Invesco

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Marty Flanagan
President and CEO
of Invesco Ltd.

Responsible Investing is fast becoming mainstream, and asset managers are rapidly putting new processes in place to keep up with the demand. At Invesco, we believe ESG should be regarded not as a separate objective, but as an integral component of the investment management process.

In keeping with this philosophy, we've complemented our successful strategies with a third and innovative element to take account of our clients' evolving needs: Responsible Asset Allocation (RAA). Developed by our multi-asset team in Henley as a new component of the asset allocation process, RAA stands alongside the well-known concepts of Strategic Asset Allocation (SAA) and Tactical Asset Allocation (TAA) to help us deliver investment results while mitigating the impact on society and the environment.

Keeping with the topic of Responsible Investing (RI), another article highlights Invesco's holistic approach that merges low volatility and ESG investing. By combining important RI principles and factor investing, we show how to optimize strategies for results that meet all of the criteria investors value.

We've also included an article on climate change and its consequences for impact strategies and municipal bond investing, as well as a summary of this year's – virtual – Advancing the Frontiers of Factor Investing conference at the Lancaster University Management School, which we co-hosted.

Turning from Responsible Investing to another key theme at Invesco – innovation – another article sets out how we convert immense volumes of unstructured financial data into a useful form for asset management. The raw data can be evaluated systematically using powerful computers and tools like natural language processing. Read this article to learn about the most effective methods and how we apply them.

We hope you enjoy this latest edition of Risk & Reward.

Best regards,

Marty Flanagan
President and CEO of Invesco Ltd.

Responsible Asset Allocation: A pioneering approach to multi asset investing

By Clive Emery

Invesco considers Responsible Asset Allocation (RAA) to be a crucial starting point when constructing multi asset portfolios for today's investors, followed by Strategic and Tactical Asset Allocation (SAA and TAA). We present our new four-step RAA process and explore a possible application scenario in a case study.

Strategic Asset Allocation (SAA) and Tactical Asset Allocation (TAA) are long-established concepts among asset management professionals. But investors' needs are no longer just financial. Our multi asset team in Henley has developed Responsible Asset Allocation (RAA) as a new element of the asset allocation process. RAA focuses on the non-financial outcomes of our investment decisions.

While Strategic Asset Allocation is used to determine long-term asset class and geographical exposures, often over a 10-year plus horizon, Tactical Asset Allocation utilizes a shorter horizon of typically one to three years and adjusts the long-term allocation accordingly. Both SAA and TAA are performance led – though they may take into account elements of ESG in terms of their materiality and impact on risk and return, they are focused exclusively on financial returns. As such, these processes may be less able to deliver a responsible, sustainable or impact outcome. To rectify this shortcoming of conventional allocation approaches, we have added a stand-alone process that focuses explicitly on non-financial outcomes: Responsible Asset Allocation (figure 1).

Of the three processes, RAA is the initial step, followed by SAA and TAA. This ensures that the focus on responsibility is at the start, and at the heart, of our portfolio management activities.

Our RAA process comprises four stages:

1. Deciding where the portfolio sits on the spectrum of Responsible Investing

2. Selecting or creating the investment building blocks

3. A commitment to transparency and to reporting non-financial outcomes of the portfolio

4. Engagement

Step 1: Where does the portfolio sit on the spectrum of Responsible Investing?
A myriad of non-financial issues, from biodiversity to climate change to human diversity, characterize the Responsible Investing landscape. And within each of these issues, there is a spectrum. Accordingly, our first step is to determine what exactly a portfolio wants to target. To this end, we need to ensure that the non-financial objectives are well established, clearly communicated and understood by both client and portfolio manager. Figure 2 shows some common approaches to Responsible Investing.

- **ESG screened** or exclusionary portfolios tend to have some basic exclusions. They are often referred to as "do no harm portfolios" as they exclude sectors deemed harmful.

- **ESG tilted** portfolios tend to have a more involved stock or credit selection process after the initial exclusions. This approach is relevant for both passive and active strategies.

- **ESG leaders** and **SRI/Impact** approaches tend to disqualify even greater proportions of the underlying index before stock and credit selections are made.

Figure 1
Responsible Asset Allocation
An essential addition to our Multi asset investing process

RAA
Responsible Asset Allocation

SAA
Strategic Asset Allocation

TAA
Tactical Asset Allocation
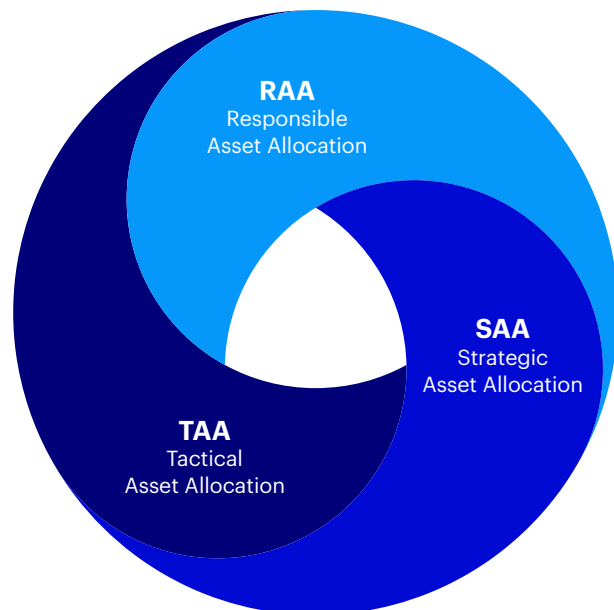
Source: Invesco. For illustrative purpose only.

Demystifying Responsible Investing

Over hundreds of thousands of years, the human eye has developed to distinguish more shades of green than any other color – a fortunate evolution for today's greenwashed world.

Indeed, there remains a huge variance of interchangeable terminology in the world of responsible, sustainable, impact, ethical, ESG and green investment. After numerous conversations with clients and consultants, we believe that the most commendable and consistent approach is that of the UK's Investment Association. They classify portfolios as: Responsible, Sustainable, or Impactful. These three descriptors suggest greater focus, scope and alignment of a portfolio to non-financial outcomes. They are not linked to performance, but to a set of criteria seen as important measures for the target of the portfolio – like reducing poverty, increasing education, improving diversity, limiting carbon emissions, etc.

- **Responsible** is seen as a catchall. Responsible portfolios tend not to have specific targets but a general focus on non-financial criteria.

- **Sustainable** portfolios have a greater focus on the non-financial outcome, often with targets upon which the portfolio can be measured.

- **Impactful** portfolios, also known as ethical portfolios, have an even greater focus on the non-financial outcome, often at the expense of the financial return.

It is also important to distinguish between portfolios that integrate ESG analysis and those that have an explicit non-financial objective. Embedding ESG analysis is not sufficient for a portfolio to be labeled Responsible. Portfolios that classify themselves as Responsible, Sustainable or Impactful should have a non-financial outcome in addition to a financial outcome.

Figure 2
The Responsible Investment Spectrum
From basic exclusions to focused impact investing
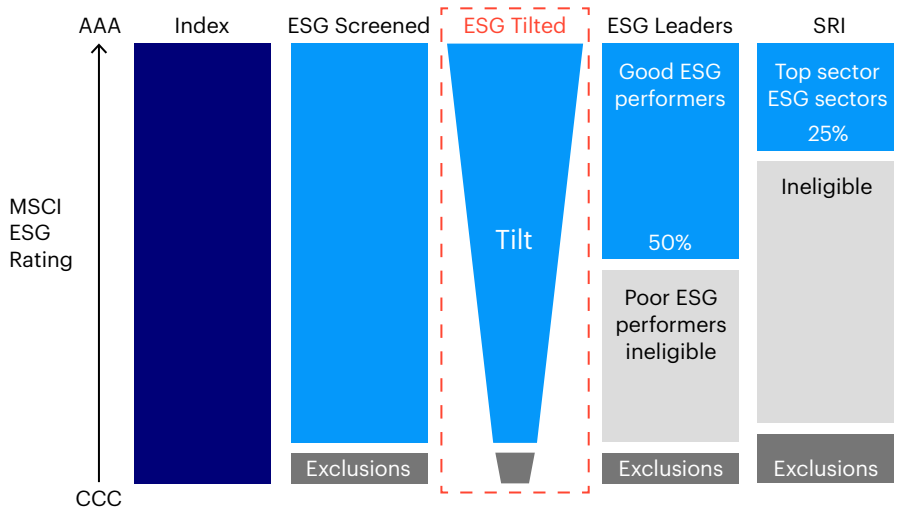
Source: Invesco, MSCI ESG methodologies. For illustrative purposes only.

The different approaches to ESG lead to varying impacts on the tracking error and responsible outcome of a portfolio. As such, there appears to be, similar to the efficient frontier for risk and return, a responsible return frontier (figure 3).

The greater the focus on improving the portfolio's overall ESG score, the greater is the impact on tracking error. This is relatively unsurprising given that the ESG screened approach typically only excludes around 5% of the underlying index, whereas the ESG leaders approach excludes about 50% of the index and the SRI/Impact approach excludes about 75%. Clearly, as one excludes more of the underlying index, the tracking error is likely to widen.

When it comes to performance, however, results are less clear. There is a significant amount of research dedicated to ESG and performance, and there is a wide range of views on whether adding ESG criteria enhances or reduces returns. We do not take sides in this article, but we are aware that a link exists. Irrespective of whether the performance differential is positive or negative, we think it constructive to consider ESG as a factor like growth or value.

Knowing that there is a spectrum of "responsibleness", we can determine a portfolio's objective at the outset. This also lends itself to the ESG approach that Invesco supports: We are fiduciaries, and just as we would not dictate to a client

Figure 3
The Responsible Return Frontier
How different approaches to Responsible Investing impact tracking error and ESG scores
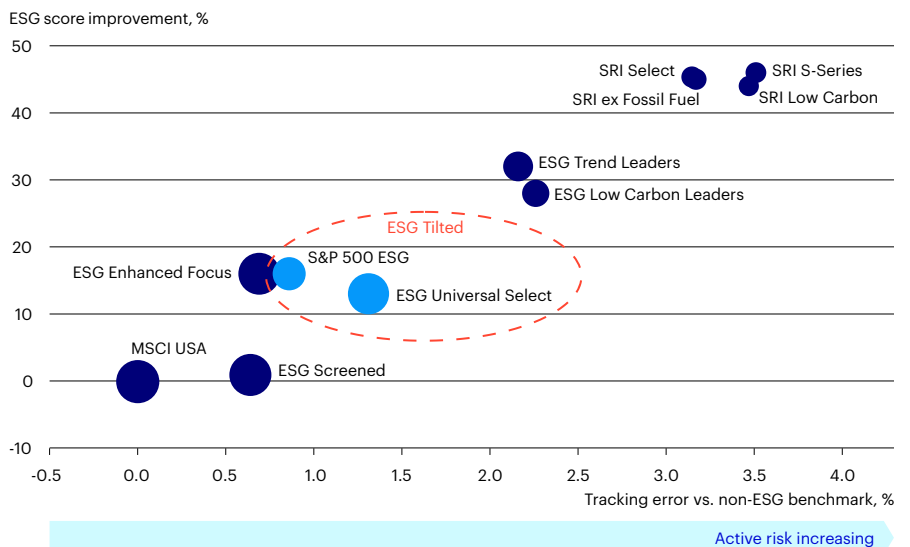
Source: Invesco, Bloomberg, MSCI, as at March 31, 2021, S&P DJI as at September 21, 2020. MSCI USA based indices except where stated. Tracking error calculated from common index inception date of November 30, 2015 to March 31, 2021. Bubble size shows % market coverage by market cap.

their level of risk appetite, neither should we tell them what their approach to responsible investing should be. We can manage Sharia Law and Catholic Principal portfolios at the same firm, without the managers needing to be either Muslim or Catholic. In the same vein, we should be able to manage a range of portfolios that incorporate Responsible Investing criteria to a greater or lesser extent.

The key of RAA is to appreciate that a spectrum of responsibility exists and then establish clear and transparent responsible objectives for a particular portfolio – in the same way one would for the risk and return. A benefit of having clear objectives is that it is easier to monitor how a portfolio delivers on those aims. Once the positioning of the portfolio in the spectrum is decided, we can move on to Step 2.

Step 2: Selecting or creating the investment building blocks
We next determine which building blocks satisfy our RAA criteria.

For single-asset class portfolios, especially in equity and credit, a bottom-up approach can be pursued. More often than not, however, the manager of a multi asset portfolio does not manage the underlying exposure. This could imply numerous investment approaches under the bonnet of a fund of funds. Hence determining the building blocks is a key step.

Many choices need to be made: What percentage of your investments should satisfy your responsible criteria? Should the underlying investments be coherent and homogeneous in their approach? Should the underlying be passive or active? Do the selected building blocks deliver on the stated responsible aims?

The percentage decision
The current marketplace for responsible or sustainable multi asset strategies offers a variety of approaches, but one of the most prevalent is to repurpose an existing portfolio by replacing some of the exposures with greener, more social and more responsible investment portfolios. As there is no clear threshold to delimit what percentage of responsible investments constitutes a responsible portfolio, a smorgasbord has developed with percentages ranging from 40-75%. Invesco has decided to target 100% – but this currently makes us an outlier.

