed income indices (figure 7) – an aggregate index and a high yield index – with high yield exposure obtained via an allocation to the iBoxx High Yield Index. The iBoxx Index has underperformed the broad market, as proxied by the Bloomberg Barclays High Yield Index.

To address this underperformance, we compare the original portfolio to an allocation that obtains its high yield exposure from a "factor-based" high yield proxy. The two portfolios are similar in terms of asset allocation and duration (figure 8), but the yield of the modified portfolio is higher due to its greater allocation to value and carry bonds.

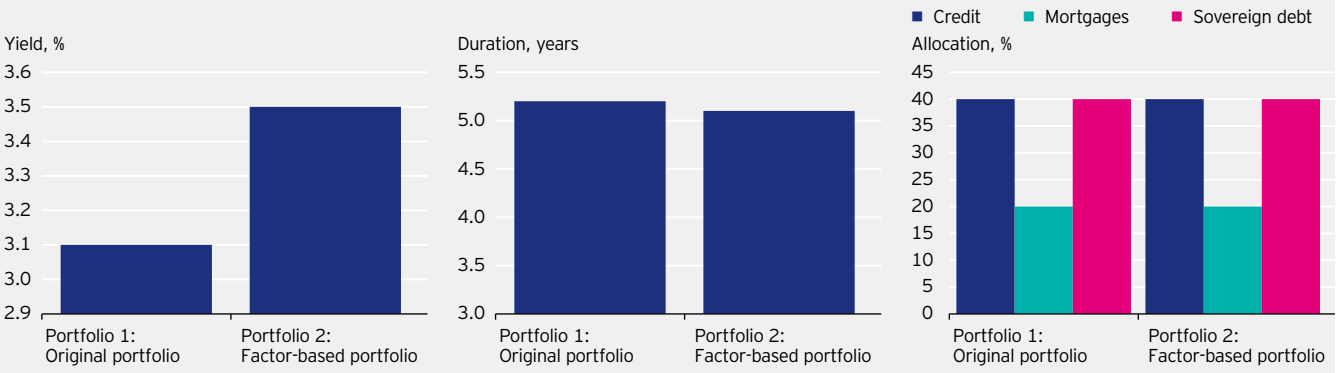
Consequently, the two portfolios are quite different from a factor perspective (figure 9).[1] The passive exposure to the iBoxx High Yield Index in the original portfolio has a negative allocation to all three factors relative to the broad benchmark. Its construction strips out less liquid bonds, which tends to filter out

Figure 7
Portfolio structure

	Original portfolio	Factor-based portfolio
US Aggregate Index	80%	80%
iBoxx High Yield Index	20%	0%
Factor-based high yield proxy	0%	20%

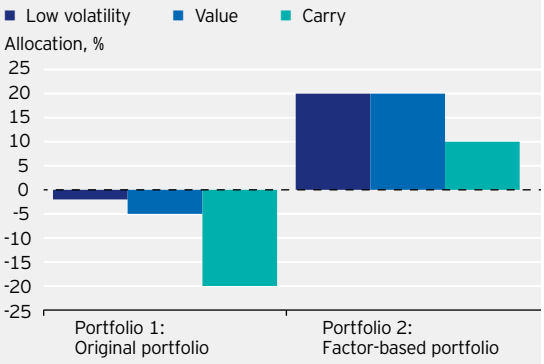
Source: Invesco. For illustrative purposes only. January 2002 to 7 December 2020. **Past performance is not a guide to future returns.**

Figure 8
Key portfolio characteristics



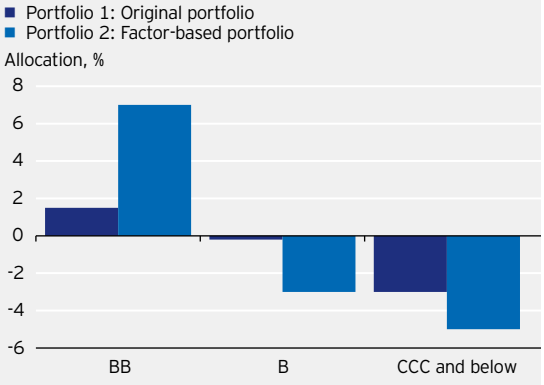
Source: Invesco, Bloomberg L.P.; data as of 30 September 2020.

Figure 9
Factor exposures before and after



Source: Invesco, Bloomberg L.P.; data as of 30 September 2020.

Figure 10
Rating allocation vs. the broad market before and after



Source: Bloomberg L.P., Invesco. Broad market as measured by the Bloomberg Barclays High Yield Index.

carry, value and low volatility securities. The iBoxx Index's tilt away from the factors that have tended to deliver positive returns over time could explain some of its underperformance.

Unlike the original portfolio, the factor-based portfolio has positive factor exposures. If bonds with attractive factor characteristics tend to outperform over time, this can positively impact the factor proxy's returns relative to the iBoxx Index.

Figure 10 shows the rating allocation of the high yield allocations of the two portfolios relative to the broad market, as measured by the Bloomberg Barclays High Yield Index. The factor-based high yield proxy is more overweight BB bonds and more underweight CCC securities than the iBoxx Index. Given the higher spread of the factor-based high yield proxy, one might expect it to have lower credit quality. But in fact, the proxy has a positive credit quality tilt – due to its bigger share of lower volatility securities that tend to be of higher credit quality. The wider spread comes not from lower credit quality but from the tilt toward value bonds. On average, their ratings do not differ from the benchmark, but their spreads are wider.

Case Study 3:
Decreasing the allocation to corporate bonds because of a bearish view on credit – without changing the portfolio's yield and duration profile
Indeed, we use factors to help reduce the portfolio's credit exposure while maintaining its yield and duration.

The portfolio was originally only allocated to the Bloomberg Barclays Global Aggregate Bond Index before the credit market selloff in spring 2020, but added credit after the selloff shortened the duration due to the rally in rates. This resulted in the portfolio in the first column of figure 11.

The objective is to maintain the duration and yield profile of the portfolio but decrease the allocation to corporate bonds, which could be more susceptible to widening corporate bond spreads. To accomplish this, we created the factor-based portfolio in the second column – decreasing credit exposure by six percentage points and reallocating it to the Global Aggregate Index.

Figure 12 examines the implications of the portfolio change. The yield remains unchanged, driven by the higher yield of the blended factor proxy relative to the passive index, even though the weight to credit was reduced. Rate duration also remains unchanged because the factor proxy portfolio hedges interest rate exposure back to benchmark levels.

Figure 13 shows the factor exposures of the two portfolios. Note that the first portfolio has negligible exposure to the factors while the second portfolio has positive exposure to all three. The higher allocation to carry and value leads to a wider spread compared to the initial allocation.

From a credit quality standpoint, despite the similar spread, Portfolio 2 is tilted toward higher credit quality securities. Figure 14 illustrates this with Portfolio 2's 2.5% overweight to AAA rated bonds, funded from the other investment grade rating categories.

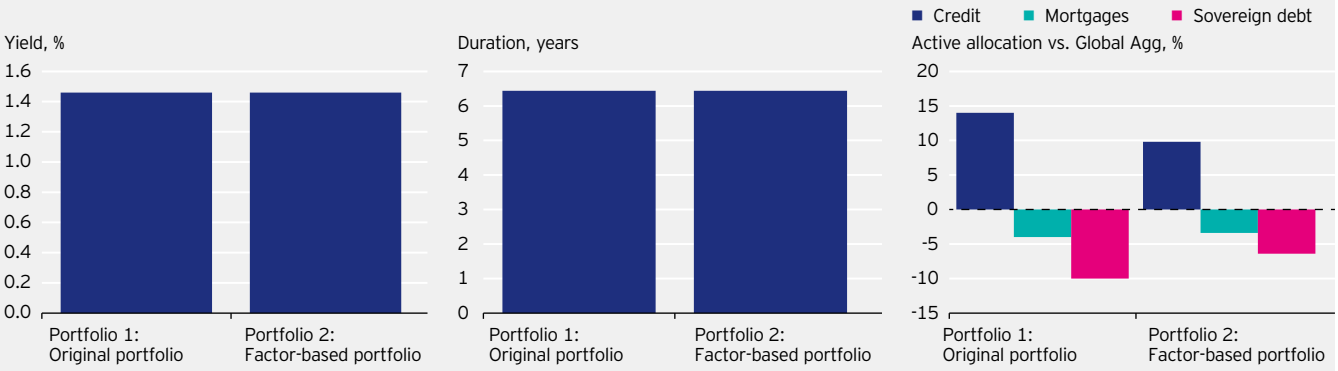
The analysis shows that we can utilize factors to deliver on the objective: a smaller allocation to corporate bonds while maintaining the yield and duration of the portfolio. But this does not come

Figure 11
Portfolio structure

	Original portfolio	Factor-based portfolio
Bloomberg Barclays Aggregate Corporate Bond Index	20%	0%
Bloomberg Barclays Aggregate Bond Index	60%	66%
Bloomberg Barclays Aggregate Corporate Bond 1-5 Year Index	20%	20%
Global credit blended factor proxy	0%	14%

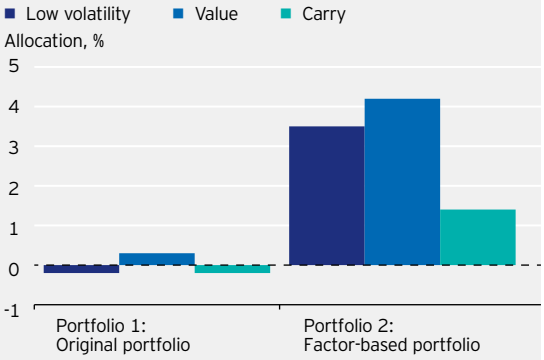
Source: Invesco. For illustrative purposes only.

Figure 12
Key portfolio characteristics



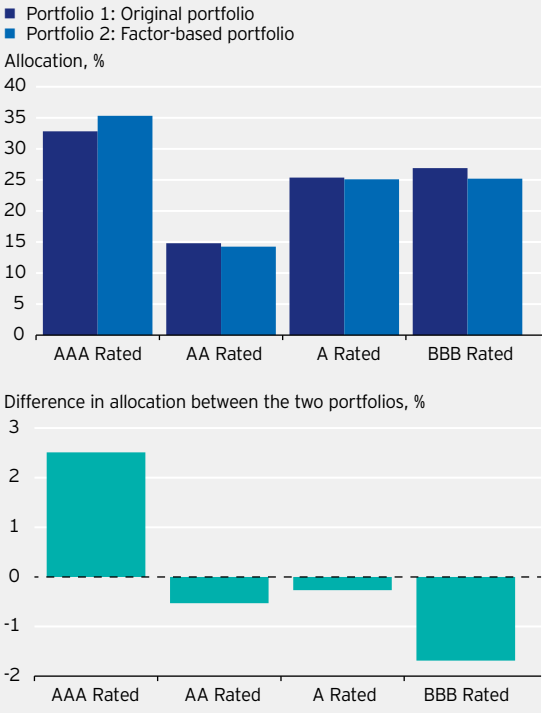
Source: Invesco, Bloomberg L.P.; data as of 30 September 2020.

Figure 13
Factor exposures before and after factors



Source: Bloomberg L.P., Invesco. Data as of December 2020.

Figure 14
Rating allocation before and after factors



Source: Bloomberg L.P., Invesco. Data as of December 2020.

