Alternative Investment Analyst Review

Dear CAIA Members and Investment Professionals

We're excited to introduce the inaugural edition of *Chronicles of an Allocator*. This monthly newsletter has been carefully curated to provide you with a selection of thought leadership pieces, designed to assist and inform the capital allocation process.

As we continuously journey through our now 100 country reach, we have the privilege of interacting with some of the largest and most influential allocators and managers around the world. The dialogue and debate generated in these interactions are invaluable and result in a broad array of blogs, webinars, events, articles, and white papers. We know that navigating the sea of content from the CAIA Association, along with other sources, can be overwhelming. That's where *Chronicles* can help.

As a result of this new initiative, this marks the final edition of the *Alternative Investment Analyst Review*. However, this does not represent the end of bringing relevant and timely content to you as readers. In fact, *Chronicles* expands upon AIAR's original objective. *Chronicles* represents a curated "best of" content newsletter, showcasing high-quality CAIA Association and third party content. Every month, our Content Strategy team, will choose a handful of the most relevant industry material to help you chart your course. Regardless of your current seat, LP or GP, buy-side or sell-side, consultant or service provider, traditional or alternative, we aim to equip all investment professionals to think like an allocator.

Moving forward, we would encourage you to do the following: First, follow our blog, *www.AllAboutAlpha.com*, where you will discover timely and relevant content from industry experts. Second, please subscribe to *Chronicles of an Allocator* by creating a CAIA.org account if you have not already. Upon account creation, you will be automatically subscribed for future editions of *Chronicles of an Allocator.* Third, and finally, please submit original or third-party content you believe should support our efforts, outlined above, by emailing us at content@caia.org.

Hope to see you in our travels,

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Editor's Letter

Text as Data

The spam folder of my email account at the University of Massachusetts contains this recent email:

> Subject: [SPAM: 93%] Check your Eligibility for a Complimentary Cellphone
>
> Dear Sir/Madam
> After a comprehensive review, it has been determined that you may be eligible for a free cellphone. Go here to claim your free cellphone.

The university's email server has determined that there is a 93% probability that this email is spam and sent it to my spam folder, preventing me from getting my free cellphone.

How did the email server assign such a probability to this email? Surely, UMass does not have thousands of employees reading faculty emails, deciding the probability that an email will be spam or not. The server uses a text-mining algorithm to make that determination. In this note, I will discuss the very basic steps of text mining and will explain how the server came up with a 93% probability.

Mining text is difficult. Text represents unstructured data. This reflects the fact that text does not appear in a structured form that we can present using an Excel table with columns and rows having specific meanings. Of course, text does have a structure, but it is not of the type that can be fed into an algorithm for analysis. The structure of a text is linguistic, which has evolved through time so that the written or spoken words can be understood by humans and not computers. Therefore, text must be preprocessed before it can be fed into a computer algorithm.

Among social sciences, finance and economics have been lucky in having access to lots of structured data. We have national accounting data, stock market data, accounting data, and so on. Having access to so much structured data led economists and financial analysts to appreciate the usefulness of text and other unstructured data rather late in comparison to other areas of social science such as political science. However, the search for information advantages by investors and analysts has created an explosion of activities and discoveries in the applications of natural language processing (NLP), and, in particular, textual analysis in the financial industry.

NLP and text mining are highly complex and specialized areas that require researchers to bring a variety of expertise into a text mining project. The following Venn diagram gives a visual description of these sets of skills.

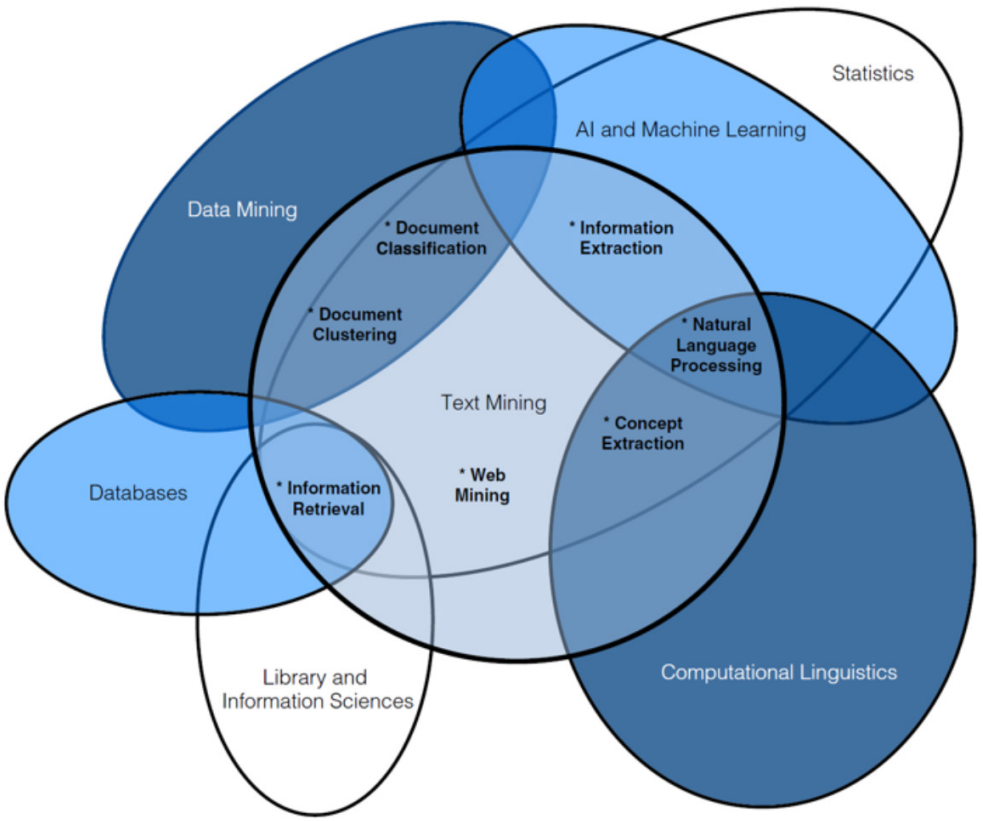

Exhibit 1

However, it is not difficult to present a very broad and high level of description of NLP and text mining. The purpose of this note is to present such a description. The goal is to familiarize the reader with some of the terminology and the basic steps employed in a text mining project.

NLP vs. Text Mining

While NLP and text mining are different, they have much in common. Some sources consider text mining to be a subset of NLP, while others consider them to be highly related but not a subset of each other. In this note, I will focus on text mining. For the purpose of this note, we define text mining as an artificial intelligence technology that uses NLP to transform the unstructured text in documents and databases into normalized, structured data suitable for analysis using machine learning algorithms.

According to Linguamatics, a provider of an NLP based AI platform, text mining identifies facts, relationships, and assertions that would otherwise remain buried in the mass of textual big data. Once extracted, this information is converted into a structured form that can be further analyzed or presented directly using tables, mind maps, charts, etc. Text mining employs a variety of methodologies, including NLP, to process the text. The structured data created by text mining can be integrated into databases, data warehouses, or business intelligence dashboards and used for descriptive, prescriptive, or predictive analytics. NLP, therefore, is a much broader area (e.g., includes voice recognition) which aims to enable machines to understand and analyze natural human language.

Text Mining

One of the earliest text mining papers in the area of finance is Niederhoffer (1971). In this study, Niederhoffer manually "mined" the headlines appearing in the New York Times. He ranked the headlines in terms of their sentiments and importance. He found out that large changes in stock prices followed days with important world events. Also, the sentiment of the headline seemed to have some predictive power, but the effects were small and did not last very long.

Text mining has applications in many disciplines. One of the most famous and influential studies was done by Mosteller and Wallace (1964), where textual analysis was employed to determine the authorship of some of the Federalist Papers when historians could not agree on the authorship between Hamilton and Madison (It turned out that Madison had written them).

Businesses have come to appreciate the power of text mining to increase revenue, reduce cost, and mitigate risk. For instance, recently, Admiral, a U.K. based insurance company, offered discounts to its car insurance clients if they agreed to give the company access to their Facebook profile. Admiral had come to realize that through text mining of Facebook pages of its customers, it could improve its underwriting practices. Admiral had developed an algorithm that analyzed its customers' posts and by analyzing the style of writing of each user, the algorithm could uncover positive and negative traits. The company believed that these personal traits could be used as predictors of a customer's driving behavior. Facebook, however, refused to give the company access.

These three examples highlight different applications of text mining. Niederhoffer used text mining to determine if the sentiments can predict the stock market. Mosteller and Wallace used text mining to explore, understand, and classify the text. Admiral attempted to use text mining to learn about the personal traits of the authors of Facebook posts. However, regardless of the goal of the study, the researcher must develop a numerical representation of the text since computers and analytical techniques can only be applied to numerical values.

The starting point of text mining is a document containing text. For example, when working with a database consisting of thousands of emails, we could refer to each email as a document. If the goal is to determine if a document (email) should be classified as spam or not, then we need to develop a numerical representation of the text, which is then used to classify the document as spam or not.

A Simple Spam Detector

Suppose an email server has received millions of messages over the last decade and wants to develop its spam filter. The IT department asks all users to mark emails that they consider to be spam. After several months, the IT department will have a large sample of emails labeled as spam or not spam. The data can then be used to train an algorithm, which, when fed a new email, will be able to assign a spam probability to the email. But how do you feed an email to an algorithm?

The first step is to breakdown each email (i.e., document) into a series of tokens. For example, the Python package "Typing" will read a text and break it down into its parts:

tokenize ("fore a complimentary") -> {"for", "a", "complimentary"}

Next, we create a table where the columns refer to the above 3 tokens, and the rows refer to each email. The cells will tell us how many times the words "for", "a" or "complimentary" appeared in each email. Here, we have the tabulated information for emails #1459 and #1460.

Documents	for	a	complimentary
1459	6	4	1
1460	10	3	0

Exhibit 2

Next, we count the number of times that each word appears in the emails that are in our training set while noting if the email was marked spam or not. Notice that we are ignoring the sequence of these words as they appear in an email. That is, we do not distinguish between "for a complimentary" and "complementary for a." Also, we may decide to ignore upper and lower cases and consider them to be the same.

A summary of our counting results may look like this.

Type	for	a	complimentary
Spam	99%	97%	60%
Not Spam	98%	95%	5%

Exhibit 3

We can see that words "for" and "a" appear in almost all emails. So, they are not useful for determining if an email is spam or not. However, we see that 60% of spam emails contain the word "complimentary", while only 5% of nonspam emails contain this word. Therefore, if a new email arrives with the word "complimentary" in it, the server will assign the following spam probability to it:

*Probability (Spam **Given that it contains** "complimentary") = 60%(60% + 5%) = 92%*

The probabilistic algorithm used above is called Naïve Bayesian. In this very naïve example, we used a "bag-of-words" approach based on N-gram (n=1) tokenization. The bag-of-words approach assumes that documents are just random collections of words drawn from the set of all available words. Therefore, it ignores the structure and placement of the word.

N-gram tokenization indicates the degree of granularity of the tokenization process. Consider the phrase "After a comprehensive review it has been determined." The tokenization can be performed with different levels of granularity:

n=1 (unigram) returns: {"After", "a", "comprehensive", "review", "it", "has", "been", "determined"}

n=2 (bigram) returns: {"After a", "a comprehensive", "comprehensive review", "review it", " it has", "has been", "been determined"}

n=3 (trigram) returns: {"After a comprehensive", "a comprehensive review," ….)

It seems obvious that using higher values of n will force our algorithm to account for the placement of words and the structure of sentences. However, this will come at the expense of having a much smaller training set. Very few spam emails may include the phrase "After a comprehensive review it has been determined" and we may never see another email with exactly the same words in the future.

The previous discussion was an oversimplified approach to document analysis. In a more sophisticated text mining application, the key point is to understand how words and punctuations appear together to express certain meanings. The incorporation of grammar rules in the text analysis is certainly important, but to create a workable representation of data, we need to simplify these issues.

Representing Text Data

To further illustrate how a document can be numerically represented, consider the following two documents each consisting of one sentence:

1. Risk management is the key to asset management.
2. Alternative assets can help reduce downside risk.

The following table is a numerical representation of these two documents:

	risk	management	is	the	key	to	asset	alternative	can	help	reduce	downside
D1	1	2	1	1	1	1	1	0	0	0	0	0
D2	1	0	0		0	0	1	1	1	1	1	1

Exhibit 3

Using this simple mechanism, we have moved from unstructured data to structured data, which can now be analyzed through the applications of machine learning and data mining algorithms. This matrix is often referred to as the Document Term Matrix.

Punctuation could play an important role in a certain context (e.g., in twitter or email messages, we may include ":)"). To create a more parsimonious numerical representation of the corpus (i.e., collection documents), we can choose to reduce the number of features. For instance, in the above documents, "assets" and "asset" were considered to be the same. If every single word were to be included in our table, the dimension of the problem would quickly exceed the computational capability of our computers.

Even the simple representation presented above allows us to make some quick calculations. For instance, we can apply algorithms that measure the similarity/dissimilarity of tabulated data. This will allow us to measure how similar these two documents are. Earlier, we mentioned the application of text mining to the Federalist papers. The approach adopted in that research relied on the same basic principles. Interestingly, the hidden structures of those papers were uncovered by paying attention to punctuation and ordinary words that appear in most texts. Using a training set consisting of labeled papers, it was discovered that Madison and Hamilton had different styles in using punctuation and ordinary words regardless of the subject.

Tokenization, PoS Tagging, Stop Words, Stemming, and Lemmatization

We have already discussed tokenization in the previous section. It is a process that consists of breaking up documents (as words, N-grams, or phrases) into elements called tokens, which are used as input to text mining procedures.

After tokenization and depending on our interest, we may continue with a Parts of Speech (PoS) tagging. PoS refers to the process of tagging words within sentences into their respective parts of speech. By applying PoS tagging, we will be able to extract those parts of speech that are of interest to us. For instance, consider the sentence "Risk Management is the key," which has five tokens. Using a PoS tagger, we tag parts of speech to each of the tokens (e.g., {(Risk, Noun}, {is, Verb}, …).

After the tokenization process, we may remove punctuation and common words as well as combine similar words (e.g., "asset and "assets", or "investment" and "security"). The words that are important to the construction of proper sentences (e.g., "the" or "and") but carry no specific meanings are called "stop-words".

After removing numbers, punctuation, and stop words, we can further simplify the numerical representation of our text using a stemming or a lemmatization process. For example, in many languages, words get transformed into various forms when being used in a sentence. For example, the word "go" might get transformed into "goes", "going" "went" or "gone". It is necessary to convert these words into their base forms, as they carry the same meaning. Stemming is a process that helps us in doing so. The most common stemming algorithm for the English language appears in Porter (1980).

Another common pre-processing step is lemmatization. The stemming process may lead to inappropriate results. For example, the word "producing" may be transformed into "produc," which has no meaning. To avoid this problem with stemming, one could use lemmatization. In this process, an additional check is being made, by looking through the dictionary to extract the base form of a word. However, this additional check slows down the process.

The basic goal of the processes mentioned above, and many others, is to produce an accurate numerical representation of a document while keeping the dimension of the numerical representation manageable.

Term Frequency and Inverse Document Frequency

Suppose we want to mine newspaper articles that focus on China. We are not looking for a specific term or phrase. Rather, we are looking for articles that are unusual and cover a somewhat unique story. A simple approach known as Term Frequency and Inverse Document Frequency (TFIDF) can provide a quick and yet powerful measure of the unusualness of thousands of articles. This is how it works.

The first step is to get a broad picture of each document (i.e., a newspaper article). For instance, we can count the number of times each token (i.e., a word or a phrase) appears in each article. This will not tell us much as there are two problems with using simple counts: (a) longer documents will contain more words, and (b) common words such as "the" are likely to have the highest count. To overcome the first problem, we can divide the count of each token by the total number of tokens that appear in each document. This is called term frequency. Still, common words such as "the" and "and" are likely to have the highest frequencies. To overcome the second problem, we need to identify the unusual tokens that appear in our corpus.

While the phrase "profit margin" is not considered unusual for articles from the business section, it will be unusual if it appears in stories from the sports section. To measure how unusual a token is, we can calculate the percentage of the documents that contain each token. For example, "profit margin" may appear in 60% of business section articles while it may appear in only 3% of sports section articles. The measure used for this purpose is referred to as inverse document frequency (IDF) because it turns out that it is more helpful to use the logarithm of the inverse of the above percentage (e.g., log(1/0.60) for "profit margin"). Therefore, a token with a large IDF is considered unusual because it does not appear that frequently in our corpus.

The final step is to examine each document for the term frequency of the token that was deemed to be unusual. For instance, if "coronavirus" turns out to be highly unusual (has high IDF) but there are only a few documents for which "coronavirus" has high TF, then those articles will require further examination.

Using the results displayed in Table 3, we can see the TF of the token "management" in document 1 is 2/8 as the token "management" appears twice and there are 8 token in the document. IDF of the token "management" is log(2/1) since there are 2 documents and the term "management" appears in 1 of those documents. Clearly, a common word such as "is" will have an IDF that is close to zero because it is likely to appear in all documents. For example, if there are 100 documents and the token "is" appearing in 99 of them, its IDF will be log(100/99)=0.01. On the other hand, a rather rare word such as "downside" is likely to have a large IDF. For example, if "downside" appears in only 2 of the 100 documents, its IDF will be log(100/2)=3.9.

Finally, if we multiply TF by IDF of terms appearing in a document, we can gain significant insights into the importance and uniqueness of that document. The measure Term Frequency -Inverse Document Frequency (TFIDF) is given below

*TFIDF = Term Frequency * Inverse Document Frequency*

We can see that it will have a high value in the case of a high term frequency and a low frequency in the collection. In other words, for a term that frequently appears in one document but rarely in other documents, it will have a high value for TFIDF. Thus, the document that contains that rare word must be special and unique.

Word List and Sentiment Analysis

Sentiment analysis is an important application of textual analysis. Suppose we want to measure the sentiments conveyed by the New York Times headlines over a period of several years. The goal is to find out if headlines with positive (negative) tones precede an increase (a decrease) in the stock market. A common approach in this area is to compile word lists that share common sentiments (e.g., positive, negative, neutral, uncertain, etc.). Using such lists, an analyst can count words associated with each sentiment that appear in each day's headline and create a measure that informs the analyst about its net sentiment.

In measuring the tone or sentiment of a document, analysts typically count the number of words associated with a given sentiment word list normalized by the total number of words in the document. Therefore, higher proportions of positive words in a document indicate a more optimistic tone. To create such word lists, researchers rely on specialized dictionaries. An important step in the process is to decide which source (i.e., dictionary) should be used to identify and calculate the proportion of the targeted sentiments or attributes. For example, the Harvard General Inquirer offers a group of lists that are suitable for sentiment research in sociology and psychology. On the other hand, the dictionary produced by Loughran and McDonald (2011) has been used for research in accounting and finance.

One of the earliest dictionary-based sentiment research is Tetlock (2007), which analyzed the media sentiment and the stock market. The paper uses word counts in the Wall Street Journal's widely read "Abreast of the Market" column. Counts from each article measuring seven different sentiments based on the Harvard IV-4 psychosocial dictionary were then tabulated. Armed with the time series of the daily sentiment scores, Tetlock creates a single measure of overall sentiment that he calls the pessimism factor. Next, the author measures the predictive power of this pessimism factor and reports that high pessimism significantly negatively forecasts one-day-ahead returns on the Dow Jones Industrial Average. Since the publication of Tetlock (2007) finance and accounting paper has been using Loughran and McDonald (2011) dictionary as it is more suitable for research in these areas.

Conclusion

In this short note, I provided a very brief outline of text mining. The goal was to demonstrate how text (unstructured data) can be given a numerical representation (structured data). We also discussed the most common pre-processing steps that are taken to make the numerical representation accurate but manageable. Of course, this short note barely scratches the surface. Also, we completely ignored any discussion of dozens of algorithms that can be applied to the numerical representations. These algorithms along with insights from the Natural Language Processing field allow us to go much further in mining text data. For example, they could help us measure the sentiment conveyed by a set of documents (e.g., tweets related to a corporate event), which can then be incorporated in the investment decision (e.g., whether act on a merger announcement).

For those who are interested in learning about textual analysis, the following sources are recommended:

Provost, F. and T. Fawcett. (2013). Data Science for Business. Sebastopol, CA: O'Reilly Media Inc, Chapter 10. This is the main textbook for Financial Data Professional program

Einstein J. (2018). Natural Language Processing. https://github.com/jacobeisenstein/gt-nlp-class/blob/master/notes/eisenstein-nlp-notes.pdf

Jurafsky, D. and J.H. Martin (2013). Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition. https://web.stanford.edu/~jurafsky/slp3/edbook_oct162019.pdf

The Stanford Natural Language Processing Group, https://nlp.stanford.edu/

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Mosteller, F. and D.L. Wallace (1964). Inference & Disputed Authorship: The Federalist. MIT Press

Porter, M.F. (1980). "An Algorithm for Suffix Stripping," Program, Vol. 14 3, pp.130-137.

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Loughran, T. and B. McDonald. (2011). "When Is a Liability Not a Liability? Textual Analysis, Dictionaries, and 10-Ks." Journal of Finance 66 (1): 35–65.

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Dr. Hossein Kazemi is the Senior Advisor to the CAIA Association's Program. Dr. Kazemi has been involved with the CAIA Association since its inception as a senior advisor and a managing director. In his current role, he helps with the development of the CAIA program's curriculum and directs the CAIA Association's academic partnership program. In addition, he serves as the editor of *Alternative Investment Analyst Review*, which is published by the Association. He has worked with universities and industry organizations to introduce them to the CAIA program. Dr. Kazemi is Michael and Cheryl Philipp Distinguished Professor of Finance at the Isenberg School of Management, the University of Massachusetts - Amherst. He is the Director of the Center for International Securities & Derivatives Markets, a nonprofit organization devoted to research in the area of alternative investments, a co-founder of the CAIA Association, and home to CISDM Hedge Fund/CTA Database and the *Journal of Alternative Investments*, the official research publication of the CAIA Association. He has over 25 years of experience in the financial industry and has served as consultant to major financial institutions. His research has been in the areas of valuations of equity and fixed income securities, asset allocation for traditional and alternative asset classes, and evaluation and replication of active management investment products. He has a Ph.D. in finance from the University of Michigan.

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Beyond Diversification: A Geographical Focus on Farmland and Real Estate

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Through our conversations with clients, we know they invest in alternatives for a number of reasons: inflation protection, income generation and, of course, diversification beyond stocks and bonds. And as global investors, we agree it makes sense to use alternatives in this way. But we also think investors would do well to take the concept of diversification in particular to the next level by focusing on specific geographies and leveraging local, specialized expertise.

We think this is particularly true when it comes to investments in real estate and farmland, which, by their nature, are highly idiosyncratic and are affected by local dynamics in the environment, economy and political backdrop. A soybean farm in Brazil, for example, has little in common with an almond farm in Australia. Similarly, fast growing cities like Tokyo, Berlin and Los Angeles share some broad demographic trends but have very different localized real estate opportunities.

At the same time, however, these asset classes are also driven by broad global trends such as changing demographics and technological advancement that can identify broad regions that could be primed for growth. That's why we think it's important to approach real estate and farmland investments through a dual approach: understanding the macro factors that make specific areas of the world and certain types of investments potentially attractive, while also relying on local experts who can uncover value in highly specific ways.

In the following sections, we offer a thousand-foot view from our Chief Investment Strategist explaining how real assets are positioned in today's environment, before diving into a region-by-region look from our on-the-ground portfolio management teams who are identifying specific opportunities. We think that by offering examples of how we are approaching specific investments,

we can explain our overall view about the best ways to identify value across investments and regions. We then bring it all together with views from our Solutions team discussing ways that investors can use these asset classes to build outcome-oriented portfolios.

Real estate and farmland investments can be complicated and potentially difficult to assess correctly. But we believe that a focused effort that combines a macro view of the world with localized assessment of individual properties and farms can help our clients create portfolios designed to meet their long-term goals.

Investing in Real Assets for an Uncertain Outlook

Global stocks are trading well above their average valuation over the past 15 years, while interest rates available on global fixed income remain close to historically low levels, making it harder for investors to generate growth and income. While our Global Investment Committee does not see a global recession on the horizon, publicly traded asset classes offer more modest return outlooks today than they have in recent decades. Therefore, we believe that alternatives such as real estate and farmland can add value in a variety of economic scenarios. But asset class diversification and manager selection are likely to be key in determining absolute and relative performance.

The Thousand-Foot View

2019 marks the 10-year anniversary of the end of the global financial crisis. The U.S. economy exited its great recession in June 2009 and has since staged its longest uninterrupted expansion in history. Investors who were willing to take risks 10 years ago have been richly rewarded for doing so. Meanwhile, global interest rates have failed to return to levels that would have been regarded as merely average prior to 2008.

While we do not believe the historic length of the current expansion makes a near-term recession more likely, we also cannot credibly expect publicly traded financial assets such as stocks and bonds to match their performance of the last decade in the next. Investors seeking to maintain their recent level of returns will very likely need to maneuver their portfolios to include more risk assets, more alternative assets or a combination of the two.

As we foresee slow global growth, geopolitical tensions rising and more volatility in the near-term, we believe investors may consider focusing on the less correlated, inflation-protected and long-term capital appreciation characteristics found in real assets. Many real assets, particularly real estate and farmland have proven resilient in economic environments similar to where we are now.

How are Publicly traded Assets Priced Today?

The decade since the crisis has been the most fruitful for diversified investors in global stocks and bonds since the one that ended at the peak of the technology bubble in the early 2000s. A 60/40 portfolio of the MSCI All-Country World Index (global stocks) and the Bloomberg-Barclays Global Aggregate Index (global bonds) returned 7% on average per year from July 2009 through June 2019.[1]

That's close to the best 10-year performance since the 1990s. While we don't expect a "lost decade" for stocks akin to the 2000s, we also do not expect returns in the 2020s to match those in the 2010s given stocks' relatively high valuations and bonds' relatively low interest rates.

U.S equities in particular have provided the bulk of the returns on the global index since 2009. Over the next 10 years, however, their current price-to-earnings ratio, the best single predictor of returns over a 10 year horizon, implies an average total return of only 4% – 5% annually through 2029, less than a third of what they've provided over the past 10 years (Exhibit 1).

How Do Alternatives Fit in?

Alternative asset classes such as real estate and farmland have the potential to improve the efficiency of an existing portfolio and provide sources of income that are relatively uncorrelated to both companies' dividends and bonds' coupon payments. Currently, the yield on U.S. commercial real estate across a variety of sectors and geographies remains historically wide compared to that of the Bloomberg-Barclays U.S. Aggregate Index (Exhibit 2).

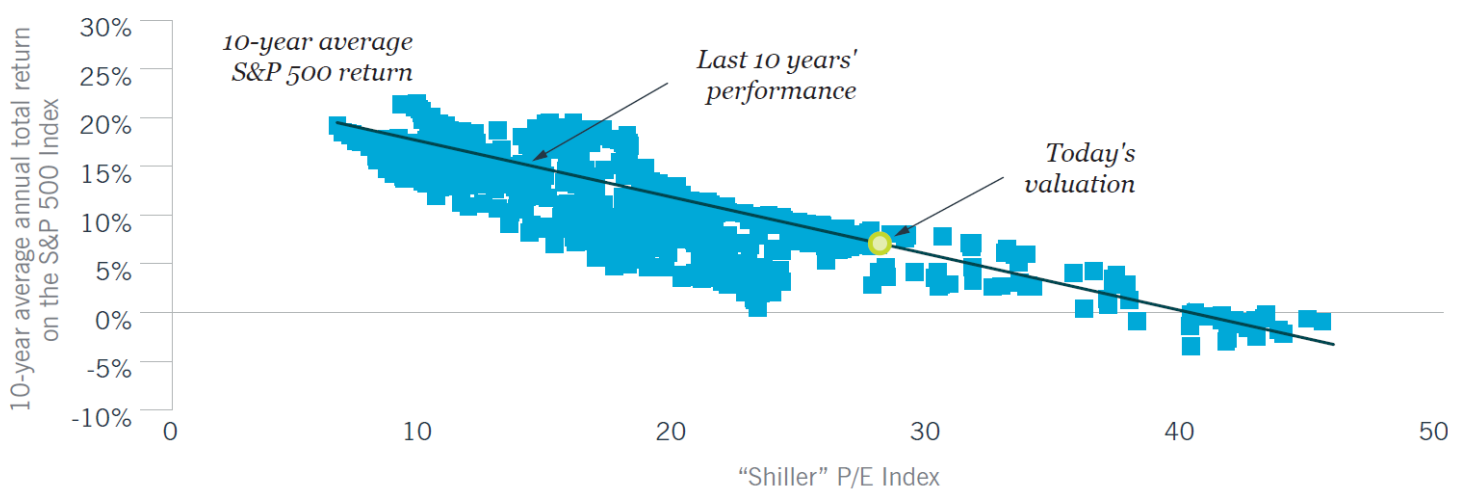

Exhibit 1: U.S. Equities are Unlikely to Repeat the Returns of the Last 10 Years
Source: Bloomberg, Yale University. It is not possible to invest in an index. Performance for indices does not reflect investment fees or transaction costs.

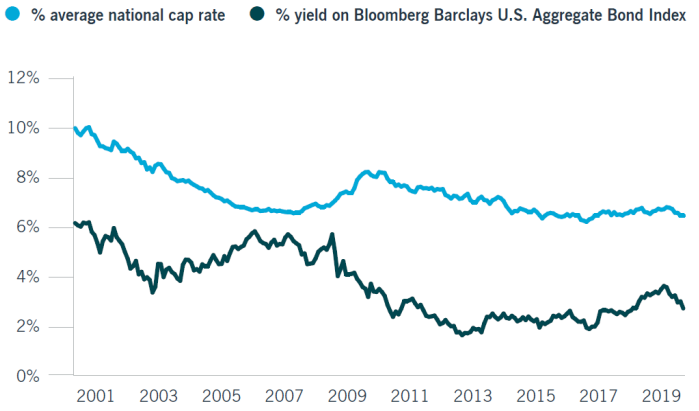

Exhibit 2: Bond Yields are Still Low Compared to Commercial Real Estate
Source: Bloomberg, RCA

While the global financial crisis certainly taught us that bubbles and busts can form in private markets just as they can in public ones, most alternative asset classes are subject to far less volatility on a month-to-month or even quarter-to-quarter basis. And while they are not immune from the ravages of a local or global recession, it is possible to build a portfolio of alternatives that emphasizes the quality and durability of income stream even during periods in which the underlying asset value is static or falling.

Not One Cycle but Many

Global growth does not run on a single engine. Our Global Investment Committee outlook calls for virtually all major economies to remain in expansion mode through the balance of 2019 and beyond. But unlike the U.S., which has experienced a nominal rise in interest rates and an uninterrupted equity bull market since the global financial crisis, most areas of the world are not at the same stage of their economic cycles. Assets tied to local economic activity such as real estate and farmland do not rise and fall in price equally in all regions at all times. As much if not more than the global equity market, global alternative assets can move independently of one another and in so doing provide risk-mitigating diversification if structured correctly in a portfolio.

In the Event of a Recession...

If we are wrong in our outlook and a severe slowdown hits one or more major economies in the next few years, we believe diversification by asset class and by geography could provide a buffer against catastrophic market loss. For alternatives, in particular, a recession can be an opportunity to acquire undervalued assets meant to be held for long periods. More broadly, regardless of the prevailing economic and market environment, we think alternatives can and should play a role in a diversified portfolio.

Americas: Structural Shifts Shine a Light on Select Geographies

Americas Farmland

Focusing on Favorable Developments in Brazil

In most cases, farmland investments are affected by factors such as rainfall amount and soil type. Brazilian farmland, however, has recently been affected by different factors: local political developments and global trade issues. While climate risks will continue to affect farmers, we believe current developments can potentially create opportunities — if investors know where to look.

We Expect an Acceleration in an Already Solid Brazilian Farmland Sector

Although Brazil's economy has experienced slow growth in recent years, recent developments provide a spark of hope. The country has been enacting a series of economic and regulatory reforms that we believe will help boost overall economic growth that should provide meaningful benefits to the agricultural sector.

Brazil's agricultural industry has long been a bright spot for that country's economy. Brazil has been able to produce enormous volume and diversity of crops and has shown an impressive ability to increase productivity. Soybean production in Brazil, for example, has grown from 20 million tons to 120 million tons in the last 30 years. This sort of strength has helped Brazil sustain employment levels and the country's trade balance. Our local farmland investment team in the region believes Brazilian farmland is well positioned for future growth and expects political reforms to help accelerate growth in Brazil's agricultural production.