Homogeneous or heterogenous?
Because a multi asset portfolio often delegates the management of the underlying investments, one needs to determine whether the management approaches should be similar or diverse.

There is a wide array of responsible, sustainable and impact products, and their approaches and criteria can differ across asset class and geography. For example, in Europe the 'E' of ESG is in far greater focus, while for clients in the US, the 'S' tends to play a greater role. Accordingly, portfolios in these different regions tend to have different aspirations and objectives.

Some responsible multi asset portfolios have simply added whatever was on their own product shelf to establish a sufficient percentage of responsible exposures, meaning that they could have active impact portfolios for one region and passive responsible products for another. This tends to add complexity and detract from both transparency and consistency. Alternatively, a more homogeneous approach would see the underlying portfolios all aligned with the stated responsible objective.

Active or passive?
Active investment management enables greater engagement than passive or benchmark approaches. But the costs are higher, and consistency may be lower since the market is still in its infancy and there are many different active approaches.

Do the building blocks deliver on the stated responsible aims?
Not all portfolios are created equal and there is a spectrum of 'green'. Therefore, it is important to ensure that the building blocks chosen match and deliver on the stated aims of the portfolio.

It is important to state that this process of review is not a one off. The criteria for the three categories of responsible, sustainable and impact investing have changed over time, and will continue to do so. A good example is coal restriction: A number of years ago, the restriction was set at 30% revenue exposure and has since moved towards 5% (coal restriction). But not all portfolios changed with the times, and some were criticized for claiming not to invest in coal while being significant holders. Obviously, regular reviews are necessary after the portfolio has been set up.

Step 3: A commitment to reporting, transparency and communication
The third element of RAA is a commitment to clear and transparent reporting on a portfolio's non-financial outcomes. Any portfolio can make bold claims and paint pretty pictures. But after a few paragraphs of inspirational prose, the details often dry up. In the knowledge that regulators around the world are keenly aware of greenwashing, we think it is important for any RAA product to stand up to the test of time and scrutiny. We believe this can best be achieved through a standardized ESG report, ideally one that is easy to read and supports the underlying claims of the portfolio.

The three Rs: Return, Risk and ... Responsibleness!
All portfolios report on their investment outcomes in terms of risk and return. So if a portfolio classifies itself as responsible, sustainable or impact, it needs to add a third R – responsibleness. Non-financial outcomes should be measured separately via non-financial metrics.

> Any fund can make bold claims and paint pretty pictures. But after a few paragraphs of inspirational prose, the details often dry up. In the knowledge that regulators around the world are keenly aware of greenwashing, we think it is important for any RAA product to stand up to the test of time and scrutiny.

Figure 4
The three Rs

R³	**I.** **Return:** What is the return going to be?
	II. **Risk:** What are the risks I'll be exposed to?
	III. **Responsibleness:** How responsible is the investment?
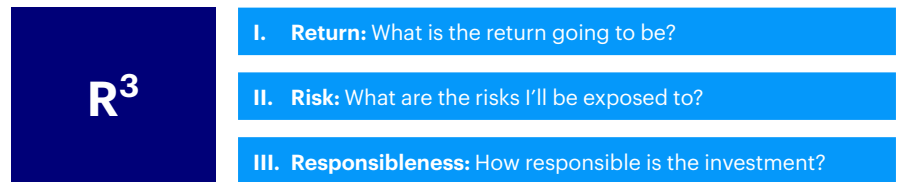
Source: Invesco. For illustrative purposes only.

In practice, given the lack of standardization and the huge focus on marketability, there is a wide range of issues when it comes to reporting. This has led to wonderful infographics showing the number of trees saved or the number of swimming pools full of oil that an investor has conserved through involvement in a specific portfolio. But these factors are not cross-comparable from portfolio to portfolio. How long, wide and deep are these swimming pools? What grade of oil is being used to fill them? This type of conundrum is ever present and it makes review and comparison of portfolio to portfolio data very difficult.

We believe standardization of non-financial reporting to be a key issue, and we expect a significant amount of work in this arena over the coming years.

Bringing the three Rs to life
In practice, comparisons are easier if third-party data is used for non-financial reporting, enabling cross comparison between portfolios. We have used MSCI data for all of our underlying holdings, which is then collated for a comparison to a standard benchmark. Possible non-financial criteria include natural capital, pollution, carbon emissions, gender diversity, etc.

In this respect, the choice of benchmark is a key consideration. Some asset managers self-mark their own portfolios' ESG score and then compare this against an unspecified benchmark, which they also score. We think it is important to precisely define the benchmarks used. This presents a slight complication for a portfolio investing in multiple asset types and regions because the availability of data differs. Specifically, there is significant difference in the granularity of data available for corporates versus that available for sovereigns, an example being the percentage of female CEOs. As such, clear delineation is required to ensure you compare apples to apples and oranges to oranges, by which I mean compare your equity and credit to similar indices and sovereign exposure to sovereign indices.

Step 4: Engagement
Engagement is a key component of Responsible Investing, and this is clearly defined for active equity and credit managers as liaising with company managements. As asset allocators tend not to select individual issuers or engage directly with corporate management teams, we have had to redefine what engagement means and looks like for a multi asset portfolio. This has resulted in us developing three distinct approaches to engagement:

CASE STUDY
Building a responsible fund range
To bring this RAA theory to life, we illustrate how the RAA process was used to build a global risk targeted responsible multi asset range.

The first step was to review the client focus in the UK. From numerous discussions, we ascertained that a Responsible approach, rather than Sustainable or Impactful, was more in keeping with demand. Clients were keen on a more benchmark-based or core approach, with some improvements in the non-financial criteria. As such, we chose to call the range "Summit Responsible" given its broad approach to delivering improvements.

This led us to setting an objective of delivering a benchmark-like return, with low tracking error to the core benchmark, while delivering a 15% improvement in ESG score combined with a reduction in carbon emissions of about 50%. The position on the scale of responsibleness is reflected by the purple circles in figure 3.

We also determined that we should target 100% of our investments to be responsible. Consequently, we selected external funds to ensure that we deliver on this target. The decision was based upon consultations with clients who indicated a preference for a more universal approach.

These conversations also indicated that a more homogeneous investment approach would be preferable. Given the lack of consistent approaches in both the active and passive landscapes, we approached our colleagues in our ETF franchise. They had three ESG ETFs using the MSCI Universal framework, which incorporated more than just exclusions but also 'tilting'. Titling is the process of allocating to stocks against a criterion. This approach fit our needs.

The sector allocation for these three ESG ETFs was kept in line with the underlying index. However, within each sector they allocated more to companies with a higher ESG score or with a better ESG momentum score (companies whose ESG score is improving). This tilting, combined with their core-like return profiles, fit well with our broad approach to responsibility.

Since three ETFs appeared to be not enough for proper asset allocation, we asked our ETF colleagues if they would launch funds using the same approach for the UK, Japan, Asia and Emerging Markets. In addition, we were able to amend the underlying investment vehicles to make them relevant and appropriate to today's demands, a key consideration given the ongoing development and change in ESG criteria. Over the second half of 2020, we worked with our Global ESG team and our ETF team to review the structure of the ETFs. The ESG team advised that there were two components they would amend – namely that we should exclude any company with a CCC or lower ESG rating and that we should tighten the restrictions on the coal industry. The original policy related to coal was to exclude companies with 30% or more revenue derived from coal. This was seen as too high, and so – working with our ETF team and with MSCI – we were able to amend the underlying funds to remove CCC ESG-rated companies and lower the threshold on coal to 5% of revenues.

As for the building blocks of the fund range, two points are worth highlighting: We have yet to allocate any capital to Emerging Market assets, whether debt or equity, because we have yet to find a vehicle that satisfies the responsible criteria of the range. Secondly, as the intent of the fund is to invest 100% in responsible investments, we chose to select a few external ESG portfolios to give us access to investment grade and high yield exposures in the US and Europe. These portfolios have a similar approach and were cost effective to include in the range.

> **"**
>
> In 2020, there were over 2,000 company meetings where ESG topics were raised, and over 130 meetings where ESG was the sole focus.

1) Engagement by selection

Though as asset allocators we are not picking the individual stocks or credit, we wanted to ensure our investments matched the criteria established for a portfolio. This led us to the development of Step 2 of our process: Selecting or creating the building blocks. This process enables us to tailor the investment approach of the underlying investments to ensure they satisfy our responsible criteria.

2) Engagement by delegation

Active ownership through proxy voting and engagement should be an integral component of any Responsible Investment process, for both active and passive strategies. Proxy voting can encourage the companies in which we invest to adopt best-in-class ESG practices.

Being one of the largest asset managers in the world allows our ETFs to follow an "echo voting" approach. Our passive ETFs leverage our wider corporate expertise and they vote in line with the position taken by the largest Invesco active portfolio manager holding the same stocks. Since independent analysis of proxy issues is a core component of the active managers' investment process, this approach can lead to better quality voting decisions.

Additionally, Invesco has recently updated its Proxy Voting Policy that sets forth the framework, broad philosophy and guiding principles that inform the proxy voting practices of our investors around the world. The guiding principle is that our voting process is driven by investment professionals and focuses on maximizing long-term value for our clients, protecting clients' rights and promoting governance structures and practices that reinforce the accountability of corporate managements and boards. The new policy creates a mechanism by which we can test adherence to our policy across the globe, as well as providing guidance on good governance practices. It provides rationales for why we vote in the best interests of clients and improves our conflict-of-interest process while allowing us to clearly substantiate our views on any given governance topics with investee companies, clients and the media.

We have also incorporated some important considerations linked to ESG. The policy establishes an internal definition of director independence and, leveraging insight from our investment teams, specifies a targeted approach to voting on common governance issues, including board composition and executive compensation. Differences in governance practices around the world are considered, ensuring that our voting approach remains market relevant. Local market expertise from across Invesco has been incorporated. Our approach to voting on diversity issues has also been expanded, setting the expectation that companies have at least two women serving on the board, or 25% female representation, whichever is lower.

Additionally, the policy addresses broader diversity issues. Having this newly improved Proxy Voting Policy gives greater confidence that ESG considerations are being incorporated into our asset allocation.

The other benefit of incorporating and leveraging of Invesco's platform of active managers is that there is direct engagement with company managements. We track that engagement for the underlying holdings and have seen a steady increase in ESG topics being discussed and addressed with company managements. In 2020, there were over 2000 company meetings where ESG topics were raised, and over 130 meetings where ESG was the sole focus. And we have an internal target for the latter number to be greater than 500 for 2021.

3) Engagement at national or industry level

The third component of our approach to engagement is to do so at a national, industry or regulatory level. As asset allocators we acknowledge that we do not directly engage with corporate managements, so our focus has instead shifted to developing and promoting Responsible Investing. As we have delegated the conversations with company CEOs on how to improve the practices of their companies to our active colleagues, it has allowed us to shift our focus and engagement to regulators, governments and trade associations when it comes to improving best practices and growing this important area of our industry and society.

Conclusion

The RAA process that our multi asset team in Henley has developed is a distinct and new approach to multi asset portfolio management. The process enables the consideration of non-financial outcomes that are increasingly important to today's investors. At Invesco, we have worked hard to ensure we have the resources at our disposal to create such a process, from the decision about where to place a portfolio on the spectrum of responsibility, to having the ability to choose or create the appropriate building blocks to satisfy these objectives and then ensuring clear and transparent reporting on those objectives. We hope that this process aids clients in delineating both their financial and non-financial requirements and that it will become as ubiquitious for Responsible Investing as SAA and TAA are for traditional multi asset investing.

About the author

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Risk warnings: There are risks involved with investing in ETFs including possible loss of money. Index–based ETFs are not actively managed. Actively managed ETFs do not necessarily seek to replicate the performance of a specified index. Both index–based and actively managed ETFs are subject to risk similar to stocks, including those related to short selling and margin maintenance.

Machine learning: Building factors from unstructured data

By Tarun Gupta, Ph.D., and Edward Leung, Ph.D.