We can utilize factors to deliver on the objective: a smaller allocation to corporate bonds while maintaining the yield and duration of the portfolio.

without risks. For example, bonds with positive factor exposures don't always outperform – and there may be periods when they underperform.

Conclusion

Fixed income investing presents asset-specific challenges, including low yields and a lack of tools to analyze portfolio allocations. We believe working with trusted partners to analyze and construct portfolios can help allocators better understand the risks in their portfolios and address those risks to produce more efficient, tailored investment outcomes. Fixed income factors are a new tool that investors can use to uncover these and other risks. In addition to enabling greater portfolio understanding, factor-based strategies in fixed income can provide similar benefits to an actively managed approach, and often at a lower cost.

Appendix

Indices
The list below outlines basic descriptions of bond indices mentioned in the paper:

- **Bloomberg Barclays US Aggregate Bond Index:** Broad market index that includes USD-denominated investment grade debt. The index has significant allocations to corporates, US Treasuries and securitized mortgage bonds.
- **iBoxx High Yield Corporate Bond Index:** A liquid subset of the broad market for USD high yield corporate bonds.
- **Bloomberg Barclays US High Yield Corporate (2% Capped):** Broad market index that includes most USD high yield corporate bonds.
- **Bloomberg Barclays Global Aggregate Bond Index:** Broad market index that includes investment grade debt of all currencies. The index has significant allocations to corporates, soverign debt and securitized mortgage bonds.
- **Bloomberg Barclays Global Aggregate Corporate Index:** The Corporate component of the Bloomberg Barclays Global Agg Bond Index.
- **Bloomberg Barclays Global Aggregate Corporate 1-5Yr Index:** The component of the Bloomberg Barclays Global Agg Corporate Index that matures between 1-5 years.

Proxy descriptions

Overview
In order to proxy factors where no standard indices exist, the live broad market index data is reweighted utilizing a mathematical process, summarized below.

- **Live universe data:**
  - HY: The Bloomberg Barclays US HY (2% Capped) Index
  - US IG: BBG Barclays Corp Bond Index for IG
- **Period:** 2000-2020
- **Mathematical reweighting process of value proxy:** Determine option-adjusted spread for each bond in the universe. Create buckets based on rating, sector and duration. In each bucket, rank each bond based on its OAS, with high-ranking bonds having the highest OAS in that bucket. Mathematically reweight the index such that the proxy is the 5% of bonds that have highest rank in each bucket for IG and the 10% of bonds with the highest rank in each bucket for HY. Repeat when the live, broad market index data is reconstituted (monthly).
- **Mathematical reweighting process of low volatility proxy:** Determine the time to maturity for each bond in the universe. Filter out the lowest credit quality bonds (BBB and below for IG and CCC+ or below for HY). Create buckets based on rating. In the filtered universe and in each bucket, rank bonds based on time to maturity with the lowest time to maturity bonds in each bucket having the highest rank. Mathematically reweight the index such that the proxy is 5% of bonds that have highest rank in each bucket for IG and the 10% of bonds with the highest rank in each bucket for HY. Repeat when the live, broad market index data is reconstituted (monthly).
- **Mathematical reweighting process of carry proxy:** Determine option-adjusted spread for each bond in the universe. Rank each bond based on its OAS with high-ranking bonds having the highest OAS in the universe. Mathematically reweight the index such that the proxy is the 5% of bonds that have highest rank for IG and the 10% of bonds with the highest rank for HY. Repeat when the live, broad market index data is reconstituted (monthly).

Overview – high yield factor proxy
In order to proxy blended factor proxies in HY (no standard indices), live broad market index data is reweighted utilizing a mathematical process. Below we summarize the mathematical process used to reweight live index data.

- **Live universe data** is the Bloomberg Barclays US HY (2% Capped) Index between 2000-2020.

- **Mathematical process:**
  - Create value, carry, low volatility proxies utilizing the mathematical process highlighted above.
  - Blend proxies at equal risk weights.
  - Allocate 3% to cash and 4% to cdx HY.
  - Hedge interest rate duration back to universe duration via 10-year index futures.

Overview – intermediate bond
In order to proxy blended factor proxies for the US intermediate bond market (no standard indices), live broad market index data is reweighted utilizing a mathematical process. Below we summarize the mathematical process used to reweight live index data.

- **Live universe data** is the Bloomberg Barclays US Aggregate Bond Index between 2000-2020.

- **Mathematical process:**
  - Intermediate credit
    1. Create value, carry, low volatility proxies utilizing the mathematical process highlighted above.
    2. Blend proxies at equal risk weights.
    3. Allocate 2% to cash and 3% to cdx IG.

  - Intermediate government bonds
    1. Start with 100% Treasury allocation in line with the live universe data.
    2. Add equal-weighted exposure to the 3 largest government bonds for 1/3 of the government bond allocation.

  - Across fixed-income segments
    1. Start with index weight to government bonds, credit and mortgages.
    2. Increase exposure to corporate bonds by 20%; decrease exposure to government bonds by 20%.

  - Portfolio level
    Hedge interest rate duration back to universe duration via 10-year index futures.

About the authors

Ward Bortz
Senior Client Portfolio Manager
Invesco Fixed Income
Ward Bortz is a Team Lead and Senior Client Portfolio Manager for Invesco's Fixed Income Factors platform. In this role, he is responsible for the ongoing product development, structuring, messaging and business development for the fixed income factors group.

Paisley Nardini, CFA, CAIA
Client Solutions Strategist
Invesco Investment Solutions
Paisley Nardini is a Strategist for Invesco Investment Solutions. In this role, she supports institutional clients in making asset allocation and portfolio construction decisions through leveraging of proprietary risk-modeling capabilities.

Note
1 See Know your factors: a case study in fixed income portfolio analysis, by Ward Bortz, Invesco, October 2020, for information on how to determine factor exposure in a fixed income portfolio.

The allure of specialty sectors in real estate investing

By John Corcoran and David Wertheim

In brief

We analyze four specialty real estate sectors, notably: data centers, infrastructure, single-family rentals and health care/life science, which could be solid plays for investors in the years to come. We show what these sectors stand to gain from long-term structural changes as well as from the economic situation post-pandemic. While the focus of our analysis in on the US, we believe that the main findings apply to other regions as well.

Real estate investments have historically coalesced around four broadly defined property types: multifamily, industrial, office and retail. But, after the corona shock of 2020, it may make sense for investors to reconsider specialty property sectors – for a more tailored approach to the post-Covid world.

"Specialty" property sectors include a variety of non-traditional residential and commercial properties.

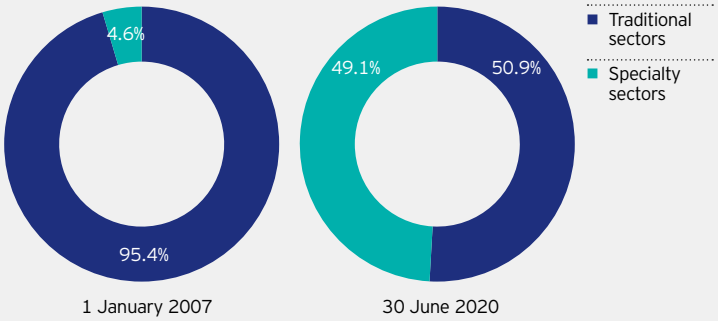
While there is no standard definition of "specialty" property sectors, they include a variety of non-traditional residential and commercial properties (figure 1). With respect to residential real estate, these specialty sectors span single-family homes for rent, manufactured housing (prefabricated factory-built homes), student housing and senior housing. In commercial real estate, they include data centers, infrastructure, self-storage, life science and medical office, among others.

Figure 1
A diverse range of specialty sectors

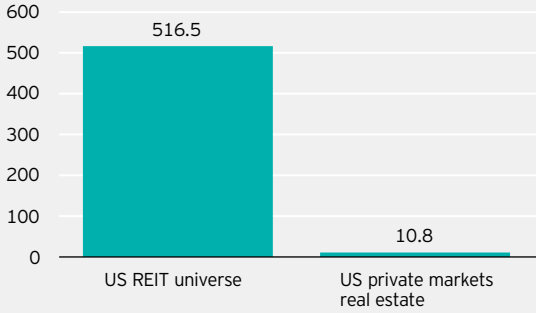
Source: Invesco Real Estate, August 2020.

Figure 2
Specialty sectors comprise half of listed real estate

US REIT universe market capitalization comparison: Listed real estate 2007 and 2020



Specialty sector market capitalization (in USD bn)



Traditional sectors: apartment, industrial, office, retail, lodging and diversified. Specialty sectors: health care, self-storage, manufactured homes, single-family rentals, data centers, timber, infrastructure and other specialty. US REIT universe represented by FTSE Nareit All Equity REITs Index. US Private Markets Real Estate represented by ODCE.
Source: Invesco Real Estate using data from FTSE NAREIT and ODCE as of June 2020.

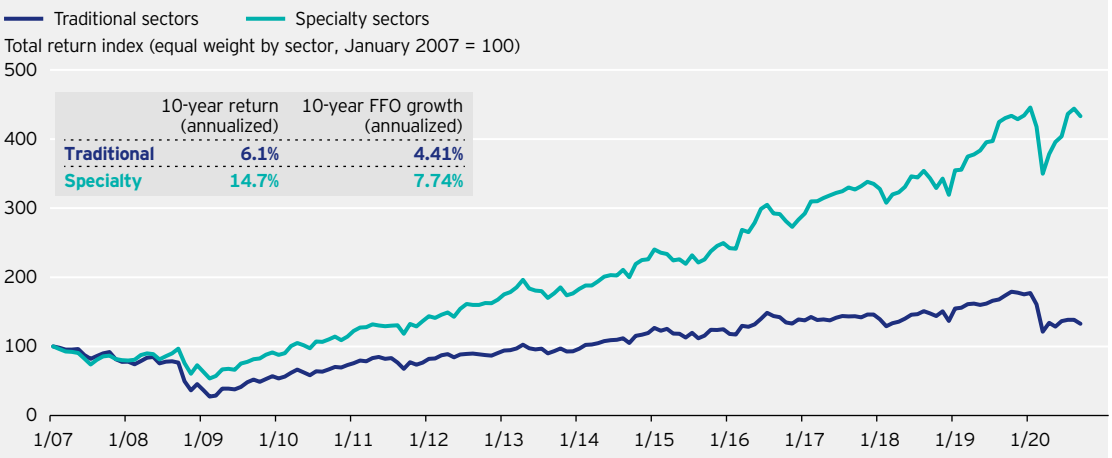
The representation of specialty sectors in real estate securities indices has grown tremendously. In June 2020, they accounted for roughly half the collective market capitalization, compared to less than 5% in early 2007. However, in many private market real estate constructs, they still play only a minor role. Whereas the total market capitalization of specialty REITs is now well above half a trillion US dollars, private vehicles account for a mere 10 billion (figure 2).

Since early 2007, cash flows in specialty sectors grew far in excess of traditional sectors and, not surprisingly, their annualized returns were more than twice as high (figure 3). This robust growth has been spurred by changes in demographics, education, preferences for renting versus owning, and even downsizing trends. In addition, a number of specialty sectors have enjoyed strong tailwinds from technological and medical advancements. Below, we present some of the most interesting opportunities.