Brazil May be One of the Few Beneficiaries of the Escalating Global Trade War

The growing U.S./China trade disputes have rattled global financial markets, but we think this sort of disruption can also create opportunities. Consider: As a result of higher tariffs and growing uncertainty, soybean prices fell in the U.S. in the second half of 2018, but actually climbed in South America and in Australia.

Trade disputes have meant that China has been reluctant or unable to import from the United States. This has provided a boon to Brazilian farmers. As shown in Exhibit 3, soybean prices have been falling in the U.S. while appreciating in Brazil, a trend that is benefiting Brazilian farmers and farmland investments in the country.

Exhibit 3: Trade Wars Can Create Possible Investment Opportunities
Source: Bloomberg, RCA

Americas Real Estate

Demographics, Urbanization and Technology: Key U.S. Cities and Sectors Appear Poised for Growth

Cities with youthful populations tend to be more influential, enjoy greater productivity and stronger-than-average economic growth. According to the United Nations, more than half of the world's population live in urban areas, and it is expected to rise to 68% by 2050. Additionally, we think cities that are able to benefit from technological disruptions like e-commerce are particularly attractive. Our research suggests several U.S. cities, such as Los Angeles, fit this description; Los Angeles is well positioned for long-term growth, and real estate investors should watch L.A. as younger populations from around the world flock to the city.

Los Angeles Benefits from Both Well-Known and "Hidden" Real Estate opportunities

The Port of Los Angeles recently experienced lower levels of imported goods in the last year due to the U.S./China trade tariffs as shown in Exhibit 4. However, the U.S./China tariffs have not affected warehouses located on the West Coast yet, as many U.S. importers have substituted goods from China with goods from Southeast Asia and other parts of the world. Unless the tariffs remain in place for years, and U.S. importers and businesses begin shifting their supply chains away from Asia, we believe the impact on West Coast warehouses will remain minimal.

Industrial demand over the last several years has been driven much more by secular shifts in supply chains (e-commerce) than by overall growth in consumption and trade. The long-term growth trend of e-commerce could insulate warehouse demand from some of the risks associated with tariffs. There is a growing need for freight storage in Los Angeles, which in our opinion makes warehouse capabilities a particularly attractive investment idea.

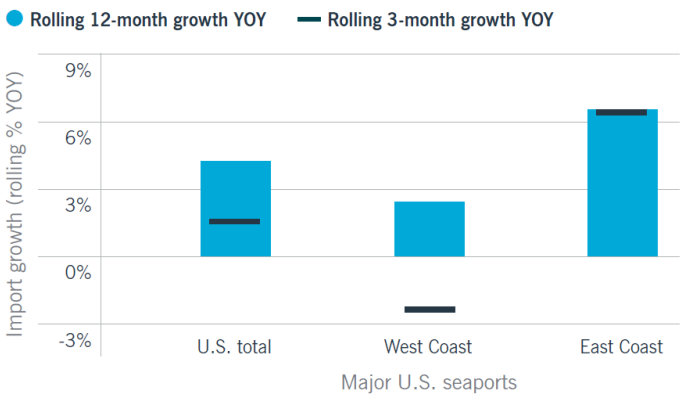

Exhibit 4: Major West Coast Seaports Are Poised for Stronger Growth
Source: Green Street Advisors, May 2019
Data depicts import growth per units of volume, measured by twenty-foot equivalent units (TEU), a common measure of shipping activity.

Europe: Favorable Developments Bode Well for Certain Regions

European Farmland

History and Unique Economics can Make a Difference

While global growth is slowing and investor optimism seems to be fading, we believe there are compelling investment opportunities in European farmland. European farmland investments can be difficult to access since the majority of farms are owned in small parcels. At the same time, there are vast differences across and between different European regions due to unique pricing structures and the fact that similar regions may be at different phases in the economic cycle. As such, we believe region-specific knowledge and local expertise are essential in identifying value. This is particularly true when it comes to often overlooked areas such as Poland and Romania. While there are many similarities between the two countries, we have found it is essential to work closely with local investors, farmers and end users to understand the unique characteristics of each region.

Romanian Farmland Appears Poised for Strong Growth

These returns tend to differ across regions. For example, an investment combination of row and permanent crops in the U.S. over the past twenty-five years would have generated returns consisting of around 40% from yield and 60% from capital appreciation, according to the National Council of Real Estate Investment Fiduciaries. Romania, in contrast, has had row crop farming business returns comparable to that of other regions, but has also seen much stronger capital appreciation.

After the fall of the Soviet Union, a restitution process divided farmland into multiple small family-owned land plots. Since then there has been an active process of swapping from an operational perspective, allowing farmers to operate large land plots through swapping with their neighbors. However, the underlying land from these operational swaps is now being actively sold, bought and swapped from a legal title perspective moving from an operational swap to a legal swap. This brings additional appreciation because of the higher intrinsic value available as a result of owning a large contiguous piece of land. At the same time, the investor base has been relatively small but is starting to garner attention from global investors.

Comparisons of Farmland Investments Between Countries can be Especially Complex

While these sorts of historical trends are important, we also find it necessary to focus on fundamental analysis, comparing the differences between individual farms and regions. Investors in these asset classes need to understand individual growth patterns, rainfall amounts, accessibility of water and soil types to determine the best investment options. Similarly, the individual politics and policies of different regions can come into play.

To see how this works in practice, consider the similarities and differences between Poland and Romania. The two countries have similar rainfall patterns and soil types but look quite different from an investment perspective. Local rent payments serve as a good example. In Poland, farmland rents have historically been paid up front, which can help mitigate risks such as the recent erratic weather that hurt the country in 2015 through 2017. In contrast, Romanian farms have historically paid rent at the end of the season, which can make issues like droughts or low yields difficult to prepare for. As such, professional farmland investors can look to shift Romanian farmland rents to up-front payment cycles to better manage unforeseen risks.

So, while on the surface, farmland investments in two similar countries such as Poland and Romania could look pretty similar, they are actually quite different, and for reasons that have little to do with such traditional factors like rainfall or soil type. We have found that understanding the nuances of additional factors like historical and local trends can provide a significant investment edge.

European Real Estate

Berlin: A Possible Diamond in The Rough

While the eurozone has experienced stagnant growth as part of a broader global economic slowdown, certain European cities offer compelling long-term real estate investment opportunities. By looking at broad-based structural trends such as economic growth, central bank policy decisions and local elections, we think it is possible to identify city-specific real estate subsectors such as housing and office space that offer attractive value. Since every city in the world is unique, we think the strategy for investing in each of them also needs to be unique. By spanning the globe and looking at a combination of local and global factors, we think it is possible to find investments that reflect a city's individual personality. A case in point: investments in Berlin.

Berlin Benefits from a Range of Demographic and Structural Advantages

Berlin is experiencing strong population growth. Berlin offers a lower cost-of-living alternative to cities such as London and Paris, and as such is attracting workers from around the globe. With three respected universities, the city continues to attract high-level students. This young and educated population creates a vibrant cultural scene filling theaters, bars, restaurants, galleries and nightclubs.

As students matriculate to the workplace, housing and workspace accommodations must be met. Our five-year office rental growth (as shown in Exhibit 5) forecast sees annualized growth rates of 3%, presenting one of the most compelling opportunities in Europe. These evolving demographic and socioeconomic trends have helped create a city we believe is attractively positioned for long-term growth.

We believe Berlin is well poised to navigate changing demographic trends, to meet evolving consumer demands. Germany itself remains vulnerable to a possible economic downturn due to factors such as a stretched debt market, anemic growth and the limited ability of the European Central Bank to provide stimulus. But Berlin may be able to buck the general negative trends and we think that city has the capacity to adapt to changing structural trends.

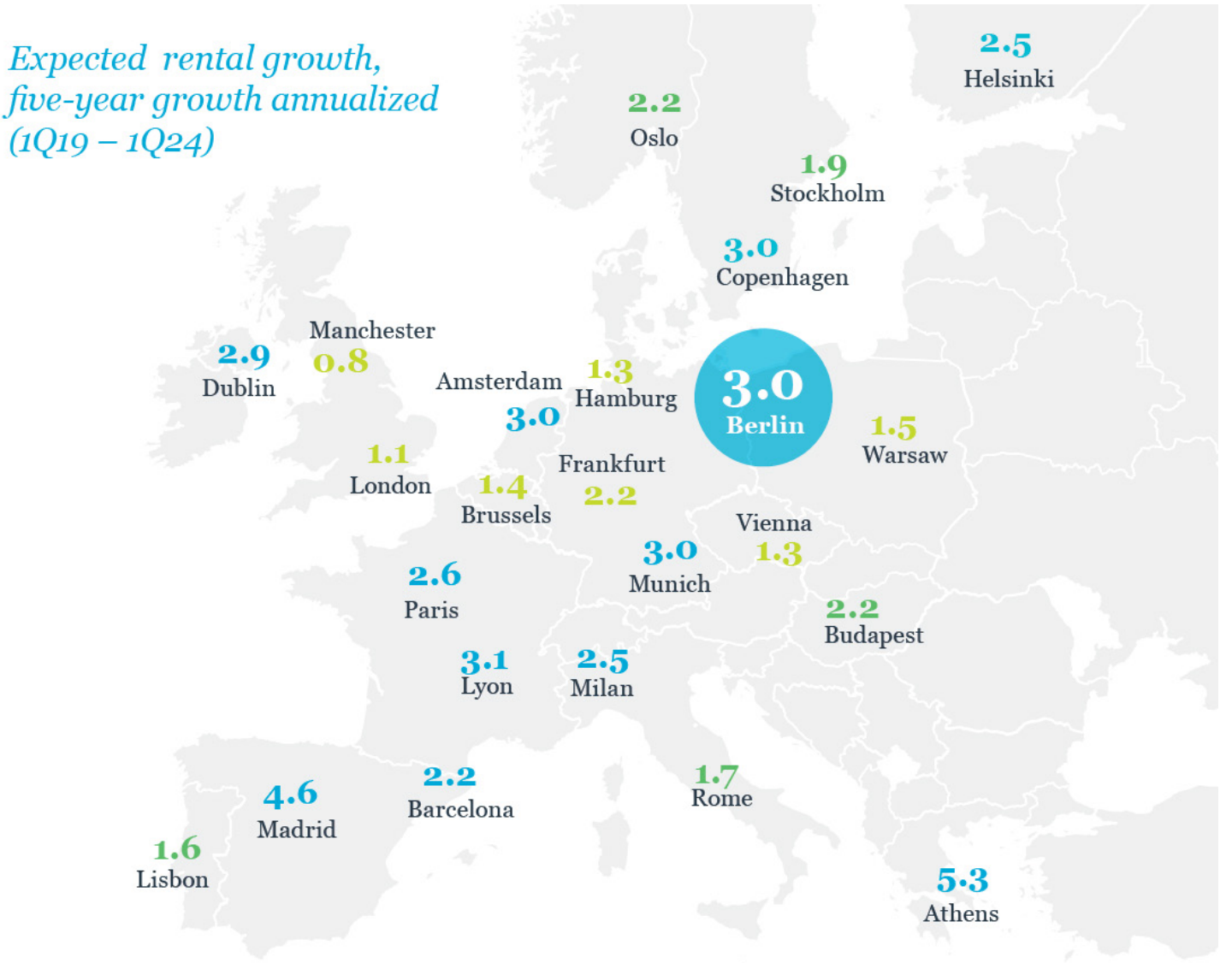

Exhibit 5: Berlin Real Estate is Poised for Strong Growth
Source: Nuveen, 1Q19.
Forecasts cannot be guaranteed.

Taking Advantage of Low Interest Rates: Student Housing, Rental Properties and Logistics

While Berlin overall is a city on the rise, we think there are specific real estate sectors that represent particularly attractive investment options. Berlin has been aggressively and smartly addressing the issues of rising population growth and an increased demand for housing. In particular, Berlin real estate developers have been capitalizing on low interest rates and high debt availability. As an example, city planning increasingly favors dynamic developments, which leads to a variety of futuristic living spaces. Similarly, the logistics sector is branching out into adjacent spaces such as data centers to accommodate the growing technological presence in the city. While structural demographics certainly support the Berlin economic outlook, certain real estate sectors of the city are better positioned for cyclical growth than others.

The bottom line is that even if a certain region or a certain country is experiencing economic pressure, that doesn't mean we can't find cities and sectors that offer potentially attractive real estate investments. Student housing, rental growth and logistics in cities such as Berlin are only one example of investments benefitting from strong structural demographics that can potentially find attractive risk-adjusted returns for long-term investors.

Asia-Pacific: Demographic Changes Lead to Positive Disruptions

Asia-Pacific Farmland

The Risks (And Hence the Opportunities) are Changing

Some things don't change: Farmland investing will always be dictated by factors such as weather patterns, water resources and availability, infrastructure and soil types. But there are other risks that are harder to identify, like technological advancement, political risks, local regulations and trade flows. We believe farmland investors with the ability and infrastructure to adapt to these changes will be competitively positioned for long-term growth.

Farmland Investing is About More Than Just Weather and Soil

Understanding which risk and return factors affect specific regions is critical in farmland investing.

Farmland opportunities sometimes exist in little understood remote areas or are affected by factors that can be incredibly complex, which is why we believe partnering with local farmers, regulators and tenants is critical, and that farmland investors with the ability and infrastructure to uncover and adapt to these changes will be competitively positioned for long-term growth.

Consider, for example, the issue of land title rights in Australia. Admittedly, title right risks probably aren't normally on top of investors' minds as they consider investments because they aren't as apparent as tangible farmland features such as soil type. But we have found that knowledge of such local regulations provides the opportunity to uncover hidden value.

In Australia, land mining rights are owned by the government (known as Crown rights), which creates possible political risks when investing in any land investment such as farmland. Debates over land use can delay investments and cause legal trouble that could take years to settle.

Similarly Appearing Regions May Actually Be Quite Different

This is an issue in several countries and regions around the world, but in actuality, Australia has a very low title land risk. The majority of Australian farmland is family-owned, which makes ownership and land right usage relatively transparent and hence, easier to invest in. This isn't always the case. To take another example from a different region, Canada is actually quite similar to Australia in terms of overall population size and crop types produced. And, like Australia, the majority of mining land rights in Canada are owned by the Crown. But there is a key difference: Farmland regulations and title rights are much more complicated in Canada than they are in Australia, heightening title risks.

Comparing Australian and Canadian land title risks may seem like an esoteric exercise, but we think it is exactly the sort of analysis that provides an edge in farmland investing. While understanding fundamental factors such as crop types, rainfall and soil dynamics certainly comes into play, navigating lesser understood risks is equally important for long-term success.

Asia-Pacific Real Estate

Compelling Real Estate Opportunities Can Be Found in Tokyo, But Selectivity is Key

Japan has long been negatively affected by structural and demographic challenges. Globally, the economic cycle is in its later stages while global monetary policy is becoming less accommodative. All of this probably doesn't bode well for Asia as a whole. But that doesn't mean there aren't compelling real estate opportunities in that region. Consider Tokyo: That city has a stable population and an expanding middle class. And at the same time the city is enjoying robust liquidity, low interest rates, solid credit ratings and should benefit from rising rents across most real estate sectors. Of course, to capitalize on these trends, investors need to know where to look.

Market Volatility Could Create Opportunities for Tokyo Real Estate

At this stage of the cycle, we think a focus on finding relative value is increasingly important. Specifically, we think a focus on individual security selection makes sense — both in terms of picking the right places to invest and avoiding cities poorly positioned for late-cycle dynamics. In the coming years, we are expecting to see higher levels of global financial market volatility, which will no doubt affect real estate prices. But, as we have seen in the past, this sort of volatility can also create opportunities. Consider the experience of the Tokyo Pacific Tower during the global financial crisis. The value of that property plummeted during the crisis, even though its intrinsic value didn't really change. Investors were panicking and dumping assets and overreacted by selling perfectly sound investments as a way to try to avoid risk. Not surprisingly, the value of Tokyo Pacific Tower recovered quickly. Investors would have been better off if they avoided the temptation to sell at fire-sale prices — or even to consider buying when prices were depressed. We wouldn't be surprised to see similar sorts of price dislocations in the coming years in Tokyo real estate.[2]

Demographic Trends in Japan Coupled with Future Growth Expectations Bode Well for the City

One of the reasons Tokyo real estate recovered from the global financial crisis so quickly was that the city had been enjoying a relatively strong increase in property values. This may be surprising considering that Japan as a whole is suffering from a decline in population, but Tokyo's population has actually been stable. And Tokyo is benefitting from an influx of Millennials who have higher disposable incomes.

and tend to contribute to a city's cultural and economic growth. We have found that there are multiple cities around the world that have been benefitting from similar dynamics (see Exhibit 6). And a focus on real estate in individual cities, rather than countries as a whole, can make good investment sense.

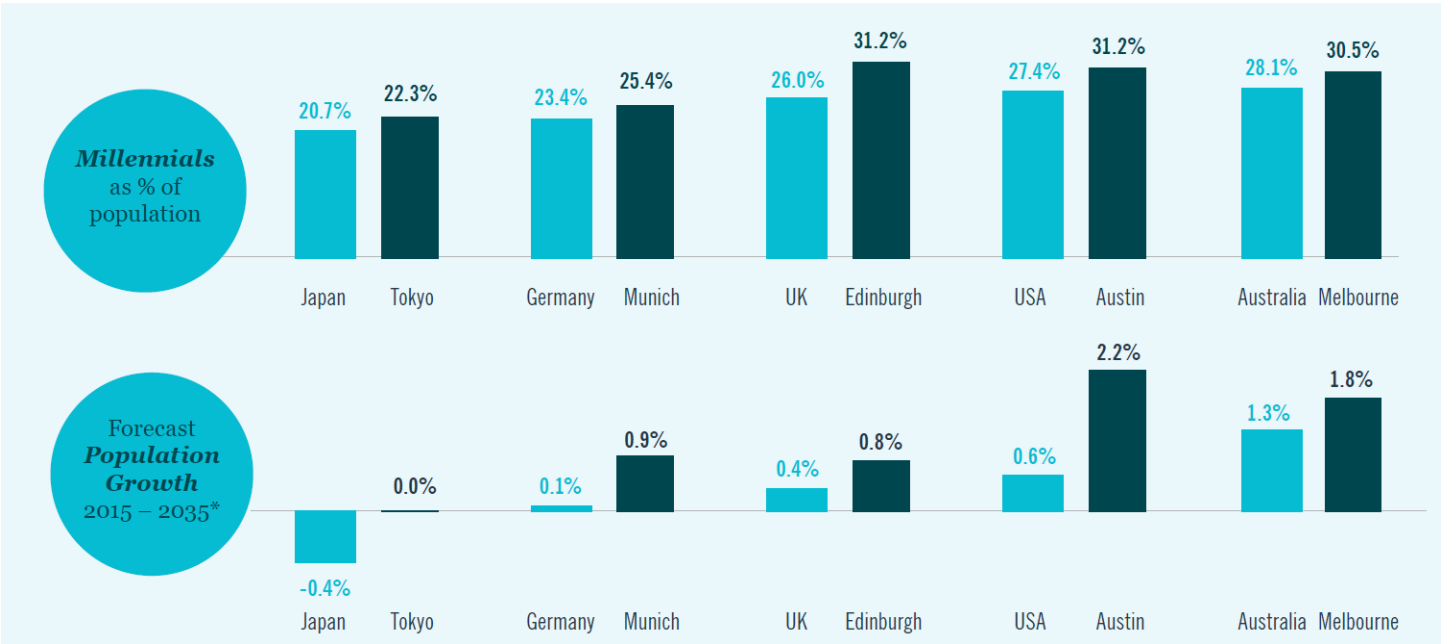

Exhibit 6: Cities Not Countries - Cities are More Youthful and Faster-Growing than Countries
Source: Oxford Economics 1Q19
*Per annum

In our view, Tokyo is quite well positioned to remain an attractive real estate market. By 2030, it is estimated that half of the world's output, more than a third of consumption and nearly half of the top twenty-five global cities will be in the Asia Pacific region.[3] The se structural tailwinds provide a compelling backdrop for Tokyo real estate. While population growth by itself cannot drive long-term returns for a city, promising future economic growth coupled with strong structural trends may.

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Endnotes

1. Bloomberg
2. IMF
3. Nuveen Real Estate

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Nuveen Real Estate

Alice manages a team of analysts, for Nuveen Real Estate, devoted to researching the direct property market in Europe, the U.S., and Asia.

Alice jointly runs the research and development (R&D) function, which ensures that our research is applied and remains at the forefront of product development. The R&D team identifies global, structural trends and finds appropriate opportunities for real estate investors. Alice is a member of the investment committee and the global product committee, ensuring that the research feeds into every stage of the investment process and product development.

Alice graduated with a B.A., honors, in Geography from the University of Southampton. She is a member of the Investment Property Forum, the Society of Property Researchers, INREV, and the International Council of Shopping Centres.

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Westchester

Skye is head of portfolio management for Westchester Group. She works closely with the investment teams and senior leadership to guide strategic and tactical decisions on existing and new portfolios.

Skye joined the firm from BlackRock where she was responsible for coverage of the agriculture sector within the natural resources equity team. In this role she managed/co-managed three strategies across eight portfolios totaling US$2.9 billion of assets under management, including US$900 million of direct agricultural exposure. Prior to BlackRock, Skye spent 15 years at Colonial First State Asset Management, working for the firm in Sydney and London to establish and manage its global agribusiness equity product.

Skye graduated with a Bachelor's of Agricultural Economics, specializing in Agribusiness from the University of New England, Armidale, NSW and a Graduate Diploma in Applied Finance and Investment from the Securities Institute Australia. She holds the CAIA designation.

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Brian is the chief investment strategist at Nuveen. He works closely with the firm's investment management team to identify investment trends and provide insights on events driving market activity, with a long-term view. He is also a voting member of TIAA's asset allocation committee.

Brian is a markets expert with a decade of experience analyzing economic, equity and fixed income data and developing investment strategies to optimize client portfolios. Prior to joining the firm, Brian served as head of tactical asset allocation for UBS Wealth Management Americas, and as a senior investment strategist at Barclays Wealth. He began his career in the markets group at the Federal Reserve Bank of New York.

Brian graduated with a bachelor's degree in Economics and Government from Dartmouth College and a master's degree in Economics from New York University. He also holds the CAIA designation.

The Wrapper Matters: Comparing Liquid Alternatives and Hedge Funds

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In a potential low-return environment, investors are continuously seeking to improve a portfolio's risk-return profile.[1] Using alternative investments is one option, though evaluating strategies is a challenging task for practitioners at all levels of experience.[2] The first part of our paper provides a framework that investors can use to evaluate the returns from strategies across public and private vehicles. Studying a manager's past returns through a variety of lenses, however, is one step in a multistep portfolio construction process. The second part of this paper provides portfolio construction commentary and analysis that practitioners may use to guide an investment decision.

Comparing Structures

We begin by briefly comparing the private and public structures that investors use to gain access to these types of strategies. We center our analysis on the pooled fund structure commonly used by both. Hedge funds predominantly operate as private placement vehicles through the general/limited partnership model. Although the limited partnership legal structure can limit an investor's liability in the fund to the amount of capital contributed, these agreements are negotiated, are generally nontransferable, and can impose restrictions on investments.

We refer to "liquid alternatives" throughout the paper as the public implementation of hedge fund strategies. Liquid alternatives are commonly discussed as a group of broadly accessible vehicles for alternative investment strategies that generally maintain low correlations to traditional asset classes. For the purposes of our research, the liquid alternatives category includes products such as mutual funds, exchange-traded funds (ETFs), and exchange-traded notes (ETNs). Exhibit 1 further summarizes key structural differences, broken into a few major categories.

		Liquid alternatives	Hedge funds
Regulatory oversight		Greater regulation. Most are regulated under the Investment Company Act of 1940 ('40 Act) as pooled investment vehicles.	Less regulation. Largely exempt under the '40 Act if offered to accredited investors/qualified purchasers.
Fees and access	Investment management fees*	Lower • Asset fee.	Higher • Asset fee. • Performance fee.
	Typical Investment minimums	Lower – Typically $5,000 to $250,000.	Higher – Typically $1 million to $5 million.*
Transparency	Specificity of strategy disclosure	Yes – more standardized reporting through prospectuses and quarterly/ annual reports.	Some – though often less standardized.
	Holdings disclosure	Yes – through quarterly reporting.	Varies – can be difficult to obtain.
	Pricing frequency and quality	Greater – daily pricing with more standardization.	Varies – frequency is often monthly
Liquidity provisions	Restrictions on sales	No – investors can redeem daily.	Yes – with lockup and gating provisions, among others.
	Leverage limitations	Yes – at least 300% asset coverage must be maintained (Explicit leverage limit).	No – though based on manager discretion.
	Liquidity requirements	Yes – 85% of a fund's net assets must be held in liquid investments that the fund reasonably expects can be sold within seven calendar days without significantly changing the market value. 15% of net assets can be held in "illiquid" investments	No – though based on manager discretion.
	Shorting requirements	Yes – the full value of liabilities created by using short sales must be covered by holding an equivalent amount of collateral within a separate brokerage or custodial account.	Portfolio margining – aligning margin requirements with the overall risk of the portfolio's positions

Exhibit 1: Structural Differences between Public and Private Vehicles are Notable
Source: Vanguard, Citi Prime Finance (2013); U.S. Securities and Exchange Commission; Investment Company Institute; Chambers, Black, and Lacey (2018); and Philips (2006).
* Additional fees may apply depending on structure, including platform fees, marketing fees, load fees, audit fees, and administrative fees, Some liquid alternatives may charge performance fees, but those are less than comparable hedge fund fees.
^ See Steme and Slattery (2002)
Notes: Some characteristics addressed in the exhibit are generalizations. Because much of our data sample consists of U.S. liquid alternatives and hedge funds, the exhibit focuses on the U.S. regulatory framework. Regulations differ around the globe, though other major frameworks (Such as UCITS) have similar restrictions on the public fund characteristics described here.

A few key differences emerge from this comparison. Liquid alternatives grant investors various benefits and protections that private vehicles do not, such as holdings transparency and daily pricing/access. Relative to private counterparts, however, many liquid alternative vehicles are constrained in the use of leverage, liquidity, shorting, and derivatives because of greater regulatory oversight.[3] These portfolio management tools allow hedge funds to both take more risk and hedge more flexibly. Notably, these characteristics are critical in design and implementation for many of these alternative investment strategies. This implies that the execution of the strategies themselves in a liquid alternative vehicle may look materially different on a category-by-category basis. The ensuing analysis explores this point in greater detail.

Strategy Mapping Framework

To conduct our analysis, we created a mapping framework to group seven subcategories of strategies into five headline categories for ease of comparison.[4] Such a framework provides a more useful comparison between categories in public and private form because data providers often use different classification systems (Exhibit 2). The framework was created by mapping categories of hedge funds from the Hedge Fund Research (HFR) database (a robust, detailed classification system) to categories used by Morningstar, Inc., to group liquid alternatives (mutual funds, ETFs, and ETNs). We used fund and category descriptions to rearrange certain categories, finalizing the mapping exercise. See Appendix A for more on our data set and methodology.

Headline category	Definition	Liquid alternatives subcategories	Mapped hedge fund subcategories	Other strategies included in the headline category
Long/short equity	Funds that take long and short (hedging) positions in equities, equity ETFs, and related derivatives using fundamental or quantitative processes.	• Long/short equity • Marketing neutral	• Long/Short equity (ex-equity market neutral) • Market neutral	• Quantitative directional • Fundamental growth/value • Sector-specific • Short-bias • Multistrategy
Relative value	Funds that seek to capitalize on mispricings between various securities including equities, fixed income, and derivatives, using fundamental or quantitative techniques	Long/short credit	Fixed income: corporate	• Fixed income: convertible arbitrage • Fixed income: sovereign • Volatility • Yield alternatives • Multistrategy
Event driven	Funds that invest in equity or fixed income securities that are currently or prospectively involved in corporate transactions including mergers and acquisitions, financial distress, and capital restructurings.	Event-driven	Event-driven	• Activist • Distressed and restructuring • Merger arbitrage • Special situation • Credit arbitrage • Multistrategy
Global macro	Funds that use systematic or discretionary strategies based on movements in macroeconomic variables and trends and their impact on various asset classes (equities, fixed income, commodities) and instruments (currencies, derivatives).	• Managed futures • Multicurrency	• Systematic diversified • Currency	• Commodities • Discretionary thematic • Active trading • Multistrategy
Multistrategy	Funds that use strategies that are a combination of major categories or subcategories above. Multistrategy approaches are often designed to blend various strategies to reduce the volatility of the overall return stream and correlation to traditional asset classes.	Multialternative	Fund of funds (FOF)	• FOF conservative • FOF diversified • FOF market defensive • FOF strategic

Exhibit 2: Alternative Investment Strategies in a Public and Private Wrapper

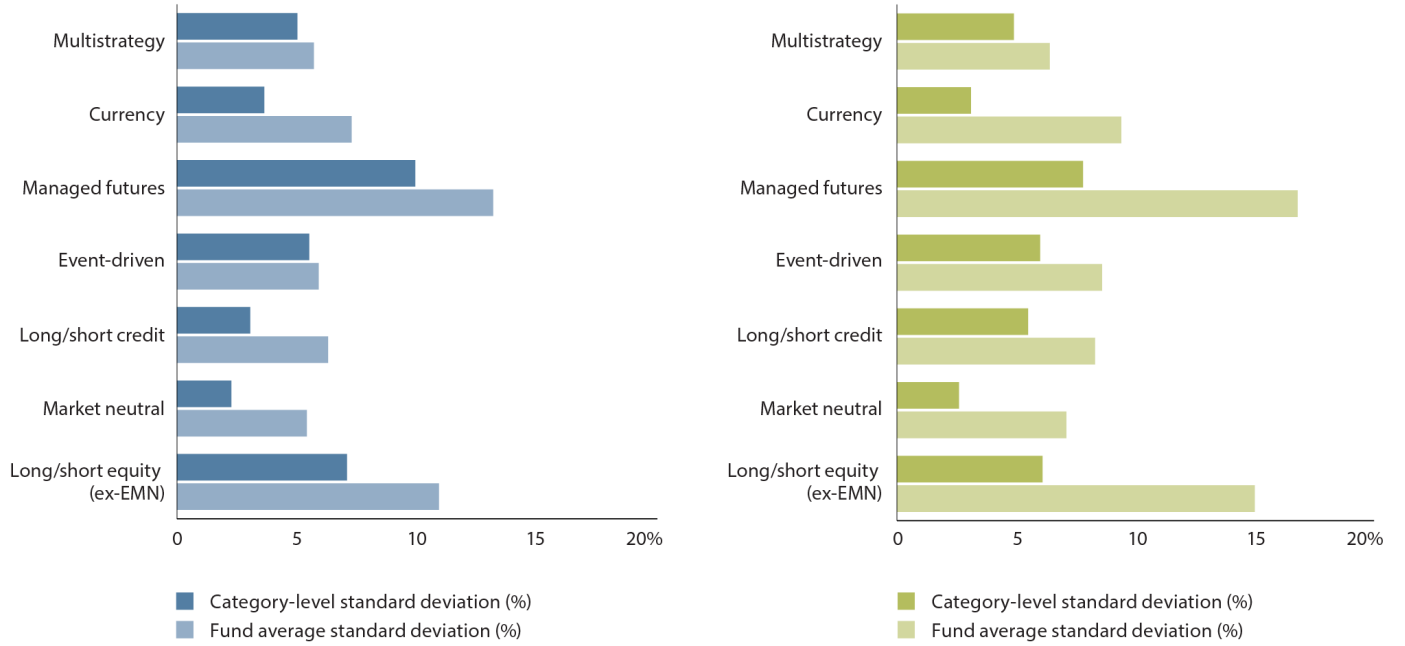
Source: Vanguard

Notes: Definitions are adapted from HFR definitions, Morningstar definitions, and Goldman Sachs Asset Management (2019). See Appendix A for select subcategory definitions. Mapped hedge fund categories are the closest matches from HFR based on available categories. In our mapping framework, some headline categories lack differentiated subcategories. The last column lists additional strategies from HFR that are not explicitly analyzed in the research; the list is not all-inclusive.