Unstructured data, like news or text data, offers substantially more observations and better coverage than structured financial market data. But investment models require structured data as inputs. We argue that machine learning/natural language processing can be ideal tools to help allocate companies to specific investment themes analyzing a large corpus of news data. Specifically, we discuss the prospect of building a modern natural language processing pipeline for any type of textual factor as an illustration of how the framework may be applied.
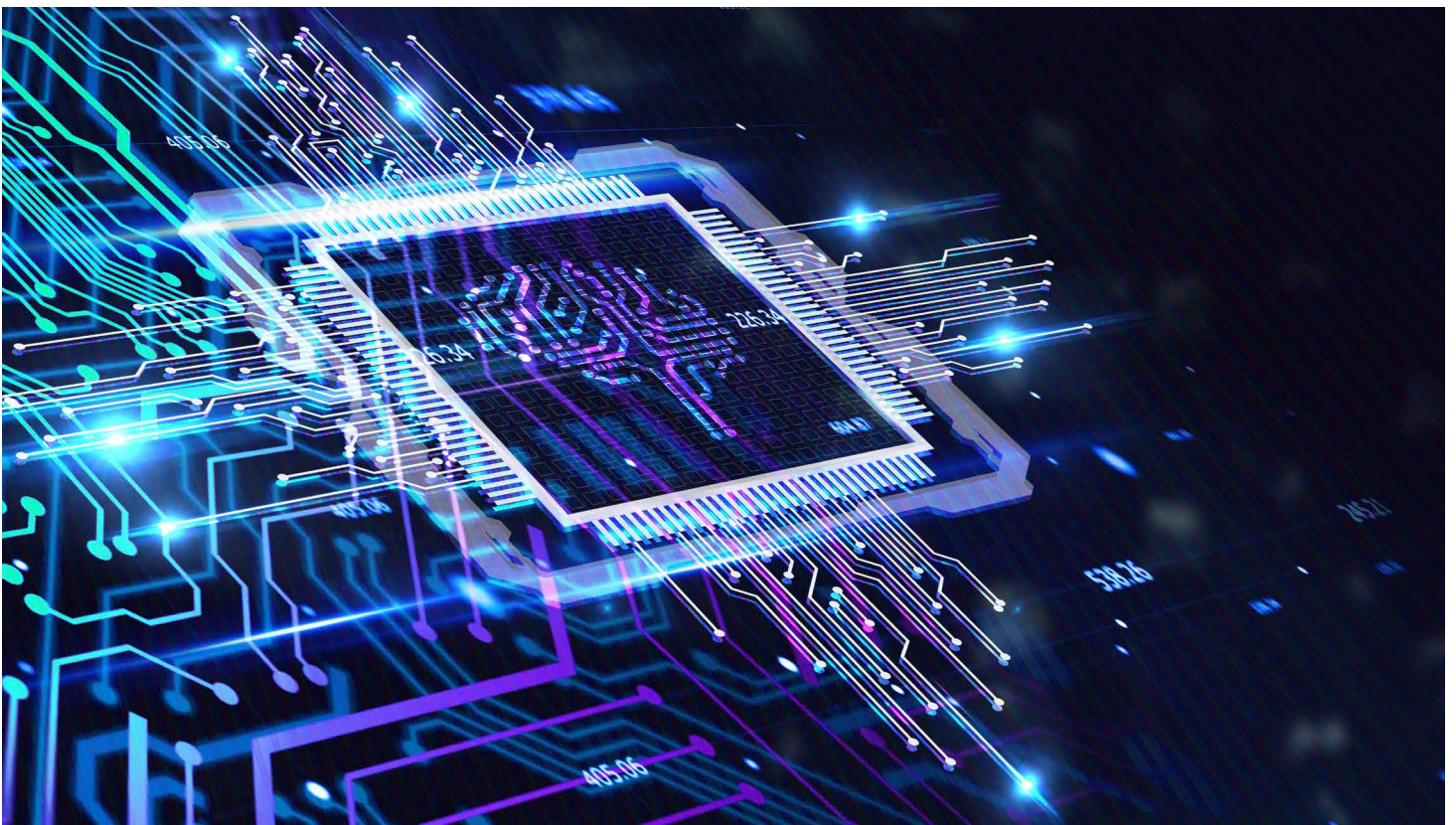
Machine learning (ML) has received considerable attention in recent years as a potential means to improve various aspects of the investment process. Exponential increases in computing power, data storage capacity and the amount of data available all enable good out-of-sample performance in many fields. Yet, in asset management, we typically deal with structured data with a low signal to noise ratio and the constant risk of overfitting. An alternative is using unstructured data, which must first be given a structure. Read more to learn how this can be done.

Machine learning is a subset of artificial intelligence, providing systems the ability to automatically learn and improve from experience without being explicitly programmed. Over the past ten years, we have witnessed a surge in the application of ML approaches for automation and prediction throughout fields such as engineering, robotics and video game design. This has been possible thanks to significant increases in computing power and data storage capacity, as well as the sheer amount of data available. This favorable environment enables complex ML models with hundreds of factors, millions of hyper-parameters and many layers ("deep learning"), with reasonable degrees of freedom.[1]

In asset management, ML research has been applied in various ways to support systematic and factor investing across asset classes including equities, fixed income and currencies.[2] ML is also applied to improve various aspects of the investment process, such as alpha generation, portfolio construction and trade execution.[3] But, in contrast to other fields, asset managers do not have the luxury of "big data". Instead, we have "small" data that comes with a low signal to noise ratio.[4] As a result, we run the risk of overfitting when building complex ML models with many factors and insufficient degrees of freedom.[5]

From unstructured to structured data – and on to factors
Given these obstacles, what can be done to help systematic investing reap the practical benefits of ML? One possibility is

using raw, unstructured data. Unstructured data, unlike data such as financial statements,[6] is unconventional information in an unorganized format, which is not easily accessible to investment managers. Some alternative data vendors are starting to offer raw panel data as part of their product offerings, not just in aggregated form such as by month or by company. Unstructured data is often "big", but it is unwieldy and requires some work to make it useable. Figure 1 shows a process that applies ML or natural language processing (NLP) to do just this, and then using the newly organized data to build factors.
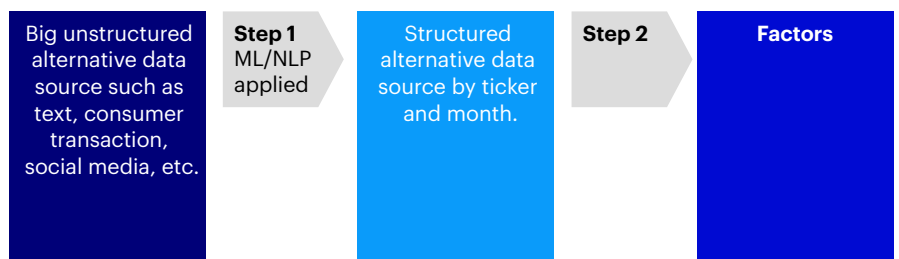
Applying ML/NLP to the conversion of unstructured data is more promising than the application of ML on traditional data, because the sample size is much bigger. Take text data as an example: there are 5,000+ documents filed daily by US public companies and, on average, there are 150,000 words in a typical 10-K filing. Coverage of text/news data is much better compared to other alternative data sources.[7] Text data is "big", making it more suitable for state-of-the-art NLP models, like static and dynamic word embeddings. These models have shown tremendous promise in extracting sentiment from text. In short, processing raw, unstructured alternative data requires significant investment in infrastructure and expertise. But combining this with ML/NLP provides benefits that may well outweigh the costs.

A modern NLP pipeline
In previous articles, we developed an innovative two-step NLP approach to help find companies exposed to the megatrends that will shape the future.[8] The thematic investment approach above depends heavily on a quantitative process that generates a dictionary of innovation-related keywords extracted from documents. Unlike our previous work, in general, dictionary approaches are labor intensive, subjective and depend on domain expertise. Furthermore, no expert can come up with the complete set of keywords.

The ideal case is to create a standard NLP pipeline that can be used to construct any textual factors or generate any themes and may be used to improve other investment process inputs. In addition to steps like

> " Text data is "big", making it more suitable for state-of-the-art NLP models.

> " Asset managers do not have the luxury of "big data". Instead, we have "small" data.

Figure 1

Applying ML/NLP to convert unstructured data to structured and then use it to build factors

| Big unstructured alternative data source such as text, consumer transaction, social media, etc. | **Step 1** ML/NLP applied → | Structured alternative data source by ticker and month. | **Step 2** → | **Factors** |

Source: Invesco. For illustrative purpose only.

data parsing and ticker mapping, the workflow/pipeline should contain:

- Specific NLP processes, such as lemmatization/stemming, collocations, named entity recognition and stop-words removal, to improve the signal to noise ratio of the text data.

- The pipeline should also depend less on using dictionaries that require subjective domain expertise.

Lemmatization is the process of mapping different forms of a word to its base word or "lemma". For instance, after lemmatization is applied, "better" is reduced to "good".

Stemming refers to the process of removing suffixes and reducing the word to some base form, so that all different variants of that word can be represented by the same form. For example, "walked" and "walking" are both reduced to "walk" when stemming is applied. Note that lemmatization and stemming are similar, but not the same. A good example is "better", which is reduced to "good" under lemmatization but remains "better" after stemming. Applying this process reduces redundancy in the text.

Collocations are phrases or expressions containing multiple words that are highly likely to co-occur, such as "New York", "social media", "machine learning" or "as long as". Quantitative processes of identifying these phrases make sense because phrases with multiple words usually have very different meanings than the individual words that make up the phrase. For example, "New York" has a very different meaning compared to "New" and "York" separately. Treating these phrases as one unit enables cleaner NLP results. Identifying collocations is a promising way to come up with innovation themes, because words like "clean" and "water" are likely to co-occur as "clean water", words like "ceramic" and "membrane" are likely to co-occur as "ceramic membrane", and so forth.

Named entity recognition (NER) refers to the task of identifying entities in the document, such as names of people, locations and organizations. For instance, recognizing that Apple is not a fruit, but a company and a reference to Apple, Inc. is important because it helps to reduce the noise of the text. In sentiment analysis, we may want to filter out such proper names from the text before applying NLP. But in projects that focus on relationships between names of people, titles and organizations, proper names are what we want to keep.

Stop-words removal refers to filtering out words that do not contain any content or meaning on their own, such as "a", "an", "as", "the", "of" or "in". These words contribute to the noise of the text. Note that it is crucial to identify collocations before removing stop-words because lots of phrases are made up of stop-words, e.g., "as well as", "as long as", "in terms of".

Figure 2 shows a generic workflow of a modern NLP pipeline, from data acquisition to final output.

The step that truly makes this NLP pipeline modern is captured in the grey box, which is an artificial neural network. This step takes the cleaned data as input and uses "shallow" neural network to produce word embeddings. One way to employ word

Figure 2
A modern NLP pipeline
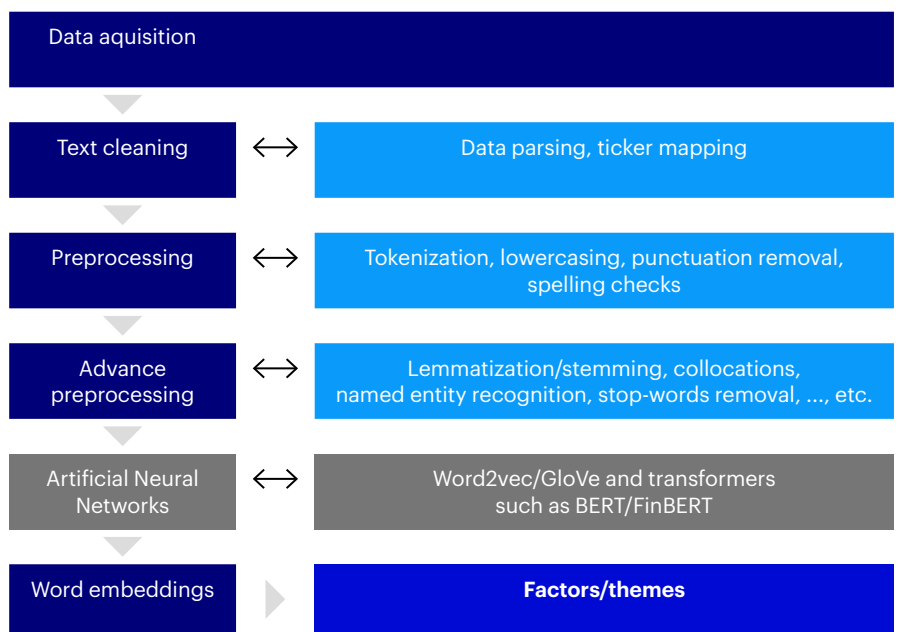
Source: Invesco. For illustrative purpose only.

Table 1
Example of word embeddings

Beautiful	Similarity score
gorgeous	0.83
lovely	0.81
stunningly_beautiful	0.73
breathtaking_beautiful	0.72
wonderful	0.69
fabulous	0.67
loveliest	0.66
prettiest	0.65
...	...
...	...
etc	etc

Source: Invesco. For illustrative purpose only.

embeddings is to augment the dictionaries used to construct factors/themes based on textual data.

Shallow neural network models, like Word2vec and GloVe, capture relationships between every word based on "closeness" – measured by a numerical score. In other words, these models project the meaning of the words onto a vector space where words with similar meanings are mathematically close to each other and words that have different meanings are further away. One can see these word embeddings as a large collection of key-value pairs, where keys are words in the text and value is the corresponding word vectors.

Table 1 is an example of word embedding using Word2vec: For instance, the word "beautiful" is most similar to "gorgeous", with the highest similarity score of 0.83. Next in similarity to "beautiful" is "lovely", with the second highest similarity score of 0.81. Note that the identification of "stunningly beautiful" is only possible because of the identification of collocations.

In essence, the table shows that, instead of hiring experts to come up with a dictionary containing a set of words with similar meanings, word embedding models take a quantitative approach that automatically generates dictionaries providing a measure of similarity, i.e., a list of words that are similar to "beautiful", depending on the score cutoff. This quantitative approach is less labor intensive, more objective and more complete.

More advanced word embedding models that consider context are starting to emerge in the forefront of factor research.[9] Models such as Word2vec or GloVe do not take the order of words into account. Consider the following 2 sentences:

- Sentence 1: Jennifer killed John.
- Sentence 2: John murdered Jennifer.

The words "killed" and "murdered" are used in a very different context, but static models like Word2vec or GloVe will treat "killed" and "murdered" as very similar. The above limitation gives rise to dynamic word embedding models or transformers, such as BERT/FinBERT.[10] These are deep learning models that involve multiple reads from left to right and right to left to model the context of language.