Data centers
Data centers typify a specialty property sector that benefits from technological changes, including how society is increasingly consuming data. At their most basic level, data centers are secured warehouses containing racks that house network equipment and servers critical for data processing and storage as well as cloud computing. These facilities provide sophisticated amenities like backup generators and industrial air conditioners to keep computer equipment cool, as well as optical connections for linking business partners and service providers.

While data center shells are relatively simple to build, the complexity of the interior infrastructure requires high upfront capital expenditures and a level of operating expertise, constituting significant barriers to entry. Not surprisingly, lease terms are often 5-15 years, and data center real estate investment trusts (REITs) typically enjoy high customer retention rates due to the complexity and cost of moving.

Figure 3
Specialty sectors have outperformed traditional real estate sectors over time



	10-year return (annualized)	10-year FFO growth (annualized)
Traditional	6.1%	4.41%
Specialty	14.7%	7.74%

Traditional: apartment, industrial, office, retail, lodging and diversified. Specialty sectors: health care, self-storage, manufactured homes, single-family rentals, data centers, timber, infrastructure and other specialty.
Source: Invesco Real Estate using data from NAREIT as of September 2020. **Past performance is not a guarantee of future results.**

Tenants often form network ecosystems through colocation (in part to achieve lower latency/higher speeds), which tends to increase the value of a data center as more tenants locate there.

The characteristics of data centers may differ markedly from traditional property types. Server racks and digital content are owned and managed by tenants, while the physical warehouse is owned by the data center. The most desirable features for tenants often relate to technology ecosystems, power availability and cost, fibre connectivity and protection from natural disasters. In contrast, tenants of more traditional property types typically place greater emphasis on location, access to transportation hubs, amenities and proximity to employees. Furthermore, the lease characteristics are based on the usage of power as opposed to the utilization of square footage.

The fundamentals for data centers appear robust.

The fundamentals for data centers appear robust based on the rapidly increasing data needs of tenants spanning the technology, financial services and communications industries. The secular growth story for data centers is buttressed by the rapid expansion of cloud computing, increasing demand for mobile data and the inexorable growth of the digital economy. The impact of the pandemic has so far been minimal on data centers, which are relatively unaffected by social distancing and were among the best performing REIT sectors in 2020. The annual size of the global datasphere is expected to triple from 2020 through 2025, and demand from both consumers and enterprises may support the data center business model for years to come.

Infrastructure

Another technology-driven and higher-growth specialty sector is infrastructure, which includes assets such as cell phone towers and small cell nodes. The largest tower companies are structured as REITs and play a crucial role in enabling wireless communications. Cell towers are the physical foundation of nearly all wireless connectivity. Tower companies own the vertical real estate – usually a tower or pole, often with a land parcel underneath – and the fiber cable underground. Wireless carriers, broadband providers, cable companies and government agencies lease space on towers to mount equipment, such as cell transmitters. By leasing space on thousands of towers domestically and globally, wireless carriers have built communications networks to handle the ever-increasing volume of mobile data traffic.

Like data center providers, infrastructure companies have benefitted from rapid growth in mobile data consumption as well as increased traffic loads in the burgeoning work-from-home environment. The lease terms for these assets are often 5-15 years, and the infrastructure providers typically enjoy high customer retention rates due to the complexity and cost of moving as well as the lack of viable alternatives in the oligopolistic US market. Furthermore, infrastructure should be a prime beneficiary of the coming wave of 5G wireless connectivity. The reason why is that the rollout of 5G will require carriers to upgrade many existing cell towers for use with 5G signals, effectively integrating current infrastructure into the new system. These upgrades should allow the infrastructure providers to charge more for carriers to lease their assets. Initial 5G smartphones are expected to consume 270x more data than 2G-era phones and roughly 3x the data of current phone models.[1]

What many investors may not appreciate is how big a change 5G will be and how long it may act as a growth pill for both of these property sectors. In our view, 5G will help expand the industrial and enterprise

use cases for mobile connectivity by enabling a volume of simultaneous connections, data speeds and ubiquity of coverage that were not previously available. New use cases could include: self-driving vehicles, remote health care, smart manufacturing, smart cities, drones-as-a-service and virtual reality, among others. Simply put, tower and data center REITs seem to be uniquely positioned to benefit from the initial multi-year infrastructure buildout for 5G, and later from the potential step change increase in data transmission that will result from widescale deployments.

Tower and data center REITs seem to be uniquely positioned.

Single-family rentals

The residential sector is one of the four traditional pillars of commercial real estate and encompasses several property types, including: apartments, single-family rental homes, manufactured housing and student housing. For a variety of reasons, the overall sector has performed well over the past several years – right up to the market downturn in February 2020. For example, residential real estate has been structurally undersupplied on a worldwide basis since the global financial crisis a dozen years ago. In addition, extremely low unemployment rates in the US and other countries have helped support high residential occupancy rates. Strong growth in the young adult age cohort was also a tailwind, as this demographic has a higher propensity to rent.

Single-family rental homes are a specialty subsector of the residential market and are growing substantially faster than apartments due to their differing characteristics (figure 4). The pandemic has only accelerated this trend, as many renters now seek a lower-density living environment in a more suburban setting. Single-family rentals total about 15 million units, similar in size to the traditional apartment market, yet have one of the most attractive multi-year demand profiles in US real estate according to industry analysts.[2] Job growth across Sun Belt-focused footprints has been solid, homeownership has been stuck in neutral, and this segment's demographic tailwind should accelerate in the next several years as apartment renters age toward prime single-family renting years.[3] In this regard, as millennials reach adult milestones (e.g. marriage, starting a family), they typically seek more living space. This property type has also benefitted from changing views among millennials and Gen Xers, as fewer of them own a home, want to own a home or even live on their own compared to prior age cohorts.[4] In fact, they value the optionality provided by renting, along with the concomitant increase in mobility. Simply put, the single-family rental market bridges the gap between apartment living and home ownership.

The single-family rental market bridges the gap between apartment living and home ownership.

Demand for single-family rentals has been strong, in part because of increased demand for lower-density environments in suburban settings. In addition, extreme financial dislocation for many consumers, combined with stress in the banking sector, has likely reduced the number of renters who can afford the move to home ownership. This, in turn, could lead to higher retention rates for residential landlords.

Figure 4
Single-family rental vs. traditional apartment rental

	Single-family rental	Apartment
		
Typical size	1,600-2,000 SF	600-1,000 SF
Typical layout	3-4 beds, 2-bath, master-suite, private yard, 2-car garage	1-2 bed, 1-2 bath, community pool, gym, surface parking
Typical rent	USD 1,300 – USD 1,700	USD 1,000 – USD 1,400
Typical stay	3-4 years	1-2 years
Typical tenant	Families/couples	Singles/couples
Typical renter age	35-54 years	Under 35 years
Typical location	Suburban	Urban/suburban

Source: Invesco Real Estate, as of 14 September 2020.

Finally, a residence is need-to-have real estate – not simply nice-to-have – which may warrant priority in a consumer's payment stack. Not surprisingly, the drop in occupancy rates for the residential sector has typically been lower than the drop for many other property sectors during prior economic downturns.

Health care / Life science
Health care is one of the largest segments of the US economy, comprising about 18% of GDP. The sector continues to grow faster than the overall economy on the back of a rapidly aging population.[5] There are multiple segments of the health care sector, but just two of them account for almost 75% of the listed health care REIT space: senior housing and medical office.[6]

However, there is another specialty subsector in health care – life science (aka lab space) – which we believe is positioned to perform well based on strong fundamentals that remain essentially untouched by Covid-19. Life science accounts for roughly 10% of US health care REIT assets and consists primarily of specialized offices for biotech and pharmaceutical tenants, who use the space to develop new drugs.[7] Lease terms are often 8 – 10 years, and renewal rates are typically high because of the complexity and cost required to build out sophisticated lab space. Demand for this kind of specialized real estate is only expected to grow as a result of the heightened global focus on new drug development.

Life science has rapidly gone mainstream.

Historically a niche sector, life science has rapidly gone mainstream in recent years, with an impressive track record. Some players are focused on biotech cluster markets like Boston, San Francisco and San Diego, while others are located on university campuses or near major medical facilities. In terms of asset value, life science fared the best in the health care sector in 2020, according to industry analysts, with values virtually unchanged compared to pre-pandemic levels.[8]

Conclusion: The bright spots of tomorrow?
Despite current dislocations in the property market, certain specialty sectors could continue to benefit from several potentially sustained tailwinds while facing limited impact from the pandemic.

Despite the many uncertainties surrounding the economy and capital markets, REITs operating in these sectors are poised to benefit from robust demand in relatively supply-constrained markets, driven in part by growth in data consumption, cloud computing and ecommerce, the coming wave of 5G, increased demand for a lower-density living environment and the heightened global focus on new drug development. This can translate into above-average revenue, cash flow and earnings growth, which is why we believe these specialty sectors present potentially attractive opportunities for investors.

About the authors

John Corcoran
Client Portfolio Manager
Invesco Real Estate
John Corcoran is a Client Portfolio Manager for Invesco Real Estate. John is responsible for real estate, infrastructure and real assets securities. In this capacity, he works with Invesco's real estate and listed real assets investment teams, serving as its representative to retail and institutional clients worldwide.

David Wertheim
Client Portfolio Manager
Invesco Real Estate
David Wertheim is a Client Portfolio Manager for Invesco Real Estate. David is responsible for real estate, infrastructure and real assets securities. In this capacity, he works with Invesco's real estate and real assets investment teams, serving as its representative to retail and institutional clients worldwide.

Notes
1 Source: Vella, H. (2019): 5G vs. 4G: What Is the Difference?, Raconteur; Western Digital (2019): 5G vs. 4G: A Side-by-Side Comparison.
2 Source: J Pawlowski, et al., Green Street, "Residential Sector Update," 3/3/20.
3 Source: J Pawlowski, et al., Green Street, "Residential Sector Update," 3/3/20.
4 Source: John Burns Real Estate Consulting, LLC, 10/2019.
5 Source: L. Hartwich, et al, Green Street, "Health Care Sector Update," 12/4/20.
6 Source: L. Hartwich, et al, Green Street, "Health Care Sector Update," 12/4/20.
7 Source: L. Hartwich, et al, Green Street, "Health Care Sector Update," 12/4/20.
8 Source: L. Hartwich, et al, Green Street, "Health Care Sector Update," 12/4/20.

About risk
Property and land can be difficult to sell, so investors may not be able to sell such investments when they want to. The value of property is generally a matter of an independent valuer's opinion and may not be realized. The value of investments and any income will fluctuate (this may partly be the result of exchange rate fluctuations) and investors may not get back the full amount invested.

Forecasting the covariance matrix: is it worthwhile?