Categories Versus Individual Funds

Although a natural place to begin examining these strategies is through categories (as represented by indexes or aggregations of managers into a single return stream), such a starting point presents challenges. By combining the returns of hedge fund or liquid alternative fund managers into a single stream, we reduced the manager (idiosyncratic) risk component that investing in individual funds entails. Generally, this biases down the standard deviation of the index return stream, as the pairwise correlations between individual managers is often less than one. Exhibit 3 highlights the larger standard deviation for individual funds relative to their category averages and intracategory fund correlations.

Nonetheless, using categories of strategies is an appropriate starting point to assess their performance and portfolio construction benefits. Categories of liquid alternatives and hedge funds are not widely investable, but they are generally representative of how a strategy type behaves.[5] In addition, individual liquid alternatives and hedge funds either have notoriously short lifespans or provide limited return history (see Figure A-1 in the Appendix). This complicates the use of individual funds in broad, comparative analysis.[6]



	Long/short equity (ex-EMN)		Market neutral		Long/short credit		Event-driven		Managed futures		Currency		Multistrategy	
Average fund pairwise correlation	0.5	0.4	0.2	0.1	0.7	0.5	0.8	0.4	0.8	0.4	NA	0.0	0.7	0.7

Liquid alternative category
Hedge fund category

Exhibit 3: Masking Manger Risk?

Source: Vanguard calculations; based on data from Morningstar, Inc., and HFR.

Notes: Funds included in the sample reported complete data over the measurement period of July 2003 through June 2018 except currency hedge funds, for which a shorter data requirement was used to match the category-level time series. The currency liquid alternative category had fewer than five funds with full return history, so no correlation was computed.

Performance Comparison

Performance Snapshot

We begin with a performance snapshot of constituent category funds over our measurement period (July 2003 through June 2018). Exhibit 4 presents return distributions for our headline category and subcategories and shows that hedge funds exhibit a higher median and wider dispersion of net returns across all categories compared with liquid alternative counterparts.

It is difficult to truly compare these types of strategies in public and private form. Because of limited reporting requirements for hedge funds, managers may not mark to-market the value of their holdings with the same frequency and transparency as liquid alternative counterparts. See Asness, Krail, and Liew (2001) for additional discussion. Nonetheless, the frameworks we used to compare and analyze these investments are a valuable reference point for investors.

The lower medians and tighter dispersion of liquid alternative returns reflect, in part, their more limited use of leverage and other portfolio management tools discussed in Exhibit 1. Investors can evaluate these lower returns as the cost of increased regulatory and structural protections and as a potential hedge against the more extreme outcomes visible in the hedge fund data. The value of these protections depends on an investor's unique objectives and risk preferences.

Although we analyzed strategy categories for much of this research, the dispersion in Exhibit 4 demonstrates that, as with many types of alternatives, investors should follow a bottom-up portfolio construction approach when allocating to any strategy. This is because managers' risk exposures can vary widely depending on the underlying strategy design and will most likely behave in a materially different way from the category as a whole.[7] See "Manager selection is mission-critical" on page 25 for more detail.

For much of the rest of the analysis, we used HFRI indexes and comparable, equal-weighted liquid alternative category fund averages to assess the characteristics of our strategy categories. See Appendix A for descriptive statistics for our hedge fund/liquid alternative categories, global equity, and global fixed income.

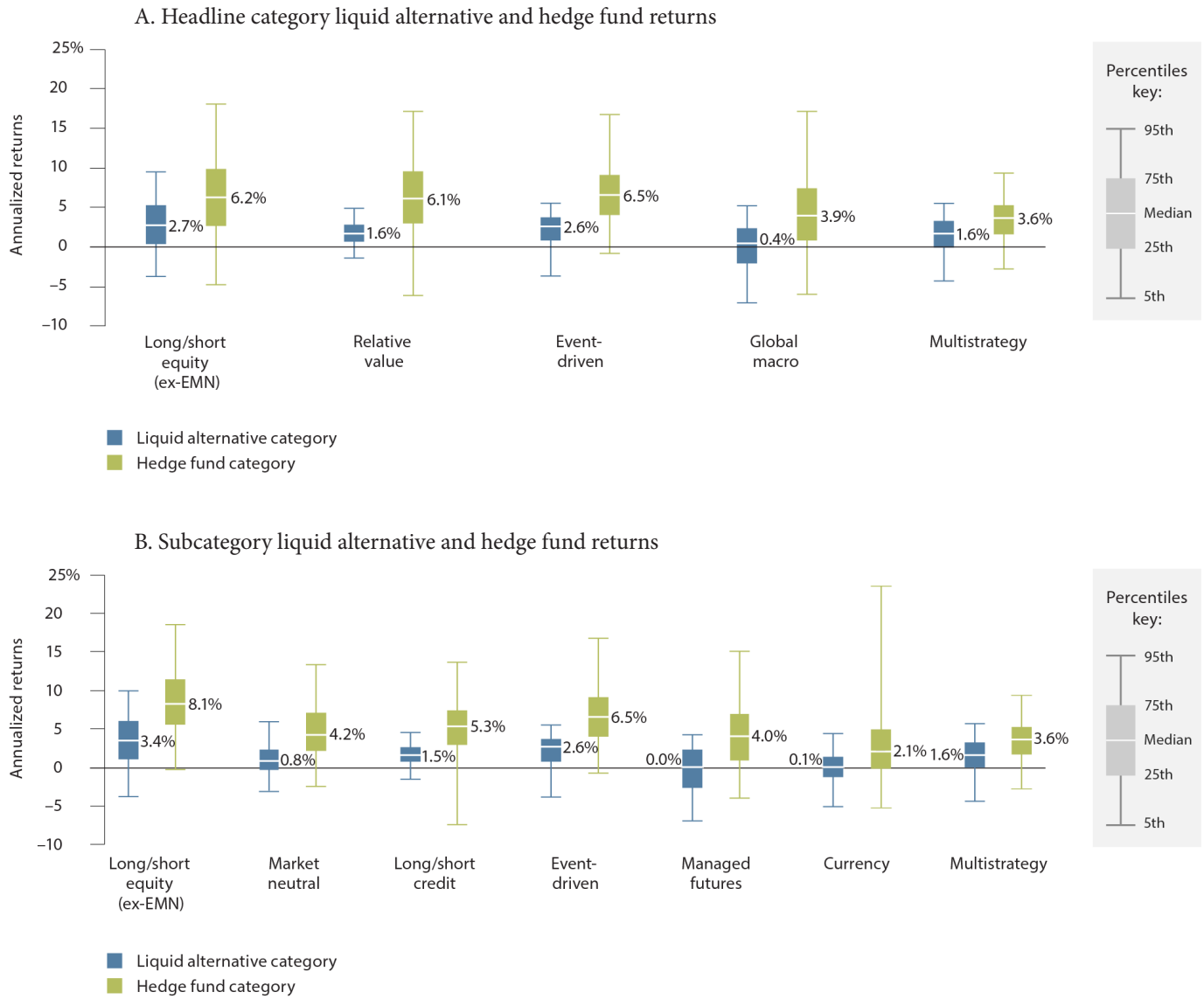


Exhibit 4: Hedge Funds Outperform their Public Peers, Though with Greater Return Dispersion

Source: Vanguard calculations; based on data from Morningstar, Inc., and HFR.

Notes: Return distributions include annualized returns for funds that were alive at any point during the 15 years from July 2003 through June 2018 and had at least 36 months of return history. Funds with less than 36 months of data were removed from the sample to improve data quality. The long/short credit hedge fund category includes fixed income (sovereign) funds from HFR. Returns are net of fees. Past performance is no guarantee of future returns.

A few points of note:

- Hedge fund Sharpe ratios were often notably higher than their liquid alternative counterparts.
- Hedge funds exhibited lower correlations to global equities and global fixed income across most subcategories, but differences often were not substantial. In addition, some strategy correlations and betas (to both global equity and fixed income) were highly time-varying over the 15-year measurement period. See "Additional portfolio construction considerations" on page 26 for more detail.
- All liquid alternative and hedge fund categories underperformed global equities over our measurement period, but this benchmark is not appropriate for the majority of strategies. In fact, the majority of the constituent funds in our seven categories underperformed global equities' 9.15% annualized return over our measurement period as well. Many also underperformed global fixed income's 3.68% annualized return. Benchmarking for these types of strategies is beyond the scope of this paper.[8]

A. Liquid alternative annualized alpha

B. Hedge fund annualized alpha

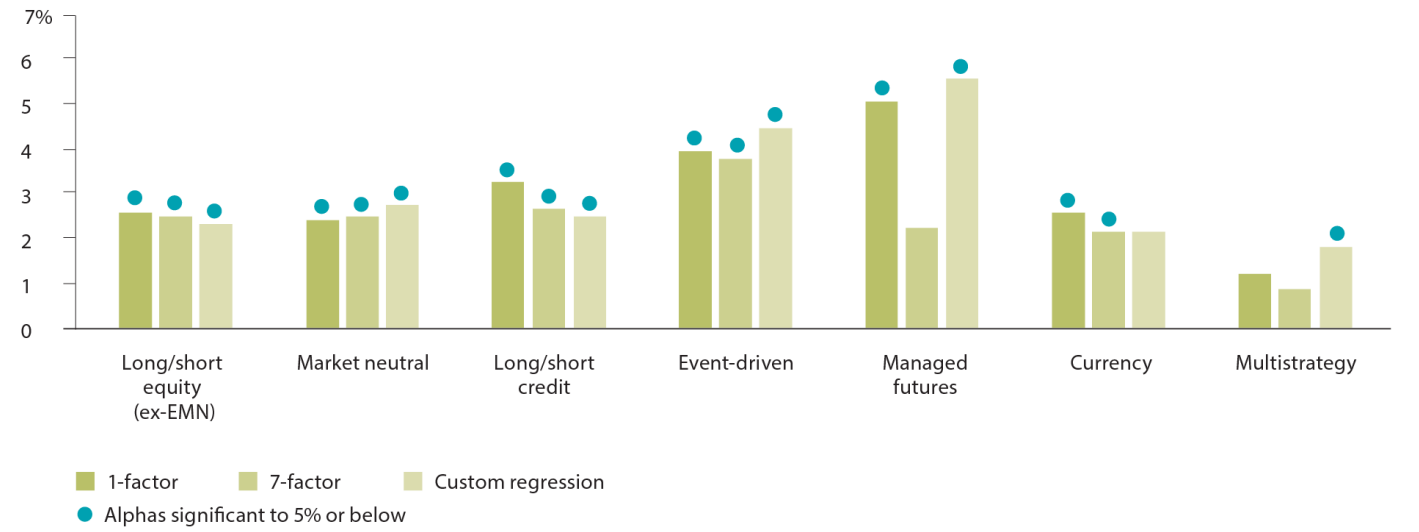


Exhibit 5: Hedge Funds Still Outperform their Liquid Alternative Counterparts after Adjusting for Risk
Source: Vanguard calculations, based on data from Morningstar, Inc., and HFR. See Appendix B for factor definitions and sources.
Exhibit 5: Cont.

Analyzing Returns through a Factor Lens

These performance differences can potentially be explained by a few considerations, including the structural differences discussed in Exhibit1 and biases in hedge fund data.[9] To address whether these, and other, considerations informed the performance differences shown in Exhibit 4, we controlled for risk by regressing categories of gross, hedge fund, and liquid alternative excess return streams on various risk factors using three different regression model specifications:[10]

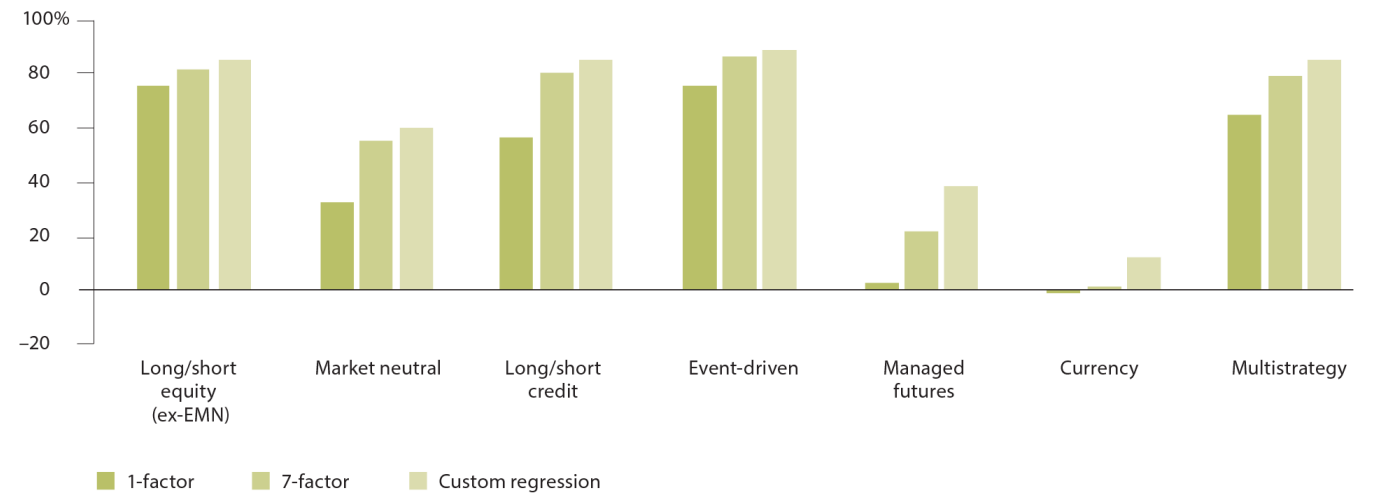
- 1-factor (market).[11]
- 7-factor (Fama-French-Carhart 4-factor with term, investment-grade credit, and high yield).
- Custom regression ("custom") using a broad array of risk factors widely cited in academic literature to explain hedge fund returns (see Appendix B for factor definitions and sources) or conduct risk factor attribution. Additional factors include liquidity, low volatility, quality, and trend-following factors.

Because we used global liquid alternative and hedge fund data, all factors covered global risk premiums to whatever extent possible. In addition, because liquid alternative and hedge fund vehicles can implement strategies long/short, we used long/short factors; such factors also removed collinearity that would likely otherwise exist across our independent variables. Finally, all excess returns and factors are gross of cost and reported in USD.[12]

Exhibit 5 reports the alphas and adjusted R-squared results from our regressions. Because we used a gross-of-cost assumption to obtain a purer measure of ex-post performance, our regression results should be interpreted as the value-add that managers generated, not what investors realized, over our measurement period. In addition, our research does not focus on forward-looking replication for our various strategy categories.[13] See Appendix B for the full regression output, including betas and t-statistics.

C. Liquid alternative adjusted R-squared

D. Hedge fund adjusted R-squared



Notes: Annualized alphas were calculated by multiplying regression intercepts by 12. Data cover July 2003 through June 2018. The custom regression specification was run through December 2017 because of liquidity factor data limitations. The currency hedge fund regressions were run starting December 2008 because of data limitations.

Exhibit 5 Cont.

Consistent with findings from academic literature, hedge fund categories outperformed their liquid alternative peers after accounting for differing levels of risk through three different regression specifications.[14] Alphas were greater almost across the board. Most hedge fund alphas were statistically significant to 5% as well. Although the adjusted R-squared results from our liquid alternative regressions were similar to those from our hedge fund regressions, the liquid alternative R-squareds were slightly higher—a conclusion we expected given the daily pricing and greater liquidity provided by public vehicles.[15]

We hypothesize that measuring alphas net of cost would shrink the gap between the liquid alternative and hedge fund categories shown in Exhibit 5. At the very least, hedge funds charge higher management fees (and performance fees) on average than liquid alternatives. In turn, hedge fund alphas should bear a disproportionally larger negative impact when studied on a net basis.

Notably, a unique combination of the 15 risk factors we tested explained individual strategy returns over our measurement period. Factor exposures differ across liquid alternative and hedge fund categories, reflecting the difference in strategy implementation for the public and private vehicles. Exhibit 6 details statistically significant factors from the custom regression specification for both liquid alternatives and hedge funds. It also highlights the more complex set of risk factor exposures that drove most hedge fund category returns relative to liquid alternative counterparts (as represented by the number of green squares relative to the blue squares).

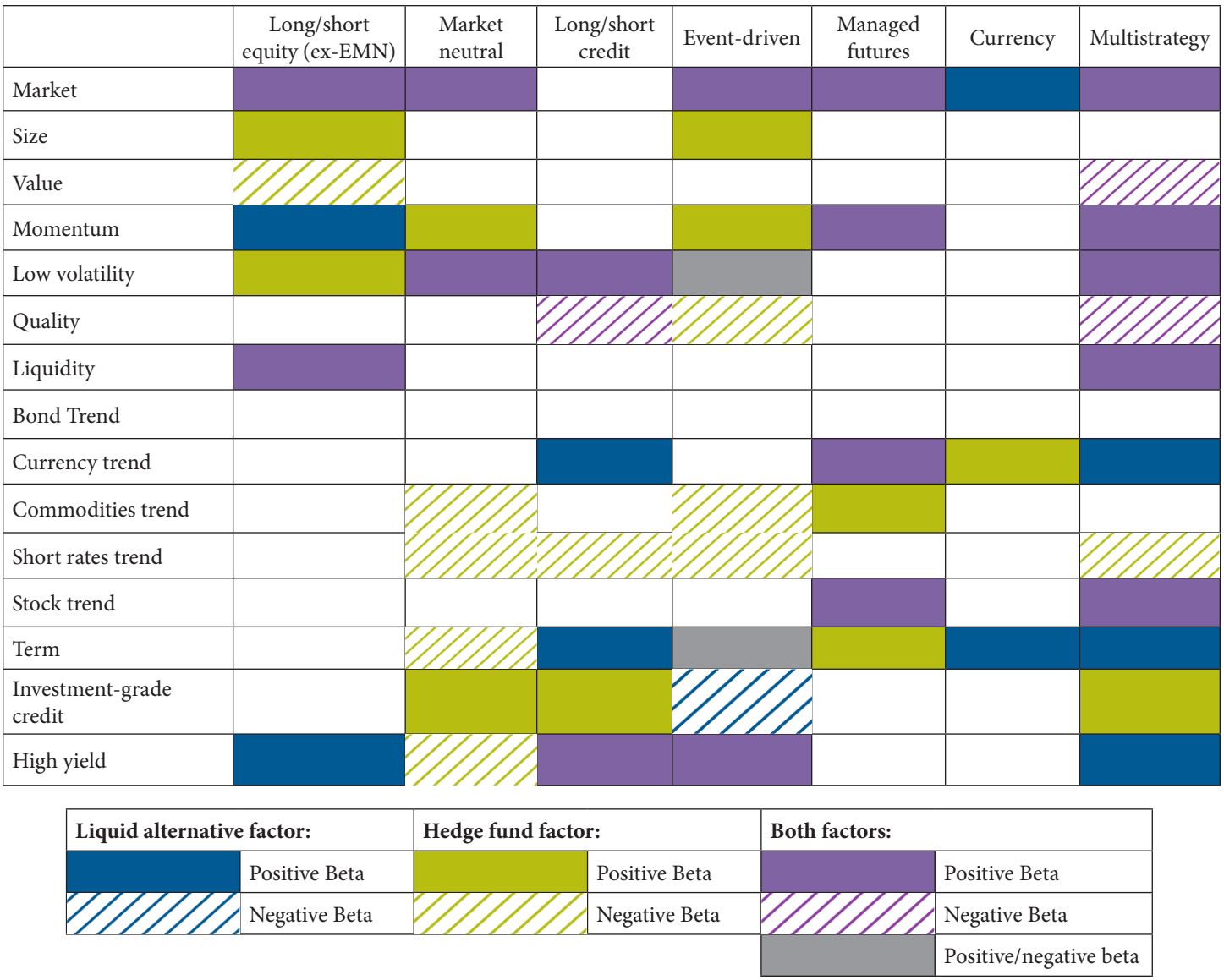


Exhibit 6: A Diverse Array of Factors Drives Returns

Source: Vanguard calculations; based on data from Morningstar, Inc., and HFR.

Notes: Risk factor in the highlighted cells were statistically significant to at least 5% in the custom regression specifications. Gray squares represent a statistically significant factor for both liquid alternatives and hedge funds where one beta was positive, and one beta was negative. See Appendix B for betas and t-statistics.

Liquid Alternatives Are Often the Prudent Option

Even assuming that a hedge fund, on average, could outperform a similar liquid alternative, investors may still prefer the public option, which may be a better choice when accounting for the considerations discussed in Exhibit 1. Many investors have preferences or constraints related to the use of leverage, liquidity, shorting, and derivatives in their portfolios; pricing transparency for holdings; and the ability to access capital with limited restrictions. These constraints may preclude an investment in many hedge funds.

And as discussed in the next section, liquid alternatives may provide valuable portfolio construction benefit for investors who are not interested in undertaking the additional due diligence required for, or paying the costs associated with, investing in private alternatives. A few considerations that are particularly relevant for private investments relative to public counterparts are presented below; see Wallick et al. (2015) for more detail on the challenging nature of hedge fund due diligence.

Fee Structures. Hedge funds often have both management and performance fees, which can substantially lower an investor's net return. Fee structures can also be complex, with added high-water marks and hurdle rates. In addition, to build a diversified hedge fund allocation, some investors choose to invest in hedge funds through a fund-of-funds structure (which often adds another layer of fees).

Holdings Transparency and Pricing Frequency. Unlike liquid alternatives, to protect proprietary trading strategies, many hedge funds will not provide specific detail on portfolio holdings (and are not required to as mutual funds and ETFs are). This can be problematic for investors looking to assess how a manager's strategy may blend with traditional assets. In addition, the daily pricing of liquid alternatives gives investors a far more consistent snapshot of investment performance.

Access to Capital. Liquid alternatives allow investors to access their investments daily—a highly valuable benefit, particularly for those who have spending requirements or who regularly rebalance their portfolios to maintain a target asset allocation. Hedge funds provide less liquidity by allowing investors to redeem less frequently (for example, quarterly or longer), with additional gating provisions, lockup periods, redemption queues, and other considerations. In most market environments, hedge funds usually provide more liquidity than other private alternatives such as private equity, but in more stressed environments, many hedge funds can become extremely illiquid.

From Analysis to Implementation

Studying the returns from these alternative investment strategies is one important step in a more holistic, multistep portfolio construction process. One of the most critical steps is manager selection. Selecting an active manager is a challenging task for investors and investment professionals alike. This is particularly true for those focused on alternative investments, whose strategies are often complex and may not be fully transparent. The performance dispersion across and within categories of hedge fund and liquid alternative managers shown in Exhibit 4 underscores this point. More specifically, because managers can deliver a wide range of outcomes (especially in private vehicles), a strong manager selection process is key to" improving the odds of success.

A Framework for Portfolio Construction

Although a deeper dive on strategy and manager due diligence for hedge funds and liquid alternatives is beyond the scope of this paper, we provide brief commentary below. For a more comprehensive review, with a particular emphasis on private investments, see Greenwich Roundtable (2010).

1. Identify an investment objective

Being explicit about an investment objective, and how a manager or strategy may help achieve it, is an important first step. Investors may use liquid alternatives and hedge funds to target a wide array of objectives, ranging from broader (such as return enhancement, portfolio diversification, or inflation protection) to narrower (such as achieving a specific target rate of return above inflation). These objectives are typically not mutually exclusive.

After identifying an objective or objectives, investors who are willing and able to select these types of managers can proceed with the bottom-up portfolio construction process—determining whether to invest through a public or private vehicle and eventually selecting a manager after thorough review. As discussed throughout this paper, investors will place varying degrees of value on the relative benefits that public liquid alternatives provide. This is critical to assess up front.

2. Determine a suitable strategy type(s)

Before selecting an individual manager, winnowing down the opportunity set of strategy types to an intended one or few can be helpful. This determination should be informed by an investor's portfolio construction preferences and constraints.[16] Various strategies can provide a wide range of benefits but are often implemented differently. Investors should carefully review how a strategy's design and execution mesh with these key considerations.

For example, from a design perspective, an investor interested in absolute return produced from equity security selection might focus more on the equity market neutral category. Another investor interested in harvesting alternative risk premiums systematically (with less manager discretion) might spend more time searching for a multistrategy or global macro manager with a transparent, quantitative orientation. In addition, certain strategies use much more leverage, short-selling, and derivatives than others. These considerations should all be carefully evaluated. Investment consultants can also help with this decision.

3. After assessing the potential benefits and risks, select a manager(s)

Upon identifying an objective and strategy type, investors should assess what ex-ante portfolio construction benefit might be achieved from a specific manager. Such analysis will help in determining, for example, an allocation's size and funding source. Investors can start by examining and decomposing a manager's past returns through time using, for instance, the types of analyses we present in the first portion of this paper. The metrics and analyses used should be matched to the objective.

For example, an investor seeking inflation protection through a global macro strategy should assess the extent to which a fund's returns generally maintain a strong correlation and beta to an inflation rate such as the Consumer Price Index and why they should be expected to do so in the future. An investor seeking to improve a portfolio's return using a long/short equity strategy should spend substantial time setting return expectations (and certainty around them) for the fund and measuring them against those of other investment options.[17] And if a strategy type is expected to produce a return distribution that is highly nonnormal, traditional mean-variance statistics may not be appropriate to use.[18]

4. Evaluate periodically

As with any other investment decision, it is prudent to periodically assess the benefits of an allocation ex-post. Once a decision is made, investors should document their definitions of success and evaluate a manager against those expectations. Documenting decision-making criteria throughout the process is also important. Addressing considerations such as those below are a helpful way for investors to determine whether the benefit of an allocation is still being achieved. For example, assess whether:

- The allocation met the intended portfolio construction objective.
- The investor's risk tolerance or portfolio construction preferences/constraints have materially changed.
- The manager consistently executed upon the stated strategy.
- Other funds/strategies are now available that might help improve the odds of achieving an intended objective.

Manager Selection is Mission-Critical

The importance of manager selection for both public and private vehicles cannot be overstated. Because many investors do invest in individual hedge funds or liquid alternatives, and because individual funds pursue a wide range of investment strategies intracategory, individual funds can produce a wide dispersion of results in a portfolio construction setting. Exhibit 7 provides two examples of sets of efficient frontiers for multistrategy liquid alternatives and hedge funds.

To test how multistrategy funds interact with traditional assets, we run backward-looking mean-variance optimization over our 15-year measurement period with a portfolio of global equity, global fixed income, and an array of individual multistrategy managers to isolate the benefits of blending in an allocation. Examining changes to efficient frontiers is a straightforward way to assess the risk–return benefit of including a new investment in a portfolio. In our example, the multistrategy allocation is fixed at 40% along the frontier, and global equity/fixed income are unconstrained. Fixing the allocation at 40% better represents how investors' portfolio outcomes would have looked had they held a significant allocation to these managers through time.

We compare these individual manager frontiers to a base-case frontier containing global equity, global fixed income, and the multistrategy category average. Clearly, individual funds can produce a wide array of outcomes, both adding or subtracting value relative to category averages. Although not shown here, this conclusion applies to all categories of liquid alternatives and hedge funds. Because of the limited data history for many hedge funds and liquid alternatives, we chose funds that reported over the full measurement period for this analysis. We recognize that this may not be a representative sample from the multistrategy population, as funds that die off (or stop reporting returns) may do so because of poor performance.[19]

Purely approaching portfolio construction by relying on category averages for strategy types (that is, the base-case frontier in Exhibit 7) can present misleading results because of both the inability to capture the category average and the potentially wide variability of outcomes across managers.[20] Instead, Exhibit 7 shows that investors who can identify, access, and hold top-tier managers through time in both public and private vehicles can improve a portfolio's risk-adjusted return profile, by either reducing overall volatility or increasing return, or both.[21] The opposite, however, holds true for investors who have selected underperforming managers.

Portfolio Construction Preferences and Constraints Matter

Two more portfolio construction considerations are important to discuss. First, the funding source for an allocation matters. The optimization in exhibit 7 tended to allocate to our alternative strategies from the equity portion of the portfolio (in particular, to create the low-risk efficient mix).[22] For investors with various preferences or constraints on funding source, this can erode the benefits from a portfolio construction perspective. For example, over our 15-year period, if an investor wanted to keep an equity allocation intact to maintain portfolio growth targets (and instead had to fund an allocation primarily from fixed income), the results of our optimization would appear quite different— the benefit might be reduced in the form of a lower Sharpe ratio.

Second, we test 40% maximum allocations in our analysis. This is a large allocation to a highly complex investment and greater than many investors may feel comfortable with. We do so to magnify impact for research purposes. Smaller allocations, however, may not add significant portfolio construction value (namely, a small Sharpe ratio improvement in exhibit 7). In particular, investors may need to judge whether a potential marginal benefit is worth the added portfolio complexity or cost if a consultant is engaged or a fund-of-funds structure is chosen to assist with manager selection.

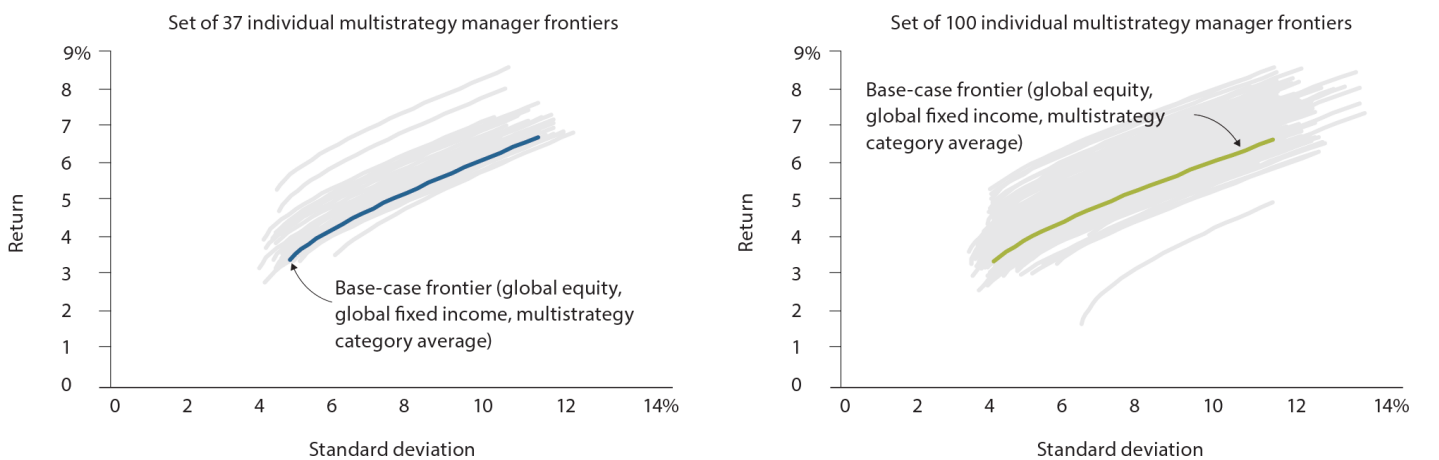


Exhibit 7: Manager Risk can Increase the Variability of Portfolio Outcomes

Source: Vanguard calculations; based on data from Morningstar, Inc., and HFR; and FactSet

Notes: Data cover July 2003 through June 2018. Each line represents an efficient frontier with an allocation to an individual liquid alternative or hedge fund manager, global equity, and global fixed income. The 37 liquid alternatives represent the total number of funds that survived over our measurement period. The 100 multistrategy hedge funds represent a sample of the funds that had a full return history over the period. Global equity is represented by the FTSE Global All Cap Index, and global fixed income is represented by the Bloomberg Barclays Global Aggregate Bond Index. The multistrategy category average for hedge funds is represented by the HFRI Fund of Funds Composite Index. Liquid alternative and hedge fund returns are net of fees. Past performance is no guarantee of future returns. The performance of an index is not an exact representation of any particular investment, as you cannot invest directly in an index.

Additional Portfolio Construction Considerations

A targeted benefit may be inconsistent through time

Although investors can clearly find value with an above-average manager, a targeted benefit may ebb and flow through time. More specifically, Exhibit 8 shows that shorter-term correlations and betas (here, rolling 36-month) can fluctuate widely, particularly for certain strategy types.[23] For example, the rolling global equity correlation for the managed futures and market neutral hedge fund categories was less stable over our measurement period than for other strategies. Most fixed income correlations and betas presented a cyclical trend as well.

From an investor's perspective, formulating expectations of how a manager's strategy may respond in various macroeconomic conditions is important. Although Exhibit 8 presents the time-varying nature of these key portfolio construction statistics for our category averages, individual funds may maintain similar time-varying correlations and betas as well. A thorough assessment of the enduring nature of a manager's philosophy and prior stability through time can both be informative data points.