In short, a generic NLP pipeline that contains specific processes to reduce the noise of the text and an artificial neural network module enables us to rely less on dictionaries that are subjective and non-exhaustive. Furthermore, the pipeline automates a process that can produce any textual factors for various applications.[11] Li, Mai, Shen and Yan (2020) apply Word2vec to earnings transcripts to develop a factor that measures corporate culture. Lopez-Lira (2020) analyze risk factors by applying NLP to the risk disclosure section of 10-K company filings. Sautner, Vilkov, van Sent and Zhang (2020) created a climate change factor using the Q&A section of earnings transcripts.

Conclusion
To reap the benefits of ML, one must ensure a very large sample size and a high signal to noise ratio, two qualities that are not always present in traditional data used in asset management. Therefore, applying ML/NLP to convert unstructured big data, e.g., text/news, to monthly structured data, and then using the converted structured data to build factors or generate themes, is a meaningful research direction. We have discussed the prospects of building a modern natural language processing pipeline for any type of textual factor to illustrate how we can apply the general framework. The same process can also be used to improve other inputs in the investment process.

ML/NLP is developing at such a rapid pace that it is difficult to keep up. It is imperative for researchers in the finance field to pay attention not only to research in finance, but also to research by data scientists. We may not have the expertise to conduct pure research in ML/NLP, but we certainly have the expertise to use the pre-trained NLP models that are made available to the public to do factor research.[12] Processing raw, unstructured alternative data requires significant investment in infrastructure and expertise. But with tremendous advancements and feasible deployment in cloud computing, this research direction should exert less and less of a burden on workloads and standard infrastructures.

> ML/NLP is developing at such a rapid pace that it is difficult to keep up.

> Word embedding models take a quantitative approach that automatically generates dictionaries.

Notes

1 See Chapter 1 of Goodfellow, Bengio and Courville (2016).
2 As examples, see Leung, Lohre, Mischlich, Shea and Stroh (2021) and Gu, Kelly and Xiu (2020) for equities; Bali, Goyal, Huang, Jiang and Wen (2020) and Kaufmann, Messow and Vogt (2020) for fixed income; Filippou, Rapach, Taylor and Zhou (2020) for currencies.
3 See Snow (2020) and Dixon, Halperin and Bilokon (2020) for various applications of ML in finance. See Briere, Lehalle and Nefedova (2020) for transaction costs.
4 In equities, the total number of observations is the number of months multiplied by the number of tickers, so around a few hundred thousand observations vs. millions of observations in other fields. In fixed income, we also have "small" data because we often separate the investment grade universe from high yield universe or select a representative bond for each issuer every month.
5 Israel, Kelly and Moskowitz (2020), Dixon and Halperin (2019), and Arnott, Harvey and Markowitz (2019) suggest using theory, variable selection and dimension reduction techniques to guide the choice of predictors. A lower factor-to-sample size ratio will increase the degrees of freedom. Another approach to overcome the issue is to build lower-complexity models. Gu, Kelly and Xiu (2020) find that "shallow" learning, i.e. a neural network that has a only few layers, predicts best out of sample. Less complex models with small data alleviate the issue of insufficient degrees of freedom.
6 For more discussion on alternative data, see Gupta and Leung (2020).
7 For example, typical earnings call transcript offerings start in 2003, covering approximately 5400 equities. Major headlines data offerings start in 2000, covering 10,000 global equities.
8 Elsaesser, Gardin, Kolrep and Rosentritt (2020), and Elsaesser, Kolrep, Cherkezov and Rosentritt (2020) discuss the motivation and design of a process for thematic investing.
9 See Siano and Wysocki (2020) on earnings sentiment and Kolbel, Leippold, Rillaerts and Wang (2020) on climate risk and CDS term structure.
10 FinBERT is BERT built for finance, and there are many versions. See DeSola, Hanna and Nonis (2019), and Liu, Huang, Huang, Li and Zhao (2020), just to name a couple.
11 See Cong, Liang and Zhang (2019) and Li, Mai, Shen and Yan (2020).
12 Word2vec by Google: https://code.google.com/archive/p/word2vec/. GloVe by Stanford U: https://nlp.stanford.edu/projects/glove/. Fasttext by Facebook: https://fasttext.cc/docs/en/english-vectors.html. Wikipedia2vec: https://wikipedia2vec.github.io/wikipedia2vec/pretrained/. BERT by Google: https://github.com/google-research/bert.

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How climate change is changing the US – and what it means for municipal bonds

By Bailey Buckner

To give our investors some background about the impact of climate change, we first present various examples of how it affects the US, sorted by regions. In the second part of the article, we discuss two important social and economic consequences for municipalities and the bonds they issue. With the help of some examples, we then show what this means for impact strategies and municipal investing in general.

> Scientists speculated on the potential negative effects of carbon dioxide on the atmosphere as early as the 1800s.

Climate change is an undeniable reality, and its consequences are already evident. We have all read about – and some of us have experienced – the natural disasters happening from coast-to-coast in the US: winter storms in Texas, wildfires in California, flooding in the Midwest and rising sea levels on the East Coast. These events are obviously devastating for the local people and economies in these regions. But what are the lessons for municipal bond issuers?

Experts have been concerned about climate change for at least 50 years – even longer if one considers the handful of scientists who speculated on the potential negative effects of carbon dioxide on the atmosphere as early as the 1800s. The term "global warming", coined in the 1950s and 1960s, has evolved into the concept of "climate change," which better represents the myriad ways our planet's weather patterns and temperatures are shifting. But the concerns remain the same. And the consequences are now so self-evident as to challenge the views of even the staunchest climate denier.

The turning tide of public opinion is reflected in the explosion of ESG portfolios and impact investing, as well as in the growing number of environmental sustainability programs and policies implemented by both public and private organizations around the world.

At the close of 2018, total assets under management in US-domiciled ESG or sustainability products was approximately USD 12 trillion, according to the Forum for Sustainable and Responsible Investment. By the end of 2020, that number had increased to USD 17.1 trillion, or 33% of total US assets under management.[1]
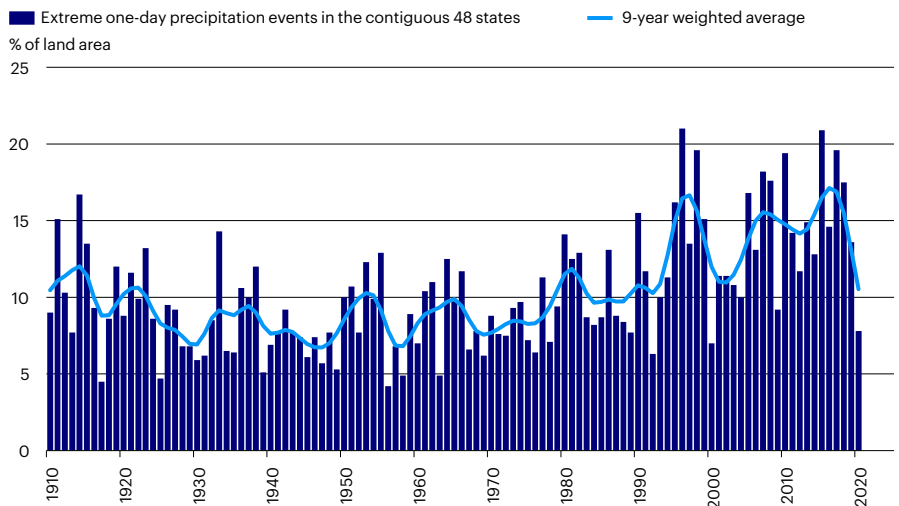
Wildfires and heavy precipitation

Figure 1
Acres burned by year (1983 – 2020)

Acres, mn
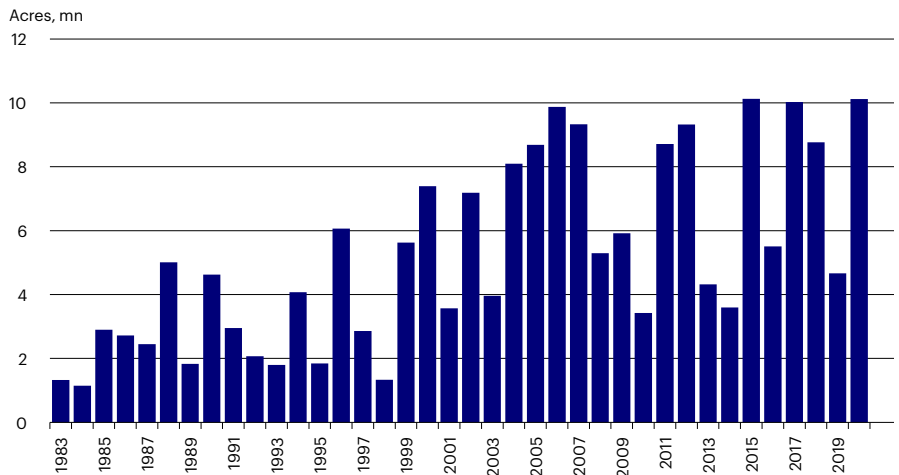
Source: National Interagency Fire Center, https://www.nifc.gov/fire-information/statistics/wildfires, downloaded May 28, 2021.

Figure 2
Areas with heavy precipitation (1910 – 2020)

■ Extreme one-day precipitation events in the contiguous 48 states　　— 9-year weighted average

% of land area

Source: United States Environmental Protection Agency (EPA), https://www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation, downloaded May 28, 2021.

Interestingly, and perhaps surprisingly, municipalities are the leading issuers of green debt in the US, according to *The Bond Buyer*.[2] But anyone paying attention to the news shouldn't be too surprised. Municipalities have always been on the front line against climate change, and now they are confronted by its consequences like never before.

How climate change affects different regions of the US

The Gulf: A winter storm in Texas

Texas presents a stark and timely example of the manifestation of climate change in the United States. In mid-February, a winter storm crippled the state's power grid, leaving millions without heat and power. Freezing temperatures also caused disruptions throughout the state's water infrastructure.

Costly disasters and heavy flooding

Figure 3
Billion-dollar disasters by type (1980 – 2020, CPI-adjusted)
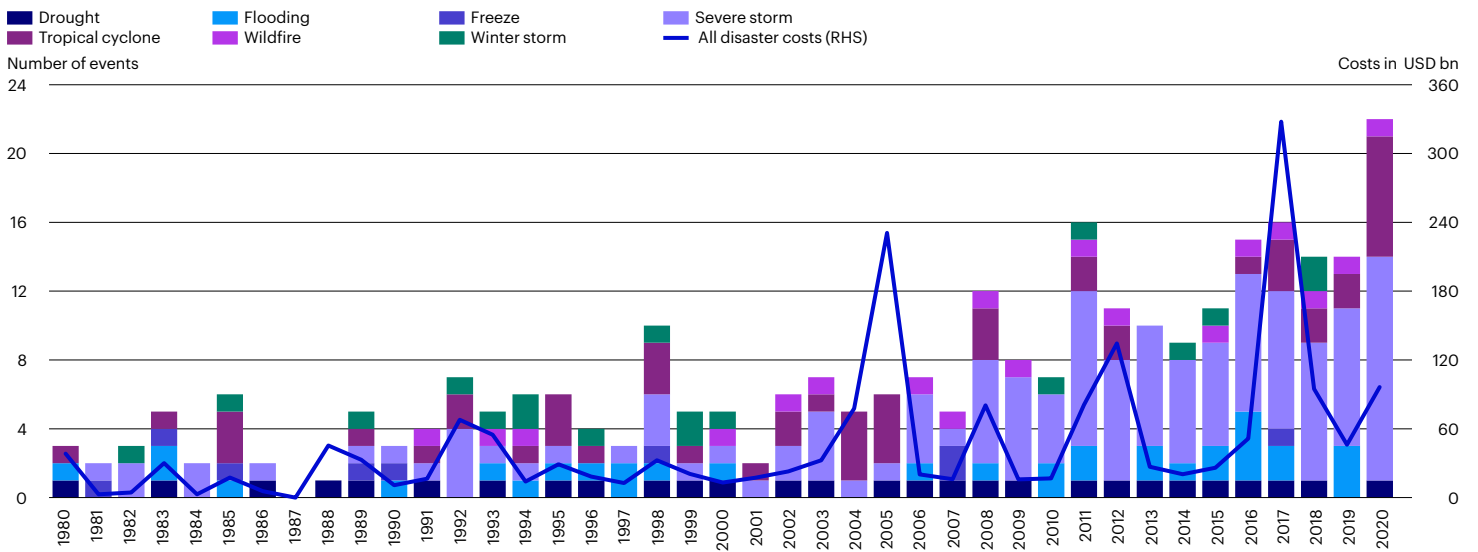
Source: National Centers for Environmental Information (NOAA), https://www.ncdc.noaa.gov/billions/time-series/US, downloaded May 28, 2021.