By Paul Jackson

In brief

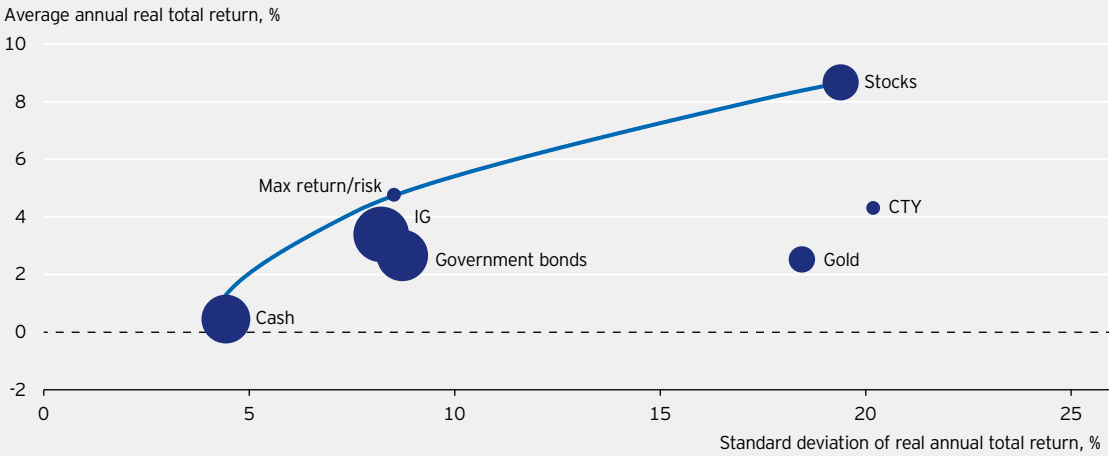
Returns, as any investor knows, have their ups and downs. Just as standard deviations of asset classes and the covariances between them vary over time. Nevertheless, it is common practice in asset allocation to spend considerable resources on return forecasts – while simply assuming that volatilities and correlations will stay more or less constant. Does this make sense? Our research suggests that it might.

Developing optimized portfolios requires forecasting of return distributions across multiple assets (including their covariances). This is easier said than done, and we often rely on historical precedent, especially for the covariance matrix. Our analysis suggests that more effort should be expended on forecasting returns than on estimating the covariance matrix.

Like all good investors, we use an optimization process to help us with model asset allocation. It is easy to rank assets based on expected returns, but not so easy to arrange them in an efficient way to achieve the desired outcome (usually to maximize return for a chosen level of volatility).

At the end of 2019, we published an analysis of themes that could impact investment returns over the remainder of this century.[1] The starting point was a long-term analysis of historical US asset returns. Figure 1 is taken from this publication, and shows a summary of the inflation-adjusted annual

Figure 1
US annual total returns 1915-2018 and efficient frontier (CPI-adjusted)



Based on calendar year data from 1915 to 2018. Area of bubbles is in proportion to average correlation with other assets. Calculated using: spot price of gold, Global Financial Data (GFD) US Treasury Bill total return index for cash, our own calculation of government bond total returns (Govt) using 10-year treasury yield, GFD US AAA Corporate Bond total return index (IG), Reuters CRB total return index until November 1969 and then the S&P GSCI total return index for commodities (CTY) and Robert Shiller's US equity index and dividend data for stocks. Indices are deflated by US consumer prices. "Max return/risk" is the point on the efficient frontier that gives the highest ratio of return to standard deviation of returns. Past performance is no guarantee of future results.
Source: Refinitiv Datastream, Global Financial Data, Reuters CRB, S&P GSCI, Robert Shiller, Invesco. **Past performance is no guarantee of future results.**

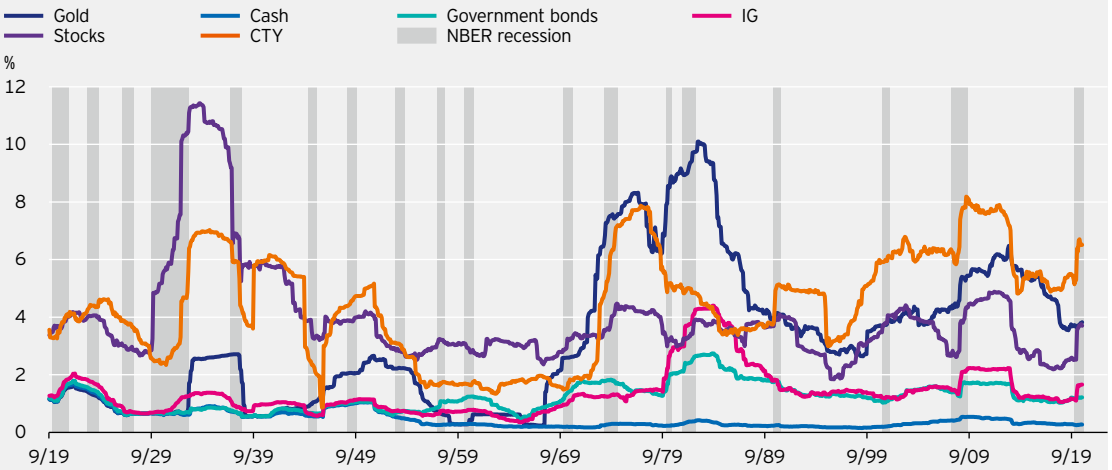
returns from 1915 to 2018. The bigger the bubble in the graph, the higher the average correlation with other assets.

Not surprisingly, stocks produced better returns on average than cash and bonds, but with higher volatility. More surprising may be that gold was nearly as volatile as stocks, even though gold returns did not exceed those of government bonds (to be fair, the price of gold was largely fixed during the first half of the period).

We then looked at a range of factors that could make future returns different to what they were in the past including low bond yields, demographics, climate change and technological innovation. We concluded that future returns on all assets would be lower than the historical precedent. But when it came to the optimization process, we relied on the covariance matrix derived from the historical data. In other words, we mixed our forecast of future returns with historical volatility and correlations, on the assumption that the covariance matrix would be relatively stable over time.

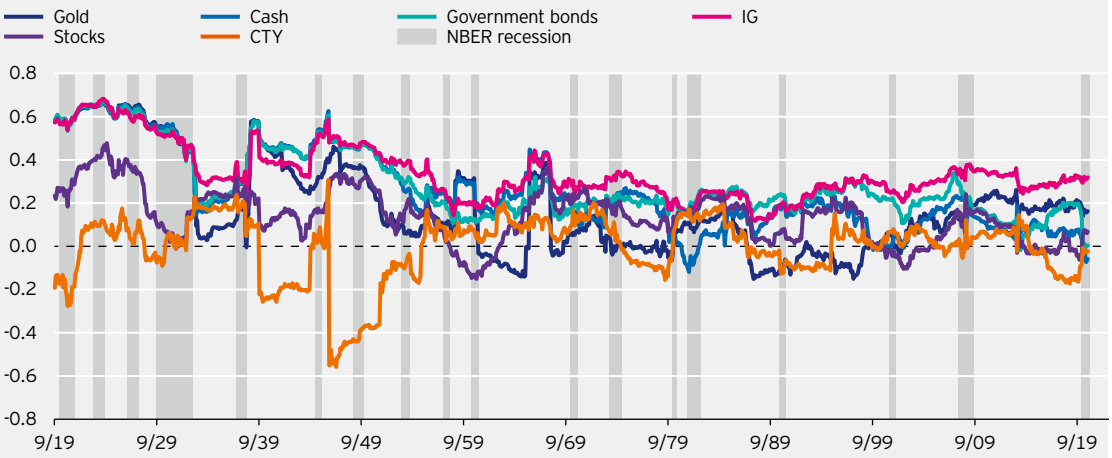
Is that a valid assumption? Figure 2, which shows the standard deviation of returns of six US asset classes over rolling five-year periods, suggests that

Figure 2
Volatility of monthly inflation-adjusted US asset returns 1919-2020



Based on monthly data from September 1919 to September 2020, showing standard deviations of monthly inflation-adjusted returns over rolling five-year periods (inflation adjustment using US consumer price index)."NBER recession" shows periods identified by the US National Bureau of Economic Research as being recessionary (NBER has not identified the end date of the 2020 recession). See notes for definitions and sources of assets.
Source: BoAML,Global Financial Data, Reuters CRB, S&P GSCI, Robert Shiller and Invesco. **Past performance is no guarantee of future results.**

Figure 3
Average correlations of six US asset classes to the other five asset classes shown, 1919-2020



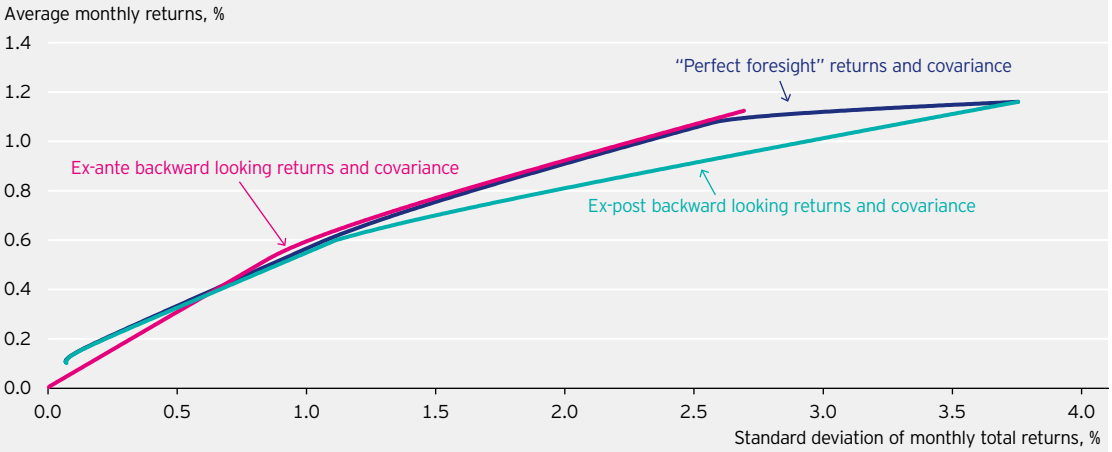
Based on monthly data from September 1919 to September 2020 and shows the correlation of monthly inflation-adjusted returns over rolling five-year periods (inflation adjustment is done using US consumer price index). For each asset class, the chart shows the average correlation with all the other assets. See notes for definitions and sources of assets "NBER recession" shows periods identified by the US National Bureau of Economic Research as being recessionary (NBER has not identified the end date of the 2020 recession).
Source: BoAML,Global Financial Data, Reuters CRB, S&P GSCI, Robert Shiller and Invesco. **Past performance is no guarantee of future results.**

one element of the matrix – variance – oscillates over shorter periods. Figure 3 suggests that correlations, too, can vary quite a lot from one five-year period to the next.[2] This is important since, even if the covariance matrix doesn't vary from one century to another (we lack the data to know), most investment portfolios are constructed with shorter horizons.

Correlations, too, can vary quite a lot from one five-year period to the next.

The forecasting of covariance matrices is a topic widely covered by academics.[3] However, the methods used are beyond the scope of most practitioners. In this paper, we wish to simply use empirical examples to explore the value of correctly estimating the covariance matrix.

Figure 4
Efficient frontiers for US assets (September 2015-September 2020)



Based on monthly total return data for six US assets: cash, gold, Treasury bonds, investment grade credit, stocks and commodities. All efficient frontiers are constructed from the perspective of investment choices over a five-year time horizon from 30 September 2015. "Perfect foresight" uses the actual data (returns and covariance matrix) over the subsequent five years (to 30 September 2020). "Backward-looking" versions were constructed using optimal allocations based on data from the previous five years (30 September 2010 to 30 September 2015). The ex-ante backward-looking efficient frontier is what would have been expected if the previous five years (2010-2015) were repeated during 2015-20. The ex-post (realized) backward-looking efficient frontier uses the same allocations as the ex-ante version but applies the actual returns and co-variance matrix (what would have happened). See notes for asset class definitions and sources.
Source: BoAML,Global Financial Data, Reuters CRB, S&P GSCI, Robert Shiller and Invesco. **Past performance is no guarantee of future results.**

Some comparisons
To this end, we compare three different efficient frontiers for a portfolio based on our six asset classes: a "perfect foresight" version and two "backward-looking" versions based on past data. Limiting the analysis to five-year investment periods and using nominal (non-inflation-adjusted) monthly data, we start by considering the five years to 30 September 2020.