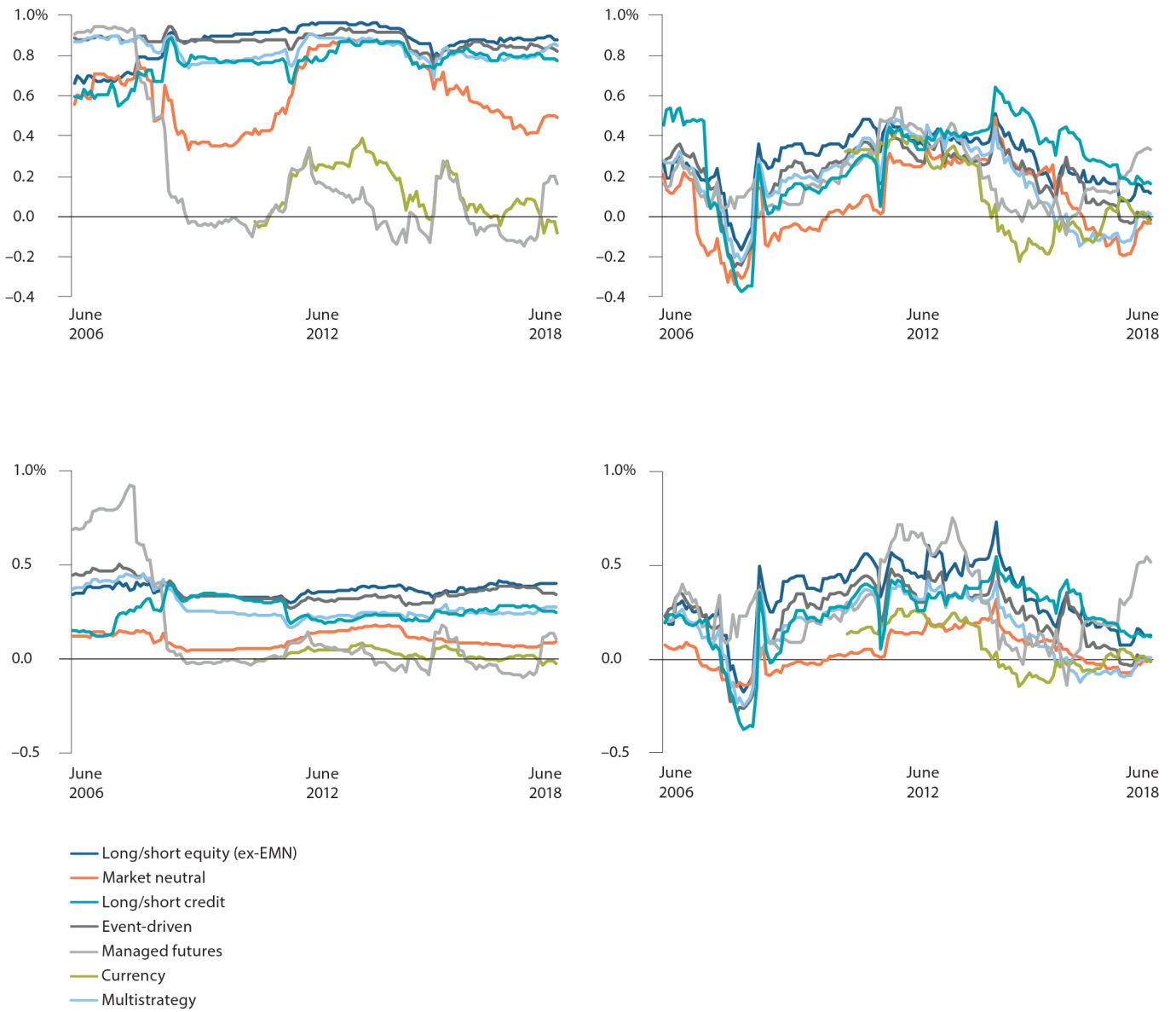


Exhibit 8: Key Portfolio Construction Statistics may be Time-Varying

Source: Vanguard calculations; based on HFR

Notes: The exhibit presents statistics for hedge fund categories. We also ran the same analysis for liquid alternatives, which showed similar time-varying trends. Data cover July 2003 through June 2018. Because of data limitations, the time series for the currency category starts January 2008. Correlations and betas are calculated relative to the FTSE Global All Cap Index and the Bloomberg Barclays Global Aggregate Bond Index. Betas are calculated using excess returns over cash.

Blending Alternative Investment Strategies Can Smooth the Ride

For investors interested in an additional layer of diversification, blending these strategies may be prudent. Exhibit 9 shows mixed results for correlations of hedge fund and liquid alternative category excess returns. Some strategies provided more of an intracategory diversification benefit than others during the measurement period.

The global macro category (including managed futures/currency) and the market neutral strategy were the best diversifiers between subcategories based on the average from each sample of managers in each category. The multistrategy category already represents a combination of a few strategy types, but we found some benefit to continuing to diversify it with other strategies. Although we use category averages to generalize below, investors seeking to combine individual hedge funds or liquid alternatives should conduct such an exercise on a fund-by-fund basis to assess how ex-post diversification benefits might inform ex-ante assumptions.

Conclusion

Investors are continuously seeking ways to improve a portfolio's risk–return profile. Our research demonstrates that certain investors who are comfortable with the implications of investing in liquid alternatives and hedge funds should carefully consider them. While categories of hedge funds have outperformed their public counterparts, liquid alternatives are often a viable option for investors who value the greater regulatory protections, ease of access, and lower costs they provide. Although both public and private vehicles can deliver valuable portfolio construction benefits, it is crucial that investors assess funds on a standalone basis, as the benefit from any alternative investment allocation will be dictated by the specific strategy of the manager(s).

A. Liquid alternative categories

	Long/short equity (ex-EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Long/short equity (ex-EMN)							
Market neutral	0.55						
Long/short credit	0.69	0.47					
Event-driven	0.94	0.45	0.68				
Managed futures	–0.08	0.13	–0.14	–0.19			
Currency	0.71	0.52	0.78	0.65	–0.04		
Multistrategy	0.94	0.57	0.75	0.87	0.03	0.74	

Correlation:
- >0.7
- 0.3–<0.7
- <0.3

B. Hedge fund categories

	Long/short equity (ex-EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Long/short equity (ex-EMN)							
Market neutral	0.65						
Long/short credit	0.81	0.51					
Event-driven	0.93	0.62	0.91				
Managed futures	0.02	0.15	–0.16	–0.08			
Currency	0.09	0.13	–0.04	0.05	0.46		
Multistrategy	0.92	0.71	0.82	0.91	0.15	0.16	

Correlation:
- >0.7
- 0.3–<0.7
- <0.3

Exhibit 9: Many Strategies are Imperfectly Correlated, Further Improving Diversification
Source: Vanguard calculations; based on data from Morningstar, Inc., and HFR
Notes: Data cover January 2008 through June 2018. Hedge fund and liquid alternative returns are in excess of cash and net of fees.

Appendix

Appendix A. Data Set and Methodology

Liquid alternatives data: from Morningstar, Inc.

- Individual funds: Global funds were used provided that they report returns in USD (base currency). Funds needed at least 36 months of returns to be included in fund-level performance analysis. All share classes were included.
- Categories: We constructed a return stream representing the equal-weighted average returns of all funds (live and dead) in the category to approximate the HFRI index methodology. Mutual funds, ETFs, and ETNs were included.
  - The "event-driven" category was custom-created using Morningstar data.
  - The "options-based" category was split apart and reallocated to the remaining categories (with many funds moved into the "long/short equity" category).
  - The "bear markets," "volatility," and "trading" categories were excluded from our mapping framework.

Hedge fund data: from Hedge Fund Research (HFR).

- Individual funds: Global funds' onshore and offshore vehicles reporting in USD were used. Funds needed at least 36 months of returns to be included in fund-level performance analysis.
- Categories: We selected HFRI indexes, which are widely used for gauging hedge fund performance. HFRI monthly indexes are designed to reflect industry performance by constructing equally weighted composites of funds. To be considered for inclusion, all funds had to report performance monthly, net of all fees, and in USD. Constituent funds had to have either at least $50 million in assets under management or a track record greater than 12 months.
  - The HFRI Currency Index began reporting in 2008, so a shorter time series was used for the currency category.
  - Our "long/short equity ex-market neutral" category was custom-created and is not published by HFR. Because Morningstar separately classifies market neutral strategies, we analyzed the category separately. Market neutral strategies may behave significantly differently from other long/short equity strategies that are more directional in nature.
  - We used funds of funds for our multistrategy hedge fund category, as they typically represent a blend of managers pursuing diverse objectives across headline categories (comparable to the structure of liquid alternative multistrategy funds). The "other strategies" multistrategy funds in Figure 2 represent a blend of strategies within one particular headline category and are not as diversified as funds of funds across strategy type.

Time period: Unless otherwise specified, our measurement period covers the 15 years beginning July 1, 2003, and ending June 30, 2018.

Cost assumptions: Unless otherwise specified, liquid alternative and hedge fund returns are net of fees. No cost assumptions are applied to our global equity and fixed income indexes, as these exposures can be obtained at very low cost.

Definitions and descriptive statistics for strategies

Select subcategory definitions
Definitions for certain subcategories are provided that are materially different from the headline category presented in Figure 2. Although there are often differences across hedge fund and liquid alternative implementation, the definitions that follow provide a general snapshot of the strategy for both categories. The definitions were adapted from HFR or Morningstar or both.

Market neutral
These funds seek to reduce systematic risk created by factors such as exposures to sectors, market-cap ranges, investment styles, currencies, and/or countries. They try to achieve this by matching short positions within each area against long positions. These strategies are often managed as beta-neutral, dollar-neutral, or sector-neutral. Funds in this category are distinguished by their typically low beta exposures to market indexes such as the MSCI World Index. In seeking to reduce systematic risk, these funds emphasize issue selection, with profits dependent on their ability to buy and sell securities long/short.

Long/short credit
These funds seek to profit from changes in the credit conditions of individual bond issuers and credit markets segments represented by credit indexes. Typically, portfolios purchase bonds, or sell credit default swaps, expecting to profit from narrowing credit spreads; or the funds sell bonds, or purchase credit default swaps, expecting to profit from the deteriorating credit of the underlying issuer. This category includes funds that use credit derivatives to hedge systematic risk of credit markets to isolate credit selection returns.

The "fixed income: corporate" hedge fund category is mapped to long/short credit. This category includes strategies that employ an investment process designed to isolate attractive opportunities among a variety of fixed income instruments, typically realizing a spread between multiple corporate bonds or between a corporate bond and a risk-free government bond.

Managed futures
These funds primarily trade liquid global futures, options, swaps, and foreign exchange contracts, both listed and over-the-counter. A majority of these funds use trend-following, price-momentum strategies. Other strategies in this category are systematic mean-reversion, discretionary global macro strategies, commodity index tracking, and other futures strategies. Often, much of a fund's exposure is invested through derivative securities. These funds obtain exposure primarily through derivatives; the holdings are largely cash instruments.

The "systematic diversified" hedge fund category is mapped to managed futures. Systematic diversified strategies have investment processes typically as functions of mathematical, algorithmic, and technical models, with individuals having little or no influence over the portfolio positioning. The category includes strategies that use an investment process designed to identify opportunities in markets exhibiting trending or momentum characteristics across individual instruments or asset classes.

Currency
Currency portfolios invest in multiple currencies by using short-term money market instruments; derivative instruments, including and not limited to forward currency contracts, index swaps, and options; and cash deposits. Funds include systematic and discretionary strategies.

	Long/ short equity (ex-EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy	FTSE Global All Cap Index	Bloomberg Barclays Global Aggregated Bond Index
Annualized return	4.11%	1.42%	3.08%	2.92%	2.81%	1.55%	3.05%	9.15%	3.68
Standard Deviation	7.16%	2.27%	3.12%	5.56%	10.06%	3.67%	5.09%	14.95%	5.64%
Sharpe ratio	0.41	0.11	0.61	0.32	0.16	0.10	0.37	0.53	0.44
Skew	-1.08	0.26	-0.22	-1.45	0.32	-0.09	-1.20	-0.92	-0.09
Excess kurtosis	0.37	-0.69	1.30	2.61	-2.15	-1.26	1.39	0.49	-2.12
Equity correlation	0.97	0.41	0.60	0.91	0.07	0.68	0.90		
Equity Beta	0.47	0.06	0.12	0.34	0.05	0.17	0.31		
Fixed income correlation	0.30	0.39	0.70	0.29	0.13	0.69	0.36		
Fixed income beta	0.38	0.16	0.39	0.29	0.22	0.44	0.32		
Average fund data (years)	3.64	3.94	4.17	4.45	3.74	4.59	4.42		
Total number of funds	1,793	490	612	226	518	324	2,049		

Exhibit A.1: Select Subcategory Statistics / Liquid Alternatives (Equal-Weighted category averages)
Source: Vanguard calculations, based on data from Morningstar, Inc., and HFR

	Long/ short equity (ex-EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy	FTSE Global All Cap Index	Bloomberg Barclays Global Aggregated Bond Index
Annualized return	5.37%	2.96%	5.38%	6.56%	5.09%	1.12%	3.45%	9.15%	3.68%
Standard Deviation	6.10%	2.55%	5.50%	5.95%	7.80%	3.08%	4.91%	14.95%	5.64%
Sharpe ratio	0.69	0.70	0.77	0.91	0.50	0.25	0.46	0.53	0.44
Skew	-1.01	-1.41	-2.36	-1.27	0.17	0.00	-1.45	-0.92	-0.09
Excess kurtosis	0.05	1.00	10.94	1.10	-2.89	-3.12	1.48	0.49	-2.12
Equity correlation	0.87	0.56	0.76	0.87	0.16	0.03	0.80		
Equity Beta	0.35	0.10	0.28	0.34	0.08	0.01	0.26		
Fixed income correlation	0.30	0.07	0.22	0.22	0.23	0.17	0.20		
Fixed income beta	0.32	0.03	0.22	0.23	0.30	0.09	0.17		
Average fund data (years)	8.75	4.45	5.36	6.12	5.62	4.99	6.30		
Total number of funds	1,391	804	472	1,288	1,037	334	3,080		

Exhibit A.2: Select Subcategory Statistics / Hedge Funds (HFRI indexes)
Notes: The exhibit presents statistics for hedge fund categories. We also ran the same analysis for liquid alternatives, which showed similar time-varying trends. Data cover July 2003 through June 2018. Because of data limitations, the time series for the currency category starts January 2008. Correlations and betas are calculated relative to the FTSE Global All Cap Index and the Bloomberg Barclays Global Aggregate Bond Index. Betas are calculated using excess returns over cash.

Appendix B: Regression Analysis

	Long/short equity (ex-EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Alpha (annualized %)	0.80%	1.69%	2.05%	0.60%	3.96%	–0.20%	1.10%
	1.79	3.07	3.10	0.92	1.71	–0.27	2.08
Market beta	0.47	0.07	0.13	0.37	0.02	0.17	0.32
	54.27	6.18	9.85	28.37	0.40	13.21	30.85
Adjusted R^2	94.27%	17.22%	34.93%	81.78%	–0.47%	58.12%	84.16%

■ Statistically significant to 1%
■ Statistically significant to 5%

Exhibit B.a: Full Regression Analysis Output
1-factor (market) Gression of monthly liquid alternative excess returns (July 2003-June 2018)

	Long/short equity (ex-EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Alpha (annualized %)	0.50%	1.24%	0.82%	–0.11%	1.96%	–0.89%	0.09%
	1.13	2.13	1.37	–0.18	0.86	–1.20	0.17
Market beta	0.44	0.06	0.06	0.30	0.29	0.14	0.29
	31.90	3.43	2.93	14.90	4.01	6.42	19.04
SMB beta	0.02	0.05	0.02	0.04	–0.05	0.06	0.09
	0.76	1.45	0.76	1.08	–0.38	1.29	3.33
HML beta	–0.04	0.02	0.06	0.00	0.00	0.04	–0.03
	–1.60	0.65	1.80	–0.02	0.04	1.24	–1.13
MOM beta	0.04	0.04	0.01	–0.02	0.21	–0.01	0.07
	3.08	2.35	0.42	–1.08	3.25	–0.58	5.20
Term beta	–0.02	0.04	0.21	0.10	0.11	0.11	0.08
	–0.99	1.44	7.85	3.39	1.07	3.17	3.68
Investment-grade credit beta	–0.10	0.09	0.07	–0.23	–0.14	–0.01	0.04
	–1.73	1.14	0.88	–2.78	–0.47	–0.16	0.56
High yield beta	0.12	–0.01	0.15	0.24	–0.38	0.06	0.09
	3.88	–0.21	3.53	5.19	–2.30	1.16	2.67
Adjusted R^2	95.03%	19.93%	53.75%	84.89%	16.40%	60.80%	88.36%

■ Statistically significant to 1%
■ Statistically significant to 5%

Exhibit B.b: 7-factor (market+size+value+momentum+term+credit+high yield)
Regressions of Monthly liquid alternative excess returns (July 2003-June 2018)

	Long/short equity (ex–EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Alpha (annualized %)	0.68%	0.57%	0.86%	–0.09%	6.01%	–1.38%	0.85%
	1.14	0.75	1.13	–0.10	2.20	–1.43	1.47
Market beta	0.44	0.07	0.03	0.32	0.19	0.16	0.27
	24.05	3.18	1.27	12.01	2.20	5.58	14.92
SMB beta	0.02	0.03	–0.02	0.06	–0.17	0.07	0.01
	0.50	0.89	–0.60	1.42	–1.22	1.39	0.45
HML beta	–0.02	0.03	0.01	0.04	–0.17	0.04	–0.06
	–0.90	0.75	0.39	1.01	–1.38	1.00	–2.50
MOM beta	0.03	0.01	0.00	–0.01	0.25	–0.02	0.06
	2.38	0.76	–0.06	–0.37	3.80	–0.88	4.14
BAB beta	–0.01	0.08	0.11	–0.06	0.15	0.05	0.08
	–0.68	3.37	4.38	–2.31	1.62	1.53	4.39
QMJ beta	0.00	0.02	–0.10	0.07	–0.31	0.04	–0.13
	0.09	0.33	–2.06	1.32	–1.75	0.60	–3.45
Liquidity beta	0.03	–0.01	–0.03	0.00	–0.03	–0.01	0.03
	2.22	–0.38	–1.70	0.22	–0.61	–0.51	2.68
Bond trend beta	0.00	0.00	0.00	0.01	0.01	–0.01	0.00
	–0.04	0.62	–1.09	1.22	0.67	–1.31	–0.13
Currency trend beta	0.00	0.00	0.01	0.00	0.03	0.00	0.01
	1.06	1.42	2.09	0.90	2.89	0.93	2.55
Commodities trend beta	0.00	0.00	0.00	0.00	0.02	0.00	0.00
	–0.90	0.23	–0.23	–1.30	1.45	–0.46	0.05
Short rates trend beta	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	–0.40	–0.68	0.60	–1.12	1.48	1.88	–1.04
Stock trend beta	0.00	0.00	0.00	0.00	0.03	0.00	0.01
	0.44	–0.47	0.96	–0.35	2.40	0.17	2.90
Term beta	–0.01	0.02	0.20	0.09	0.11	0.12	0.09
	–0.33	0.57	7.11	2.95	1.06	3.00	4.02
Investment–grade credit beta	–0.10	0.05	0.03	–0.19	0.01	–0.03	–0.02
	–1.72	0.70	0.33	–2.19	0.03	–0.36	–0.40
High yield beta	0.12	–0.02	0.16	0.25	–0.22	0.07	0.08
	3.48	–0.48	3.73	5.12	–1.38	1.35	2.39
Adjusted R^2	95.05%	23.48%	59.21%	85.64%	29.95%	61.60%	91.02%

Statistically significant to 1%
Statistically significant to 5%

Exhibit B.c: Custom Model
Regressions of monthly liquid alternative excess returns (July 2003-December 2017)

	Long/short equity (ex–EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Alpha (annualized %)	2.60%	2.44%	3.23%	3.93%	5.06%	2.58%	1.25%
	3.25	4.45	3.34	5.06	2.51	2.60	1.64
Market beta	0.36	0.10	0.29	0.36	0.08	0.00	0.27
	23.09	9.21	15.08	23.43	2.11	–0.04	18.18
Adjusted R^2	74.83%	31.91%	55.83%	75.38%	1.88%	–0.80%	64.79%

Statistically significant to 1%
Statistically significant to 5%

Exhibit B.d: 1-factor (Market)
Regressions of monthly hedge fund excess returns (July 2003-June2018)

	Long/short equity (ex–EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Alpha (annualized %)	2.49%	2.52%	2.69%	3.73%	2.25%	2.13%	0.85%
	3.38	5.21	3.87	5.81	1.16	2.02	1.35
Market beta	0.31	0.10	0.03	0.24	0.29	0.04	0.22
	13.51	6.92	1.43	11.92	4.69	1.34	11.19
SMB beta	0.20	0.02	0.07	0.22	0.10	0.06	0.16
	4.98	0.80	1.95	6.28	0.93	1.04	4.71
HML beta	–0.11	0.01	0.04	0.06	–0.03	–0.05	–0.08
	–2.82	0.47	1.03	1.98	–0.29	–1.07	–2.45
MOM beta	0.05	0.09	0.04	0.06	0.21	0.00	0.11
	2.63	6.70	2.17	3.43	3.78	–0.06	6.38
Term beta	–0.06	–0.08	0.07	–0.06	0.22	0.06	–0.04
	–1.76	–3.56	2.25	–2.03	2.54	1.34	–1.47
Investment-grade credit beta	0.16	0.32	0.38	0.24	–0.15	0.06	0.35
	1.71	5.05	4.19	2.92	–0.58	0.49	4.26
High yield beta	0.06	–0.12	0.40	0.14	–0.23	–0.10	0.01
	1.11	–3.39	7.92	2.95	–1.61	–1.36	0.13
Adjusted R^2	81.71%	54.51%	80.46%	85.53%	20.87%	1.24%	79.14%

Statistically significant to 1%
Statistically significant to 5%

Exhibit B.e: 7-factor (market+size+value+momentum+term+credit+high yield)
Regressions of monthly hedge fund excess returns (July 2003-June 2018)

	Long/short equity (ex–EMN)	Market neutral	Long/short credit	Event-driven	Managed futures	Currency	Multistrategy
Alpha (annualized %)	2.34%	2.70%	2.48%	4.42%	5.52%	2.17%	1.83%
	2.63	4.47	2.98	5.75	2.46	1.69	2.54
Market beta	0.30	0.09	0.00	0.19	0.23	0.05	0.17
	11.02	4.74	0.13	7.89	3.26	1.32	7.63
SMB beta	0.14	–0.02	–0.03	0.10	0.05	0.06	0.04
	3.22	–0.72	–0.67	2.66	0.43	0.89	1.07
HML beta	–0.09	0.01	0.02	0.04	–0.15	–0.08	–0.12
	–2.25	0.38	0.45	1.06	–1.49	–1.37	–3.81
MOM beta	0.02	0.08	0.01	0.05	0.24	0.01	0.09
	0.72	5.52	0.50	2.73	4.41	0.40	5.21
BAB beta	0.08	0.04	0.15	0.10	0.04	0.06	0.12
	2.66	2.08	5.61	4.02	0.51	1.22	5.24
QMJ beta	–0.08	–0.05	–0.16	–0.20	–0.13	0.00	–0.20
	–1.44	–1.33	–2.90	–3.98	–0.90	–0.04	–4.37
Liquidity beta	0.10	0.02	0.01	0.03	–0.01	–0.04	0.03
	5.37	1.59	0.62	1.64	–0.21	–1.25	2.20
Bond trend beta	–0.01	0.00	0.00	0.00	0.01	–0.01	0.00
	–1.38	–1.00	–0.22	–1.11	0.73	–1.23	–0.04
Currency trend beta	0.00	0.00	0.00	0.00	0.03	0.02	0.00
	0.79	0.71	–0.98	1.56	3.19	3.55	1.66
Commodities trend beta	0.00	–0.01	0.00	–0.01	0.03	0.00	0.00
	–0.94	–2.95	–1.27	–2.16	3.18	–0.74	–0.20
Short rates trend beta	0.00	0.00	0.00	0.00	0.00	0.01	–0.01
	0.25	–2.17	–2.31	–2.35	0.67	1.20	–3.51
Stock trend beta	0.01	0.00	0.00	0.01	0.03	0.01	0.01
	1.96	1.62	0.26	1.65	2.69	0.93	2.63
Term beta	0.00	–0.08	0.05	–0.06	0.24	0.08	–0.05
	–0.06	–3.47	1.57	–2.02	2.82	1.44	–1.74
Investment–grade credit beta	0.06	0.25	0.23	0.13	0.02	0.07	0.23
	0.66	4.05	2.67	1.67	0.11	0.54	3.06
High yield beta	0.01	–0.13	0.34	0.11	–0.06	–0.03	–0.02
	0.23	–3.78	7.02	2.44	–0.48	–0.38	–0.47
Adjusted R^2	85.00%	59.49%	84.52%	88.56%	38.21%	11.98%	84.74%

Statistically significant to 1%
Statistically significant to 5%

Exhibit B.f: Custom model
Regressions of monthly hedge fund excess returns (July 2003 - December 2017)

Definitions and Sources for Regression Analysis

Fama-French-Carhart

1. Market-Rf (market): The return on a region's value-weight market portfolio minus the 1-month U.S. Treasury bill rate.
2. SMB (size): The equal-weight average of the returns on the three small stock portfolios for a region minus the average of the returns on the three big stock portfolios.
3. HML (value): The equal-weight average of the returns for the two high (B/M) portfolios for a region minus the average of the returns for the two low B/M portfolios.
4. MOM (momentum): The equal-weight average of the returns for the two winner portfolios for a region minus the average of the returns for the two loser portfolios.

Data and additional detail for the above can be found

at mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

AQR Capital Management

5. BAB (low volatility): Securities in a country are ranked in ascending order based on their estimated beta, and the ranked securities are assigned to one of two portfolios: low beta and high beta. The BAB factor is a self-financing zero beta portfolio consisting of the long low-beta and short high-beta portfolios.
6. QMJ (quality): Securities are assigned a quality score that is the average of profitability, growth, safety, and payout. The QMJ factor is the average return on two high-quality portfolios (sorted by size) minus the average return on two low-quality portfolios.

Data and additional detail for the above can be found at www.aqr.com/Insights/Datasets

Pastor-Stambaugh

7. LIQ (liquidity): The traded factor is the value-weighted return on the "10-1" portfolio from a sort on historical liquidity betas. The "10-1" spread goes long decile 10 (stocks with high-liquidity betas) and short decile 1 (stocks with low-liquidity betas).

Data and additional detail for the above can be found at faculty.chicagobooth.edu/lubos.pastor/research/.

Fung-Hsieh

8. Bond straddle (bond trend): The return on a portfolio of lookback straddles on bond futures.
9. Currency straddle (currency trend): The return on a portfolio of lookback straddles on currency futures.
10. Commodities straddle (commodities trend): The return on a portfolio of lookback straddles on commodities futures.
11. STIR straddle (short rates trend): The return on a portfolio of lookback straddles on short-term interest
12. Stock straddle (stock trend): The return on a portfolio of lookback straddles on stock futures.

- Fung and Hsieh (2001) identified that trend-following strategies can be modeled as portfolios of lookback straddles.
- A lookback straddle consists of a pair of lookback call and put options. A lookback option is a call/put option giving the holder the retroactive right to buy/sell the underlying asset at its minimum/maximum during the lookback period.
- Similar to option buyers, trend-following strategies make money when markets are volatile.

Data and additional detail for the above can be found at faculty.fuqua.duke.edu/~dah7/HFData.htm.

Global active bond fund returns: A factor decomposition

13. Term: The Bloomberg Barclays Global Government Bond Index 10+ year total return (base currency-hedged) minus the 1-month Treasury bill total return. .
14. Investment-grade credit: The Bloomberg Barclays Global Aggregate Float Adjusted Index (base currency-hedged) corporate credit excess return. The corporate credit excess return is the corporate credit total return minus the duration-neutral Treasury total return.
15. High yield: The Bloomberg Barclays Global High Yield Bond Index (base currency-hedged) total return minus the Bloomberg Barclays Global Aggregate Bond Index (base currency-hedged) total return.

Endnotes

1. See Davis et al. (2018) for Vanguard's capital markets outlook.
2. Throughout this paper, we refer to the combined group of hedge funds and liquid alternatives as "alternative investment strategies."
3. The use of derivatives by '40 Act funds has been regulated under Section 18 of the act and through a series of no-action letters from the U.S. Securities and Exchange Commission. See Miller (2018) for more information. Hedge funds generally maintain similar margining requirements as with short-selling.
4. Various classification frameworks exist for alternative investment strategies in practitioner literature. For example, see Goldman Sachs Asset Management (2019). Academic literature often relies on classification structures provided by data sources such as Hedge Fund Research (HFR) or Credit Suisse/Tremont.

5. A large number of broadly accessible, commingled products does not currently exist. Replication products are a common way to gain access. For example, HFR Asset Management will build separate accounts to seek to track HFRX indexes (daily hedge fund index return streams). HFRX indexes follow a different construction methodology from HFRI indexes. Other replication products use regression analysis to estimate exposures to investable factors that have a high degree of correlation to categories of hedge fund strategies through indexes that publish category returns. These products then invest in these specific assets. See Kazemi, Black, and Chambers (2016) for more detail. Investors should be mindful that replication products may produce high tracking error and underperformance relative to the underlying index.

6. From a practitioner's perspective, building a diversified allocation of hedge funds outside of investing through a fund of funds or a replication product requires substantial portfolio assets, as fund investment minimums are often high (see Figure 1). In turn, for those planning to invest in one hedge fund or a small number of hedge funds, using individual fund characteristics may be a more representative starting point for assessing an allocation.

7. See Wallick et al. (2015) for more detail. The bottom-up portfolio construction process begins with manager selection.

8. See Fung and Hsieh (2004) for an additional perspective on hedge fund benchmarking. See Hughen and Eckrich (2015) for more detail on the challenges of liquid alternative benchmarking.

9. Biases and limitations with hedge fund data sets have been documented extensively in academic literature, often cited as influencing reported returns upward. The more common biases include selection bias, survivorship bias, and backfill bias. Other notable data limitations include relatively short data history and a lack of transparency into fund holdings. See Asness, Krail, and Liew (2001), Fung and Hsieh (2004), and Ennis and Sebastian (2003) for more discussion.

10. Returns are in excess of the 1-month U.S. Treasury bill rate. Hedge fund returns are reported to HFR net of all fees. We gross up returns using a similar methodology as in Bhardwaj (2010).

11. As discussed earlier, many hedge funds hold illiquid securities that are difficult to price continuously. Stale pricing for these securities (due to either illiquidity or managed pricing) can reduce estimates of volatility and correlation with traditional assets. In the presence of stale or managed prices, and outside of using longer-horizon returns, equity betas may be biased downward. Using lagged market returns to estimate beta captures the magnitude and statistical significance of this effect, providing a more accurate beta estimate. For example, Asness, Krail, and Liew (2001) find notable increases in (summed) equity betas when using lagged equity returns relative to the simple market model.

12. Although we have reliable net returns for our hedge fund and liquid alternatives data, we lack a reliable, systematic way to apply cost assumptions to our righthand-side variables required for a net-of-cost specification. Theoretically, analyzing net alphas rather than gross alphas would be a more practical way to assess the value-add that managers deliver to investors after fees are accounted for. Academic work provides some implementation cost assumptions we could have used as a starting point for a few of our risk factors, but we determined that this would introduce more noise into our alphas, and we opted to leave our excess returns and risk factors gross of cost to obtain a purer snapshot of performance.

13. See Hasanhodzic and Lo (2007) and Simonian and Wu (2019) for more detailed discussions of hedge fund replication.

14. See Agarwal, Boyson, and Naik (2009) and Hartley (2019).

15. Our linear regression models did not show great explanatory power for global macro substrategies (managed futures and currency). Nonlinear relationships may be present, or these categories may be difficult to explain with systematic risk factor exposures. Other regression model specifications might improve results, though this analysis is b beyond the scope of our paper.

16. Institutional investors, for example, have many of these portfolio construction preferences and constraints documented in an investment policy statement.

17. Setting return, volatility, and correlation expectations is critical for the use of any strategy—regardless of investment objective—in a forward-looking portfolio construction exercise.

18. Some strategies may produce return distributions that are highly nonnormal (that is, with large negative skew and/or high excess kurtosis). In turn, other metrics that focus on downside volatility, such as the Sortino ratio, may be prudent to evaluate. See Philips (2006) for more discussion.