Figure 4
Frequency of flooding along US coasts, 2011–2020 versus 1950–1959
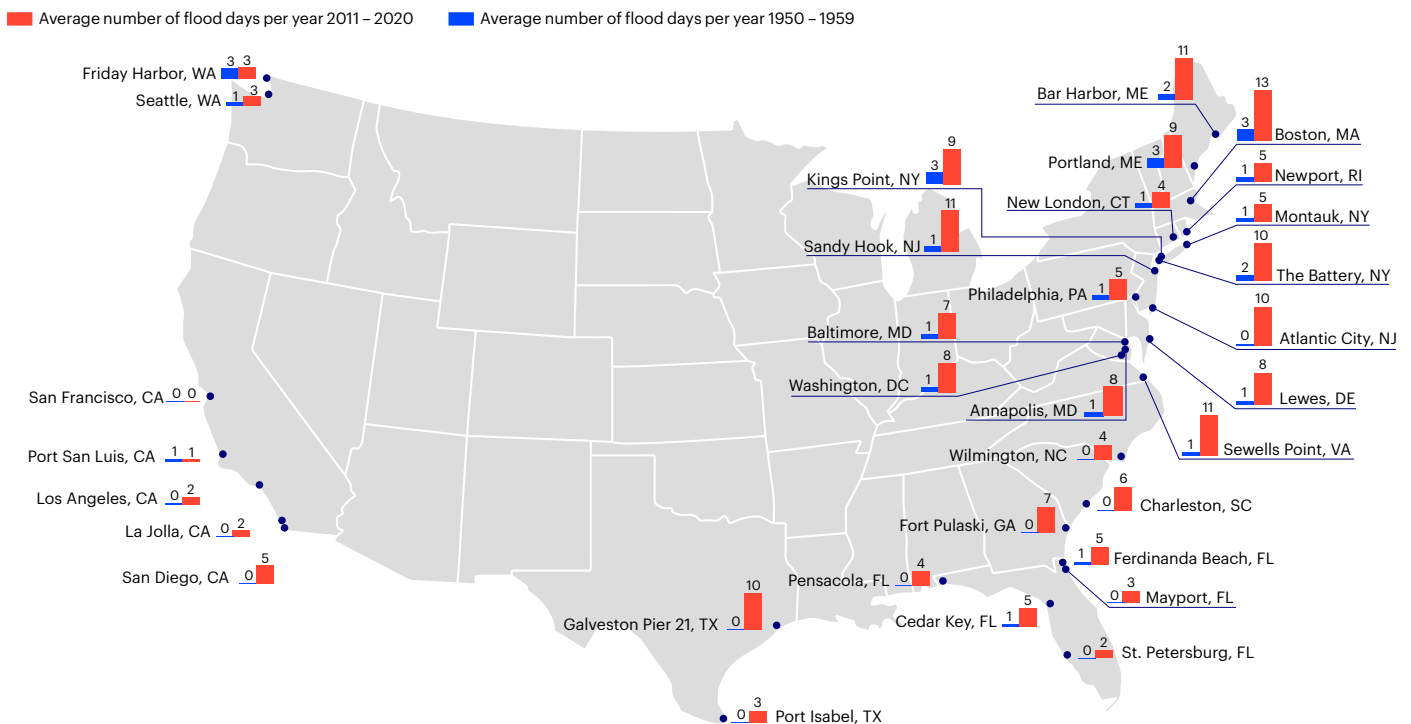
Source: NOAA, https://www.epa.gov/climate-indicators/climate-change-indicators-coastal-flooding, downloaded May 28, 2021. Numbers are rounded.

For some, the storm proved fatal: around 57 Texans are known to have died as a direct result of the storm[3] – but the number is likely much higher. Some of these deaths were caused by hypothermia. Others were caused by carbon monoxide poisoning or fire as Texans desperately tried to stay warm. Numerous fires erupted during the storm.[4] In some cases, firefighters had little or no access to water, making it difficult or impossible to do their jobs.[5, 6]

The communities most negatively affected by the storm were minority and disadvantaged, highlighting not only the state's lack of preparedness but also how failures in infrastructure disproportionately affect the most vulnerable. Examples of this were provided in an article from *The Guardian*; as Texas skylines – filled with empty office buildings – continued to glow with electricity, nearby neighborhoods, many of them low-income, had none.[7, 8]

Many of those who survived the storm are now facing new hardships, including USD 10,000 electricity bills and severe damage caused by burst pipes. At the state-level, some experts estimate that the damage could end up costing Texas USD 200 billion, surpassing the damage caused by Hurricane Harvey in 2017.[9]

It's difficult to imagine things being worse than they were. But according to officials, Texas was on the brink of a total power grid failure that would have resulted in not days, but months without power.[10] In addition to addressing the damage, the state's utility infrastructures will need to be modernized and weatherized appropriately to prevent such mass failures in the future.

The West Coast: wildfires in California
In 2020, wildfires burned approximately 4.26 million acres in California.[11] Hellish photos of tourist sites like the Golden Gate Bridge shrouded in a deep orange haze made rounds in the media.

Wildfires in California are no new thing, but their frequency, size and fatality rates keep rising as severe and ongoing droughts create increasingly dangerous conditions. The longest drought experienced by the state lasted from December 2011 to April 2017.[12] Not only was this the longest period of drought in the state's history, it was also one of the most intense. The intensity of this drought was at least partially attributable to the state's increasing temperatures, which also cause vegetation to burn hotter which in turn makes wildfires more difficult to fight. According to the California Department of Forestry and Fire Protection (Cal Fire), six out of the 20 largest California wildfires occurred in 2020. Five of these 2020 fires were among the top six largest in the state's history.[13]

Over the years, many wildfires in California have been caused by faulty electrical utility infrastructure. Infrastructure maintained by one of California's largest electric utility providers, which serves northern and central California, has caused approximately 1,500 fires in the past six years. This includes the Camp Fire in 2018, the state's deadliest wildfire and one of the deadliest fires ever in the United States.[14]

California – like many states – is paying the price for climate change. From 1979 to 1980, Cal Fire expenditures for fire suppression totaled roughly USD 12 million. Adjusted for inflation, that number today would be approximately USD 38 million. In 2018-2019, expenditures for fire suppression were USD 890 million, with estimates for 2020-2021 as high as USD 1.047 billion.[15] For context, the Camp Fire resulted in USD 18 billion in damages;[16] the 2020 wildfires resulted in an estimated USD 10 billion.[17]

The Midwest: flooding in the heartland
In 2019, heavy flooding along the Missouri River – and to a slightly lesser extent, the Mississippi River – affected approximately 14 million Midwesterners and at least six states.[18] According to Reuters, roughly one million acres of farmland were flooded.[19]

Because the flooding occurred just weeks before planting season, the planting of wheat and corn crops was also limited and delayed. This delayed the planting of crops later in the year as well. Renewed heavy rains in the autumn forced farmers in parts of the Midwest to abandon their crops altogether. Farmers also lost significant portions of their sugar beet, potato and bean crops, which were destroyed by rain or freezing weather in the last half of 2019.[20, 21]

What is notable about the 2019 flooding – other than its unprecedented scale – is that it was not localized to cities and counties along the Missouri and Mississippi Rivers. It was a catastrophe that affected the entire system. The National Oceanic and Atmospheric Administration (NOAA) estimates the flooding to have resulted in USD 6.2 billion in damages.[22] Federal disaster funding was sought for 400+ Midwest counties.[19]

According to a recent report by the First Street Foundation, current flood insurance premiums fail to adequately cover the real risk. To account for the current level of risk, insurance rates through the National Flood Insurance Program (NFIP) would need to rise by 4.5x and 7.2x to cover the risk by 2051.[23]

The East Coast: sea levels rise in Florida and North Carolina
The rise in sea levels has led to increased flooding and saltwater intrusion in coastal cities along the eastern seaboard. Saltwater intrusion – or the encroachment of saltwater into sources of freshwater – is turning freshwater brackish and degrading its quality. The negative effects of this include the destruction of coastal ecosystems, erosion of wetlands, degradation of coastal agricultural soil and loss of potable water sources.

In Miami-Dade County, Florida, sea levels have already risen by four inches in the last

" Texas was on the brink of a total power grid failure.

" Current flood insurance premiums fail to adequately cover the real risk. To account for the current level of risk, insurance rates would need to rise by 4.5x.

27 years. The county is facing flooded roadways, business interruptions, insurance costs, higher storm surges and an inability for public safety vehicles to reach those in need.[24]

Residents in Avon, North Carolina are facing the possibility of significantly increased property taxes to prevent the road in and out of the community from washing away. But this is only a stop-gap measure. According to *The New York Times*, the community is losing six feet of beach a year in some places, and the island itself is only 24 or so feet above sea level at its highest point.[25]

Coastal cities are in a race against time and rising tides. They must adapt by constructing flood barriers, rebuilding old water and wastewater infrastructure to better withstand severe and frequent flooding events and diversifying their water sources. For example, the City of Tampa recently expanded its desalination plant to address the growing reality of saltwater intrusion, water shortages and drought.[26] But these are defensive strategies. Offensive strategies are just as important – if not more so – to the future of the US coasts.

Municipalities must invest in the restoration and conservation of vital coastal ecosystems, such as wetlands and mangroves, which help protect the coast from storm surges and flooding. They must also rethink the way their cities are planned, explore alternatives and prepare to move whole neighborhoods before the ocean comes in and does it for them.

Two important economic and social consequences for municipalities
Stranded assets
The term "stranded assets" is often used in reference to certain risks faced by corporate issuers. For example, if an oil company fails to transition to cleaner energies, they could be left with assets they can neither use nor readily sell.

From a municipal perspective, the risk of stranded assets is different but not by much. Sea level rise will make whole neighborhoods unhabitable. If coastal communities fail to prepare, physical infrastructure such as public transportation infrastructure (rail and subway, especially), water utility infrastructure, wastewater utility infrastructure and electric utility infrastructure could become stranded assets.

And stranded assets are not limited to the physical. Carbon Tracker also highlights risks of economic stranding and regulatory stranding.[27] We know that climate change is going to result in both economic damage and tighter regulations. We know because it is already happening. And as the cost of climate change rises and as regulations change at both national and state levels to address climate change, municipalities that have failed to prepare sufficiently could find themselves with bills they can't pay, literally and figuratively.

Climate injustice
The current climate crisis is not just an environmental crisis but a social one as well. In addition to the physical risks, climate change is threatening the capacity of cities to make good on their most basic mandate of providing reliable infrastructure and safe living environments.

To prevent further wildfires in California caused by faulty infrastructure, the CEO of the energy provider said that the state can expect to experience rolling blackouts for the next decade as the utility improves its infrastructure.[28] While these improvements are necessary (delaying them has not only caused approximately 1,500 preventable wildfires but made rolling blackouts necessary in the first place), they put low-income communities and citizens with medical needs at risk.[29, 30]

Rolling outages were enacted to prevent Texas' entire power grid from collapsing. Unfortunately, the outages were not as short-lived as Texans were led to expect. Many low-income and minority households were without power for days at a time in sub-zero weather.

More broadly, issues such as rolling power blackouts (or outages caused by extreme weather events), flooding and toxic contamination due to rising sea levels are realities that disproportionately affect low-income and disadvantaged communities. According to a 2020 article by Scientific American, coastal and urban flooding both affect minority populations to a significantly greater extent than white populations. Black populations are particularly hard-hit during flooding events.[31]

Exacerbating this issue is a lack of disclosure available to tenants moving into rental units prone to flooding or located in a floodplain. Flood disclosure to tenants is only legally required in one US state, and only if a rental unit has flooded three or more times in the previous five years.[32, 33] Tenants ill-informed about the flood risks of their rental units are vulnerable to a lack of adequate insurance coverage or, in extreme cases, injury or fatality.

Issues and opportunities for municipal bond investing
The private sector leads the public sector in climate change awareness and sustainability, due in part to proxy voting, increased pressure from stockholders, and/or public pressure for accountability and meaningful change. The same mechanism for applying pressure doesn't really exist in the muni bond space. Engagement calls with issuers of municipal bonds – be they governing structures like a city or government agencies like a housing finance agency – just don't wield the same amount of leverage.

However, governments and government agencies do respond, or should respond, to real and present dangers or crises. This is baked into their very structure. It is in their mandate to protect their residents.

> These are defensive strategies. Offensive strategies are just as important – if not more so.

> From a municipal perspective, the risk of stranded assets is different.

> **Issuers of municipal debt are growing wise to the real risks associated with climate change.**

> **Investors in municipal bonds are flocking to ESG and Impact strategies.**

Issuers of municipal debt are growing wise to the real risks associated with climate change. Over the past two years, cities and counties in particular have significantly increased disclosure of their environmental performance. They are also more forthcoming with detailed, science-based solutions to the unique problems they face. Some of these solutions are older than the states themselves. In the case of California, indigenous forest management techniques such as controlled or prescribed burns are being considered again after decades of policy away from these techniques.

Invesco integrates environmental data and environmental risk considerations at both the ESG scoring level and during portfolio construction. As data becomes available from municipal issuers, material ESG datapoints are folded into the ESG scoring process. These datapoints can include items such as the number of combined sewer overflows and sanitary sewer overflows, which can be used as an indicator of a wastewater system's resilience, or lack thereof. We also consider whether a city has adopted a resilience or sustainability plan. If so, are they publishing annual sustainability reports or maintaining a sustainability dashboard? And at the portfolio construction and management level, we are integrating more geographical risk into investment decisions.

When it comes to environmental factors, infrastructure is the natural focus – whether it is the resilience of existing infrastructures, planned improvements or the installment of new sustainable or renewable infrastructure.