The "perfect foresight" efficient frontier is constructed using the actual return and covariance data from that period (as though we knew in September 2015 what would happen). In the two "backward-looking" versions, allocations are based on returns and covariances from the previous five years (to 30 September 2015). Whereas the ex-ante version assumes that the next five years (2015-20) look exactly like the previous five years (2010-15), the ex-post (realized) version applies the actual return data from 2015-20.

Figure 4 shows the outcome. The ex-ante backward-looking efficient frontier shows the result gotten if optimizations were performed using the returns and covariance matrix from the previous five years (and supposing that history repeated itself). The ex-post backward-looking efficient frontier shows the result occurred using those same allocations based on what the returns actually turned out to be. The perfect foresight efficient frontier is an illustration of what would have been possible if we had known in advance what the pattern of returns would be.

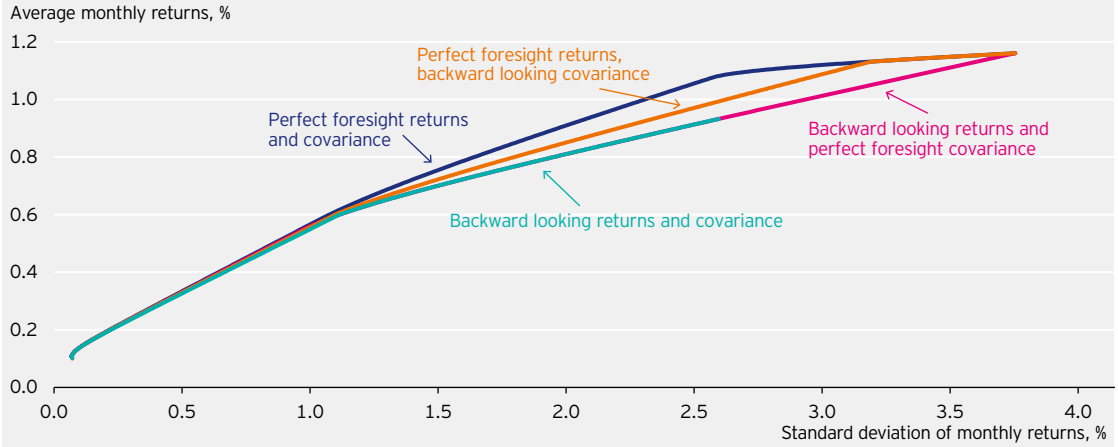
Not surprisingly, the perfect foresight efficient frontier offers a better range of outcomes (more return for a given level of volatility) than the ex-post backward-looking version (both use the same returns but applied to different allocations). Interestingly, the ex-ante backward-looking efficient frontier resembles the perfect foresight version but, of course, was never available. We suspect this to be coincidence, which we will later test by looking at other periods.

Covariance or return forecasts: which is more important?
The question we need to answer is whether, in transitioning from the ex-post backward-looking frontier to the perfect foresight frontier, is it more important to get the returns or the covariance matrix right? To find out, we ran two further optimizations: one in which we used historical returns and the perfect foresight covariance matrix, the other in which we used perfect foresight returns along with the historical covariance matrix. Figure 5 shows the outcome.

For the period considered, it appears that, if a choice had to be made, forecasting returns would be more important than forecasting the covariance matrix: knowing the shape of the covariance matrix using historical returns rendered little improvement versus the efficient frontier based on historical data alone, while perfect foresight of returns shifts the efficient frontier roughly halfway towards the perfect foresight frontier. Interestingly, though knowledge of the covariance matrix alone doesn't improve results, it does seem to add incremental value over and above solutions where returns alone are known.

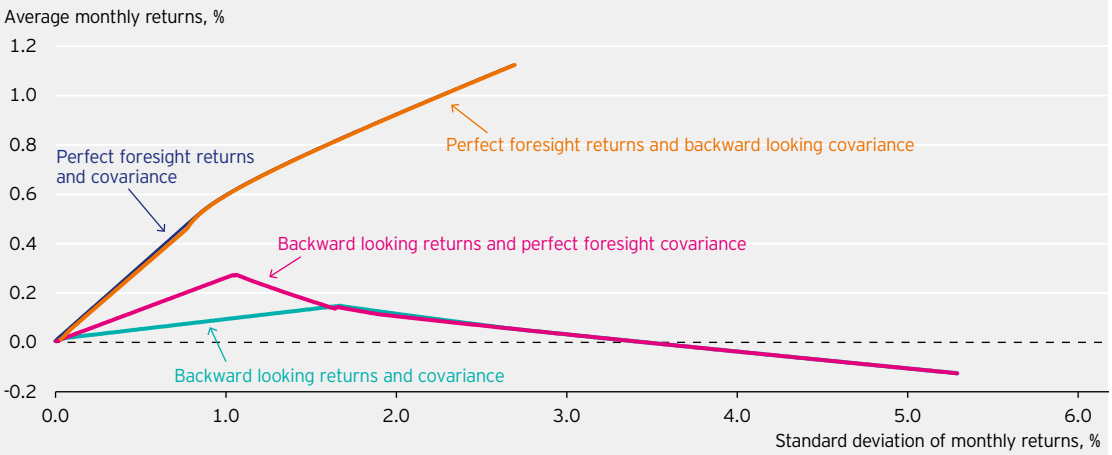
How robust are the results?
Of course, the results from a single five-year period cannot necessarily be generalized. As a first test of the robustness of these results, we repeated the exercise for another five-year period. Given the extraordinary nature of the global financial crisis (GFC), we thought it would be interesting to see what would happen if we used September 2005 to September 2010 as the historical period upon

Figure 5
Efficient frontiers for US assets with varying degrees of foresight (September 2015–September 2020)



Based on monthly total return data for six US assets: cash, gold, treasury bonds, investment grade credit, stocks and commodities. All efficient frontiers are constructed from the perspective of investment choices over a five-year time horizon from 30 September 2015 and are ex-post, i.e. they apply returns and covariances from the 2015-20 period to optimal allocations derived as follows: "Perfect foresight" uses the actual data (returns and covariance matrix) over the subsequent five years (to 30 September 2020); "Backward-looking returns and covariance" was constructed using optimal allocations based on data from the previous five years (30 September 2010 to 30 September 2015); "Backward-looking returns and perfect foresight covariance" uses returns from the previous five years (2010-2015) and the covariance matrix from subsequent five years (2015-20) and "Perfect foresight returns, backward-looking covariance" uses the subsequent five-year returns (2015-20) and the covariance matrix from the previous five years. See notes for asset class definitions and sources.
Source: BoAML, Global Financial Data, Reuters CRB, S&P GSCI, Robert Shiller and Invesco. **Past performance is no guarantee of future results.**

Figure 6
Efficient frontiers for US assets with varying degrees of foresight (September 2010-September 2015)



Based on monthly total return data for six US assets: cash, gold, treasury bonds, investment grade credit, stocks and commodities. All efficient frontiers are constructed from the perspective of investment choices over a five-year time horizon from 30 September 2010 and are ex-post, i.e. they apply returns and covariances from the 2010-15 period to optimal allocations derived as follows: "Perfect foresight" uses the actual data (returns and covariance matrix) over the subsequent five years (to 30 September 2015); "Backward-looking returns and covariance" was constructed using optimal allocations based on data from the previous five years (30 September 2005 to 30 September 2010); "Backward-looking returns and perfect foresight covariance" uses returns from the previous five years (2005-2010) and the covariance matrix from subsequent five years (2010-15) and "Perfect foresight returns, backward-looking covariance" uses the subsequent five-year returns (2010-15) and the covariance matrix from the previous five years. See notes for asset class definitions and sources.
Source: BoAML, Global Financial Data, Reuters CRB, S&P GSCI, Robert Shiller and Invesco. **Past performance is no guarantee of future results.**

which to base decisions for the subsequent five years (September 2010 to September 2015). Though not shown in our graphs, we can report that the ex-ante backward-looking efficient frontier again matches the perfect foresight version (it is worth re-emphasising, however, that it was never attainable in practice).

We then looked at the results for 2010-15 (figure 6). Once again, it appears that perfect foresight of the covariance matrix offers limited advantage over a process using historical data for both returns and covariance (compare "Backward-looking returns and perfect foresight covariance" to "Backward-looking returns and covariance"). At least this time it offers some advantage at lower volatilities, but the two frontiers converge once the return on the fully backward-looking version has peaked. Note that both efficient frontiers have a non-classic shape, with returns declining beyond a certain standard deviation. This is because these are ex-post versions of frontiers that in their original ex-ante format took the normal shape, i.e. we continued to successively higher levels of volatility until returns peaked.

On the other hand, if we assume perfect foresight of returns combined with a historical covariance matrix (orange efficient frontier), the outcome is virtually identical to that constructed with perfect foresight of both returns and covariance. In fact, the two outcomes are so close that it is hard to see the blue line. For this time period, adding perfect foresight of covariance to perfect foresight of returns provides no extra advantage.

For this time period, adding perfect foresight of covariance to perfect foresight of returns provides no extra advantage.

Conclusion

For the two time periods chosen, it was more important to correctly forecast asset returns than covariances. This is not to say that there is no value at all in forecasting the covariance matrix, but the (limited) evidence presented justifies expending more effort on forecasting returns. This supports our continued use of historical covariance matrices.

Of course, this conclusion comes with several caveats. First, we have only considered two five-year periods, and it would be premature to believe these results can be generalized. Second, for computational ease we have limited the analysis to portfolios of six US dollar assets. Third, we assume perfect foresight in order to compare other results to that "gold standard", but we are unlikely to achieve such excellence in a real-world situation, even when only forecasting returns.

The obvious next step is to perform the same analysis for a larger sample of historical periods, for example going back to the 1930s. It will also be interesting to verify that the same conclusions hold when a broader set of assets are included (though computation times then rise dramatically) and to look at global rather than just US assets.

Notwithstanding the preliminary conclusion that expected returns matter more than the expected covariance matrix, it is intellectually unsatisfactory to source them from different places. Because returns and covariances are simply different

moments of the same return distributions, they should be forecast as part of one single process. Using historical data provides the needed consistency but doesn't work if the future is unlike the past. The real challenge in terms of next steps will be to develop a way of forecasting a coherent distribution of returns.

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About the author

Paul Jackson
Global Head of Asset Allocation Research
Global Thought Leadership Team

Paul Jackson is Global Head of Asset Allocation Research at Invesco and regularly produces several publications, including "Uncommon Truths" and "The Big Picture", in addition to a comprehensive study annually.

Notes

1 The 21st Century Portfolio, November 2019.
2 Uncommon truths: A change of regime?, October 2020.
3 E.g. Markowitz, H. (1952); Bollerslev, Engle and Wooldridge (1988); Engle and Kroner (1995); Engle and Rodrigues (1989); de Brito, Medeiros and Ribeiro (2018).