19. When we relaxed our 15-year data requirement to include funds with at least ten years of data history and reran the analysis in Exhibit 7, a larger percentage of efficient frontiers populated the area below the base-case scenario, particularly for liquid alternatives. Nonetheless, this is a reasonable way to highlight the variability in the portfolio construction process when examining individual managers.

20. More specifically, because we find that hedge funds outperform their liquid alternative peers on average, such analysis can lead investors to prefer a private vehicle over a public option based on inappropriate analysis.

21. Although this analysis essentially focuses on risk-return benefits as we use mean-variance optimization to assess how multistrategy funds improve an efficient frontier, this general conclusion holds true for various investment objectives that investors may target.

22. In a historical context, the optimization funding source will also be time-period-specific, as the risk-adjusted return profile and correlations of various asset/sub-asset classes change through time.

23. Correlation captures the directional co-movement of the strategy and global equity-fixed income, while beta captures the magnitude of that co-movement.

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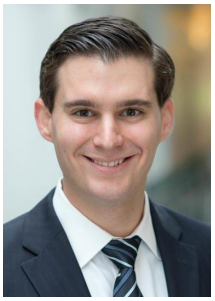
Chris Tidmore, CFA, CPA, is a senior investment strategist in Vanguard Investment Strategy Group, where he leads the team that conducts research and provides thought leadership on issues related to active management. Before joining Vanguard, Chris managed an event-driven hedge fund, worked as an arbitrage trader and portfolio manager for a large family office, an options trader on the American Stock Exchange and was employed as an auditor and consultant.

Chris has developed and taught on a variety of financial and accounting topics, earned a B.S. in accounting at the University of Delaware and a past president of the CFA Society of Philadelphia.



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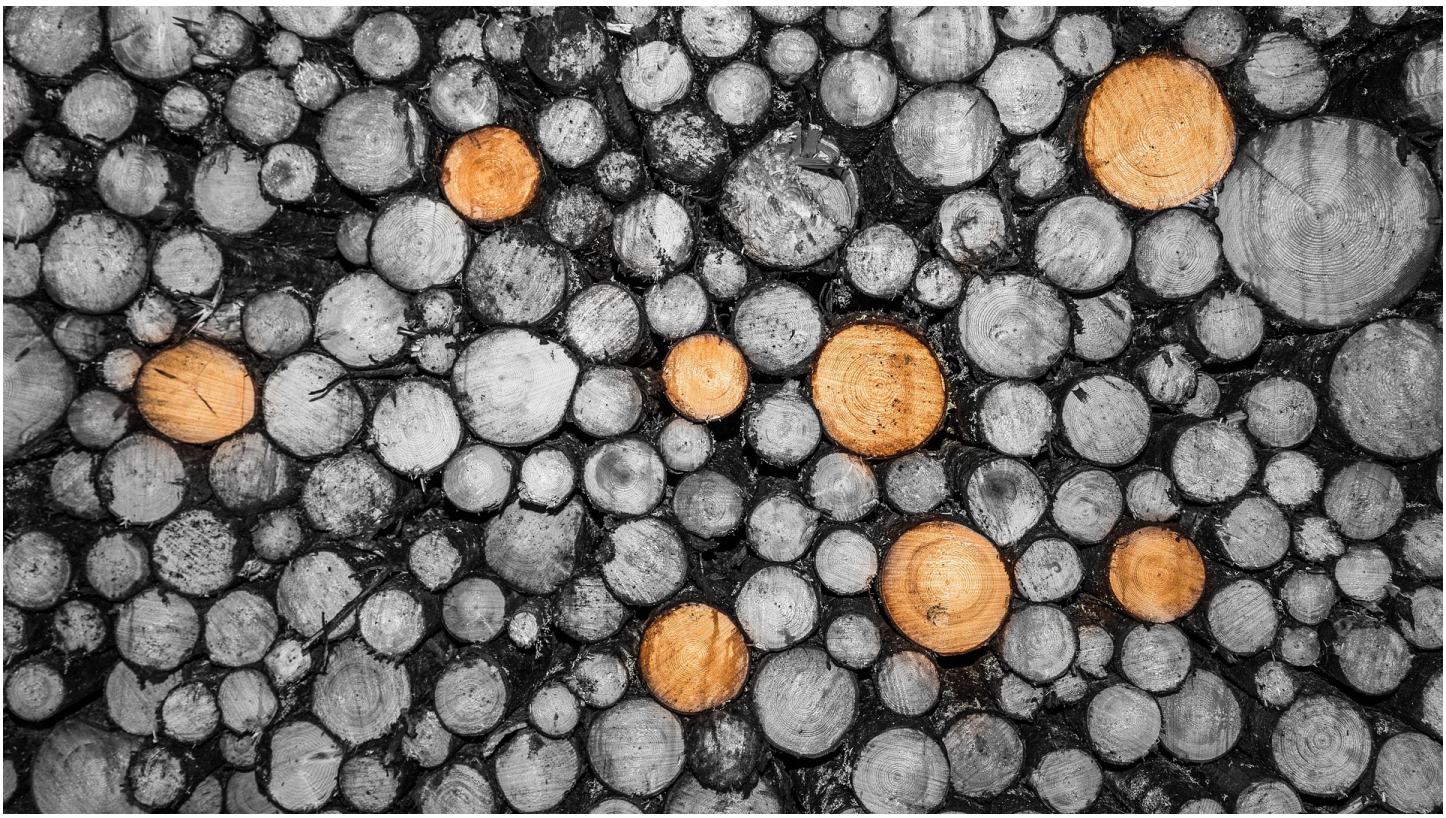
At the time of publication Daniel Berkowitz was an investment analyst in Vanguard Investment Strategy Group. He covered a wide range of investment topics, with a specific focus on the use of active management in portfolio construction, including active/passive combinations, alternative investments, and factor-based investing.

Mr. Berkowitz joined Vanguard in 2014 through the Vanguard M.B.A. Development Program, rotating through Vanguard International, Institutional Advisory Services, and Investment Strategy Group. He officially joined the Investment Strategy Group in 2015.

Mr. Berkowitz earned both a B.S. and M.B.A. from Cornell University. He also is a CFA® charterholder and member of the CFA Society of Philadelphia.



Transforming the Forestry Asset Class

David Brand
New Forests

New Forests' CEO David Brand remarks on the history of the forestry asset class and major forces that will underpin a successful forestry investment strategy. He outlines five major trends facing the forestry sector that will transform the asset class into a kind of natural infrastructure that can provide both renewable materials and ecosystem services.

Imagine an asset class that has low correlation with other major asset classes, positive correlation with inflation, and generally good returns relative to risk and volatility. Imagine that the underlying assets are perpetual in nature, with continuing cash yield once properly managed. What if I suggested that same asset class can provide an important contribution to addressing global challenges like climate change, biodiversity conservation, ensuring fresh water supply, and rural economic development? It might sound too good to be true, but that asset class is forestry.

Forests cover 31% of the world's land surface, about 4 billion hectares. Most of the world's forest, is remote, extensive government-controlled lands, and is not considered "investible" under current market conditions. Several hundred million hectares more have extensive, but active forest management under government control in areas like Canada, the United States, Russia, Southeast Asia, Africa, and Latin America. The remainder is around 100 to 200 million hectares of intensively managed forest, which forms today's "timberland" asset class (Exhibit 1).

Most of these assets are forests managed primarily for wood production, often as timber plantations. If you look around the world at where these forests are located, there are about 30-40 million hectares in the United States, mostly in the US South and Pacific Northwest; 7-8 million hectares in Brazil, and another 3-4 million hectares in Uruguay, Argentina, and Chile; about

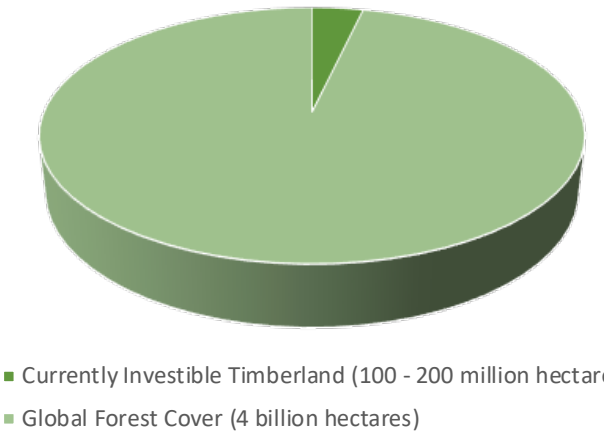


Exhibit 1: Investible Timberland is a Small Proportion of the World's Forest Cover

4 million hectares in Australia and New Zealand (included in Oceania as a region); 3 or 4 million hectares in Southeast Asia; 2 million hectares in Africa; and 4 or 5 million hectares in Europe. There are also intensively managed natural or semi-natural forests that could be considered part of the forestry investment universe both on privately owned land and government leases. This would include parts of Scandinavia, Canada, Southeast Asia, and Africa, for example.

When you look at the total value of this "investible universe" of timberland, it is relatively small as a pool of assets, probably in the order of USD 200-400 billion depending on how you define "investible." Exhibit 2 provides an estimate of the current investible universe, considering what is already investor-owned and what assets might be made available to investors in the near term. Of the total investible universe, around USD 100 billion is already owned by timber REITS and institutional investors, whether via investment managers or directly.

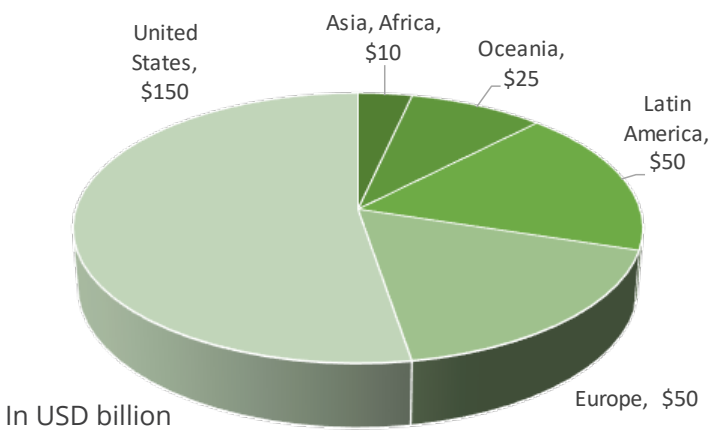


Exhibit 2: Distribution of the World's Investible Timberland

The forestry asset class began in the United States. Owing to GAAP accounting rules and the tax-free status of pension funds, it became clear that having forestry assets owned by the forest industry was inefficient, and a steady process emerged from the mid-1990s until about 2008 with the US forest industry selling billions of dollars of forestry assets to institutional investors. As a track record emerged of the investment performance of these assets, a consensus arose that this was a financially interesting asset class, and investor demand increased. As the asset class grew, discount rates declined as demand outstripped supply and investors determined that rising liquidity and predictability of returns reduced the risk premium needed. For example, basic timberland discount rates for US Southern pine plantations dropped from about 800 bp over the risk-free rate in 2000 to about 500 bp over the risk-free rate by 2007.

Alongside this was the early stages of an internationalization of the asset class. Initial institutional forestry investments in Latin America, New Zealand, and Australia began in the 1990s. Over the past 15 years, this has accelerated—in Australia and New Zealand more than half the forestry plantation estates are now in institutional ownership and that trend is still evolving. Latin America has been somewhat more challenging for international investors to navigate for various reasons, including restrictions on foreign landholding in some countries, competition from local firms often backed by government loans, bureaucratic regulations, and volatile currencies. Other emerging markets like Asia or Africa have attracted some investor interest, but for many investors the risks associated with emerging markets have run counter to the desire for forestry assets with low volatility and stable, predictable returns.

As noted above, there is around USD 100 billion of institutional and REIT-owned forestry assets today, of which approximately 70% is in the United States, 20% is in Australia and New Zealand, and 10% is in the rest of the world. Putting aside the REITs, about 60% of institutional investment is via funds, and more than half of the capital is from public pension funds.

The large-scale rationalization of first the US and then the Australia-New Zealand forestry sectors has largely run its course and asset turn-over is slowing. The wave of capital seeking real assets over the past 20 years has meant that forestry has been a sellers' market, much like core real estate and infrastructure. Some investors are becoming frustrated and saying that the forestry asset class is overbought.

All this brings us to the central question for investment strategy: where to from here?

I see a set of five big trends that are transforming the nature of forestry markets, forest production, and even the fundamental purpose of the forestry asset class and believe that these are the road map for investors today (Exhibit 3).

Exhibit 3: The Five Big Trends Transforming the Forestry Sector

The Rise of Asian Demand

The first trend is the rise of demand for all types of wood fibre, timber, and biomass in Asia, principally China. If we go back 20-25 years, there were three big forestry markets—the United States, which was serviced by US and Canadian forestry production; Europe, which was largely serviced by timber from Scandinavia and central Europe, supplemented by hardwood from Africa; and Japan, which was largely serviced by softwood from North America and hardwood from Southeast Asia. China was a small market, with almost enough wood supply domestically to meet its own needs and even exporting some raw materials like woodchips.

That began to change in the 2000s, and today China is the largest importer of wood in the world. That includes round logs, woodchips, lumber, and pulp. In some ways, the accommodation of China's rising demand was facilitated by the global financial crisis of 2008-2009 where US and European housing collapsed, and suddenly there was substantial excess wood supply that could be diverted to China. Trade has now re-adjusted around China, with Australia and New Zealand set up to export logs and woodchips into coastal China, Russia restructuring to provide lumber exports via Northern China, Vietnam expanding rapidly as a woodchip exporter to China, and excess log and lumber supplies from Western Canada and the US also flowing into the Chinese demand vortex (Exhibit 4).

China's continuing demand increase is now starting to cause supply imbalances. For example, hardwood fibre supply is now unable to meet demand, and relatively significant upward price adjustments have occurred. Softwood log prices used to have an 18 to 24-month cycle and then would drop about 20% to 30% before recovering. There has been no down cycle now for more than three years, and buyers are clamouring for more supply. In early 2018 it appeared that exports from the US south in containers may have ameliorated the rising softwood log supply shortage, but now rising tariffs are hampering that trade.

The challenge for China is that Australia and New Zealand are at peak supply of softwood logs and hardwood fibre, and future Siberian wood supply remains uncertain despite recent softwood lumber production increases. Southeast Asian natural forests are largely logged out, and while plantation supply from Vietnam has grown rapidly, it is questionable as to how much further that can expand. China will likely need to shift to importing wood pulp from low-cost producers like Brazil, rather than woodchips from Australia, and the country will likely need to import more lumber from all around the world, rather than increasing softwood log imports much further.

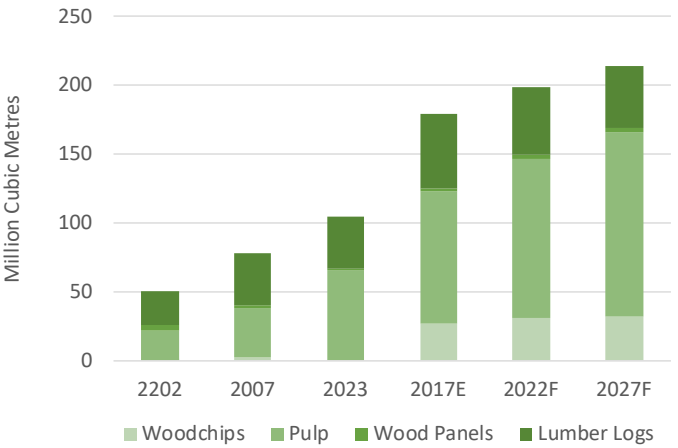


Exhibit 4: China's Rising Import of Wood Products
Source: RISI (2017.) 2017 China Timber Supply Outlook

The Shift to Plantation-based Wood Supply

The second trend is changes in the sources of supply of wood. The forestry sector originally operated using natural forests as a kind of reservoir where market demand and price would create economically viable timber supply in regions with abundant timber resources. Over time, the inevitable process of harvesting the best timber first led to rising operating costs in natural forests and a move to intensify production in the most productive, economically attractive regions. Today about 1.8 billion cubic metres of industrial roundwood are harvested annually around the world, of which about 1 billion are from natural or semi-natural forests, and the remainder are from intensively managed timber plantations.

In general, the old reservoirs of wood are depleting or already depleted. Canada's timber supply has peaked, as has the US since policy changes in the 1990s. The most viable natural timber in Southeast Asia, Africa, and Latin America has been exploited. On the other hand, plantation production has been growing in the southern hemisphere, especially Latin America, Oceania, Southeast Asia, and, to a limited extent, Africa. While there is still substantial timber production in Europe, the establishment of new plantations is limited by access to land.

Plantations in the southern hemisphere, while capital intensive, often grow 10 to 20 times as fast as the production from natural forests. At the extreme in Brazil, eucalyptus plantations can grow at 60 cubic metres of wood fibre per hectare per annum. Plantation production is also steadily rising as better genetics, cultural practices, and control of physical and biological risks improves. These plantations also produce very homogenous log quality and fibre quality, which increases processing efficiency. I expect all incremental wood supply will come from plantations (Exhibit 5).

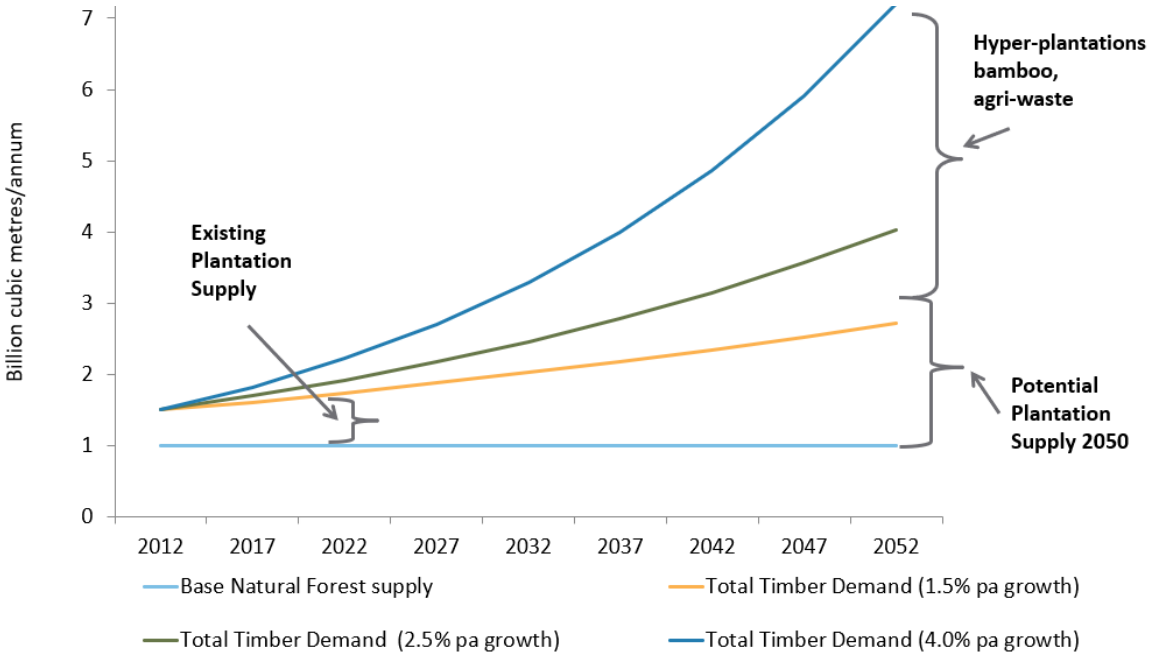


Exhibit 5: Demand and Supply Outlook at Different Demand Growth Rates to 2050
Graphic based on New Forest's estimate and analysis of *Sources: WWF 2013, ""Living Forests Report." FSC 2012 Strategic Review on the Future of Forest Plantations.*

Ultimately, these trends suggest ongoing investment in highly productive timber plantations in the southern hemisphere is needed to supply growing Chinese growing demand.

Changing Timber, Wood Fibre, and Biomass Markets

There is a fundamental shift occurring in the forestry sector itself. When New Forests was founded in 2005, there was no iPhone or iPad, and people read newspapers, mailed bills, read books, etc. Today, while newsprint has declined substantially, and we have probably reached peak printing and writing paper usage worldwide, an array of new markets for wood, wood fibre, and biomass is emerging. Companies like Stora Enso or UPM Kymmene have begun operating bio-refineries and produce bio-plastics and other exciting new materials.

The industry is moving away from the need for large logs and heavy sawn wood to more engineered or refined materials. Again, that leads to potential opportunities for intensively managed forestry plantations that can provide substantial volumes of homogenous materials that can be processed into engineered wood products, forms of wood fibre for everything from packaging to fabrics to diaper fillings; and biomass that can produce energy, fuels, and biochemicals (Exhibit 6). There is a growing need for investors in the forestry feedstock and processing businesses to work together to create efficient, value adding systems to support this bio-economy transition.

Sustainability Performance and Management

The fourth trend relates to the concept of sustainability in the forestry sector. There is a set of forest sustainability performance considerations, such as forest management standards, certification schemes, ESG (enviromental, social, and governance) metrics, and sustainability reporting. However, what is changing is the recognition that sustainability is not a cost, but an opportunity

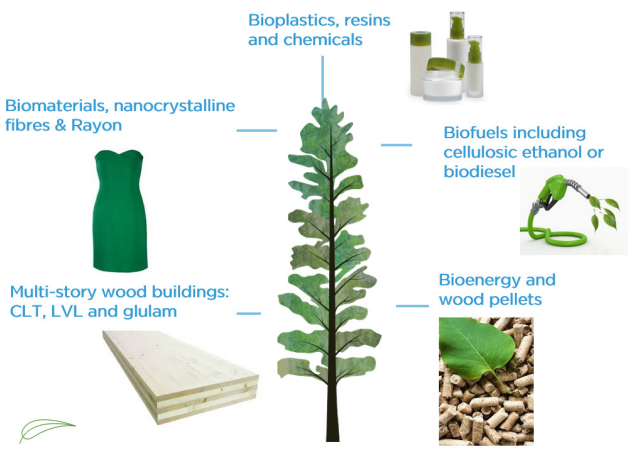


Exhibit 6: The Rising Bio-Economy Includes Growing Demand for Timber and Wood Fibre in a Wide Range of Applications

for forests to be a central part of solutions to major challenges like climate change, biodiversity conservation, freshwater regulation, and community development and land rights. This opportunity requires a transformation from the forestry sector of the past, as well as a new way of thinking about the value of forests.

Forestry was seen in the past as destructive and unsustainable, and forests were often viewed as an impediment to land development for agriculture. Natural forest harvesting often ignored or made modest accommodation to environmental or social values.

The underlying issue was unpriced externalities. Forests contain 1.6 trillion tonnes of carbon dioxide equivalent, which is more than the carbon dioxide in the atmosphere. Forests support about 50% of the diversity of life on earth. Almost all freshwater cycles though forests, and forests regulate water flow and water quality for downstream users. These benefits are called ecosystem services, and they are provided to our human society for free by nature. In an economic context, they are unpriced positive

externalities from maintaining, enhancing, or restoring forests. The problem with free goods is that they are used wastefully or destroyed, often alongside economic activities where the value of a market good or service is more attractive. For this reason, we see deforestation associated with commodities like soy, cattle, and palm oil. This has been a central threat to forests and has led to substantial deforestation driven by agriculture and has made forestry a less commercially valuable land use than market crops.

Fortunately, this trend is changing. Forest conservation, reforestation, and forest plantations are now seen as a central part of action on climate change. The California carbon market, operating since 2012, has shown that forests can be valued for their carbon storage as well as their timber value, and there are also emerging and expanding policies related to using green infrastructure for watershed management as opposed to grey infrastructure based on concrete, pipes and treatment plants. In some ways we are in a race to create price signals for the positive externalities of forests so that they become a kind of natural infrastructure asset class providing both renewable, environmentally sustainable goods and ecosystem services on a perpetual basis.

The Rising Role for Investment

To realize the opportunities inherent in the first four trends, we require the fifth and final trend: the rising role for investment. The global forestry sector needs to be transformed and recapitalized by long-term, patient capital. The old paradigm of a "timberland" asset class is going to be replaced by new investment models that encompass both conservation and production as commercial businesses; embrace community forestry and shared rights to land with community groups or indigenous peoples; may be increasingly focused on emerging markets, rather than the traditional forestry regions of the US and Europe; and may integrate development, philanthropic, and commercial capital together.

That is not just a tinkering with the existing timberland asset class, it is disrupting it and re-inventing it. But what does that do for the portfolio characteristics of forestry investment? First, the underlying nature of forestry assets remains based on biological characteristics that generate the low correlation with other asset classes, and timber value will remain an important part of the return characteristics of the asset class. Second, the low volatility of timber comes from the optionality of trees—they can be grown for capital appreciation or cut for income. In poor market conditions the forest still generates capital appreciation even if there is a decision to reduce harvest rates. Exposure to markets for carbon offsets, watershed conservation, biodiversity conservation, etc. creates even more optionality and ability to optimize returns over decadal periods of time. Lastly, the perpetual nature of the asset class is preserved and even enhanced in such a new structure.

This transformed forestry asset class may also include a changing risk profile. There may be greater exposure to emerging market risks, for example, but when we think about portfolio construction, the bulk of forestry assets for the next 20 or 30 years will remain in developed markets with a geographic shift slowly but steadily over time. In a successful global economy, emerging markets will also steadily decline in risk and improve in their business characteristics. It may even be that new forms of blended finance structures mitigate the emerging market risk and provide investors the capacity to segregate financial and sustainability related outcomes. All this is already emerging.

New Forests and the Evolving Forestry Asset Class

The five trends above describe the economic drivers and rationale that can fuel and sustain the evolution of the forestry asset class. How would this change the investible universe of forestry? What types of forestry and forestry investment would we see? New Forests suggests that by 2050 we could see a trillion-dollar forestry asset class, comprised of forests with combined production and conservation value (Exhibit 7).

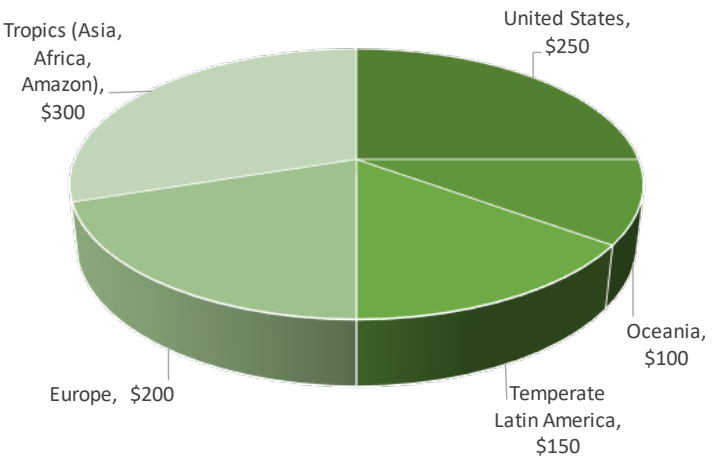


Exhibit 7: What Might the Investible Universe of a New Trillion-Dollar Forestry Asset Class Look Like in 2050? (in Billions USD)

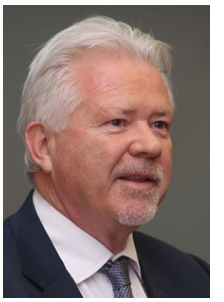
New Forests' business is organized around regional investment programs that start by asking the question of what the market opportunity for sustainable forestry in this region is, and then designing investment strategies to target those opportunities.

- In Australia and New Zealand, a large-scale restructuring of retail forestry investment schemes, government plantations, and corporate plantations is occurring alongside the rising demand from Asia. This presents an opportunity for recapitalization, enhancing core operations and efficiency, and providing reliable supplies of timber and wood fibre to both domestic and Asian markets.
- In Asia, the decline of natural forest timber supply and the need for sustainable timber plantations, especially of high-quality tropical hardwood timbers, presents the opportunity to establish both highly productive and highly valuable timber plantations.
- In the United States, an opportunity to re-segment a mature market, targeting forests with both timber market access and exposure to the increasingly secure California carbon offset market, is creating an opportunity for a differentiated approach to US forestry.

In managing these three distinct investment programs, we have been able to add value by stepping back and thinking about how the forestry sector is changing. For example, our activities have included integrating investment in processing facilities with our forests as well as applying agroforestry and agricultural strategies to optimize land use in an extensive estate. In Asia, we are working across three countries, and integrating community forestry, out-grower schemes, and community benefit sharing into the investments we manage. In the United States we have worked with Native American tribes and tribal corporations to unlock carbon value from well-managed forests. We have also used advanced technologies to develop proprietary approaches that identify forests that offer high climate impact.

These are innovations within an existing asset class but are also reflecting a shift of the asset class to take advantage of new opportunities and market changes. This will continue, and the rate of innovation will increase. As we head towards a world with 10 billion people earning an average of $30,000 per capita, that means one planet with a $300 trillion gross world product. Sustainability will be central to everything, and renewable materials from sustainably managed natural infrastructure will need to become a key asset class.

Author Bio



David Brand, PhD
New Forests

David Brand is the Chair and CEO of New Forests. New Forests, founded in 2005, is a sustainable forestry investment manager offering leading-edge strategies in forestry, land management, and conservation with approximately USD 4 billion in assets under management across the US, Australia, New Zealand, and Southeast Asia. David has over 35 years of experience in timberland investment, forest management, science, and public policy. David is dedicated to innovative, responsible investment strategies in the forest sector that address climate change mitigation, community development, and expanding the use of sustainable renewable materials in society. Previously, David was responsible for investment programs that integrated timber management with emerging environmental market opportunities at Hancock Natural Resources Group (HNRG). Prior to joining HNRG, David was the Executive General Manager of State Forests of NSW where he led pioneering transactions in the commercial development of environmental markets. From 1985-1995 David worked with the Canadian Forest Service as a scientist, director of scientific programs, and ultimately as national Director-General of Science and Sustainable Development. He serves on the Board of Directors of the Washington, DC-based non-governmental organization Forest Trends and on the Board of Trustees of Bangkok-based Intergovernmental Organisation, The Centre for People and Forests. David has a PhD from the University of British Columbia and a Bachelor of Science in Forestry from the University of Toronto in Canada.

What is Happening to the U.S. Shale Production?

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Please note that the views and commentary expressed in this article were made in Q3 2019

What's happening to US shale production? After growing by a torrid 145,000 b/d per month in 2018, shale production growth has ground to a screeching halt. Since December, shale oil production has grown by only 50,000 b/d per month–a collapse of almost 65% versus 2018's phenomenal rates. Despite this slowdown, most energy analysts are still hoping for strong shale production growth both this year and next. For example, Rystad Energy, the Norwegian-based energy consulting firm, still believes total US liquids production will surge by another 1.8 mm b/d in 2020. However, our research suggests these optimistic projections will be difficult if not impossible to achieve.

In past letters, we defined what we believe are the factors that drove improved shale productivity growth over the last five years, and we explained why robust US shale oil production growth of the past decade was rapidly nearing an inflection point. Conventional wisdom held that productivity gains were the result of operators drilling and completing larger and better wells (longer laterals, larger proppant loadings, and greater fluid volumes). However, our research pointed us in an entirely different direction. We believe the surge in drilling productivity over the last five years is largely the result of where operators drilled them. In particular, we believe the improved drilling productivity was the result of a practice known as "high-grading." High-grading is an age-old practice used in both the oil and gas industry as well as the mining industry which simply consists of selecting and drilling your most productive prospects first. Over the last five years, the E&P industry has shifted significantly away from drilling their less productive Tier 2 acreage in favor of drilling their more productive Tier 1 acreage. Since drilling a Tier 1 well is nearly 100% more

productive than a Tier 2 well, the industry has created the illusion of ever-improving productivity growth by narrowing their focus to only their best prospects. If our research is correct, then future increases in shale drilling productivity will be more a function of continued "high-grading" and less a function of ever-changing drilling and completion techniques.

In our last letter, we detailed the proprietary artificial neural network we built to analyze the acreage quality of the US shales. We concluded that both the Eagle Ford and Bakken shales were quickly running out of Tier 1 acreage and that production growth from these plays was set to significantly disappoint in the coming years. We also concluded that while the Permian basin had more remaining Tier 1 inventory than the other two, it would also begin to experience the first signs of exhaustion sooner than most people expected. Now that the US shales have started slowing dramatically, we have turned to our artificial neural network to help shed light on the reasons why.