For example, we might look at the differences between two energy companies to understand the various ways ESG is being integrated and how infrastructure plays into that equation.

For example, utility company A's fuel mix surpasses Invesco's exclusion thresholds and its faulty infrastructure has been responsible for numerous wildfires in California. Such severe infrastructure risks and failures prohibits inclusion of the credit in the ESG & Impact Strategy.

Utility company B as a credit may not be eligible for our ESG & Impact Strategy due to its fuel mix, but its wind projects are eligible. Wind or solar projects from ineligible issuers may qualify. These types of exceptions make it possible to include renewable infrastructure projects with positive environmental impacts, even if the issuing credit is ineligible.

Luckily, we are seeing an increase in the number of positive environmental infrastructure projects. For example, cities in drought-prone areas are replacing non-native flora with native plants that are better suited for a region's natural climate. In southern California and the Southwest region of the US, this often takes the form of replacing non-native grasses that require heavy watering with native cacti and succulents that require far less water. This also helps prevent erosion, as native plants do a better job of protecting the land itself. For municipalities in these areas, projects like this can only be beneficial.

Conclusion

Investors are asking important questions about climate change adaptation strategies and social equity programs. And evidence suggests that issuers in the municipal bond market are listening. Given the increasing frequency and severity of extreme weather events, they can't afford not to.

Furthermore, due to the prevalence of zero and negative rate environments globally, the taxable municipal bond market has also grown more attractive to foreign investors. While foreign investors cannot benefit from the tax breaks associated with the tax-exempt muni bonds, the higher yields found in taxable munis may provide positive yield for these investors. Combined with the rising global interest in ESG, ESG taxable munis are likely to stand out.

Notes

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Investment Risks

Municipal securities are subject to the risk that regulatory or economic factors could affect an issuer's ability to make payments of principal and/or interest and the fund's ability to sell it. Municipal securities, which are in the medium and lower-grade categories, generally offer higher yields than are offered by higher-grade securities of similar maturity, but they also generally involve more volatility and greater risks, such as greater credit, market, liquidity, management and regulatory risks.

Low volatility and ESG investing combined: Invesco's holistic approach

By Manuela von Ditfurth, Thorsten Paarmann and Erhard Radatz

The low volatility factor in conjunction with the style factors Quality, Value and Momentum, has empirically proven to be able to moderate market risks and improve a portfolio's overall risk-return profile. By integrating ESG into such a factor portfolio, future risks may be mitigated. We present a proprietary approach to managing ESG risks that can maximize sensitivities to the desired multi-factor characteristics, and we calculate Climate VaR under different global warming scenarios.

> **Low volatility portfolios tend to provide more stability.**

> **A multi-factor model can replace adverse ESG assets with better stocks without adversely affecting factor returns.**

Low volatility investing has become mainstream – and so has ESG. And since Invesco is a pioneer in both fields, it seems only natural to combine the two and develop a low volatility ESG approach to equity investing.

When Invesco Quantitative Strategies started managing low volatility portfolios in 2005, they were a niche play. More than a decade later, they have gone mainstream. The most likely reason is the low volatility anomaly – the observation that lower-risk stocks have, on average, higher risk-adjusted returns. Moreover, low volatility portfolios tend to provide more stability with less-pronounced drawdowns in market corrections. Hence, they can offer better Sharpe ratios and provide a more attractive investment proposition, especially for absolute return-minded equity investors.

Similarly, we've played a pioneering role in ESG investing, having started incorporating ESG aspects two decades ago and steadily increasing the scope of ESG mandates across different regions and products. While we apply an ESG-integrated investment approach as default, a significant share of our portfolios embraces sustainability criteria beyond basic ESG integration.

In this article, we develop an approach that combines the two concepts to create a low volatility ESG strategy for equities.

Our approach to low volatility investing
Invesco Quantitative Strategies has always combined a low volatility approach with multi-factor stock selection. Instead of constructing a portfolio with risk reduction as the sole objective, we target factors that can enhance performance. This results in a portfolio that benefits from the low volatility anomaly while enhancing return potential from allocations to the factors Quality, Value and Momentum. Each of these factors can improve the portfolio's risk-return characteristics in the long term,

particularly since low correlations between them provide additional diversification. Figure 1 illustrates typical factor exposures of a low volatility strategy relative to a reference index.

The question is how to best combine the two objectives: a low volatility positioning and exposures to other rewarded factors, Quality, Value and Momentum. While one can combine them in one optimization, you face the challenge that they may interfere with each other as large exposures to Quality, Value and Momentum will increase the portfolio volatility and reduces or even offsets the benefit of the intended low volatility positioning.[1] Therefore, we have developed an improved portfolio construction approach that separates the different objectives: first, a low-risk equity portfolio is constructed that focuses purely on capturing the low volatility anomaly. Then, we run an optimization relative to this defensive portfolio to establish intended exposures to the other factors Quality, Value and Momentum. This two-step process controls interference between the two effects.

Our tiered approach is perfectly suited to other settings, e.g., when additional aspects like ESG integration are considered. The first optimization defines a sensible starting point, which is then enhanced in a second step to target return-driving factor exposures.

Integrating ESG in low volatility portfolios
We integrate ESG aspects at multiple levels, beyond pure risk management.[2] This follows our conviction that, though certain adverse effects of weak ESG profiles may not have materialized in the past, they could – and likely will – drive capital market valuations in the future. We applied a set of well-chosen exclusions and best-in-class screening to identify companies with a higher probability of materializing ESG risks. Our research shows that a multi-factor model can replace adverse ESG assets with better

Figure 1
Standardized factor exposures in comparison
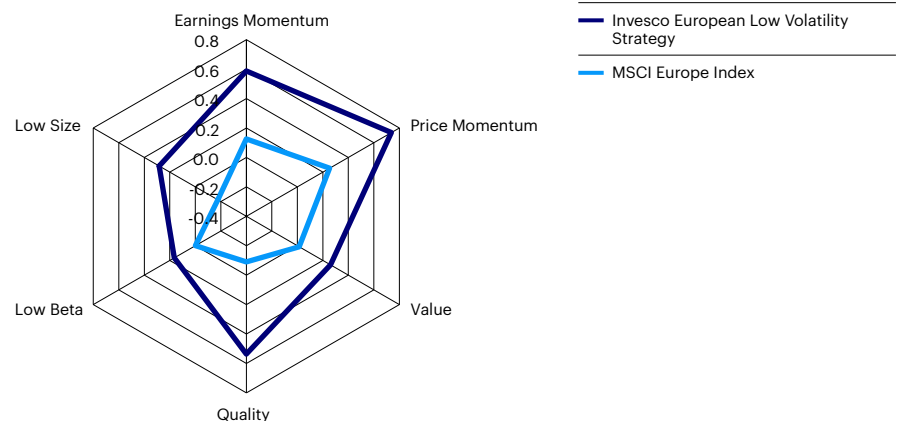
Source: Invesco. In line with previous publications. Data as at March 31, 2021. "Momentum" is split into "Price Momentum" and "Earnings Momentum". For illustrative purposes only.

ESG integration at Invesco Quantitative Strategies

Invesco Quantitative Strategies follows a fully integrated ESG investment process, built on longstanding experience in customized ESG solutions, active engagement with companies and the Invesco proxy voting approach.

In our multi-factor optimization process, we consider the impact of key ESG aspects (both explicit and implicit) at single stock, portfolio and risk management level. We incorporate proprietary aspects of governance in the Quality factor, implement a dedicated ESG exposure control in the construction phase of all portfolios and employ an adverse ESG Momentum measure to restrict companies with weak ESG scores and significant risk of ESG downgrades.

Elements of our integrated ESG investment approach
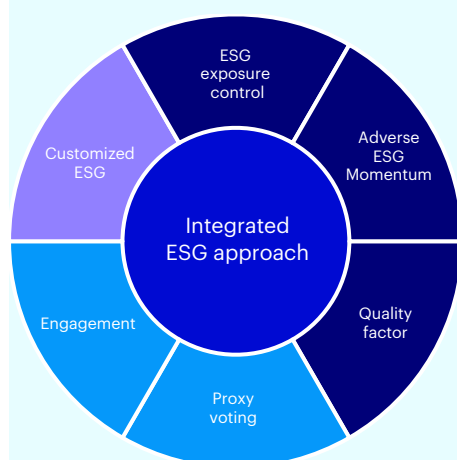
Source: Invesco. For illustrative purpose only.

Beyond broad-based integration across all portfolios, customized ESG criteria can be implemented to meet client-specific requirements as well as internationally recognized norms, conventions and ESG quality labels, such as the Eurosif Transparency Code and Febelfin Towards Sustainability, among others.

stocks without adversely affecting factor returns or substantially altering the risk-return profile.[3]

Table 1 shows the exclusion criteria for a typical low volatility portfolio. We also apply a best-in-class approach to filter out companies that lack the ability to transform into a low carbon economy. This filter, as with every element in our investment process, is applied by comparing companies against their sector and regional peers to build meaningful peer groups and ensure comparability.

Our criteria focus on environmental issues while avoiding significant harm in both the social and the governance pillar. Controversy screening is based on a proprietary methodology using data for the frequency, severity and responsiveness of a company when it comes to controversies – to filter out those with weak policies which face the risk of recurring controversies.

Using two optimizations, one with ESG constraints and one without, we can compare sensitivities to the desired factors. The theory of factor investing

Table 1

Invesco Quantitative Strategies criteria for ESG screening in low volatility portfolios

	Controversial Activities	Excluded if
Coal	Revenue from thermal coal mining	**Exceeds threshold**
	Revenue from burning coal for power generation	**Exceeds threshold**
	Proportion of coal in electricity generation fuel mix	**Exceeds threshold**
Unconventional oil & gas	Revenue from projects or the extraction of tar sands and oil shale, as well as the proportion of reserves in tar sands or oil shale	**Any involvement**
	Involvement in fracking activities	**Any involvement**
	Involvement in arctic drilling activities	**Any involvement**
Fossil fuel industry	Revenue from fossil fuel industries	**Exceeds threshold**
Environmental strategy	Company's commitment to defining clear objectives and appropriate measures to manage the environmental impacts of products and services	**Insufficient environmental strategy**
Chemicals of concern	Production of restricted chemicals	**Any involvement**
Biodiversity	Controversies in the field of endangering biodiversity	**Significant controversies**
Community involvement	Controversies in the field of community involvement (including, e.g. impact of operations on the local economy, responsible tax strategy, transfer of technology and skills)	**Any involvement**
Nuclear power	Revenue from nuclear power	**Exceeds threshold**
	Proportion of nuclear power in electricity generation fuel mix	**Exceeds threshold**
Civilian firearms	Manufacture or sale of civilian firearms or related products	**Exceeds threshold**
	Manufacture of civilian firearms or related products	**Exceeds threshold**
Military	Revenue related to military sales, including key parts or services for conventional weapons	**Exceeds threshold**
	Controversial weapons & financing of cluster munitions or anti-personnel landmines	**Any involvement**
Tobacco	Revenue from tobacco production and distribution	**Exceeds threshold**
	Revenue from tobacco production	**Exceeds threshold**
UN Global Compact	Failure to pass Global Compact screening	**Failures**

Source: Invesco, as at December 31, 2020.

Figure 2
Factor sensitivities in comparison
Realized sensitivities
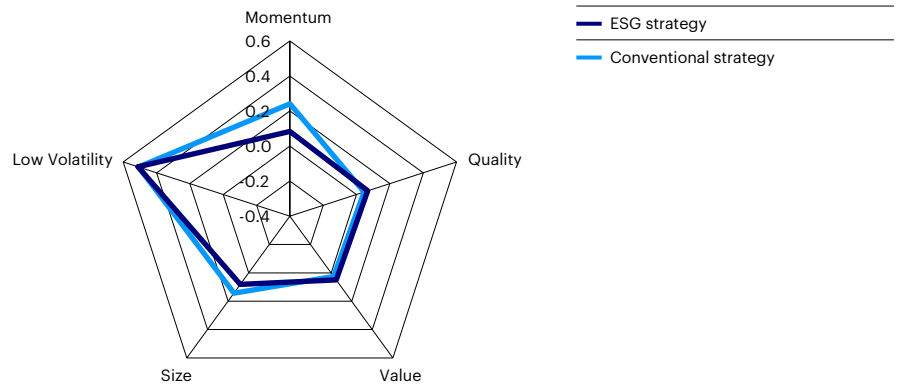
Source: Invesco, based on data from April 12, 2019 to December 31, 2020.

> To quantify the impact of ESG aspects on portfolio risk, scenario analysis can be a useful alternative.

claims that single securities are merely the carrier of the factor exposure and that the exclusion of some stocks can be mitigated by using other securities with similar characteristics. Figure 2 shows a regression of the active return on the most prominent investment factors of two European low volatility strategies: one including the criteria from table 1 and one without. Obviously, the returns of both strategies are driven by similar factors, thus the ESG overlay does not impede harvesting of the desired factors.

As expected, the ESG strategy shows stronger ESG metrics than the conventional low volatility strategy. As an example, figure 3 compares the greenhouse gas intensity of the two strategies. The ESG strategy can massively reduce the carbon footprint of the portfolio.