Definitions and sources for the assets used in figures 2, 3, 4 and 5 are: spot price of gold (Gold); Global Financial Data (GFD) US Treasury Bill Total Return Index until December 2018 and then BoAML 0-3 Month Treasury Total Return Index (Cash); our own calculation of government bond total returns using 10-year Treasury yield until January 1978 and then BoAML US Treasury Index (Govt); GFD US AAA Corporate Bond Total Return Index until February 1976 and then BoAML US Corporate Index (IG); Reuters CRB Total Return Index until November 1969 and then the S&P GSCI Total Return Index for commodities (CTY) and our own calculation of total returns on US equities based on index and dividend data from US academic Robert Shiller and Datastream (Stocks). The index prior to 1926 is Robert Shiller's recalculation of data from Common Stock Indexes by Cowles & Associates (see http://www.econ.yale.edu/~shiller/data.htm). From 1926 to 1957, the Shiller data is based on the S&P Composite Index and, thereafter, on the S&P 500 as we know it today.

A strategic asset allocation perspective on multi-asset class factor premia: A preview

By Kenneth Blay, Stefano Cavaglia, Scott Hixon and Louis Scott

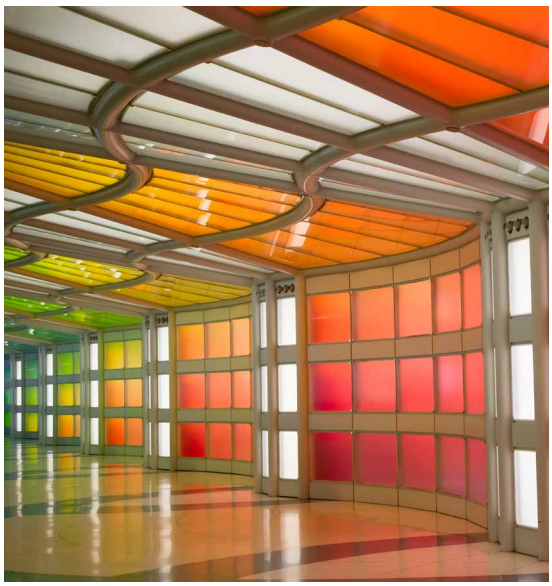
In brief
We analyze how factor overlays can benefit traditional equity and bond-based retirement portfolios. As it turns out, both during the accumulation phase and the decumulation phase, overlays comprising asset class-specific factors can enhance as well as smooth returns, so that investors can enjoy both higher income and greater peace of mind.

Smart beta and other factor-based strategies are marketed as stand-alone strategies designed to provide enhanced returns to a passive, market cap-weighted base asset (equity or fixed income) or a moderate, alternative source of total return. The liquidity, cost effectiveness, scalability and potential Sharpe ratio improvements offered by these strategies are particularly appealing to asset owners and investment managers.[1]

This excerpt of a forthcoming paper presents a complementary perspective on mainstream factor-based products by focusing on the strategic (long-term) allocation to factors in a portfolio context.[2] Specifically, we examine how multi-asset class factors can help investors attain specific objectives.

We focus on a few mainstream goals to illustrate the characteristics of such an approach. In particular, we review how factors can enhance investors' ability to attain their long run wealth accumulation and decumulation goals, and how the path to attaining those goals is affected.

We believe our focus on strategic asset allocation provides a greater appreciation for the tendency of some factors to generate positive payoffs in adverse markets. Mitigating downside risk allows investors to realize the compounding benefits of exposures to traditional mixtures of equities and fixed income assets, making it likelier that they will attain their goals.



The portfolios (and strategies) we consider are comprised of two components: a base asset and a long-short factor overlay. This construct allows us to identify the return contribution of each component and its portfolio interaction over time. From a holistic perspective, this is a more general formulation of portfolio construction. Today's mainstream products are constrained versions of the more general portfolio problem.[3] In fact, a factor overlay portfolio can be viewed as a completion portfolio aimed at increasing the likelihood of attaining targeted risk-reward profiles.

We consider a variety of portfolio construction rules applied to factor premia spanning four asset classes: equities, fixed income, foreign exchange and commodities.

Methodology and key questions
We extend the research of Scott and Cavaglia (2017), who used bootstrap simulations to examine the impact of mainstream equity risk factors on

goals-based, capital accumulation strategies with equities as a base asset. In this article, we explore the benefits of factors across multiple asset classes with a variety of base assets. We also consider the impact of factors in mitigating drawdowns and enhancing decumulation (spending) outcomes. The construct used is as follows:

- A prospective retiree invests in a passive reference base asset portfolio that is held for 20 years.
- This portfolio is compared to an alternative portfolio of the base asset with a factor overlay (here, a 130/30 portfolio).[4]
- Three base asset portfolios are considered: 100% global equities, 100% global bonds and 60% equities/40% bonds.
- We consider premia across commodities, rates, foreign exchange and equities spanning the traditional value, momentum, carry and defensive strategy styles.[5] For each asset class, we create an equal-weighted portfolio of asset class-specific factors, which are then merged into an equal-weighted composite.[6] The portfolios are as follows:
  - **C**: equal-weighted composite of commodity factors (momentum, value, carry and defensive);
  - **R**: equal-weighted composite of rates factors (momentum, value, carry and quality);
  - **FX**: equal-weighted composite of foreign exchange factors (momentum, value and carry);
  - **EQ**: equal-weighted composite of equity factors (price momentum, earnings momentum, value, quality and low volatility);
  - **ALL**: equal-weighted composite of the four asset class factor portfolios (C, R, FX and EQ).
- Overlay exposures are adjusted monthly.

We address four key questions:

1. To what extent do overlays help attain target accumulation and decumulation goals?
2. Do factor overlays make the investor's journey smoother or more turbulent?
3. How do factor premia interact with the base assets?
4. How sensitive are the results to alternative views about the future persistence in the historical returns of factor premia?

To address these questions, we apply block bootstrap simulations to the historical returns for the base assets and premia to generate terminal wealth distributions from investing USD 1 across alternative investment strategies over 20-year horizons.

Our long/short overlay provides an effective representation of a range of smart beta strategies. Indeed, conventional smart beta strategies can be viewed as a mixture of a passive underlying exposure to a base asset plus an exposure to a risk premium.

Multi-asset factors – insights from historical data

Our analysis uses return data from July 1998 to March 2020.[7] For each strategy, we report the long/short return ("unhedged") and the long/short return adjusted for joint exposure to the equity market, the fixed income market and the commodity market, through regression and beta adjustment ("hedged").[8] We believe accounting for these three factors provides a "purer" view of the return contributions of risk premia, particularly during risk-on and risk-off events.[9]

Figure 1 suggests that factor premia exhibit low correlations to one another, and to the base assets, and tend to exhibit lower volatilities. This indicates that they should be attractive diversifiers for holders of such base assets.

According to figure 2, the average return of the hedged risk premia is close to that of the unhedged premia, suggesting that return variation due to residual market exposures plays a negligible role. Unhedged risk premia exhibit payoff asymmetries under different market conditions, while hedged risk premia deliver more balanced payoffs across market conditions. In any case, the composition of a completion factor portfolio should vary with the

Figure 1
Assessing the premia
Volatility and correlation for base assets and factor premia composites

	Volatility	Correlations							
		Equities	Bonds	Comm.	C	R	FX	EQ	ALL
Equities	15.5%	1.00							
Bonds	6.5%	0.10	1.00						
Commodities	23.3%	0.41	0.13	1.00					
C	6.9%	0.08	-0.04	0.00	1.00				
R	1.7%	-0.01	0.19	-0.09	0.06	1.00			
FX	3.2%	0.42	-0.11	0.25	-0.02	0.12	1.00		
EQ	3.8%	-0.57	0.15	-0.12	0.07	0.06	-0.34	1.00	
ALL	2.1%	-0.04	0.03	0.02	0.84	0.32	0.23	0.38	1.00

Source: Invesco. Based on data from July 1998 to March 2020. Green: lowest correlation; red: highest correlation.

Figure 2
Looking for complements
Average monthly returns for base assets and factor portfolios

Panel A: Unhedged average monthly returns (%)

	Conditional							Regime			
	All periods	Equities > 0	Equities < 0	Bonds > 0	Bonds < 0	Comm > 0	Comm < 0	Contraction	Expansion	Recovery	Slowdown
Equities	0.50	3.22	-3.74	0.86	0.03	1.60	-0.84	-1.64	0.60	1.26	0.79
Bonds	0.38	0.40	0.35	1.62	-1.28	0.49	0.25	0.81	-0.02	0.28	0.60
Commodities	0.04	1.66	-2.49	0.94	-1.16	4.71	-5.63	-2.90	0.70	-0.11	0.58
C	0.69	0.67	0.73	0.61	0.80	0.72	0.65	0.35	0.79	0.90	0.63
R	0.09	0.09	0.09	0.16	0.00	0.03	0.15	0.21	0.05	0.07	0.08
FX	0.28	0.51	-0.07	0.23	0.36	0.38	0.16	0.29	0.18	0.62	0.21
EQ	0.58	0.16	1.23	0.71	0.40	0.52	0.65	0.73	0.50	0.40	0.67
ALL	0.41	0.36	0.49	0.42	0.39	0.41	0.41	0.39	0.38	0.50	0.40

Panel B: Hedged average monthly returns (%)

	Conditional							Regime			
	All periods	Equities > 0	Equities < 0	Bonds > 0	Bonds < 0	Comm > 0	Comm < 0	Contraction	Expansion	Recovery	Slowdown
Equities	0.50	3.22	-3.74	0.86	0.03	1.60	-0.84	-1.64	0.60	1.26	0.79
Bonds	0.38	0.40	0.35	1.62	-1.28	0.49	0.25	0.81	-0.02	0.28	0.60
Commodities	0.04	1.66	-2.49	0.94	-1.16	4.71	-5.63	-2.90	0.70	-0.11	0.58
C	0.69	0.57	0.88	0.66	0.73	0.72	0.65	0.43	0.77	0.86	0.63
R	0.06	0.06	0.07	0.07	0.05	0.05	0.08	0.14	0.06	0.05	0.05
FX	0.27	0.25	0.30	0.28	0.27	0.22	0.33	0.53	0.11	0.54	0.19
EQ	0.61	0.59	0.65	0.63	0.58	0.62	0.60	0.43	0.58	0.57	0.71
ALL	0.41	0.37	0.47	0.41	0.41	0.40	0.42	0.38	0.38	0.51	0.40

Source: Invesco. Based on data from July 1998 to March 2020. **Past performance is not a guide to future returns.** Values are conditionally colored across rows for various conditions and then for regimes. Green: greater than zero; red: less than zero.

composition of the base asset. For instance, currency premia will best complement a bond portfolio.

To provide an economic perspective, we also look at the performance of factors under different economic regimes. We partition our historical sample period into four regimes – contraction, expansion, recovery and slowdown – in accordance with work by Polk, Haghbin and De Longis (2020) that explores time-series variation in factor premia and the influence of the business cycle.[10] The data suggests that equities perform best in recovery, while commodities perform best in expansion and slowdown. Factor premia may also outperform under certain regimes: for instance, currency and commodity factor premia tend to provide significantly higher payoffs during a recovery. However, hedging factor premia for systematic market exposure does not seem to affect the relative attractiveness of a given economic state. In any case, investors holding some combination of equities or bonds need to consider the significant time variation in factor premia performance.