Our neural network has accomplished two things. First, we were able to pinpoint the factors leading to this year's dramatic slowdown and second, we can see these same factors will only become more severe in the next several years. For the first eight months of 2019 shale production grew by 57,000 b/d per month on average. This represented a slow-down of 60% compared with the eight months ending August 2018, during which production grew by 132,000 b/d per month on average. Remarkably, this slowdown occurred even though the industry completed 10% more wells during the first eight months of 2019 than in the same period last year. In aggregate, production from all new wells actually accelerated between the two periods--from 571,000 b/d per month to 640,000 b/d per month due mainly to the higher number of wells completed. However, drilling productivity, although still growing slightly, has now slowed dramatically. For the eight months ending August 2018, a new well flowed 460 barrels of oil on average during its first full month of production compared with 470 barrels this year—a rise of only 2% and a dramatic slowdown from the 10% drilling productivity growth experienced in the first eight months of 2018 versus the first eight months of 2017.

Also strongly contributing to the slowdown has been the dramatic increase in the underlying base declines. For the eight-month period ending August 2018, production from existing wells declined by 440,000 b/d per month on average. By August 2019, this figure had accelerated to 590,000 b/d per month – an increase of 150,000 b/d. The acceleration in the base decline overwhelmed all other factors and net production growth ground to a halt. Two factors explain the acceleration in base declines: a larger production base and a higher decline rate. Total production increased by 20% between the two periods. Therefore, even with a constant decline rate, the total barrels of depletion would have increased materially. However, base decline rates accelerated from 54% annualized for the eight months ending August 2018 to 58% by August 2019. The reason: new wells have much higher declines than old wells and the surge in new wells drilled and completed in 2018 significantly increased the overall decline rate in the production base.

We also considered another interesting comparative period: the eight months ending July 2017. This period marked the last time average monthly production growth was comparable to today (50 k b/d per month). Remarkably, two years ago the oil industry turned 650 rigs to reach this level of growth whereas 810 rigs are required today. Furthermore, drilling times have collapsed over the last two years resulting in more completions per well operating. In total, we estimate that nearly 60% more wells were completed in the eight months ending August 2019 than in the period ending July 2017. Moreover, today's average well is 11% more productive than in 2017 (for those that are interested, our neural network predicts this modest productivity boost was a function of both improved drilling techniques and high-grading). The combination of 60% more completions and 11% more productive wells doubled new well production from 370,000 b/d per month in 2017 to 640,000 b/d per month today. While the contribution from new wells increased massively over the last two years so did the base declines. In fact, base declines accelerated by nearly 270,000 b/d between the two periods, offsetting the entire increase in new production. In other words, the shale industry now needs 60% more wells, each of which is 11% more productive, to reach the same level of growth as it did two years ago.

Production growth is set to slow even more now that the oil rig count has fallen materially. After peaking at 890 rigs in November 2018, the rig count has fallen 20% to reach 713 rigs at present with the bulk of this decline occurring in the last four months. There tends to be a two-month lag between rig count and first production and so we believe the impact of this dramatic slowdown will be felt as we progress through Q4. In past shale cycles, a slowing rig count has always been offset by an increase in per-well productivity. The reason is simple: rigs drilling the least productive wells are laid down first. During the 2009 slowdown, the major three shale oil basins (Eagle Ford, Bakken and Permian) lost 60% of their rigs. However, per-well productivity increased by 75% on average. Production from new wells drilled thereby decreased by only 33%--far less than the decline of the rig count itself. In 2013, the three basins lost ~15% of their rigs but drilling productivity increased by 60% allowing production from new wells to actually accelerate by 35% despite a falling rig count. In 2016, the three basins lost 80% of their rigs while productivity increased nearly 200% resulting in production from new wells to slow by half despite losing 80% of all rigs.

Our models tell us something very different is happening this time. While this year's rig slowdown is comparable with the 2013 experience (both 15%), the increase in per-well productivity has been much more muted. Per-well productivity increased by 60% in 2013 while our models suggest the improvement so far this year has been less than 15%. The sample size is fairly small, and the data is preliminary and subject to revision, however we now believe the high-grading effect may be responsible. In 2013, 45% of the wells drilled in the three major shale basins were Tier 1. As operators dropped rigs, they were able to select and drop their worst locations and high-grade their inventory, increasing their per-well productivity in the process. By 2018, operators had high-graded to the point where nearly 70% of all wells were Tier 1. As the rig count comes down this time, our models suggest there will be much less of an opportunity to high-grade compared with 2013. We don't expect the per-well productivity to be able to offset the slowdown, as it did in past cycles.

In our view, the next twelve months will be a critical test of the US oil shales. Our models tell us the remaining inventory of prime Tier 1 drilling locations is much less than widely believed. While many analysts believe the shales are capable of producing a near-limitless volume of crude, we know this is not the case. The shales must now contend with a large base of existing legacy production that relentlessly declines and must be replaced. We have seen how sensitive net shale production growth can be: a slight slowdown in productivity gains combined with a slight uptick in the base decline rate can very quickly take production growth from record rates to near-flat production in a matter of months. None of these pressures show any signs of letting up and now the rig count has started to materially decline. We expect production growth to slow even more from here as a result.

We want to once again emphasize how important the US shales are to global oil balances. We first published exhibit 1 in our Q2 2018 letter. The table in the exhibit clearly shows that conventional non-OPEC oil production outside of the US and Canada has declined by almost 130,000 b/d each year over the past decade. The fact that conventional non-OPEC oil production has rolled over is a huge problem that has received little attention by oil analysts. To put this in perspective, conventional non-OPEC oil production still represents 45% of global oil production and now appears to be in sustained decline. Furthermore, if you include other sources of non-OPEC production, such as Canadian Oil Sands (which is not considered "conventional"), biofuels, refinery gains, and OPEC NGLs (which are not part of the OPEC quota systems), the US shales still represent an enormous 75% of the total non-OPEC liquids growth over the last decade. Now that the Bakken and Eagle Ford are facing exhaustion issues that are readily becoming apparent, nearly all of non-OPEC's production growth will have to come from just one play in West Texas– the Permian. Never before has the global oil industry been so dependent on one field in such a concentrated geographic area for all of its future growth. What happens in the dozen counties that make up the Permian will make or break the global oil market over the next 10 years.

Global oil demand has surged by over 13 mm b/d over the last eight years alone. As a result, even with the surge in US shale oil production OPEC has needed to add nearly 3 mm b/d of new supply to keep the market balanced. With conventional production growth turning negative outside of the US and Canada, it is easy to see how dependent the world has become on the growth of the US shales in general, and the Permian basin in particular. Any faltering in shale production growth should result in a rapid market tightening. In this situation, robust oil demand will need to be rationed by price – a situation not unlike what occurred between 2000 and 2008—a period that eventually saw oil prices exceed $140 per barrel.

	2010	2018	Change
Conventional Oil Production	47.2	45.9	(1.3)
US Oil Shale	0.7	6.5	5.8
US Shale NGL	0.3	2.6	2.3
Canadian Oil Sands	1.5	3.0	1.5
Bio Fuels	1.8	2.6	0.8
Refining Gains	2.1	2.3	0.2
OPEC NGL's	4.4	5.5	1.1
Total Non-OPEC Liquids Production	58.0	68.4	10.4
OPEC Crude Production	29.1	32.2	3.1
Total World Liquids Production	87.1	100.6	13.5
IEA Global Demand Estimates	88.2	99.3	11.1
(+/-) IEA's "Missing Barrels"	(1.0)	1.0	2.0
G&R Demand Estimate	87.2	100.3	13.1

Exhibit 1: Non-OPEC Supply 2010-2018 (Millions of Barrels per Day
Source: IEA, BP, G&R Models.
Notes: Pro-Forma For OPEC Additions Gabon (2016), Equatorial Guinea (2017)

In our last letter, we laid out our projections for shale oil growth for the next several years. We explained how 2019 would likely be the last year the shales grew in excess of 500,000 b/d and that average annual growth over the coming decade would slow 70% from 1 mm b/d in both 2017 and 2018 to 325,000 b/d. We also said that 2019 might actually see fairly robust growth of ~700,000 b/d from January 1 to December 31. In retrospect, we may have been too optimistic. For the first eight months of the year, total shale production grew by only 400,000 b/d and we now expect that January 1 to December 31 growth will likely come in closer to 600,000 b/d or even below. The slowing of shale production growth is occurring as we speak.

In our oil section we will discuss how these dynamics play into the supply and demand balances for the remainder of the year and into 2020. We will also discuss what strategies we are using to take advantage of these developments. The only material source of growth in the non-OPEC world over the past decade is now showing signs of exhaustion and nobody seems to notice. The implications could be tremendous.

Q3 Natural Resource Market Commentary

Worries about a looming global recession and fears that global trade wars will continue to expand produced weakness in almost all commodity markets in Q3. "Risk-on" investments, which included most natural resources, were the poorest performers during the quarter, whereas "risk-off" investment strategies flourished. Demonstrating the extent of investors' fear and their desire to pile into "risk-off" assets, US Treasuries soared in price and yields plummeted. The 30-year US Treasury yield hit an all-time low of 1.97% in August. Also, the dollar amount of sovereign bonds sporting negative yields surged to $17 trillion, up from $10 trillion earlier this year. The US stock market actually rose slightly during the quarter—a little over 1%--but resource related equities were weak. For example, the S&P North American Natural Resource Sector Index (an index heavily weighted to the North American energy sector) fell 7.5%, and the S&P Global Natural Resource Index, which has a much heavier weighting in metals and agriculture, fell 6.7%. The only bright spots in global resource markets occurred in nickel and precious metal prices. Indonesia pushed forward its ban on nickel concentrate exports from 2022 to 2019 which caused nickel prices to surge 35% during the quarter. Nickel is a necessary metal in the production of lithium-ion batteries and Indonesia is trying to force nickel users, primarily China, to build a nickel smelting and processing industry within Indonesia. Precious metal prices were strong during the quarter. Weakening economic activity, combined with two interest rate cuts by the US Federal Reserve, with increasing talk of more interest rate cuts to come, put a firm bid under the precious metal complex.

But by far the most serious event to shake global resource markets in Q3 was the drone attack and partial destruction of the Khurais oil field and the Abquiq processing facilities in Saudi Arabia over the week of September 14. Approximately 5 mm b/d of production and processing capacity was knocked out. Although the news coming from Saudi Aramco indicated that a significant amount of this lost capacity has been brought back on line, our sources tell us that 2 to 3 mm b/d of processing capacity remains off line. Oil prices surged 15% on the Monday following the attack, but since then oil prices had given back all their gains. Even with the September price spike, oil prices for Q3 fell 7%. Oil-related equites were even weaker. E&P stocks, as measured by the XOP ETF, fell almost 18% and oil service stocks, as measured by the OIH ETF, fell over 20%. Since bottoming in Q1 of 2016, oil prices are now up over 120% off their lows. In one of the biggest divergences we have ever seen, oil stocks are now down 10% and oil service stocks are now down over 40% over the same period. As we have repeatedly pointed out, energy-related equities have never been priced cheaper relative to underlying value and we believe that huge profits will be made by investing in the energy stocks today. We know we sound like a broken record on the subject of oil-related investments, but our research continues to point us in a very bullish direction.

As we discussed in the at the beginning, the production slowdown experienced by the US oil shales in the last nine months is the inflection point we have long discussed. Our research tells us that the robust growth exhibited by the shale plays in the US will be near impossible to repeat as we progress into the coming decade. At the same time the shales are slowing, non-OPEC conventional oil production outside of the US has turned negative and our analysis tells us that large disappointments loom in this still critical and underappreciated sector of the oil market. Everyone thought that 2019 would see a year of strong non-OPEC growth outside of the US. For example, the International Energy Agency (IEA) originally estimated that non-OPEC/non-US supply would grow by 600,000 b/d. However, the IEA has severely revised downward these optimistic estimates to only 100,000 b/d and we believe these numbers will be revised negative before 2019 is over. For 2020 the IEA is again projecting strong non-OPEC production outside of the US—up 800,000 b/d. Again, we believe this number is far too optimistic. Please read the oil section of this letter in which we talk about the reasons why the IEA's 2019 projection of for non-OPEC ex the US was far too hopeful, and why their 2020 projection will be far too optimistic as well. Although it has received no attention, global inventories for the first six months of 2019 should have built by over 160 mm b/d according to IEA numbers; however, actual OECD inventory builds, according to the IEA have only built by 60 mm barrels. The 100-mm-barrel discrepancy between the IEA's projected builds versus actually builds represents "missing" barrels—barrels that are supposed to be in inventory according to the IEA figures, but aren't. The IEA has spent most of 2019 revising down its estimates for demand, but the slowdown is not manifesting itself in inventory behavior. For the first six months of 2019, the IEA has reduced its estimates of demand to only 500,000 b/d, but if we are right, and these 600,000 barrels per day (b/d) of "missing barrels" represent demand underestimation, then oil demand is far stronger than generally portrayed. For a further discussion of all the missing barrels please make sure to read the oil section of this letter.

Regarding the bombings in Saudi Aramco and the October 11, 2019 news that an Iranian oil tanker was struck by two missiles in the Red Sea: historically, from 1970 to 2010, most analysts believed some sort of risk premium should be incorporated into oil prices to reflect the inherent instability in the Middle East. The Iran-Iraq war lasted nine years and constantly threatened Gulf oil supply. The Iraq invasion of Kuwait, resulting in the partial destruction of Kuwait's oil fields, completely curtailed Kuwait's oil supply (3% of world supply) for almost six months which took years to recover. Because of Middle East instability, oil prices traded significantly above their theoretical prices, based upon global inventory levels during this period. However, over the last several years, as investor bearishness towards energy has surged and US shale oil production has soared, not only has the Middle East risk premium disappeared, but you can make the case that a "negative" risk premium has crept into the market. This "negative" risk premium refuses to dissipate even after 50% of Saudi Arabia's production was curtailed after the drone attack. Our models show that oil prices should be $10 higher, given today's global inventory levels. Back in 1980, we calculated that the five Gulf state producers (Saudi Arabia, Kuwait, Iraq, Iran, and the UAE) represented 30% of world pumping capability. Today, even after surging production from the US shales, these same Gulf state producers still represent 24% of the world pumping capability. To think that a sustained supply disruption from the Gulf States will not have a significant impact on global oil supply-demand balances goes to show how out-of-whack and bearish investor psychology has become.

The natural gas bear market continues to grind on. Prices continued to drift downward during the first half of the quarter, bottoming at $2.10 in early August—a new low for the year—and then rallying in September. Continued weakness in natural gas continues to revolve around a simple issue---surging supply. For the three-month period ending in July, the Energy Information Agency (EIA) reported that US dry gas supply surged over 9% from the same period a year ago. Continued production growth from the Marcellus shale in Pennsylvania and West Virginia, the Utica shale in Ohio, and continued surging growth of gas production from the Permian basin shales, primarily the Delaware side, were the biggest contributors to a huge gain in supply.

After peaking at almost $14 per thousand cubic feet back in the summer of 2008, natural gas prices have declined by almost 90% and are about to enter the eleventh year of their bear market. As most of you know, we love to get involved in long, drawn-out bear markets. The more bearish investors become, the more we like to roll up our sleeves and do the research to uncover important trends in supply and demand before they become recognized by the general investment public.

As the natural gas bear market dragged on and on, we have made repeated attempts to get bullish on North American natural gas prices. Each time, we quickly realized our mistake and retreated to the sidelines. Extremely strong demand was continually overwhelmed by surging supply. Today, fundamentals in North America natural gas markets look as bleak as they have ever been--the surge in gas supply seems endless. However, our research has picked out a potentially emerging data point that could have hugely bullish implications for North American natural gas markets. By far the biggest contributor to surging gas supply over the last 10 years has been the Marcellus shale. From almost zero production pre-2010, production of gas from the Marcellus shale in Pennsylvania and West Virginia has reached almost 23 bcf/day which today represents almost 25 % of total gas supply. Although investors often believe that production growth from such fields as the Marcellus is endless, this is not the case. Although they receive little attention today, the first two gas fields to be put into production, the Barnett and Fayetteville both rolled over and currently only produce half of their peak reached several years ago. In an interesting similarity, production from each field peaked once half of their ultimately recoverable reserves were depleted. In the case of the Marcellus, we do not have a good idea of what total recoverable gas reserves are, so trying to pick peak production in the field from both a standpoint of amount and time is extremely difficult to do. Over the years, we have made several attempts to estimate what the Marcellus's ultimate recoverable reserves might be, but we haven't been satisfied with our results. Using our self-teaching deep neural network, we have decided to try to again. Our initial findings are extremely important and produce a potentially bullish point. Given surging by-product gas production from the Permian, especially from the Delaware side, we are still neutral on the North American natural gas market. However, our neural network is telling us that we might be much closer to a peak in Marcellus (and Haynesville) gas production than we originally thought. If we are right, then the end stages of the great natural gas bear market might be playing out right in front of us.

Precious metals are one of the few sectors in the global resource markets to exhibit positive returns. Gold prices rose by over 7%, silver prices rose by almost 12%, and platinum and palladium prices rose by 6% and 9%, respectively. Gold- and silver- related equities were also strong. Gold stocks, as measured by the GDX ETF, and silver stocks, as measured by the SIL ETF, both rose by almost 5%. In last quarter's letter, we put forward our belief that the great bull market in precious metals has begun. The first leg of the gold bull market, which started back in 1999 and peaked out in 2012, was dominated by Asian buyers, both Chinese and Indian. We believe this leg of the gold bull market will be dominated by Western investors. As precious metal prices advance, we believe huge levels of speculation will emerge in various precious metal markets. We remain extremely bullish on gold and we continue to recommend investors carry full positions in both physical metals and precious metal-related equities. Rumors continue to circulate about an upcoming significant trade deal between the United States and China. If such a trade deal were to be agreed to, we believe we could see a significant short-term pullback in the gold price. If this happens, we would see the weakness as another great buying opportunity for precious metal investors.

Grain prices had a weak bias during Q3, as Trump continued to escalate his trade war rhetoric. During the quarter, corn and wheat prices both fell approximately 7% and soybeans actually eked out a small gain. Possibly signaling a desire to return to trade talks, the Chinese purchased 600,000 tonnes of soybeans in September, their largest purchase in over a year. Continuing a trend that started this spring, North American agricultural markets continue to be buffeted by extreme weather. This spring's record flooding in the Midwest, combined with an early onslaught of winter in the upper Midwest at the beginning of October, demonstrate how precarious global weather conditions have become over the last nine months. We have extensively discussed our belief that we are now entering a cooling period in global weather--a condition that will produce more unfavorable global growing conditions as we progress into the coming decade. Global temperatures have steadily risen over the last 70 years and consensus opinion believes this global warming will be massively disruptive to agriculture. We believe just the opposite. The warming trend experienced over the last 70 years has produced long stretches of incredibly good growing conditions for crops. For example, over the last 15 years, except for the North American drought year in 2012, most grain-growing basins have experienced an unprecedented stretch of excellent global conditions. Thus, global grain supplies have swelled even in the face of extremely strong global grain demand.

We believe we are entering into an extended period of global cooling, brought about by a long period of declining sunspot activity. (Please see our 1st quarter 2019 letter where we discuss at length this very controversial subject.) If we are correct, the world will experience an ever-increasing number of disruptive weather events that will negatively impact crops and their growing cycles. Although it's impossible to make a causal link, we are intrigued by the two very disruptive (and record-breaking) weather events that occurred this spring and in early October. In previous letters, we discussed how warmer weather had significantly boosted crop yields by extending the Northern Hemisphere's growing season: late spring and early fall frosts occurred with decreasing

regularity. If we are right in our cooling trend thesis, we should see more disruptive weather events occur, especially during both spring and fall periods. The record-breaking rains experienced this spring and the near record-breaking blizzard of October 10th —a coincidence? We don't know, but we will continue to monitor global weather conditions closely.

We believe the weather disruptions experienced in 2019 have a high probability of being repeated in some form as we progress into the 2020 planting season. We believe we have entered into the first stages of a huge global agricultural boom and we recommend significant exposure to agriculture-related investments.

Uranium markets were quiet again in Q3. Spot prices increased by $1 over the last three months while contract prices were flat. Uranium-related equities fared worse with the majors down 9% on average during the quarter. In our last letter, we explained how the pending Section 232 ruling had resulted in fuel buyers waiting on the sidelines before renegotiating their expiring long-term contracts. As a reminder, the proposed ruling would have mandated a quota for domestic uranium far in excess of current US production. The administration struck down this proposal in July, but uranium buyers have been slow to reenter the market. We expect this will change in Q4 and could result in a uranium rally similar to what occurred in 2018.

While the market was largely quiet during the quarter, there were several bullish developments that went largely unreported. First, Kazatomprom extended their production cuts until at least 2021. Second, we believe Cameco is about to enter the spot market in a dramatic way during Q4 and this could have a material impact on price. Ever since Cameco curtailed production last year from their world-class McArthur River mine, they have stated their mine production would not be enough to meet their commitments. As a result, they would meet their obligations through a combination of purchased material and sales from their inventory. We estimate that Cameco's inventory has already declined from 20 mm pounds as recently as June 30, 2018 to 12 mm pounds today and so more and more material will need to come from the spot market to meet commitments going forward. While uranium bears believe there is an abundance of excess material around the world, something very strange happened when Cameco tendered for spot pounds earlier this year. Instead of being inundated with many offers, Cameco was only able to secure a small fraction of the material it tendered for. Nor did price seem to be the issue. Instead, the sellers all were willing to offer material for delivery many months away. This suggests that easily mobilized uranium inventories are much lower around the world than widely believed. Furthermore, the long lead time suggested the material would be sourced from small mining operations that would use the tender as a backstop to increase or restart production. We expect to see prices respond strongly over the next few months as several of these fundamental trends begin to be better appreciated by the market.

Except for a surge in nickel prices (up 34% during the quarter), most base metal markets were weak. For example, both zinc and aluminum prices fell 4.5% and copper prices fell 5%. Copper remains by far our favorite base metal. After a strong 2018, both copper and the related stocks have been lackluster performers so far in 2019. While investors remain concerned about Trump-related trade wars, they risk missing several critical bullish developments now showing up in the data. In September, the World Bureau of Metals Statistics (WBMS) made several revisions to an historical dataset that dramatically tightens copper's supply and demand balances. Demand was revised higher in both South Korea and Russia by 100,000 tonnes in a market that has grown on average 500,000 tonnes per year over the past several years. More dramatically still, mine supply was revised lower by an incredible 500,000 tonnes in 2018 due to revisions in Zambia, Kazakhstan, and Indonesia. Looking forward, we predict disappointments in mine output will continue. Several major projects suffered delays or postponements including Rosemont in Arizona and most notably Oyu Tolgoi in Mongolia. Oyu Tolgoi, one of the most anticipated new mining projects in the world, announced major geotechnical problems in the development of its underground block cave operation. While it remains to be seen what ultimate impact this will have on the project, it has certainly resulted in a multi-year delay. Complicating matters further, political turmoil in Chile has resulted in widespread labor disputes there that will impact production. We believe the net result is a copper market that has already slipped into deficit and will continue. We are maintaining our copper investments, confident it has one of the best supply and demand outlooks of any commodity.

Oil: A Market Divorced from Reality

In the thirty years we have been investing in global natural resource markets, we cannot remember seeing greater value than we do today in the global oil markets. With both crude and oil-related securities, the price action appears to have completely divorced itself from underlying fundamentals.

By any measure, oil and oil-related securities are radically undervalued. Over the last 120 years, we estimate it took 17 barrels of oil on average to buy one unit of the S&P 500. Today it requires over 53 barrels. The only time it has taken more was during the parabolic dotcom blow off–incidentally an excellent time to become an oil investor. At the same time, energy-related equities now make up a mere 4% of the S&P 500 by weight. Not only does this represent the lowest level in at least 20 years (when our records begin), 75% below the peak levels reached in 2008 at which point energy stocks made up 16% of the S&P 500.

In particular, the bear market in oil exploration and production companies has created value that can hardly be believed. We analyzed the universe of all US-listed E&P companies with market capitalizations over $100 mm and proved reserves that are at least 50% oil. We then compared the current stock price to the net-debt adjusted SEC PV-10 measure from their 2018 10Ks. As you may recall, a company's PV-10 measures the discounted cash flow of all proved reserves at the prevailing oil and gas prices. Under normal market conditions, E&P stocks trade at a premium to their SEC PV-10, reflecting the expected value of any future reserves not yet "booked" in the reserve statement. However, due to the overwhelming bearishness among energy investors, the average company now trades at a 12% discount to its net-debt adjusted SEC PV-10 per share value. While we have seen individual companies trade at a discount, we cannot recall a time when the industry average was less than its SEC PV-10 value. We should point out that the price used in most companies' SEC PV-10 analysis for 2018 was $55 per barrel, not materially higher than today's price.

We also computed the discounted value of the companies' proved developed producing reserves (PDPs). This represents the most conservative possible measure of value: a company's discounted cash flow from currently producing wells only. As you might imagine, it is very unusual for an E&P company to trade at a discount to this most conservative measure. Today, we estimate that twelve of the twenty-nine companies in the universe are trading at a discount to their PV-10 value using only their PDP reserves. Furthermore, the average premium to PDP PV-10 value across the entire industry is now only 7%. Once again, we have never seen anything remotely like this before. Investors often act irrationally at the bottom of long, drawn-out bear markets and we believe that is what we are witnessing today.

While the market can famously stay irrational longer than most investors can stay solvent, what we are experiencing today is truly extreme. An entire industry is nearly priced as though it will simply run off its existing assets. How can this be? We believe there are simply no buyers left. In past cycles, as energy prices fell and E&P stocks sold off, two groups of investors would begin to accumulate positions: natural resource specialists and value investors. Our analysis tells us that natural resource funds continue to suffer material redemptions as investors look to reallocate capital away from the industry. We estimate that nearly 25% of the industry's assets under management are flowing out through redemptions each year and this figure shows no sign of abating. As a result, resource fund managers are constantly forced to sell positions to meet redemptions, instead of stepping in to take advantage of the deep value. Value managers are also suffering net redemptions. After a difficult ten-year period, growth continues to outperform value and investors continue to chase the momentum of the former by selling the latter. In past cycles, value investors could be counted on to buy during extreme bear markets. but today they are either on the sidelines or liquidating positions to meet redemptions as well. In fact, active managers in general are seeing capital being allocated away into passively managed index funds. As we mentioned earlier, energy now makes up its lowest ever weighting in all the major indices. Therefore, as capital gets redirected from actively managed funds towards passive index funds, energy shares end up being liquidated.

There are no natural buyers for natural resource stocks in general and energy stocks in particular. This has allowed the sell-off to be more severe than past cycles and resulted in unprecedented value for those able to invest in this most contrarian space.

Often at the bottom of intense, grinding bear markets or the top of bull markets, investors will create a narrative to help explain the extreme price action. The prevailing consensus view is that oil market fundamentals are bad today and getting worse. Most analysts believe the market is currently in surplus and that this surplus will accelerate as weak demand is met by ever-growing shale production. At the same time, the EV threat looms and is expected to leave oil worthless within several years. This outlook appears to be corroborated by the sell-off in E&P stocks, reinforcing the negative feedback loop.

Unfortunately, the story investors have created to help explain today's energy bear market is fundamentally incorrect. While it may be counter-intuitive, the oil market is in deficit today and has been for nearly three years. After peaking at nearly 450 mm bbl above average, OECD inventories have repaired themselves by 75%. In the US (by far the largest source of OECD inventories), core inventories drew relative during the first nine months of 2019 by 40 mm bbl during a period that normally sees them build by 1.4 mm bbl. This implies the market was undersupplied by 150,000 b/d. While the data for the OECD as a whole came in slightly weaker, it still suggested a balanced market for the first nine months of the year based upon preliminary data. We should point out that the IEA has been revising its most recent inventory data and so we will have to wait to see if the most recent data ends up being revised down from here. Both WTI and Brent markets remain firmly "backwardized," confirming the market is indeed tight.

Investors remain very concerned about the impact of slowing economic growth on global oil demand. While Q2 did show some softening, there have been several very bullish developments that most investors seem to ignore. For example, analysts focused all of their attention on the IEA's recent downward revision of 2020 global demand projections by 100,000 b/d over the course of the last three months. However, at the same time the IEA quietly revised historical demand higher by 190,000 b/d in 2017 and 110,000 b/d in 2018–a fact that few people wrote about. Notably, Q4 of 2018 was revised higher by a very large 300,000 b/d.

Our models tell us that more revisions are forthcoming. As always, our analysis revolves around the "missing" barrels. For example, the IEA still claims after its latest set of historical revisions that global demand for all of 2018 equaled 99.3 mm b/d while total supply equaled 100.3 mm b/d. This suggests that inventories should have grown by 1 mm b/d or 365 mm b for the full year. Instead, the IEA reports that inventories were unchanged for the year. We refer to the "missing" barrels as oil that was produced but neither consumed nor put in storage. We have long argued that "missing barrels" are a clear indicator that the IEA will revise higher its demand figures and once again that has been correct. The IEA has a long history of demand underestimation. In 8 of the last 9 years, they have been forced to revise global demand higher by 1.1 m b/d on average (a number that is creeping higher). Despite this chronic underestimation and the continued presence of "missing barrels," investors continue to ignore the warning signs of stronger than expected demand. For example, all of the headlines we've read focused on the small downward revisions to future demand projections (by an agency that systematically underestimates demand) while none have focused on the larger positive revision to actual historical data. If we are right and the majority of the "missing" barrels are eventually included in global demand, then 2018 demand likely averaged 100.4 m b/d or an incredible 2.2 m b/d higher than 2017. That is the largest annual growth in eight years.

In our introduction, we discussed how US shale growth has rapidly slowed. As a result, total US crude production (both shale and conventional) was flat from January 1 to June 30. Compare that to nearly 700,000 b/d of growth for the first half of last year. Even adding in natural gas liquids, total US liquids production only grew by 300,000 b/d for the first six months of

the year compared with 1 mm b/d for the first half of last year. Given that US oil rig counts have now fallen by 15% and that drilling productivity seems to have stagnated, we expect these trends will only get worse from here. Investors have become far too complacent about global oil supply. For example, the IEA still expects US liquids production to grow by a very robust 1.6 mm b/d year-on-year in 2019. For this to occur, US liquids production would have to surge by 1.0 m b/d between June 30 and December 31, completely bucking the trend of the first half. Given the falling rig count this simply is not feasible. Furthermore, the IEA expects this growth to continue into 2020. Their latest report projects the US will grow production by another 1.3 m b/d which implies growth of 1 m b/d from January 1 to December 31–again, something we think is not possible without a material increase in drilling.

Adding to the supply issue, conventional non-OPEC production outside of the US continues to disappoint. We first addressed this issue in our 3Q2016 letter and have revisited it several times since then as we believe it remains the most ignored driver of global oil balances going forward. Last year marked the worst year ever for conventional oil discoveries and caps nearly two decades of lackluster results. We estimate that conventional non-OPEC production has exceeded discoveries by a staggering 170 bn bbl over the past six years. Conventional non-OPEC reserves are being hollowed out and we have long made the case that you are actually starting to see this in the production numbers. When the IEA first released estimates for 2019 last summer, it expected total non-OPEC supply outside of the US and Russia (we are excluding Russia because their production is actively being curtailed today) would grow by 350,000 b/d including biofuels and refinery processing gains. We have long argued this would be impossible based upon the dearth of new projects coming online. In their latest report, the IEA has now revised this growth down to zero. Even including OPEC NGLs (not part of the OPEC quotas), non-OPEC supply outside the US and Russia is only expected to grow by 100,000 b/d in 2019. However, our models tell us more revisions are needed. For example, while the IEA revised down their growth assumptions for Norway and Brazil for the first half of 2019, they actually increased their estimates for the second half and for 2020. The IEA now expects 2020 non-OPEC growth outside of the US and Russia to reach a robust 1 m b/d including OPEC NGLs. Once again, these figures are far too high and will need to be revised down.

Analysts point to new production from the Brazilian Lula and Búzios pre-salt fields (expected to reach 400,000 b/d) and the Johan Sverdrup project in Norway (expected to reach 440,000 b/d) when justifying 2020's expected growth. While these projects are indeed large, our models tell us they simply will not be enough to reach the IEA's overly optimistic growth assumptions. While this may sound outlandish, consider that every year major projects contribute to new non-OPEC production and every year this is offset by a certain amount of base decline. We model all major non-OPEC projects and can compare the gross additions expected in 2020 with those of the past years. Focusing on non-OPEC conventional production outside the US and Russia, we estimate that new projects have added 1.2 m b/d of new production each year between 2012 and 2018. In 2019 we estimate this figure accelerated to 1.5 m b/d of production. At the same time, we estimate that production from this group has not grown since 2012 suggesting that base declines have been roughly 1.2-1.4 m b/d. Our same models suggest that even with the new projects in Brazil and Norway, total major projects will only add at most 1.7 m b/d of production next year. Given 1.5 m b/d of new production from major projects in 2019 has so far led to no net growth, it seems unlikely that 1.7 m b/d of production from new projects will result in 1 m b/d of new net growth in 2020. Instead, we think that the IEA will be forced to revise down its projections materially, much the same as it did in 2018 and 2019.