ESG risks
Since most dominant ESG risks have not yet materialized, they are not evident in

covariance matrices, which are based on historic data. To quantify the impact of ESG aspects on portfolio risk, scenario analysis can be a useful alternative. We applied the MSCI Climate VaR methodology[4] to three different portfolios:

1) a conventional European low volatility portfolio

2) a European low volatility portfolio promoting ESG criteria, as described above

3) the MSCI Europe index as a reference

We assumed two different scenarios.[5] In scenario 1 (mitigation), global warming is limited to a 1.5°C increase in temperatures compared to pre-industrial levels – the goal set out in the 2015 Paris Agreement. This scenario will lead to high costs for companies that are not yet aligned to a net-zero greenhouse gas emission economy or that have high reserves of

Figure 3
Carbon profiles in comparison
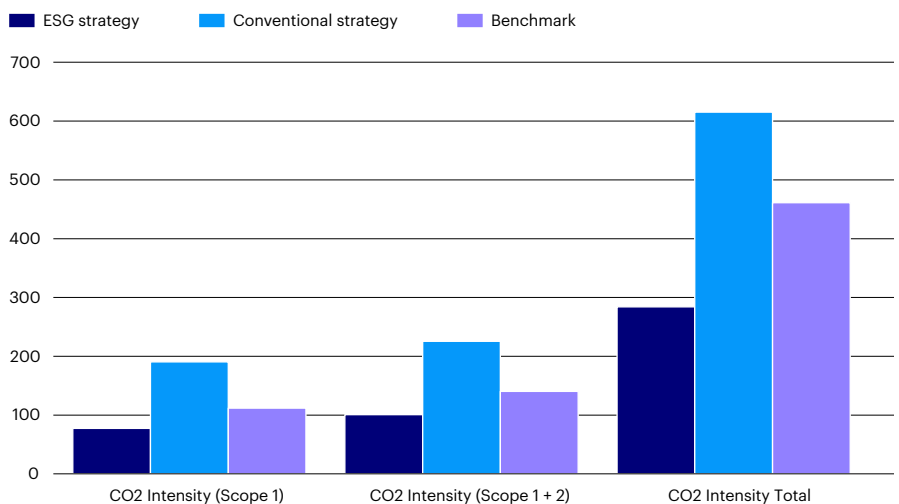
Source: ISS Climate Solutions, Invesco, as at December 31, 2020; carbon data from 2019. Carbon intensity is calculated as the weighted average of the respective scope emissions (CO_2 equivalents) per USD million of revenue.
Past performance is not indicative of future results.

Figure 4
Climate VaR of three different strategies

■ Portfolio 1: Conventional European Low Volatility Strategy
■ Portfolio 2: European Low Volatility Strategy promoting ESG characteristics
■ MSCI Europe

Climate VaR, in %
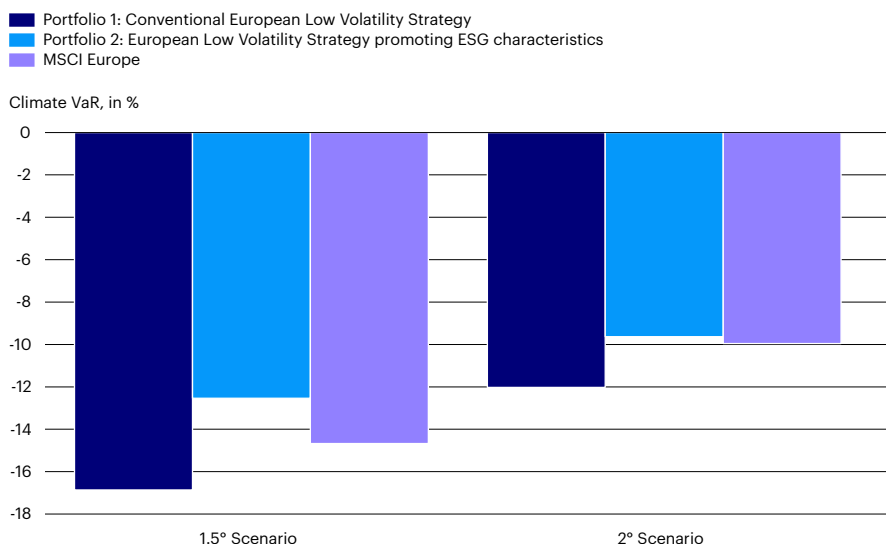
Source: Invesco, MSCI, as at December 31, 2020. **Past performance is not indicative of future results.**

fossil energy. Scenario 2 sets a 2°C limit – the upper limit in the Paris Agreement. This would require less in the way of greenhouse gas reduction efforts but more investment into adapting to a warmer climate.

Figure 4 shows that portfolio 1 has a higher Climate VaR than the index. While this might be counterintuitive, as the portfolio is constructed using a low volatility approach, the sector exposure of a typical low volatility strategy (overweighting utilities) leads to higher carbon intensity and, ultimately, a risk of stranded assets. The ESG portfolio (portfolio 2) can mitigate this bias. In fact, the portfolio exhibits a reduction of the Climate VaR relative to both portfolio 1 and the index. Even though we did not explicitly control for the Climate VaR calculation, the ESG criteria lead to a financial materiality in reducing exposure to mitigation risks.

These policy risks become less significant for the 2°C scenario and, since potential losses are smaller, less can be gained from mitigating them.[6]

But there are some caveats: When interpreting the difference of mitigation costs in those two scenarios, one should keep in mind that they are based on listed mid to large-cap companies only (i.e., quite a limited part of our society and economy). Furthermore, the analysis does not consider broader systemic costs and benefits due to the wider economic effects of endogenous factors such as the introduction of policy obligations or new technologies and innovations like carbon capture.

Conclusion
Invesco played a pioneering role in the mainstream establishment of low volatility and ESG investing. We have developed an approach that links low volatility investing with other return factors and ESG considerations, drawing on the established strengths of Invesco Quantitative Strategies and emphasizing measures to conserve environmental integrity and slow global warming. ESG integration improves a portfolio's Climate VaR and thus insulates it against the risks to come. While we used a European universe as an example, the robustness of our portfolio construction method means this strategy can be applied to other universes, including global equities.

> Invesco played a pioneering role in the mainstream establishment of low volatility and ESG investing.

Notes
1   See also Fraikin, Gerard, Roberts (2020).
2   For a detailed explanation, please see von Ditfurth, Fraikin, Uhlmann (2018).
3   See also Elsaesser, Nerlich (2020).
4   The MSCI Climate VaR methodology (MSCI 2020) estimates the impact of different climate scenarios using a range of transmission mechanisms: the risks of climate change to business models (e.g. extreme weather, flooding), the risks of policy changes to business models (e.g. higher carbon prices) and the opportunities (e.g. higher value of patents in certain greenhouse gas mitigation techniques).
5   The scenarios utilize carbon prices from the AIM CGE model.
6   Since climate change mitigation can be more costly than adaptation to higher temperatures, one may well ask why policy makers actually care about the degree of global warming. However, the answer is obvious: the overall cost of a failure to mitigate the climate crisis will by far exceed the costs of a successful decarbonization strategy; see also OECD (2015).

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Shifting the frontiers of factor investing

By Mustafa Berke Erdis and Dr. Harald Lohre

Invesco regularly engages with the academic community to promote research into systematic and factor investing. Our most recent event was co-hosting the Frontiers of Factor Investing Conference held virtually at the Lancaster University Management School in January 2021.
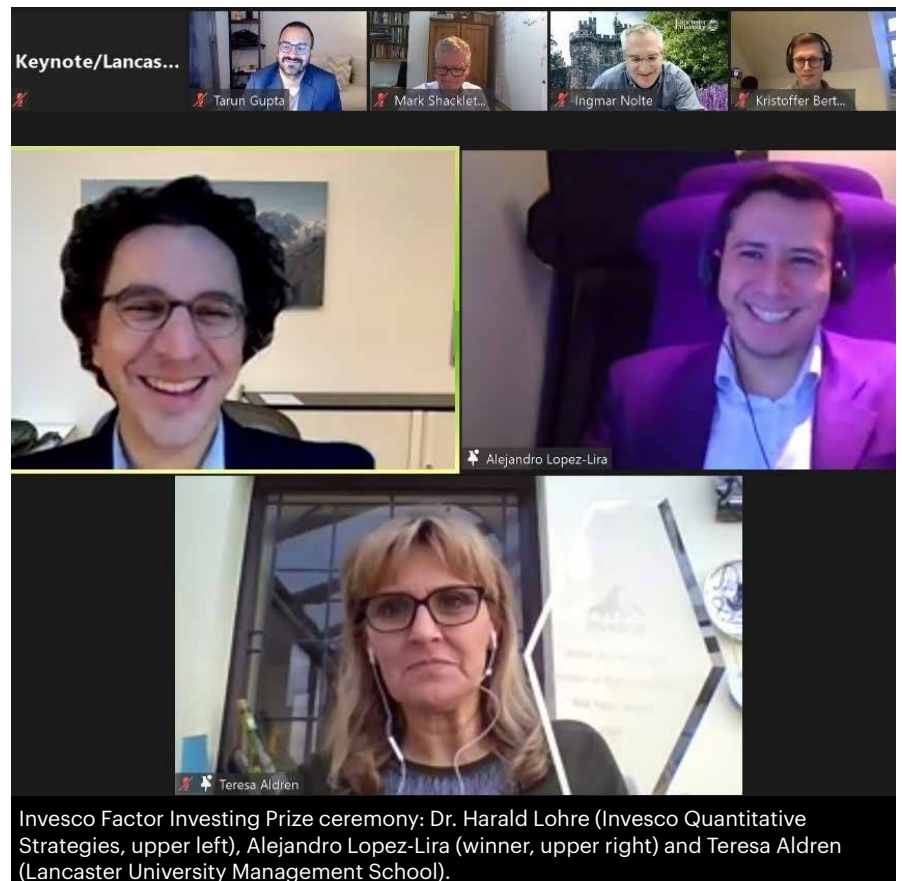
Invesco Factor Investing Prize ceremony: Dr. Harald Lohre (Invesco Quantitative Strategies, upper left), Alejandro Lopez-Lira (winner, upper right) and Teresa Aldren (Lancaster University Management School).

> " Corporate bonds provide an excellent laboratory to further explore explanations for book-to-market return patterns in asset prices.

Building on the success of the first conference in 2018,[1] scholars from the Centre for Financial Econometrics, Asset Markets and Macroeconomic Policy (EMP) at Lancaster University Management School and the Centre for Endowment Asset Management (CEAM) at Cambridge Judge Business School joined forces with Invesco Quantitative Strategies to organize the sequel.

Three keynote speakers provided the frame for a multitude of parallel sessions exploring research avenues into factor investing, including advances in asset pricing and factor modeling, factor investing beyond equities, as well as the use of machine learning and NLP techniques to tease out potential new factors from alternative data sources:[2]

- **Söhnke Bartram**, Professor of Finance at the University of Warwick and CEPR, talked about the predictive power of the book-to-market ratio for corporate bonds;

- **Guofu Zhou**, Frederick Bierman and James E. Spears, Professor of Finance at Olin Business School of Washington University in St. Louis, discussed various improvements to conventional factor models;

- **Tarun Gupta** of Invesco Quantitative Strategies showed how the use of alternative data can lead to better factor investing outcomes.

Also presented was the paper of this year's Invesco Factor Investing Prize winner:

- **Alejandro Lopez-Lira**, Assistant Professor at BI Norwegian Business School.

The event was held against the backdrop of factor investors recently experiencing a mixed bag of investment results. In particular, value investors have suffered profound underperformance, spawning a controversial 'Is value dead?'-debate. Given these developments, the conference opened with a keynote talk on value investing.

Söhnke Bartram:
Book-to-market – mispricing or risk?
Book-to-market (BM) is a well-known predictor of equity returns, proxying for the value effect. There are two schools of thought on the cause of its predictive power, citing either risk premia or mispricing explanations.

Söhnke Bartram and his co-authors[3] investigated the book-to-market factor for corporate bonds. Corporate bonds provide an excellent laboratory to further explore explanations for book-to-market return patterns in asset prices since the bond market provides better proxies for risk, such as yield-to-maturity and default risk. Given that the future cash flows of corporate bonds are far less risky than their equity counterparts, bond price movements have to arise largely from discount rate variation rather than from changes in projections of future cash flows.

They studied an extensive sample of 8925 corporate bonds from 817 firms based on the bond book-to-market (BBM) ratio. The main obstacle to exploring corporate bond returns is infrequent trading. To remove it, the authors chose to include noisy return estimates by applying the martingale property of asset pricing theory. Controling for risk factors as well as bond and equity characteristics, the highest quintile BBM portfolio (i.e. the cheapest corporate bonds) returned 3 percentage points more p.a. compared to the lowest quintile (i.e. the most expensive corporate bonds); see figure 1.