Wealth accumulation…
We consider the performance of 130/30 factor portfolio strategies[11] consisting of a base asset and an overlay of each of the equal-weighted asset class factor premia composites. In addition, we consider an overlay that is equally weighted across the four asset class factor premia composites.

Our analysis compares empirically obtained distributions of terminal wealth. For each strategy, we run 10,000 simulations, each providing a hypothetical return series over a 20-year period, summarized by an accumulated wealth level at the end of the period. We first assume that the expected returns of the premia equal their historical returns. We then assume a more conservative estimate for premia returns: half their historical returns.

The strategic focus of our analysis is well-characterized by goals-based strategies that focus on achieving investors' specific goals rather than a singular focus on returns. The goal could thus be a target wealth level required to support a future retirement income stream. Investors typically view deviations from the goal in an asymmetric fashion. Falling short of the goal is extremely undesirable while exceeding the goal is viewed as a "nice to have". Similarly and in a broader context, it is well accepted that individuals dislike large fluctuations in their consumption and hence invest or disinvest to support a smooth consumption stream over time.

Figure 3 presents the terminal wealth distributions from simulations using a 130/30 overlay strategy with the various base assets considered. These distributions capture the uncertain outcomes of the various strategies. We consider the 5th, 25th, 50th and 75th percentiles to assess how well each

Figure 3
Greater certainty
Terminal wealth distributions (USD 1 invested for 20 years); 130/30 strategy with various base assets

		Expected return: Historical						Expected return: 50% of historical				
		Equities base	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL
Percentile	0.05	0.74	1.34	0.74	0.88	1.20	1.02	0.97	0.73	0.80	0.94	0.86
	0.25	1.66	3.13	1.67	2.01	2.70	2.32	2.26	1.66	1.82	2.12	1.96
	0.50	2.86	5.42	2.89	3.47	4.67	4.01	3.92	2.87	3.14	3.66	3.39
	0.75	4.91	9.39	4.97	5.99	7.96	6.89	6.80	4.95	5.43	6.24	5.83
	CE	2.02	3.79	2.04	2.45	3.29	2.82	2.74	2.03	2.22	2.58	2.38
		Bonds base	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**
Percentile	0.05	1.85	3.33	1.86	2.20	2.98	2.57	2.41	1.85	1.99	2.33	2.17
	0.25	2.14	3.97	2.16	2.58	3.47	2.99	2.87	2.15	2.34	2.72	2.53
	0.50	2.37	4.50	2.40	2.89	3.86	3.31	3.25	2.38	2.62	3.03	2.80
	0.75	2.62	5.09	2.66	3.21	4.28	3.68	3.68	2.64	2.91	3.35	3.11
	CE	2.34	4.42	2.37	2.84	3.80	3.27	3.20	2.35	2.57	2.98	2.77
		60/40 base	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**
Percentile	0.05	1.32	2.41	1.34	1.59	2.16	1.85	1.74	1.33	1.44	1.69	1.56
	0.25	2.09	3.91	2.11	2.54	3.40	2.92	2.83	2.10	2.30	2.67	2.47
	0.50	2.84	5.41	2.87	3.46	4.63	3.99	3.91	2.85	3.13	3.63	3.37
	0.75	3.87	7.42	3.93	4.73	6.28	5.44	5.37	3.91	4.29	4.93	4.60
	CE	2.55	4.79	2.57	3.09	4.14	3.55	3.46	2.56	2.80	3.25	3.00

Source: Invesco. Based on data from July 1998 to March 2020. **Past performance (actual or simulated) is not a guide to future returns.** Values are conditionally colored across rows for each expected return scenario. Green: greater than one; red: less than one.

strategy achieves its objectives. Assuming historical premia returns, USD 1 invested in a global equity portfolio is worth less than USD 0.74 in the worst-case scenario (5th percentile) but grows to at least USD 2.86 in more than 50% of the simulations.

When a commodities factor overlay is added to the equity base portfolio, the worst-case payout increases from USD 0.74 to USD 1.34, making a loss of invested capital significantly less likely. The median payout also increases to USD 5.42. Even when we assume that future premia will be only half of past premia, the worst-case payout is USD 0.97.

Following von Neuman and Morgenstern (1944), the expected utility of possible outcomes is computed and inverted to obtain the certainty equivalent (or CE),[12] which expresses the utility (value) of a risky gamble in terms of a certain outcome. Just as CEs can be used to evaluate the attractiveness of lotteries, we can use CEs to rank the attractiveness of investment strategies that expose investors to different risks.

Our reported CEs capture the gains from additional returns of the factor overlay and from the diversification benefits of mitigating drawdowns in the base assets. For instance, the CE for equities is USD 2.02, implying that the volatile wealth gains equal a "certain" gain of USD 1.02. Put differently, the retiree in our example would gladly exchange an equity investment for a bond with guaranteed growth of at least USD 1.02. The higher CEs associated with factor overlays suggest that exposures to factor premia provide clear long-term benefits to investors.

The results suggest that, for all base assets, overlays enhanced accumulated wealth. This holds both when we assume the expected return on factor premia to equal their historical value and when expected return is set to half of the historical value. The marginal utility of premia benefits (captured by the differences in CE) is positive for all overlays. Overlays can mitigate extremely undesirable outcomes, as demonstrated by comparing the relevant CEs across both expected return assumptions.

Overlays can mitigate extremely undesirable outcomes.

In Figure 5, we further analyze the information contained in the certainty equivalent data that capture the distributional properties of the risky assets. We also compare the information provided by the CE to that provided by a return attribution.

Figure 4
Shock absorbers
Pre-retirement balances after drawdowns; 130/30 strategy with various base assets

		Expected return: Historical						Expected return: 50% of historical				
		Equities base	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**
Percentile	0.05	0.29	0.36	0.29	0.31	0.35	0.33	0.32	0.29	0.30	0.32	0.31
	0.25	0.45	0.51	0.45	0.47	0.50	0.48	0.48	0.45	0.46	0.48	0.47
	0.50	0.55	0.59	0.55	0.57	0.59	0.58	0.57	0.55	0.56	0.57	0.57
	0.75	0.64	0.67	0.64	0.65	0.66	0.66	0.65	0.64	0.64	0.65	0.65
	CE	0.49	0.55	0.49	0.51	0.54	0.53	0.52	0.49	0.50	0.52	0.51
		Bonds base	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**
Percentile	0.05	0.92	0.92	0.92	0.92	0.94	0.93	0.90	0.92	0.91	0.93	0.92
	0.25	0.94	0.94	0.94	0.94	0.96	0.95	0.93	0.94	0.94	0.95	0.94
	0.50	0.95	0.95	0.95	0.95	0.96	0.96	0.94	0.95	0.95	0.96	0.95
	0.75	0.96	0.96	0.96	0.96	0.97	0.97	0.95	0.96	0.96	0.96	0.96
	CE	0.95	0.95	0.95	0.95	0.96	0.96	0.94	0.95	0.95	0.95	0.95
		60/40 base	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**	**Base + C**	**Base + R**	**Base + FX**	**Base + EQ**	**Base + ALL**
Percentile	0.05	0.58	0.64	0.58	0.60	0.63	0.62	0.60	0.58	0.58	0.61	0.60
	0.25	0.70	0.73	0.70	0.71	0.73	0.72	0.71	0.70	0.70	0.71	0.71
	0.50	0.76	0.78	0.76	0.77	0.78	0.78	0.77	0.76	0.76	0.77	0.77
	0.75	0.80	0.82	0.80	0.81	0.82	0.82	0.81	0.80	0.81	0.81	0.81
	CE	0.73	0.76	0.73	0.74	0.76	0.75	0.74	0.73	0.74	0.75	0.74

Source: Invesco. Based on data from July 1998 to March 2020. **Past performance (actual or simulated) is not a guide to future returns.**

Figure 5
Attributing the benefits of factor premia
Return and CE attribution of factor premia; 130/30 strategy with various base assets

	Return (%)	**CE (USD)**		**Return (%)**	**CE (USD)**		**Return (%)**	**CE (USD)**
Equity base asset:	0.40	2.02	**Bonds base asset:**	0.36	2.34	**60/40 base asset:**	0.41	2.55
Overlay contribution:			Overlay contribution:			Overlay contribution:		
C:	0.05	0.22	C:	0.05	0.22	C:	0.05	0.22
R:	0.00	0.05	R:	0.00	0.05	R:	0.00	0.05
FX:	0.02	0.00	FX:	0.02	0.00	FX:	0.02	0.00
EQ:	0.05	0.16	EQ:	0.05	0.16	EQ:	0.05	0.16
Interaction:	0.00	0.36	Interaction:	0.00	0.49	Interaction:	0.00	0.56
Total overlay contribution:	0.12	0.80	Total overlay contribution:	0.12	0.93	Total overlay contribution:	0.12	1.00
Base asset + overlay:	**0.52**	**2.82**	**Base asset + overlay:**	**0.48**	**3.27**	**Base asset + overlay:**	**0.53**	**3.55**

Source: Invesco. Based on data from July 1998 to March 2020. **Past performance (actual or simulated) is not a guide to future returns.**

Focusing first on the 130/30 strategy with equity as the base asset, we note that the mean (geometric) monthly return of the base asset of 0.40% is enhanced by the overlay to achieve a return of 0.52%. The largest contributors to this enhancement are commodity and equity factors, accounting for improvements of 0.05% and 0.05% respectively. An analysis of the certainty equivalents provides a richer picture as to the impact of the overlay. The CE of the base asset is USD 2.02; namely, the certain value of the volatile accumulation of market returns over a 20-year horizon is USD 1.02 over the initial investment of USD 1.00. When the overlay is added, the CE increases to USD 2.82, which indicates that the certain value of the overlay's enhancement to wealth is USD 1.82.

The return enhancement of the overlay is about one-quarter of the return on the equity market (0.12%

Figure 6
Little added risk
Volatility of base assets and alternative portfolios

(%)	Base	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL
Equities	15.5	15.6	15.5	15.5	15.5	15.5
Bonds	6.5	6.8	6.5	6.5	6.5	6.5
60/40	9.9	10.1	9.9	9.9	9.9	9.9

Source: Invesco. Based on data from July 1998 to March 2020.

vs. 0.40%); from a utility or "well-being" perspective, however, the overlay provides a significantly larger enhancement (USD 1.82 vs. USD 1.02). This striking difference originates from the diversifying properties of the overlay and its ability to provide positive returns in adverse equity market conditions. Drilling down into specific asset class contributors, we note that, on a stand-alone basis, the commodity factors provide greater enhancements than the equity factors (USD 0.22 vs. USD 0.16). But there is also a portfolio effect of USD 0.36, which we label "interaction", representing the additional return-compounding benefit resulting from the capital protection of the overlay. The interaction effect is larger than the benefit provided by commodity or equity factors alone. This result contrasts the cross-product term of returns across asset class factors, accounting for a small benefit (less than 1 basis point) for the return attribution.

When we examine the cases of bonds and a 60/40 portfolio as the base asset, we see that the portfolio effect of the overlay is economically significant and varies with the base asset. This is in line with the overlay providing differing levels of capital protection depending on the base asset. The portfolio effects of the overlay may appear large, but they are perfectly explainable.[13]

Figure 6 shows the volatility of alternative portfolios. The 130/30 strategies generate only marginal increases in portfolio volatility, suggesting that the wealth-enhancing benefits of the factor overlays are achieved with little incremental risk.