As a result of stronger than expected demand, slowing shale growth, and modest non-OPEC growth outside the US, we expect global oil markets will remain in deficit as we move through the remainder of 2019 and into 2020. For the second half of 2019, the IEA estimates global demand will average 101.3 m b/d while total non-OPEC supply will average 65.4 m b/d. Assuming OPEC NGLs average 5.5 m b/d that leaves the call on OPEC at 30.4 mm b/d while production in Q3 averaged 29.4 m b/d. These balances imply a market in deficit by 1 m b/d as we progress through the rest of the year.

Turning to 2020, the IEA expects global demand to average 101.5 m b/d, but we believe this figure will need to be revised higher. The "missing" barrels averaged 450,000 b/d during the first half of 2019, and we expect demand will ultimately need to be revised higher by a comparable amount for both 2019 and 2020. If our models are right (and they have been so far to date) then demand could reach 102 m b/d in 2020. Non-OPEC supply is expected to grow by a very strong 2.2 m b/d next year, but as we have discussed we believe this is not possible. The IEA still expects the US can grow by 1.3 m b/d next year, but we think this figure is overstated by at least 300,000 b/d under the most lenient assumptions. Non-OPEC production outside the US (including OPEC NGLs) is expected to grow by 1 m b/d but as we discussed earlier this seems unlikely. Instead, we think this group will be lucky to see growth of 400,000 b/d. As a result, we expect non-OPEC production outside the US to average 53.6 m b/d in 2020. These balances would leave the call on OPEC at 30.3 m b/d – or nearly 1 m b/d more than OPEC's recent levels.

Global oil markets remain tight despite investor concerns regarding global growth, shale production, and the EV. At the same time, we think it will become more challenging to find high-quality E&P investment opportunities with ample remaining drilling inventory. This is where we continue to focus all of our attention as we move forward. We are now turning our neural network to individual companies to better analyze their asset bases and the results thus far have been very interesting. In our next letter, we will write extensively about our results and hopefully put to bed the notion that all shale companies are chronic value destroyers.

Natural Gas: A Potential Turning Point in a Decade's Long Bear Market?

The shale gas revolution began in earnest in 2005. Even though the shales were being aggressively developed, shale gas production in 2010 still represented only 20% of US supply. Of the 21 trillion cubic feet (tcf) of dry gas produced in 2010 (or 58 billion cubic feet per day [bcf/d]), 80% was still produced from conventional reserves. Shale gas production in 2010 remained concentrated in two basins: 40% of total shale production came from the Barnett; 30% came from Haynesville.

Today, US dry gas production has surged to over 90 bcf/d and the contributions from shales and conventional sources have flipped. The shales now represent almost 80% of total US dry gas production (70 bcf /day) while conventional gas production represents just a little over 20%. The contributions from various basins have also shifted significantly over the last nine years. The Barnett and Haynesville have gone from representing 65% of US natural shale gas production in 2010 to only 12% today. The largest source of gas supply growth by far over the last nine years has come from the Marcellus shale. Today the Marcellus produces 22.5 bcf/d, representing almost 25% of total US dry gas supply, making it the largest basin in the country by a wide margin. You cannot overstate the importance of the Marcellus to the US gas market.

As we mentioned in the Q 3 Natural Resource Market commentary of this letter, we have spent much time over the last five years trying to better understand when the grinding North American natural gas bear market might end. We are seeing an extremely interesting data point emerge in the Marcellus shale (as well as the Hayneville, the second largest gas field in the US) that could provide an answer. While we do not believe the natural gas bear market is gas is yet over, this potentially bullish trend must be closely monitored. These trends may provide investors the signal that the great gas bear market is now entering its final innings.

Back in November 2016, I was the luncheon speaker at the Doyle Trading Consultants' annual fall conference. Although the event was a coal conference, I spoke on the future of North American natural gas and whether there was any hope that the bear market, then in its ninth year, might be drawing to a close. Absent a short-term weather-related spike, we offered little evidence that the bear market was nearing an end. We explained how supply growth would continue to exceed demand growth even given the coming build-out of US LNG export facilities.

However, we did mention at the very end of our presentation that any bullish long-term thesis would need to revolve around one issue that few investors were discussing. A shale field (whether it be gas or oil) has many of the same characteristics as a conventional field. In conventional oil and gas fields, production typically peaks and then declines once half of the recoverable reserves have been produced. This principle was first put forward by the famous and controversial geologist King Hubbert in the 1940s. Although petroleum geologists and engineers debate the underlying drivers, the empirical evidence is hard to refute, and the principal is largely accepted as fact today. For those trying to pick the end of the natural gas bear market, one had to determine when the Marcellus gas field would peak and then decline.

The difficulty in applying Hubbert's theories revolves around estimating a field's total recoverable reserves. The relentless advancement of technology has pushed recovery factors constantly higher across almost all oil and gas fields. This in turn has led to rising recoverable reserve estimates. In our previous letters, we used Hubbert's theories to make several predictions, some of which have been right and some of which have been wrong. For example, we correctly estimated when the giant Saudi Ghawar field would roll over. However, we were too early in claiming that the Bakken and Eagle Ford had peaked. Our Q3 2016 letter, discusses Hubbert and his theories, including all the drawbacks and limitations.

Hubbert's theories are controversial, but natural gas production from two of the three oldest gas shales, the Barnett and the Fayetteville, has long since rolled-over, and the production profiles from both fields are now tracing out near-perfect "Hubbert Curves."

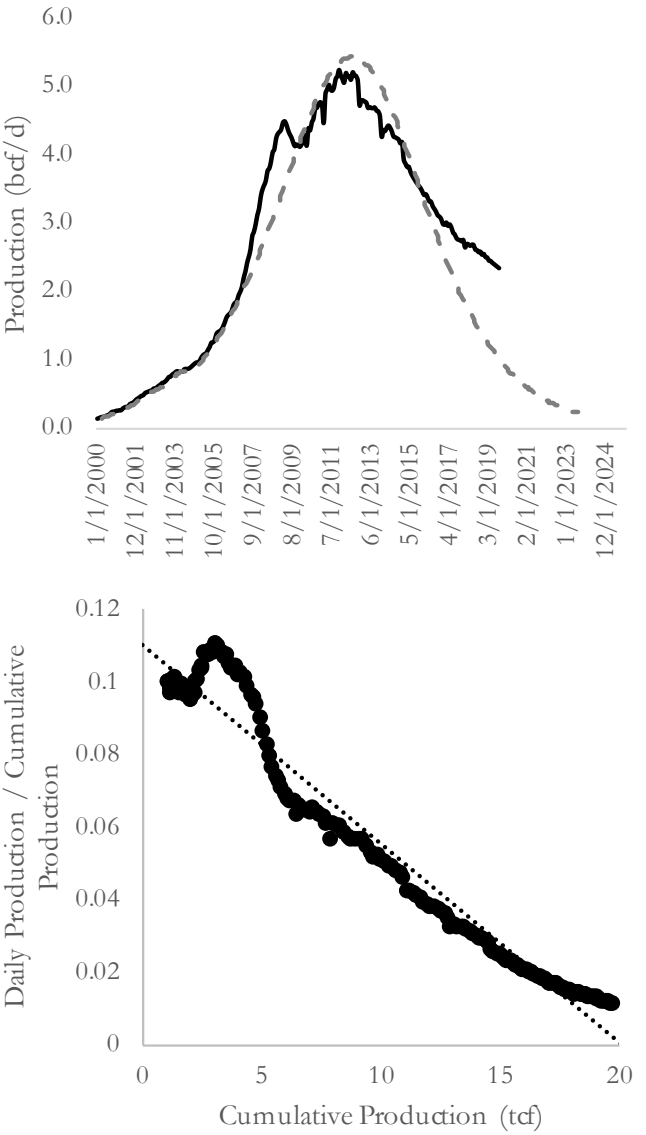

Exhibit 2: Barnett Production Profile & Hubbert Linearization
Source: EIA, G&B Models.

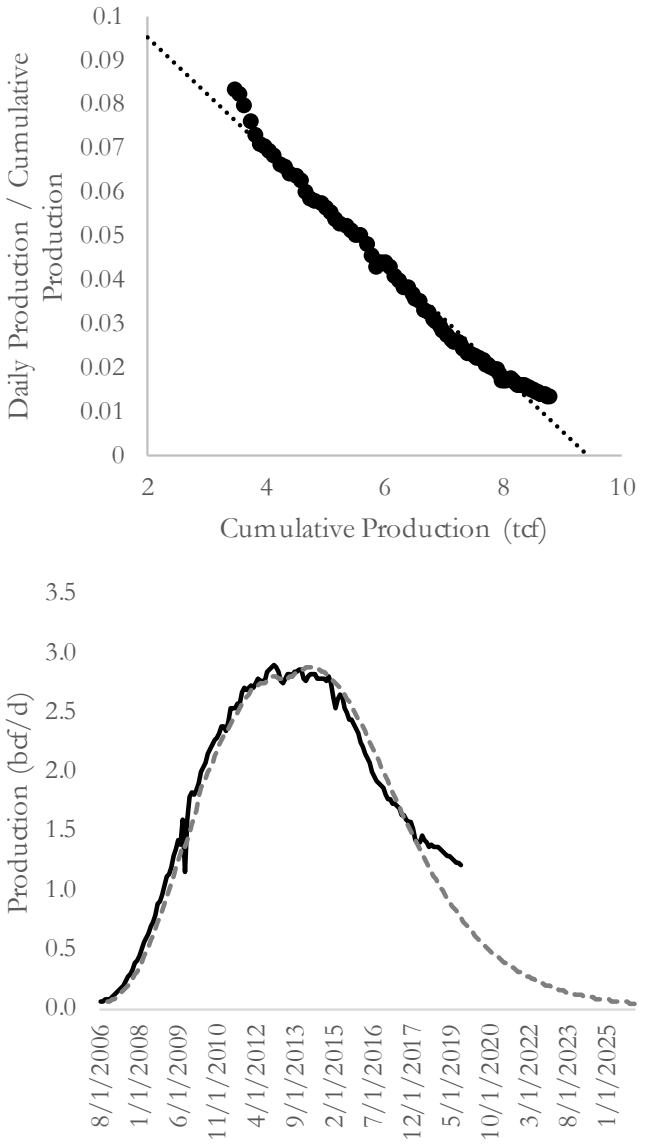

Exhibit 3: Fayetteville Production Profile & Hubber Linearization
Source: EIA, G&B Models.

The third field, the Haynesville, highlights one of the major problems with Hubbert's theories. The Haynesville first produced significant quantities of gas in 2009. By 2012, production had surged to over 7 bcf /day and represented 10% of total US supply. Production peaked unexpectedly and by early 2016 had fallen by half as the economic parts of the field were drilled up. Many natural gas investors (including ourselves), thought the Haynesville would continue to decline. However, by 2016 Haynesville operators had significantly increased both the lateral lengths and proppant loadings of their wells with tremendous positive results. By 2017 production once again started to strongly grow. Today, production has reached new highs at nearly 9 bcf/d. The productivity improvements associated with longer laterals, larger proppant loadings, and more frac stages significantly increased the ultimate recovery of the field.

With the Marcellus, if we can predict when gas production from the field peaks, it could be extremely important data in determining when the gas bear market might end. However, our previous attempts to estimate total recoverable gas from Marcellus have proved frustrating. But now we can ask our newly designed neural network to make that estimate and be more confident about when the Marcellus's production will peak.

We have become more motivated to undertake this project after meeting with multiple Marcellus operators. We always ask managements how much Tier 1 drilling acreage remains in their inventory. In the past, Marcellus operators would respond that they had decades and decades of Tier 1 acreage left to drill. However, the responses from these same companies' have recently become more somber with some operators even suggesting their Tier 1 drilling inventories might be less than 10 years.

Before we discuss the Marcellus, let's step back and analyze the production history of both the Barnett and Fayetteville fields -- the first two gas shales to be developed. Both fields have peaked, and production has clearly rolled over. As you can see from the two charts below, both the Barnett and the Fayetteville have traced out near-perfect "Hubbert Curves." The "Hubbert Linearization" suggests the Fayetteville will ultimately recover 9 tcf while the Barnett will recover 20 tcf. We compared the Hubbert Linearization with the recoverable reserve estimation made by our neural network, and the results were remarkable. Our neural network identified 17,000 possible Barnett wells of which 15,000 have been drilled and completed. Total expected reserves from these 17,000 wells is expected to total 23 tcf of natural gas of which 20 tcf (or 85%) have already been produced. Unlike the Hubbert Linearization, our neural network identifies each individual well location making it very much a direct or "bottoms up" estimate. Remarkably, the neural network predicted that total recoverable reserves would be within 15% of the Hubbert Linearization. Moreover, according to the neural network, production from the Barnett peaked and rolled over within a few months of when half the recoverable reserves were produced.

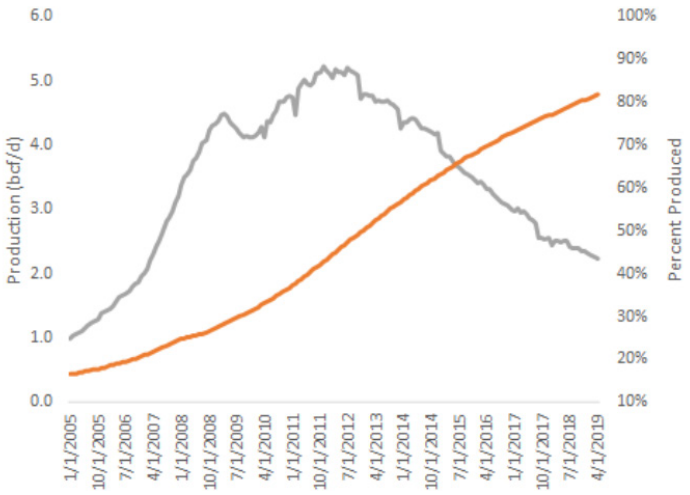

Exhibit 4: Barrnett Production & Field Recovery Neural Network
Source: ShaleProfile, G&R Neural Network

Turning to the Fayetteville, our neural network identified just over 6,000 drilling locations of which 5,600 have been drilled to date. In total, our neural network estimated total recoverable reserves at 10 tcf of which 8.9 tcf have already been produced. Once again, our neural network (based on projections of individual wells) comes very close to the Hubbert Linearization, which projected 9 bcfof recoverable gas. Just like the Barnett, production from the Fayetteville seems to have peaked and rolled over within a few months of reaching the "half-way" point in terms of recoverable reserves. Our neural network tells us that 85% of the Fayetteville's reserves have now been produced and that production has little to no chance of ever recovering.

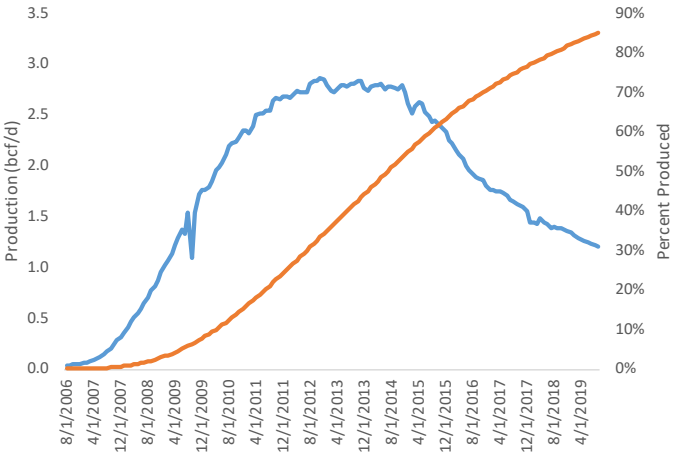

Exhibit 5: Fayetteville Production & Field Recovery Neural Network

Source: ShaleProfile, G&R Neural Network

The neural network is equally as insightful when considering the Haynesville. Our models identified 10,000 possible drilling locations that will recover 50 tcf of natural gas in aggregate. As we discussed, production from the Haynesville first peaked at 8 bcf/d in 2011 before declining by nearly half. The field had only produced 4.5 tcf of gas by 2011 and in retrospect, given we expect the total recoverable reserves are 50 tcf, it is no surprise that production picked back up. Indeed, today production is nearing 10 bcf/d – nearly 20% higher than the last peak. We estimate the Haynesville's cumulative production to date is approximately 20 tcf or 40% of projected total. As such, we believe the Haynesville will continue to grow somewhat from here.

What predictions can we make about the Marcellus? A Hubbert Linearization of the Marcellus is somewhat problematic because the field has been pipeline constrained for much of its development (Hubbert's theories apply to unconstrained development). Looking at the plot, Marcellus production appears to still be in its early "noisy" stage of growth before the linearization settles into a straight line from which recoverable reserves can be estimated. This is precisely why we have avoided making a prediction about the Marcellus in our past letters.

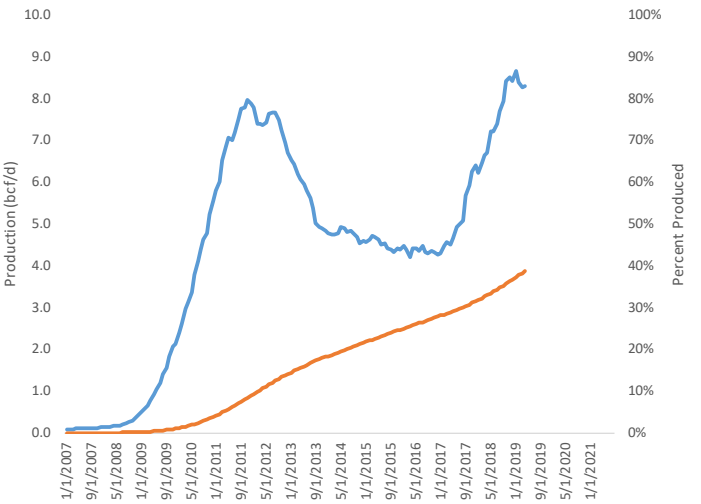

Exhibit 6: Haynesville Production & Field Recovery Neural Network

Source: ShaleProfile, G&R Neural Network

Our model identified 20,000 drilling locations in the Marcellus of which 14,000 have been drilled to date. In total, we expect these wells will recover 92 tcf of natural gas making the Marcellus nearly twice as large as the second largest shale gas field, the Haynesville. We estimate the Marcellus has produced 37 tcf of gas to date, or 40% of the total recoverable reserves. This implies that the Marcellus can continue to grow until another 8 tcf of gas has been produced. At today's production levels this amounts to only another 12 months before the Marcellus has produced half of its ultimate recoverable reserves. While this claim may sound shocking, if we extrapolate the Hubbert Linearization form the last 30 months of data, it implies total recoverable reserves of 90 tcf of gas, very close and consistent with the recoverable reserve estimate made by our neural network.

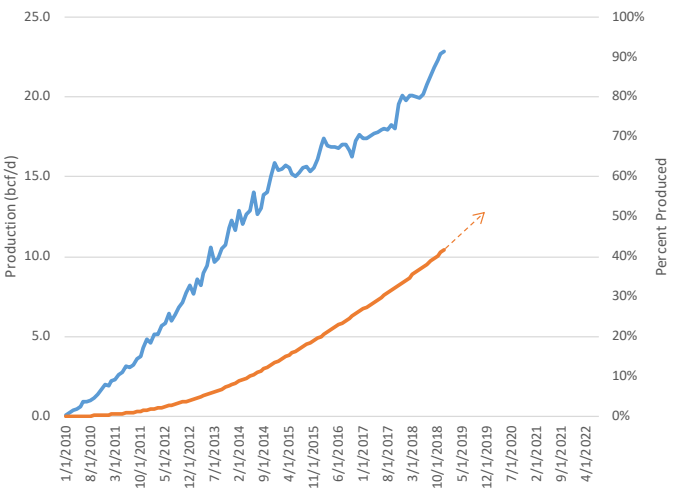

Exhibit 7: Marcellus Production & Field Recovery Neural Network

Source: ShaleProfile, G&R Neural Network

If this analysis is correct, then the largest bearish factor in today's natural gas market (i.e. Marcellus production) may be nearing an end.

In carrying out our analysis, we came across another very interesting observation that lends credence to our claims. Production in both the Barnett and the Fayetteville peaked once half of their reserves were produced. However, another commonality to both fields is that production peaked once 60-65% of their Tier 1 wells had been drilled and completed. Today, we estimate that both the Marcellus and the Haynesville have produced 40% of their recoverable reserves. We also estimate that the 60% of the Marcellus's Tier 1 well have been drilled and that 55% of the Haynesville's Tier 1 inventory has been drilled as well. If both of these fields follow a Hubbert Linearization and peak within the next 12-18 months having produced half of their reserves, they will also do so having drilled 60-65% of their best wells---just like the Barnett and Fayetteville. It's another data point confirming that both fields are very close to peaking.

Again, we do not think the bear market in US natural gas is over, but we now believe the end is quickly approaching. The fact that both the Marcellus and Haynesville—25% and 10% respectively of US production--are very close to peaking means that future growth in US gas supply will slow dramatically in the next five years. Most of the future growth in US production will have to come from the Permian. In our next letter, we will discuss the implications of slowing US shale production, as well as the global demand trends now firmly in place. We will also use our neural network to refine projections of future natural gas production from all the gas fields, including the Marcellus and the Haynesville.

We have been bearish on gas for a very long time, but we want our readers and investors to know that evidence is gathering that the grinding bear market in natural gas, now in its 12 year, is now drawing to close.

The Western Investor Reenters the Gold Market

We believe that the upcoming next leg of gold's bull market will be driven by western buyers, a subject we discussed in our last letter. Last decade's gold bull market, which lasted 10 years and saw the price of gold rise almost seven-fold, was dominated by buyers from the East—primarily from China and India. In the first leg of last decade's bull market, which ended in 2008 when gold hit $1,000 per ounce, western gold market participants spent most of their time not buying but selling gold. For example, western central banks only stopped selling their gold in 2008 and hedge funds and other western speculators were significantly short throughout much of the advance. Also, a large number of western gold producers were still forward-selling their gold production as the first leg of the gold bull market unfolded. It took all the way until 2009 for the biggest proponent of gold forward-selling—Barrick Corp—to admit that it could no longer stand the financial pain of maintaining a massive short position. In September 2009, they announced they were closing out their forward sale program and would take a $5.6 billion loss. Also, it was only after the 2008 financial crisis that we began to see any interest in gold from western investors. Several high-profile hedge funds made pronouncements that they had accumulated gold positions, but the hedge funds were late to the game. By 2009, the first leg of the gold bull market only had three years left before it peaked out and, once the gold price began its pullback at the end of 2011, western investors spent the next four years liquidating all the gold they had accumulated since 2008—almost 1,500 tonnes.

The complete absence of western buying, combined with the measured buying by both the Chinese and Indians, who thought gold was a cheap asset class that deserved long-term accumulation, produced a long bull market characterized by low volatility and little speculative activity. As opposed to the gold bull market of the 1970s, the gold bull market of the 2000s was extremely measured and orderly and the advance from $250 to $1,900 per ounce received little comment from the financial press.

For those with long memories, remember how different the 1970s gold bull market was from the one experienced last decade. The final leg of the 1970s bull market in gold was driven by western investors and both gold and silver exhibited high levels of speculative activity which included the attempted corner of the silver market by the Hunt Brothers. In 1979 alone, the gold price advanced by over 150% and silver exploded by over 230% in price.

Are we beginning to see the return of the western interest in the gold markets? We believe that we are. Tracking the accumulation of gold and silver through their respective physical ETFs is a good way to gauge the movement. The 17 physical gold ETFs we follow have shown consistent accumulations throughout 2019. By our calculation, they have accumulated 40 tonnes of metal in Q1, 59 tonnes in Q2, and 214 tonnes in Q3. The accumulations continue into Q4. In the first three weeks of October, another 35 tonnes was accumulated. For all of 2019, physical gold ETFs have accumulated 350 tonnes of metal and total holdings now stands at 2,560 tonnes— almost equal to their 2012 peak. Accumulations also continue in the physical silver ETFs we track. In Q1, the nine we track shed 166 tonnes of metal. However, starting in Q2, they began an aggressive period of accumulations. In Q2, silver ETFs accumulated 470 tonnes, in Q3, they accumulated 2,900 tonnes, and the accumulation continued into Q4. For the first three weeks of October, silver ETFs accumulated an additional 59 tonnes. Over the last eight years, the total silver held by ETFs traded in a range between 15,000 and 16,000 tonnes, but as you can see from the chart below, total accumulations, now standing at 19,500 tonnes, have definitely broken out to the upside after being range-bound for 10 years.

In our last letter, we reiterated our gold price target of $12,000 per ounce—a price target that will potentially be reached in a period of huge speculation not unlike one we saw 40 years ago. The huge amount of money created by central banks has combined with the massive increase in total indebtedness over the last nine years have led to major distortions including the emergence of widespread speculation in the global bond markets. This distortion in particular is apparent when considering the recent sale of 30-year German debt with negative yields. All of these distortions have created the perfect backdrop for the upcoming bull market in precious metals.

Western investors have begun to recognize this and have started placing their bets. The gold bull market has now begun.

Will US Crop Conditions Disappoint?

Crop conditions in North America continue to be strained because of the record- breaking spring rains and resulting flooding in the upper Midwest that caused the 2019 crop to be planted later than ever.

The extremely late planting of crops has resulted in both corn and soybean crops of relatively poor condition. For example, according the United States Department of Agriculture (USDA), the corn crop is only 58% mature, the slowest maturity on record for the beginning of October. Normal corn maturity at this point should be 85-90%. Only 72% of the US soybean crop has dropped its leaves versus 90% last year.

The condition of both crops is below last year's levels and the five-year averages. Only 56% of this year's corn crop is rated "good to excellent" versus last year when 69% met that rating. On a five-year basis, 60% of the corn crop usually meets that rating by this point. Only 53% of this year's soybeans are rated "good to excellent" which unfavorably compares with last year's 68% which is also the five- year average.

Both corn and soybean harvests are far later than average because of their late maturities. As of the first week of October, only 15% of corn has been harvested versus a five-year average of 25%. In soybeans, only 14% of the crop has been harvested versus a five-year average of 20%.

The late maturity of both crops combined with their poorer-than-average conditions make them vulnerable to any adverse fall weather conditions. The huge near record-breaking blizzard and resulting freeze in October which extended from southern Colorado through western Nebraska, from the Dakotas up into Canada, can only produce further harvesting problems. Although most grain analysts have shrugged of the effect of the early blizzard, we believe we could see further reductions in yields of both crops. An October 14 Bloomberg News story reported that "Roger Rix, who farms near Grotton, SD, was hustling with his sons last Wednesday to harvest soybeans before the storm hit. He suspected two thirds of their soybean acreage would still be in the field when the storm was forecast to arrive this week. 'We know it's going to be a disaster,' said Mr. Rix."

The article went on. "Farmers in the Dakotas say the snow could delay their harvest by as much as three weeks. That will leave them scrambling to harvest as colder weather advances. Some crops could go unharvested until next spring."

Even absent the recent blizzard, we believe we will see further downward revision to both corn and soybean harvests. The USDA has historically overestimated both corn and soybean yields in years when there is a late start to the planting season and crops fall well behind in their maturation cycles. For example, in three years that had late planting and maturation cycles—1983, 1993, and 1995—the USDA overestimated their midsummer yield estimates of corn by, on average, 10 bushels per acre and soybean's yield by 2.5 bushels per acre. Back in August, the USDA estimated US corn yields to be 169.5 bushels per acre. In their most recent October Crop Production report, they only reduced their yield estimate slightly to 168.4 bushels per acre. Given that 2019 has been the worst in history regarding lateness, we believe there is a high probability that corn yields will be reduced significantly in upcoming USDA Crop Production reports. Regarding soybeans, it looks like the downward revisions in their yields has begun. In its most recent report, the USDA reduced soybean yields to 46.9 bushels per acre—a drop of 1.6 bushels per acre from its August estimate. If history is any guide, we should expect another 1 bushel drop in soybean yields in the upcoming USDA reports.

Further reduction in yield assumption will have a big impact on both crops. The 1.6 bushel per acre drop in soybean yields has already put huge downward pressure on the 2019-2020 soybean carryout estimates. Soybean carryout estimates, originally projected to be as large as 750mm bushels, have been reduced to only 460 mm bushels in the latest USDA reports. Because of the reported USDA resiliency in corn yields, 2019-2020 corn carryout still stands at almost two billion bushels of corn. However, just to show you how sensitive this carryout figure is to yield assumptions, if corn yields fell by 10 bushels per acre, the 2019-2020 corn carryout would collapse to only a billion bushels.

The historical relationship between late planting seasons and downward revisions of crop yields in North America, combined with the near record blizzard conditions in the upper Midwest which has significantly delayed the 2019 harvest in those areas, leads us to believe there will be significant tightness in global grain markets. The USDA has already reduced its 2019-2020 soybean carryout by almost 40% because of yield estimate reductions. At 460 mm bushel carryout, the stocks-to-usage ratios in soybeans is nearing 10%--a point where we usually begin to see significant upward price pressure. Although the downward pressure on corn yields has only started, we believe that we will see further downward revisions, which will produce significant market tightening.

Corn, soybeans, and wheat have all rallied between 10% and 20% since their lows in September and we believe prices will continue to rally as yield estimates for both soybeans and especially corn are lowered again.

2019 has been marked by two extreme weather events: the 2019 spring floods in the upper Midwest and the near record October blizzard. Although we really don't know, we have a sneaking suspicion that both weather events are the first signs that the world climate is about to enter a sustained cooling phase that will be related to reduced sunspot activity. The long-term weakening of the 11-year solar sunspot cycle, a subject we have discussed in a previous letter, may already be impacting global weather in ways that will become more and obvious as the years unfold.

We believe the bull market on grains has started and will cause continued upward pressure on grain prices as grain yield assumptions are reduced and carryout estimates drop. We remain bullish on grain, and we believe investors should have significant exposure to agricultural related equities.

Authors Bios'

Leigh R. Goehring
Goehring & Roxencwajg Natural Resource Investors

Mr. Goehring has 25 years of investment experience specializing in natural resource investments. From 2005 until the end of 2015, Mr. Goehring was the portfolio manager of Chilton Global Natural Resources Fund. This dedicated natural resources focused hedge-fund grew to over $5 billion of assets under management at its peak.

Prior to joining Chilton Investment Company, Mr. Goehring served as the manager of the Prudential-Jennision family of natural resources funds between 1991 and 2005. These funds accumulated over $3 billion of assets under management at their peak.

Mr. Goehring started working on Wall Street in 1982 in the Trust Department of the Bank of New York. He holds a Bachelors of Arts degree with a major in Economics and a minor in Mathematics from Hamilton University.

Adam A. Roxencwajg, *CFA*
Goehring & Roxencwajg Natural Resource Investors

Mr. Rozencwajg has nine years of investment experience. Between 2007 and 2015, Mr. Rozencwajg worked exclusively on the Global Natural Resources Fund at Chilton Investment Company with Mr. Goehring.

Prior to joining Chilton Investment Company, Mr. Rozencwajg worked in the Investment Banking department at Lehman Brothers between 2006 and 2007.

Mr. Rozencwajg holds a Bachelor of Arts degree with a major in Economics/Philosophy from Columbia University.

Mr. Rozencwajg is a CFA charter-holder.

Tactical Investment Algorithms

Marcos López de Prado
True Positive Technologies

Two major epistemological limitations prevent finance from becoming a science, at par with physics, chemistry or biology. First, finance does not comply with Popper's falsifiability criterion, because financial theories cannot be tested in a laboratory in controlled experiments. Claims such as "value and momentum factors explain the outperformance of stocks" cannot be proven wrong, even if they are. All researchers have is the outcome from a single realized path (a price time series) produced by an unknown data-generating process (DGP). We cannot draw millions of alternative paths from the same DGP and evaluate in how many instances value and momentum factors had explanatory power, while controlling for environmental conditions.