The three authors then investigated the causes for the BBM return effect. The use

Figure 1

Average monthly returns of BBM quintile portfolios
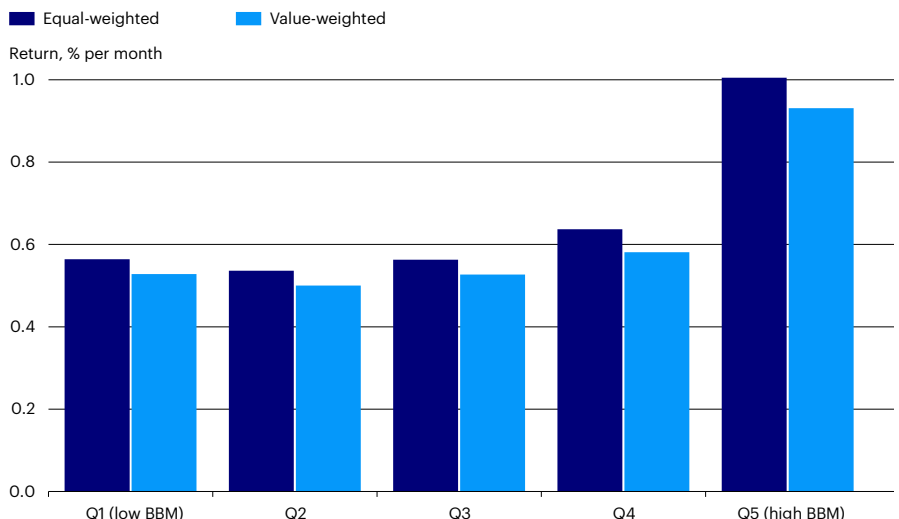
BBM = bond book-to-market.
Source: Bartram et al. (2021b), table 2, panel B.

of relevant risk controls and the presence of greater transaction costs point to mispricing. On the other hand, the market is dominated by institutional investors and cash flows are very transparent. This should lead to considerable market efficiency and favors a risk explanation.

However, a key argument against such a risk explanation is the irrelevance of default risk for the BBM signal: on average, the BBM signal has the same efficacy for the 20% of bonds closest to default as it has for the remainder of the universe. Furthermore, the authors applied interest rate risk measures that are common to all bonds. If the risk explanation were correct, Treasury securities should also exhibit a BBM anomaly. But this not the case, regardless of the specifications and time periods considered.

Evidence for mispricing, on the other hand, emerges from investigating signal delay, Treasury notes and BBM alphas: Bartram and his co-authors gradually delayed the BBM signal, ending up with no predictive value when a seven-month delay was applied. In all, mispricing turns out to be the best explanation for BBM effects , emphasizing the need to analyze and understand the effects of mispricing in other asset classes with lesser risk control standards. However, the risk-adjusted excess returns to BBM vanish when transactions costs are accounted for. Nevertheless, as the authors point out, active bond fund managers enhance performance by tilting cost-inducing transactions that would be made in any case towards underpriced and away from overpriced bonds.

Guofu Zhou:
Factor models – limitations and extensions
Guofu Zhou explored limitations and extensions of factor models, drawing from his rich body of work in asset pricing. Referencing a normalized pricing error measure to gauge the accuracy of equity factor models, he emphasized that existing factor models are flawed and fail to capture important macro, trend and behavioral factors: one would expect returns of decile portfolios sorted according to such pricing errors to be flat if the associated factor models are correct. However, empirical results show a roughly 1% monthly return for equities.[4] Zhou further investigated a similar pricing error measure for corporate bonds, once again reporting significant returns.[5] He then proposed finding new factors to address the troubles of existing factor models.

First, he put forward a new approach to fundamental momentum, combining moving averages of seven major fundamental measures, rather than using one nominal fundamental ratio. Notably, the associated factor strategy has a higher average return compared to price momentum. To assess robustness, this trend factor approach was tested utilizing data from US corporate bonds and the Chinese stock market. Both empirical studies revealed the trend factor to significantly outperform existing factor models in terms of explanatory power and returns.[6]

Then, Zhou and his co-authors implemented an information factor by following either corporate insiders to buy stocks or short sellers to sell stocks, thus simulating sophisticated investors' allocations. This long-short factor portfolio earns at least 1.20% alpha per month when measured against standard factor models.[7]

Next, Zhou alluded to macro risk factors in the economy based on 120 monthly macro variables from 1960 to 2018.[8] Given the associated dimensionality, he advocated the use of a sparse Principal Component Analysis (PCA) to synthesize major macro risk factors. While a regular PCA features weights on all variables (thus retaining excessive noise), the sparse method extracts around 10% of the most relevant variables. The results demonstrate that a sparse 3-macro-factor model has a lower pricing error compared to existing factor models.

Finally, Zhou investigated the cross-section of equity returns by combining 299 firm and option characteristics.[9] Related regressions with many regressors are either infeasible or poorly behaved, therefore the LASSO method was used to reduce the dimension and identify the most useful predictors. The LASSO results indicate that only half of the predictors "work".

In summary, Zhou aptly showed ways to mitigate the flaws of factor models, stressing the importance of focusing on economically sound factors.

Tarun Gupta:
Alternative data – applications for factor investing
Recent factor performance challenges have led investors to question their faith in factor investing as a whole. Committed factor investors, therefore, face a tough choice: They can leave everything as it is, abandon underperforming factors, conceive new factors or even try timing the factors.

Another potential remedy is to improve factor definitions by investigating return patterns associated with alternative data sources. In this vein, the closing keynote of the conference, delivered by Tarun Gupta of Invesco Quantitative Strategies, shared the practitioner's perspective on the alternative data landscape.

Advancements in technology have led to the availability of unstructured and big data. Transactions, location, media, scraping and crowdsourcing data are among the most common examples, and these novel data sources may help construct better economically motivated factors. Gupta argued that, if we intend to use alternative data to improve factor

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Existing factor models are flawed and fail to capture important macro, trend and behavioral factors.

Figure 2
Credit card transactions and stock prices

Credit card sales

Daily stock prices for US retailer Bed, Bath & Beyond
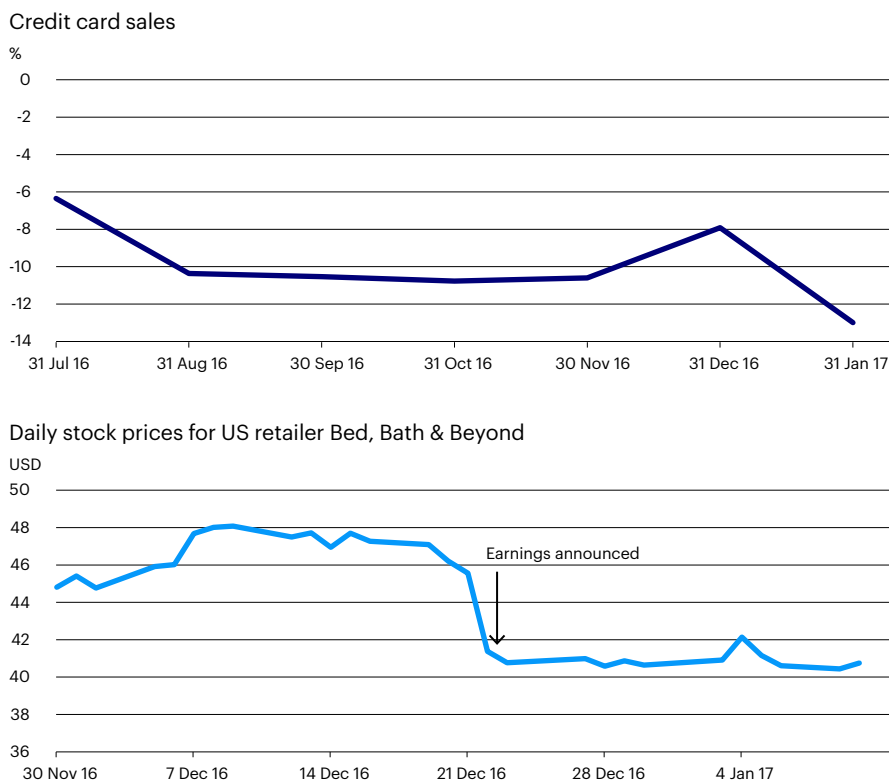
Source: Invesco calculations. Credit card transaction data (August 31, 2016 to November 30, 2016) and stock price data (November 30, 2016 to January 10, 2017) for US retailer Bed, Bath & Beyond.

> **A successful alternative data factor should be robust in order to withstand economic tests and perform out-of-sample.**

definitions, two questions need to be answered: What is being measured? And how does it add value to existing signals?

Additional hurdles are short history, low coverage, security mapping, regulatory risk and cost – all of which may hinder the pursuit of improvement. After all, a successful alternative data factor should be robust in order to withstand economic tests and perform out-of-sample.

To illustrate, Gupta built an alternative data factor using credit card transaction data to derive the year-over-year percentage change in credit card sales. This signal is considered a valuable alternative to the earnings momentum factor for predicting fundamental surprises. Gupta utilized a transaction sample of five million cardholders, mapping them to 300 US stocks, mostly from the consumer discretionary sector. Compared to the traditional earnings momentum factor, the credit card factor signal generates a well-timed and higher-frequency signal.

Figure 2 shows how declining credit card transactions can lead declining revenues. The example is based on daily credit card transactions of US retailer Bed, Bath & Beyond from August 31, to November 30, 2016 and its stock price from November 30, 2016 to January 10, 2017. Indeed, the company released a disappointing earnings statement on December 22, 2016, which led to a stock price decline of 10%.

Gupta then put the credit card factor to an economic test, analyzing whether it can add value as an earnings momentum predictor using Fama-MacBeth cross-sectional regression. Regressing the factor against future earnings per share surprises, it yielded positive beta – indicating an economically meaningful, highly significant factor.

Finally, Gupta constructed an investment strategy using the credit card factor: Dividing the universe into terciles, the strategy buys the stock in the highest terciles and shorts the stocks in the lowest tercile, ultimately resulting in a net information ratio of 1.44. Yet, one has to be mindful that this outcome is restricted to a narrow slice of the overall investment universe, rendering it less than straightforward for investors to invest into the costly maintenance of such signals.

Alejandro Lopez-Lira:
Risk factors that matter – textual analysis of risk disclosures for the cross-section of returns
To help attract high-quality conference submissions, the Invesco Factor Investing Prize was promoted for the best conference paper. After careful consideration, the jury awarded it to Alejandro Lopez-Lira from BI Norwegian Business School. Lopez-Lira puts forward an innovative approach, applying unsupervised machine learning and natural language processing techniques to annual reports to determine potential risk factors.[10]

Figure 3
Risk topics that firms face
Bigger font indicates a bigger weight for that word

Source: Lopez-Lira, A (2020).

In their annual reports, US firms are legally obliged to elaborate on their most significant risk factors. The accounting literature shows that the reported risk factors are not merely uninformative boilerplate text, but can assist investors in identifying new risk factors.[11] Lopez-Lira analyzed the risk factor sections in the 10-K annual reports of US firms starting from 1994. Text data was pre-processed to generate a document-term matrix, counting the number of occurrences of each word. The rationale behind this matrix is to determine frequently repeated words, identifying potential topics.

Specifically, the generated document-term matrix was processed using the latent Dirichlet allocation (LDA) model. The matrix is factorized by mapping words to risk topics and topics to risk weights, bringing an immense reduction in dimensionality while retaining information. Then, matrices from LDA processing are used to determine the systematic and idiosyncratic risks of companies. The risk buckets affecting the largest number of firms are technology risk, production risk, international risk and demand risk; see figure 3 for the associated word clouds. Around half of the universe allocates more than 25% of their risk disclosures across these four risk topics.

Following the determination of risk factors, Lopez-Lira employed Fama-Macbeth regressions, controlling for beta, size, profitability, investments and value. These regressions provide evidence that the constructed textual risk factors perform as well as the standard CAPM and Fama-French 5-factor model, but without using any price information.

Finally, despite not being designed to price the cross-section of returns, Lopez-Lira investigated the performance of the four most common risk factors by measuring mispricings of factor models on 49 industry, 25 book-to-market and 11 anomaly portfolios using the Gibbons, Ross and Shanken (GRS) test.[12] The GRS test showed that four firm-specific risk factors describe portfolios significantly better than the Fama-French 5-factor model or the q-factor model, and without using any price data. On the other hand, when the portfolios are evaluated separately, the q-factor model performs better for 11 anomaly portfolios and 25 book-to-market portfolios. Overall, the paper suggests that companies have a good knowledge of their risks – and that textual analysis might enrichen investors' information set.

Conclusion
Factor investing is well-established with many institutional investors. Yet, for factor investing approaches to stay relevant, we must constantly scrutinize and advance its key pillars. Given its origins in asset pricing theory, such evolution can naturally be achieved through constant interaction with the academic community. This year's Frontiers of Factor Investing Conference in Lancaster brought together a select group of researchers to present cutting-edge results in the theory and practice of factor investing. We covered a broad spectrum of topics, including factor investing in credit markets, the benefits of machine learning and NLP techniques, as well as the generation of factors based on alternative data sources. Obviously, translating such propositions into the practice of portfolio management is at the heart of our approach.

Notes
1   "Advancing the frontiers of factor investing", Risk & Reward #3/2018.
2   See Bartram, Lohre, Pope and Ranganathan (2021a) for a survey on the recent literature to navigate the factor zoo.
3   Bartram et al. (2021b).
4   He, Huang and Zhou (2020).
5   Guo, Lin, Wu and Zhou (2018).
6   Huang, Zhang, Zhou and Zhu (2020), Liu, Y., Zhou, G., & Zhu, Y. (2021).
7   Ma, Martin, Ringgenberg and Zhou (2019).
8   Rapach and Zhou (2021).
9   Han, He, Rapach and Zhou (2020).
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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.