Figure 7
Overlays have it covered
Coverage ratios for various alternative 130/30 strategies with a 4% real withdrawal rate over 30 years

		Expected return: Historical						Expected return: 50% of historical				
		Equities base	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL
Percentile	0.05	0.55	0.81	0.55	0.59	0.70	0.64	0.66	0.55	0.56	0.61	0.59
	0.25	0.88	2.02	0.89	1.04	1.51	1.26	1.34	0.88	0.95	1.14	1.05
	0.50	1.43	3.89	1.46	1.80	2.78	2.28	2.48	1.45	1.60	2.02	1.83
	0.75	2.54	7.57	2.59	3.32	5.24	4.26	4.67	2.56	2.90	3.69	3.36
	CE	1.23	2.58	1.24	1.45	2.00	1.72	1.82	1.24	1.33	1.57	1.47
		Bonds base	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL
Percentile	0.05	0.84	1.61	0.84	0.95	1.30	1.12	1.13	0.84	0.88	1.02	0.96
	0.25	0.94	2.01	0.95	1.10	1.54	1.31	1.37	0.94	1.01	1.19	1.11
	0.50	1.03	2.35	1.04	1.23	1.75	1.48	1.58	1.03	1.12	1.33	1.24
	0.75	1.13	2.75	1.15	1.37	1.98	1.66	1.82	1.14	1.24	1.49	1.38
	CE	1.03	2.29	1.04	1.22	1.72	1.46	1.55	1.03	1.11	1.32	1.23
		60/40 base	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL	Base + C	Base + R	Base + FX	Base + EQ	Base + ALL
Percentile	0.05	0.74	1.46	0.74	0.83	1.14	0.96	1.00	0.74	0.77	0.90	0.85
	0.25	1.03	2.46	1.04	1.24	1.83	1.53	1.62	1.03	1.13	1.37	1.26
	0.50	1.36	3.54	1.38	1.69	2.57	2.12	2.28	1.37	1.51	1.87	1.72
	0.75	1.82	5.09	1.85	2.34	3.60	2.94	3.23	1.84	2.06	2.59	2.36
	CE	1.28	3.06	1.30	1.55	2.27	1.90	2.03	1.29	1.40	1.70	1.57

Source: Invesco. Based on data from July 1998 to March 2020. **Past performance (actual or simulated) is not a guide to future returns.** Values are conditionally colored across rows for each expected return scenario. Green: greater than one; red: less than one.

... and wealth decumulation
Next, we consider the investment strategy while drawing on savings in retirement, using the coverage ratio.[14] The coverage ratio is defined as the proportion of periods over which the accumulated wealth supports a 4% real spending rate over 30-year periods. A coverage ratio of one indicates that a strategy provides for spending across the entire investment horizon. A coverage ratio of less than 1 indicates that a strategy fails to cover spending before the end of the investment horizon. We assume our investor seeks a coverage ratio of at least 1.

Simulation results are provided in figure 7. As a base investment, equities may very well fail to deliver full spending coverage. However, investors reap significant benefits from the overlays which enhance the distribution of coverage ratios across all base assets.

Conclusion
An overlay of factor premia, even conservatively applied, can help achieve a retiree's goals, whether the reference portfolio is all equities, all bonds or any mix in between. A factor overlay is also likely to smooth the path to goal attainment. Worst-case (5th-percentile) outcomes, in particular, are generally mitigated by the overlay. These results hold just as well over the decumulation (retirement) phase, where factor premia overlays exhibit the ability to improve spending coverage.

An overlay of factor premia, even conservatively applied, can help achieve a retiree's goals.

Our results highlight how a simple factor overlay can enhance the risk-reward profile of base assets; they also indicate that a carefully devised completion portfolio could be constructed to build on these results.

Our forthcoming paper will provide additional details, including results from 200/100 factor overlay portfolios, rebalancing considerations and a comparison of completion portfolios to maximum Sharpe ratio portfolios.

Appendix

The analysis presented in this article uses long/short exposures to a variety of factors across various assets classes. We offer concise factor definitions below. For additional details, please contact your Invesco representative.

Commodities
- **Momentum:** seeks to capture the outperformance of commodities with the highest risk-adjusted returns.
- **Value:** seeks to capture the outperformance of commodities whose spot prices have fallen, versus those that have risen, relative to longer-term average spot prices.
- **Carry:** seeks to capture the outperformance of commodities where roll yields are the positive relative to commodities that offer negative roll yields.
- **Defensive:** seeks to capture the outperformance of commodities by altering the tenor (i.e. front month versus deferred month) of the exposure.

Rates (developed and emerging markets)
Developed markets: AUD, CAD, CHF, EUR, GBP, NOK, NZD, SEK, USD.
Emerging markets: BRL, CLP, CZK, HUF, INR, KRW, MXN, PLN, RUB, SGD, THB, ZAR.
Factor time series used for this analysis employed a 50/50 weighting of developed and emerging market factors, where both were available (January 2000 through March 2020), and a 100% weighting to developed market factors otherwise.
- **Momentum:** seeks to capture the outperformance of the interest rate curves with the highest currency-hedged total return.
- **Value:** seeks to capture the outperformance of curves with higher real yields as measured by 6-month inflation expectations and the 10-year yield.
- **Carry:** seeks to capture the outperformance of steeper curves over flatter curves as measured by the difference between the 10-year and 2-year yields.
- **Quality:** seeks to capture the higher risk-adjusted return of the lowest volatility interest rate curves.

Foreign exchange (developed and emerging markets)
Developed markets: ATS, AUD, BEF, CAD, CHF, DEM, EUR, FRF, GBP, ITL, JPY, NOK, SEK.
Emerging markets: BRL, CLP, CZK, HUF, IDR, INR, KRW, MXN, PHP, PLN, RUB, SGD, THB, TRY, ZAR.
Factor time series used for this analysis employed a 50/50 weighting to developed and emerging market factors, where both were available (January 2000 through March 2020), and a 100% weighting to developed market factors otherwise.
- **Momentum:** seeks to capture the outperformance of currencies with the highest median 12-month return.
- **Value:** seeks to capture the outperformance of currencies trading at a discount to their PPP and productivity-implied valuations.
- **Carry:** seeks to capture the outperformance of currencies with a higher forward discount relative to currencies with a lower forward discount. The forward discount (or yield) is measured using 1-month forwards.
- **Quality:** seeks to capture the outperformance of low volatility currencies.

Equities
- **Price Momentum:** seeks to capture the outperformance of stocks whose historical share price performance exceeds sector or market averages.
- **Earnings Momentum:** seeks to capture the outperformance of stocks whose earnings growth performance exceeds sector or market averages.
- **Value:** seeks to capture the outperformance of stocks perceived to be "inexpensive" relative to sector or market averages based primarily on various financial ratios such as price-to-cashflow or price-to-earnings.
- **Quality:** seeks to capture the outperformance of stocks that demonstrate a stronger balance sheet (e.g. lower levels of debt, higher profit margins) relative to sector or market averages.
- **Low Volatility:** seeks to capture the higher risk-adjusted returns of low volatility stocks.

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About the authors

Kenneth Blay
Head of Research
Global Thought Leadership, Invesco
Kenneth Blay works closely with investment teams to lead the development of original research, white papers and articles for publication in practitioner journals, focused on strengthening Invesco's profile as a global thought leader in asset allocation, risk management, systematic and factor investing, and portfolio implementation.

Stefano Cavaglia
Invesco Research Consultant
Stefano Cavaglia is a consultant to Asset Owners and Asset Managers. His work on global equity investing is widely cited. He has applied his research in practice as a hedge fund portfolio manager. His more recent work on factor investing has been featured in several CFA and professional investor forums.

Scott Hixon
Portfolio Manager and Head of Research, Global Asset Allocation, Invesco
Scott Hixon is a Portfolio Manager and the Head of Research for Invesco's Global Asset Allocation team, which invests in stock, bond and commodity markets worldwide. Mr. Hixon oversees and helps steer the team's research initiatives in the areas of model and strategy development, as well as portfolio construction.

Louis Scott
Invesco Research Consultant
Louis Scott is the founder of Kiema Advisors where he collaborates on research and incubates strategy ideas. He has worked as a quantitative researcher in foreign exchange and global equities as well as a portfolio manager. Louis is a mathematician trained at Brown and MIT. He serves as a member of the London Quant Group's management committee.

Notes

1 Carhart et.al. (2018) and Ilmanen et. al. (2019) present evidence supporting multi-asset risk premia portfolios. Mercer's (2018) survey summarizes how these strategies have been implemented in practice.
2 Our work complements the rigorous intertemporal goals-based analytics of Das et. al. (2018 and 2019) and the intertemporal asset-liability framework of Horvitz, and DiBartolomeo (2008) and Blay et. al. (2020). We believe the empirically derived statistics presented here capture many of the key features of this recent research.
3 E.g. investors may be restricted from shorting, constrained into long-only factor exposures.
4 These constructs can be easily implemented with futures. For instance, for USD 100 of initial investment USD 10 are used to buy futures on margin providing a notional exposure of USD 100 to the base asset. The remaining USD 90 can be invested in a long/short strategy that could exhibit varying leverage; for simplicity we assume the total long/short gross exposure to be USD 160.
5 Descriptions of these factors and the markets they span is outlined in the Appendix.
6 There are many ways to group factors. We believe that aggregation within each asset class diversifies the portfolio across asset class and event specific risk. Similarly, there are many ways to weight factors. Our equal-weighted approach provides a somewhat agnostic view on the relative importance of each premia while reflecting the view that some exposure to the factors may enhance the ability to attain the retiree's goals.
7 Returns are reported gross of transaction and borrowing costs; the analysis of Briere et.al. (2020) suggests that factor-based strategies can be scaled significantly by effective management of these costs.
8 "Beta adjusted" returns are obtained by subtracting the systematic market contributions to the factor returns. Our beta adjustment suffers from look ahead bias as the betas applied to the factor attribution are obtained from a single historical estimation. The resulting error is unlikely to affect the qualitative conclusions of our analysis, however, which focuses on long-run (strategic) asset allocation considerations.
9 Liu (2017) examines the benefits of controlling for equity market exposure in traditional factor premia.
10 De Longis (2019), De Longis and Ellis (2019), and Polk, Haghbin, and De Longis (2020) provide an extensive discussion of the methodology for identifying the state variables and their economic interpretation.
11 Style analysis shows that many long-only smart beta strategies have a beta exposure to L/S factors ranging from 0.1 to 0.3. Hence the 130/30 strategy we review is stylistically similar to these long-only strategies though the benchmark relative weight for some stocks (in absolute value) may be larger in our construct.
12 The constant relative risk aversion (CRRA) of 2 has the functional form $U = \{1-\exp(-2w)\}/w$. The expected utility E(w) can then be used in the inverse function of the CRRA to obtain the CE.
13 They are smaller than those documented by Scott and Cavaglia (2017).
14 Estrada and Kritzman (2018) provide this goals-based metric to analyze this problem, defined as $C_t = Y_t/L$, where Y is the number of years of withdrawals sustained by a strategy and L is the length of retirement. Their mainstream assumption is a retirement period of 30 years and a 4% real withdrawal rate per annum.

About risk

The value of investments and any income will fluctuate (this may partly be the result of exchange rate fluctuations) and investors may not get back the full amount invested.

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