The second epistemological limitation afflicting finance is non-stationarity. Financial systems are extremely dynamic and complex, with conditions that quickly change over time. Financial cause-effect mechanisms are not invariant, due to changes in regulation, expectations, economic cycles, market regimes and other environmental variables. For instance, even if value and momentum factors truly explained the outperformance of stocks in the 20th century, that may no longer be the case as a result of recent technological, behavioral or policy changes. Perhaps value and momentum only worked under certain conditions that are no longer present. Consequently, claims made by financial economists are typically based on anecdotal information, and do not rise to the standard of scientific theories.

Due to these epistemological limitations, researchers rely on backtesting for developing investment algorithms. A backtest infers the performance of an investment algorithm under the general assumption that future observations will be drawn from the same DGP that produced past observations. In this paper, I explain the different types of backtesting methods, and the specific

assumptions underlying each method. I also argue that one particular type of backtesting method can help address finance's epistemological limitations, and bring financial theories closer to scientific standards.

The Three Types of Backtests

In general terms, we can differentiate between three types of backtests. First, the walk-forward method (WF) assesses the performance of an investment algorithm under the assumption that history repeats itself *exactly*.[1] A first caveat of WF is that past time series merely reflect one possible path produced by the DGP. If we were to take a time machine, the stochastic nature of the DGP would produce a different path. Since WF backtests are not representative of the past DGP, there is no reason to believe that they are representative of the future DGP. Accordingly, WF is more likely to yield a descriptive (or anecdotal) than an inferential statement (see López de Prado [2018], chapter 11). A second caveat of WF is that the DGP is never stated: should the DGP change, the researcher will not be able to decommission the algorithm before it loses money, because she never understood the conditions that made the algorithm work.

The second type of backtest is the resampling method (RS), which addresses WF's first caveat. RS assesses the performance of an investment algorithm under the assumption that future paths can be simulated through the resampling of past observations. The resampling can be deterministic (e.g., jackknife, cross-validation) or random (e.g., subsampling, bootstrap). Because RS can produce many different paths, where the historical is just one possibility, it allows us to consider more general scenarios consistent with the DGP. For instance, through a RS backtest we can bootstrap the distribution of the algorithm's Sharpe ratio, which is much more informative than the single-path Sharpe ratio derived by WF. Whereas it is trivial to overfit a WF backtest, it is more difficult to overfit a RS backtest. Still, resampling on a finite historical sample may not yield paths representative of the future (see López de Prado [2018], chapter 12).

The third type of backtest, the Monte Carlo method (MC), addresses both of WF's caveats. The MC method assesses the performance of an investment algorithm under the assumption that future paths can be simulated via Monte Carlo. MC requires a deeper knowledge of the DGP, derived from the statistical analysis of the observations or theory (e.g., market microstructure, institutional processes, economic links, etc.). For instance, economic theory may suggest that two variables are cointegrated, and empirical studies may indicate the range of values that characterize the cointegration vector. Accordingly, researchers can simulate millions of years of data, where the cointegration vector takes many different values within the estimated range. This is a much richer analysis than merely resampling observations from a finite (and likely unrepresentative) set of observations (see López de Prado [2018], chapter 13).

A Practical Example of MC Backtest

Consider a researcher that wishes to design a market making algorithm. Market microstructure theory tells us uninformed traders cause short-term mean reversion as a result of temporary market impact, and informed traders cause permanent impact on market prices. Informed traders arrive at the market at a rate μ and uninformed traders arrive at the market at a rate ε, where both rates can be modelled with a Poisson process. The statistical analysis of historical time series gives us a range of fluctuation of μ and ε, which can be used to simulate long series under various scenarios. For a given combination of μ and ε, MC allows us to derive the optimal market making algorithm, that is, the set of profit taking and stop loss levels that maximize the Sharpe ratio in a MC backtest. In contrast, WF and RS would backtest the overall performance of the market making algorithm, over all historical values of μ and ε, without allowing us to estimate the performance at specific pairs of μ and ε, and without allowing us to derive optimal market making algorithms for each specific pair.

Exhibit 1 shows the performance of a trading algorithm under various profit-taking and stop-loss scenarios, where the underlying price follows an Ornstein-Uhlenbeck process with a half-life of 5, zero drift and noise with unit variance (see López de Prado [2018], chapter 13). The half-life is so small that performance is maximized in a narrow range of combinations of small profit-taking with large stop-losses. In other words, the optimal trading rule is to hold an inventory long enough until a small profit arises, even at the risk of experiencing some 5-fold or 7-fold unrealized losses. Sharpe ratios are high, reaching levels of around 3.2. The worst possible trading rule in this setting would be to combine a short stop-loss with a large profit-taking threshold, a situation that market-makers avoid in practice. Performance is closest to neutral in the diagonal of the mesh, where profit-taking and stop-losses are symmetric.

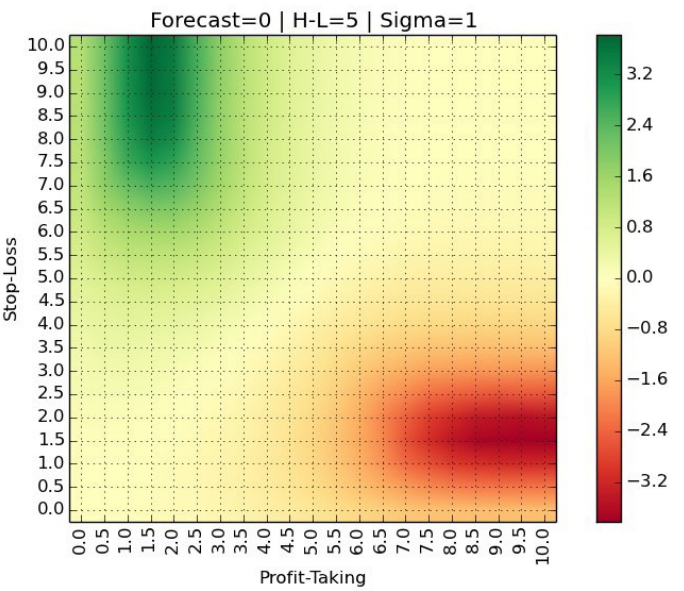

Exhibit 1: Sharpe Ratios Associated with Various Combinations of Profit-Taking and Stop-Loss, for an Ornstein-Uhlenbeck Process with Half-Life 5, No Drift, and Noise with Unit Variance.

Exhibit 2 shows what happens when the half-life increases from 5 to 10. The areas of highest and lowest performance spread over the mesh, while the Sharpe ratios decrease to levels around or below 2. This is because, as the half-life increases, so does the magnitude of the autoregressive coefficient, thus bringing the process closer to a random walk. For a sufficiently long half-life, even the optimal combination of profit-taking and stop-loss levels yield an unacceptably low return on risk.

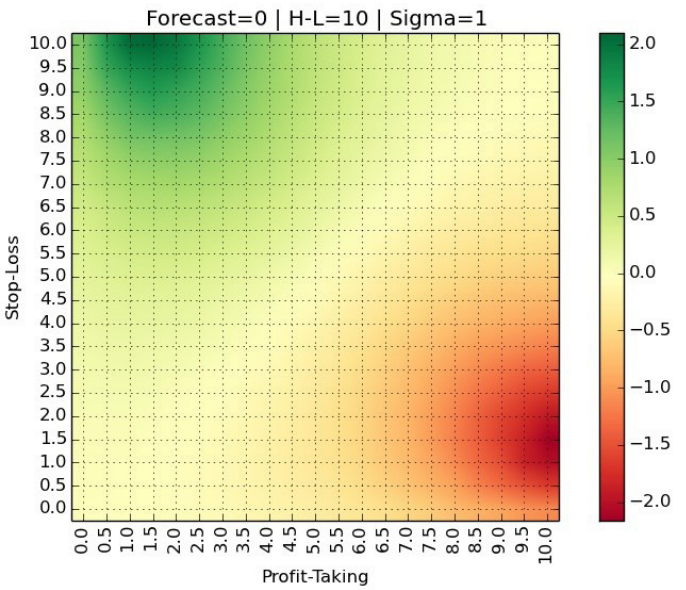

Exhibit 2: Sharpe Ratios Associated with Various Combinations of Profit-Taking and Stop-Loss, for an Ornstein-Uhlenbeck Process with Half-Life 10, No Drift, and Noise with Unit Variance.

Four Unique Advantages of MC Backtest

MC offers four critical advantages over WF and RS. First, MC backtests help address the first epistemological limitation of finance, because they allow researchers to conduct randomized controlled experiments. Admittedly, these experiments require the assumption of a particular DGP, but at least that DGP is explicitly stated (unlike in the WF backtests published in financial journals). In MC backtests, the researcher declares the hypothesis underlying her findings. If the investor believes that the true DGP is different, she just needs to propose an alternative DGP and repeat the analysis. We can consider MC backtests a particular case of Ersatz tests, where statistical methods are tested on computer-generated data from known models (Jarvis et al. [2017]).

Second, MC backtests help address the second epistemological limitation of finance, because the researcher does not need to assume that the DGP is immutable. Instead, the discovery is connected to a particular DGP, where realizations may be drawn from different DGPs over time. In other words, MC backtests allow us to develop "tactical investment algorithms," as opposed to the "strategic investment algorithms" developed with the help of WF or RS.[2] The probability that a particular DGP is producing the realizations can be evaluated statistically, which allows researchers to commission or decommission tactical algorithms as conditions evolve.

Third, MC backtests enable the incorporation of priors, which inject information beyond what we could have learned from a finite set of observations. When these priors are motivated by economic theory, MC offers a powerful tool to simulate the most likely scenarios, even if some of those scenarios have not been observed in the past. Unlike WF or RS, MC backtests can help us develop tactical algorithms to be deployed in the presence of black swans.

Fourth, the length of MC backtests can be expanded for as long as needed to achieve a targeted degree of confidence. This is helpful in that MC backtests avoid the indetermination inherent to working with finite datasets.

The Criticism of MC Backtest

Investors are sometimes skeptical of MC backtests, because they compute the performance of investment algorithms on synthetic data, which may not be representative of future realizations of the true DGP. This skepticism is misplaced, for two reasons: (a) estimating a DGP is not necessarily a harder problem than forecasting the markets. It is intellectually incoherent to assume that, on one hand, statistical methods can lead to successful investment outcomes but, on the other hand, statistical methods cannot identify a DGP; (b) the observations used by WF and RS are unlikely to reoccur in the future exactly as simulated, and the paths generated by MC are not necessarily less likely.

Another concern is that a researcher may select a DGP that is particularly favorable to the investment algorithm. This concern is also misplaced: the MC method explicitly declares the assumptions underlying the performance simulations, so if the DGP is unrealistically favorable to the algorithm, the investor can object. In contrast, the WF and RS methods imply those assumptions through the selection of the historical dataset used by the simulations, obfuscating the dangers of selection bias and confirmation bias

Examples of DGPs

A Monte Carlo randomly samples new (unobserved) datasets from an estimated population or DGP, rather than from an observed dataset (like a bootstrap would do). Monte Carlo experiments can be parametric or non-parametric. An instance of a parametric Monte Carlo is a regime-switching time series model (Hamilton [1994]), where samples are drawn from alternative processes, $n=1,\ldots,N$, and where the probability $pt,^{n}$ of drawing from process n at time t is a function of the process from which the previous observation was drawn (a Markov chain). Expectation-maximization algorithms can be used to estimate the probability of transitioning from one process to another at time t (the transition probability matrix). This parametric approach allows researchers to match the statistical properties of the observed dataset, which are then replicated in the unobserved dataset (see Franco-Pedroso et al. [2019]).

One potential caveat of parametric Monte Carlo is that the DGP may be more complex than a finite set of algebraic functions can replicate. When that is the case, non-parametric Monte Carlo experiments may be of help, through the use of variational autoencoders, self-organizing maps, or generative adversarial networks (De Meer Pardo [2019]). These methods can be understood as non-parametric, non-linear estimators of latent variables (similar to a non-linear PCA). An autoencoder is a neural network that learns how to represent high-dimensional observations in a low-dimensional space. Variational autoencoders have an additional property which makes their latent spaces continuous. This allows for successful random sampling and interpolation and, in turn, their use as a generative model. Once a variational autoencoder has learned the fundamental structure of the data, it can generate new observations that resemble the statistical properties of the original sample, within a given dispersion (hence the notion of "variational"). A self-organizing map differs from autoencoders in that it applies competitive learning (rather than error-correction), and it uses a neighborhood function to preserve the topological properties of the input space. Generative adversarial networks train two competing neural networks, where one network (called a generator) is tasked with generating simulated observations from a distribution function, and the other network (called a discriminator) is tasked with predicting the probability that the simulated observations are false given the true observed data. The two neural networks compete with each other, until they converge to an equilibrium. The original sample on which the non-parametric Monte Carlo is trained must be representative enough to learn the general characteristics of the DGP, otherwise a parametric Monte Carlo approach should be preferred. See López de Prado [2019] for additional details.

The Tactical Algorithmic Factory

The WF and RS backtesting methods attempt to find "all-weather" algorithms, that is, strategic investment algorithms that are not associated with a particular DGP, and are deployed under all market conditions. The notion of strategic (all-weather) investment algorithms is inconsistent with the fact that markets go through regimes, during which some algorithms are expected to work and others expected to fail. Given that markets are adaptive and investors learn from mistakes, the likelihood that truly all-weather algorithms exist is rather slim (an argument often wielded by discretionary portfolio managers). And even if all-weather algorithms existed, they are likely to be a rather insignificant subset of the population of algorithms that work across one or more regimes.

In contrast to WF and RS backtests, MC backtests help us define the precise sensitivity of an investment algorithm to the characteristics of each DGP. Once we understand what characteristics make the algorithm work, we can deploy it tactically, while monitoring the idoneity of market conditions, and derive the appropriate ex-ante risk allocations. When used in this way, MC backtests allow us to trade the algorithms rather than the markets. Under this investment paradigm, a firm will develop as many tactical investment algorithms as possible (López de Prado [2018], chapter 1), and then deploy only those algorithms that are certified to work under the prevalent market conditions. These algorithms are DGP-specific, not instrument specific: the same algorithm will be deployed tactically on different instruments over time, when those instruments temporarily follow the DGP associated with that algorithm. The main difference between the tactical algorithmic factory (TAF) approach and the strategic algorithmic factory (SAF) approach is that TAF's objective is to develop DGP-specific algorithms, which are not required to work all the time. Instead, TAF's algorithms only need to work during the DGP for which they have been certified.

DGP Identification

MC backtests allow researchers to pose the algorithm selection problem in terms of a DGP identification problem. This is advantageous, because finding an algorithm that works well across all possible DGPs is much more challenging than estimating what is the current DGP (which in turn determines the algorithm that should be run at a given point in time). Also, from a mathematical perspective, identifying the optimal algorithm associated with a particular DGP is a well-defined problem.[3]

One practical way of identifying the prevailing DGP is as follows: First, through MC backtests, develop many tactical investment algorithms for a wide range of DGPs. Second, select a sample of recent market performance. Third, evaluate the probability that the sample of recent market performance was drawn from each of the studied DGPs. This probability can be estimated through different methods, the total variation distance, the Wasserstein distance, the Jensen-Shannon distance, some derivation of the Kullback-Leibler divergence, or the Kolmogorov-Smirnov test. The resulting distribution of probability can then be used to allocate risk across the algorithms developed by the TAF. In other words, an ensemble of optimal strategies is deployed, and not only the most likely optimal strategy.

In practice, it takes only a few recent observations for the estimated distribution of probability to narrow down the likely DGPs. The reason is, we are comparing two samples, where the synthetic one is comprised of potentially millions of datapoints, and it typically does not take many observations to discard what DGPs are inconsistent with recent observations.

Another possibility is to create a basket of securities with a returns distribution that matches the distribution of a given DGP. Under this alternative implementation, rather than estimating the probability that a security follows a DGP, we create a synthetic security (as a basket of securities) for which a given algorithm is optimal.

One virtue of running an ensemble of optimal algorithms is that the ensemble strategy does not correspond to any particular DGP. This allows the ensemble strategy to dynamically and smoothly transition from one DGP to another, and even profit from a never-seen-before DGP.

Conclusion

In this paper I have argued that MC backtests offer to financial researchers the possibility of conducting randomized controlled experiments. Absent financial laboratories, this is as close as finance can get to the Popperian criterion of falsifiability.

An MC backtest can be understood as a certification of the performance of an algorithm subject to certain declared environmental conditions, similar to how an engineer would certify the performance of a type of equipment. In contrast with the WF and RS methods, MC backtests inform us about the conditions under which the tactical investment algorithm should be deployed. This information also helps investors pinpoint the circumstances under which the algorithm is most vulnerable, when the algorithm should be decommissioned, and how much risk should be allocated to it.

Given that markets are adaptive and investors learn from mistakes, the likelihood that truly all-weather algorithms exist is rather slim (an argument often wielded by discretionary portfolio managers). And even if all-weather algorithms existed, they are likely to be a rather insignificant subset of the population of algorithms that work across one or more regimes. Accordingly, asset managers should embrace the TAF paradigm, hence developing as many tactical investment algorithms as possible, through MC backtesting.

Endnotes

1. The main argument in favor of WF is that it prevents leakage from look-ahead information. However, if a walk-backwards backtest does not exhibit significantly better performance than a WF, look-ahead leakage is not a concern, making the main argument for WF rather weak.

2. In recent years, it has been proven fashionable for some asset managers to promote certain investment factors through long WF backtests (in some cases, covering over a hundred years). Consider the validity of that work when, for instance, the current environment of negative interest rates has never been experienced before. In contrast, it is straightforward to conduct a MC backtest on data simulated by a DGP with negative interest rates.

3. Most journal articles promote investment algorithms without stating the DGP that those algorithms supposedly exploit. Without knowing the DGP, we cannot know the conditions under which that algorithm is supposed to be run, or when to decommission it.

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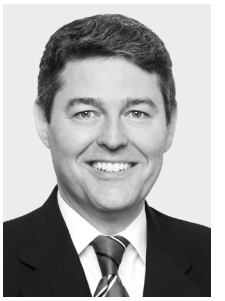
Author Bio



Marcos López de Prado, *PhD*
True Positive Technologies

Prof. Marcos López de Prado is the CIO of True Positive Technologies (TPT), and Professor of Practice at Cornell University's School of Engineering. He has over 20 years of experience developing investment strategies with the help of machine learning algorithms and supercomputers. Marcos launched TPT after he sold some of his patents to AQR Capital Management, where he was a principal and AQR's first head of machine learning. Marcos also founded and led Guggenheim Partners' Quantitative Investment Strategies business, where he managed up to $13 billion in assets, and delivered an audited risk-adjusted return (information ratio) of 2.3.

Concurrently with the management of investments, between 2011 and 2018 Marcos was a research fellow at Lawrence Berkeley National Laboratory (U.S. Department of Energy, Office of Science). He has published dozens of scientific articles on machine learning and supercomputing in the leading academic journals, is a founding co-editor of *The Journal of Financial Data Science*, and SSRN ranks him as the most-read author in economics. Among several monographs, Marcos is the author of several graduate textbooks, including *Advances in Financial Machine Learning* (Wiley, 2018) and *Machine Learning for Asset Managers* (Cambridge University Press, forthcoming).

Marcos earned a PhD in financial economics (2003), a second PhD in mathematical finance (2011) from Universidad Complutense de Madrid, and is a recipient of Spain's National Award for Academic Excellence (1999). He completed his post-doctoral research at Harvard University and Cornell University, where he is a faculty member. Marcos has an Erdős #2 according to the American Mathematical Society, and in 2019, he received the 'Quant of the Year Award' from *The Journal of Portfolio Management*.

Capturing Alpha from Internal Digital Content

Peter Hafez
RavenPack

In this paper, we explore the benefits of using internal digital content, such as emails, attachments and instant messages, to generate differentiated investment insights and trading signals by leveraging our proprietary AI platform and NLP engine. Each organization owns and accumulates massive amounts of digital content, which largely remains under analyzed and untapped. Identifying signals from the noise within the vast volumes of unstructured textual data presents a significant challenge. Intuitively, it is safe to assume that each organization's unique digital footprint contains distinct information that can yield actionable insights.

For instance, it is well-known that institutional investors benefit significantly from corporate access. A substantial amount of analyst insights come from one-on-one meetings with management or private conference calls with sell-side analysts or expert networks. The nature of the discussions during these meetings is likely to be more direct and honest than the scripted rhetoric coming from earnings calls, analyst days and otherwise officially scheduled presentations. Buy-side sector specialists form close relationships with C-level executives and investor relations over the years, and are able to discern nuanced changes in tone or body language that are likely to be shared in internal notes as a part of a "mosaic theory" approach to forming investment decisions. Sell-side analysts, who publicly tend to be more long-biased in their coverage in an effort to preserve investment banking relationships, are frequently more honest about their views on private calls. More often than not, these insights get documented internally in a sea of pre-earnings write-ups and postmortems. The main goal is to capture as much of this information across the entire organization. Additionally, internal research collaborations and content sharing can offer interesting insights into the team's analytical process, adding a human layer to the equation.

The content we analyzed consists of three years of internal data (2016-2019), comprising of hundreds of thousands of emails, attachments and Skype messages in over 1,000 different file formats. While the data is anonymized, we know that the content includes broker research, desk commentary and internal research notes. This content is likely to be highly curated and differentiated by nature, and within the purview of a firm's mandate.

We demonstrate that there is incremental value to be captured within an investment organization's own data as opposed to using public content alone, particularly when considering longer investment horizons. This is a real-world case study conducted on the internal content of a $1 billion European discretionary hedge fund, which focuses on the utilities, infrastructure and commodities sectors in broader Europe.

We collect, store and build a historical archive of all internal content, which we then run through the proprietary NLP engine to capture events and companies tied to those events, structuring and enriching the data in the process. The identified events are categorized under our event taxonomy of over 6,800 events detected by our algorithm, assigning several sentiment scores to each and determining a number of other metrics, such as event novelty and relevance.

We proceed to create a real-world portfolio that captures this incremental information. Exhibit 1 details the incidence of captured internal content that gets passed through our NLP engine for structuring and enrichment.

Methodology

We compute the daily trading signal for each stock by aggregating an Event Sentiment Score (ESS) captured throughout the day, weighted by Event Relevance and Event Similarity. ESS is a granular sentiment score between -1 and 1 that represents the sentiment for a given event identified inside a body of text, and is determined dynamically by our pattern matching algorithm, using scores from similar events categorized by financial experts as having short-term negative or positive impact. Below formula is an example of how granular ESS can be aggregated to a tradeable daily signal by security.

$$signal = \frac{1}{n}\sum_{i=1}^{n} ESS_i \left(\frac{ER_i}{100}\right)^2 \left(\frac{ESD_i}{365}\right)^2 \quad (1)$$

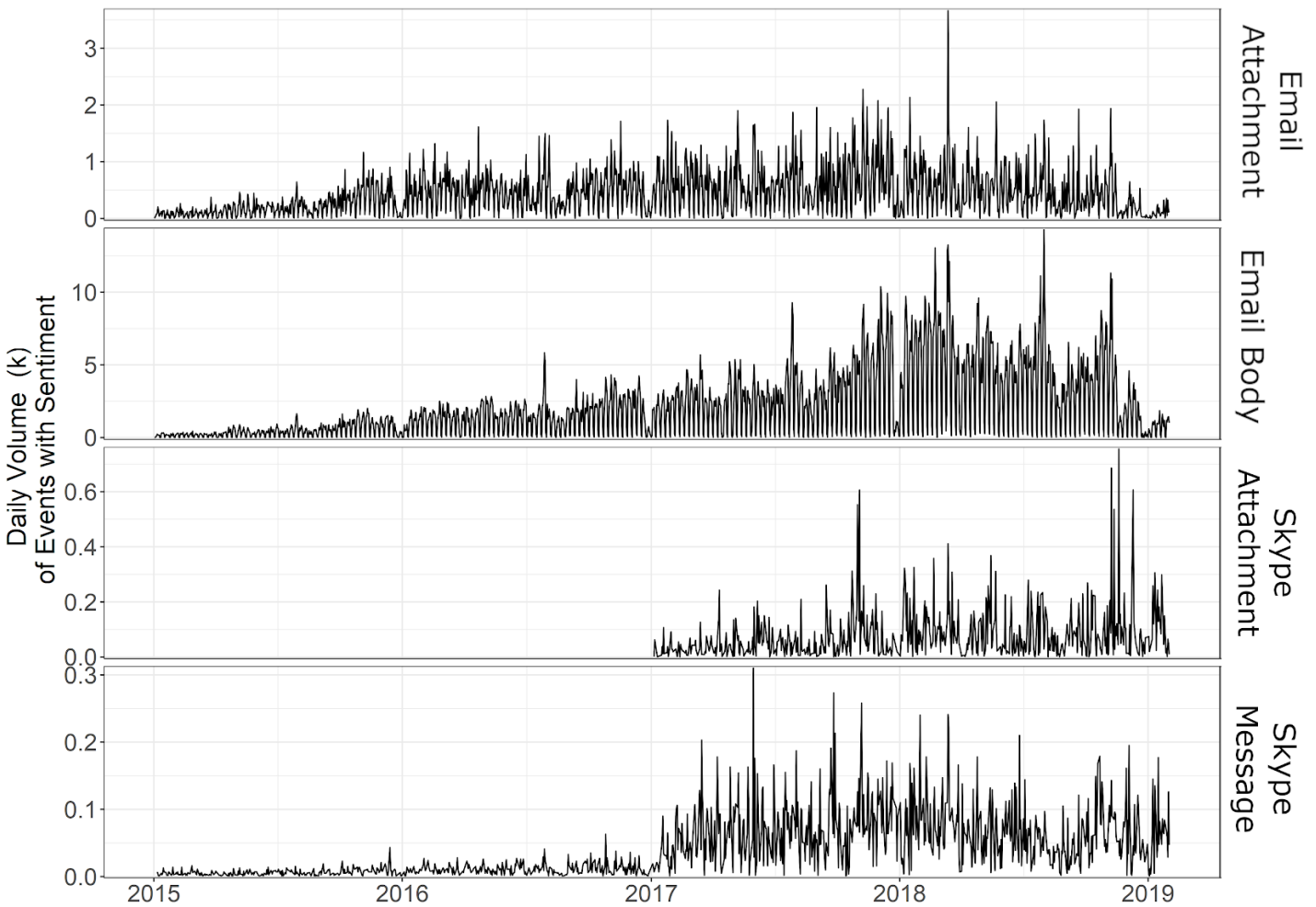


Exhibit 1: Volume of Internal Content Captured Over Time
Source: RavenPack, May 2019

Weighting each ESS score by Event Relevance and Event Similarity Days ensures that relevant and novel events have a higher impact on the daily score, which will be used in a portfolio construction framework. To examine longer investment horizons, we can average the signal over several periods, arriving at a more stable indicator, which results in lower turnover and longer holding periods. Such time-averaging not only lowers portfolio turnover and trading costs, but also allows us to capture some of the post-event drift often missed by fast-moving signals.

While more sophisticated weighting techniques are available, such as using exponentially weighted averages, Kalman filters or utilizing more granular segmented sentiment signals, we illustrate this simple approach to demonstrate the concept in a more straightforward fashion. In this paper, we focus only on internal content. However, a more sensible strategy would combine public news analytics with topical narratives extracted from internal content. We will revisit other methodologies in future research.

Portfolio Construction

The investment universe consists of approximately 180 companies belonging to the utilities, infrastructure and commodities sectors in broader Europe, mirroring the fund's asset coverage. In an effort to replicate the discretionary investment approach, we analyze the performance of relatively concentrated long-only and long-short portfolios at a target AUM level of $100 million, while applying the following constraints to ensure a realistic trading framework:

- Exclude illiquid stocks with less than 0.1% of target AUM as a percentage of 21-day trading volume
- Restrict maximum allocations to 10% of target AUM or to 10% of the 21-day average exchange traded volume, whichever is less (client also uses dark pools to tap additional liquidity)
- Assume continuous rebalancing to maintain constant AUM within the strategy

Taking into account the above constraints, we construct long-only and long-short portfolios with allocations proportional to the aggregated daily sentiment signals, focusing on the Top 40 names.

Results

Approximately 80% of identified stock-related events were detected in the firm's internal content and 20% originated from public news and social media. We found strong long-only signals across the universe that extended into holding periods of several weeks. Signals derived from public news show similar performance or outperform those from the fund's internal content over a 1 to 5 day investment horizon. Nevertheless, the positive sentiment signals derived from the hedge fund's internal content provide better value for longer horizons, up to several weeks (for this particular universe). Exhibit 2 shows long vs. short portfolio performance using internal vs. public content for varying sentiment averaging windows in columns.

In order to get a better sense for the types of events that are captured in the dataset and their impact on strategy performance, in Exhibit 3, we plot the volume and annualized returns of the Top 10 event-group based strategies, captured by the RavenPack event detection algorithm. While product-services and acquisitions-mergers generates lots of volume, the analyst-ratings, equity-actions earnings, and assets event groups produce greater returns.

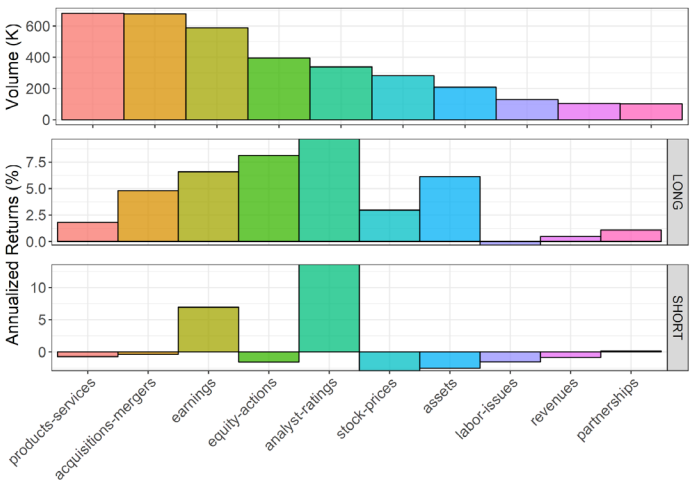


Exhibit 3: Top 10 Event Signals Captured in the Fund's Data
Source: RavenPack, May 2019

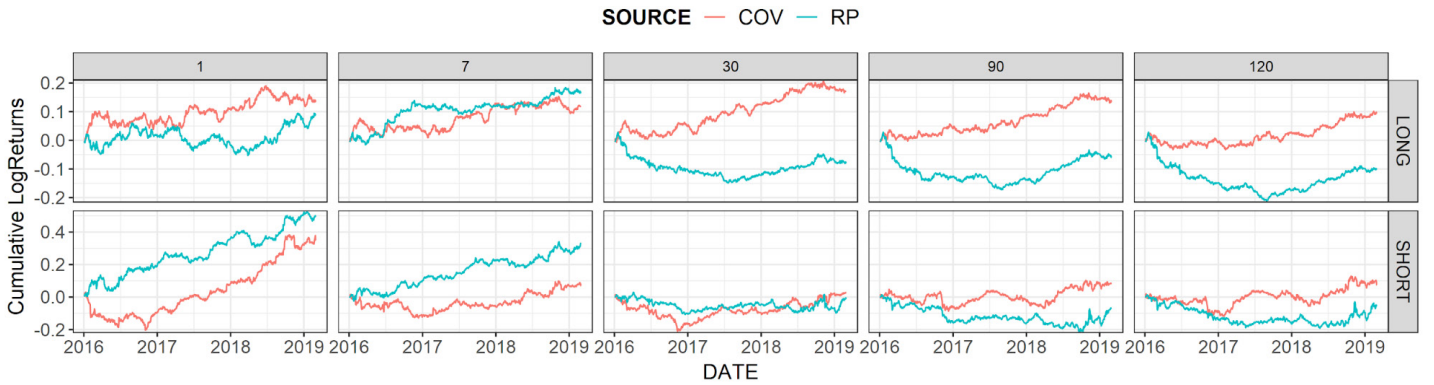


Exhibit 2: Performance Comparison of Internal vs. Public Content
Source: RavenPack, May 2019

Exhibit 4 shows the sentiment distribution of the detected events by category. We can see how many groups have a clear positive sentiment imbalance, which is also reflected in the fact that long portfolios benefit of a larger volume of signals. This is one of the reasons why individual groups usually show better performance for the long side. Note how analyst-ratings, which seems to bring good value for both long and short portfolios (as seen in Exhibit 3), is in fact balanced in sentiment direction. Although those group-specific analytics give us an idea of the event composition, it is not immediate to extrapolate any of these results towards longer trading horizons.

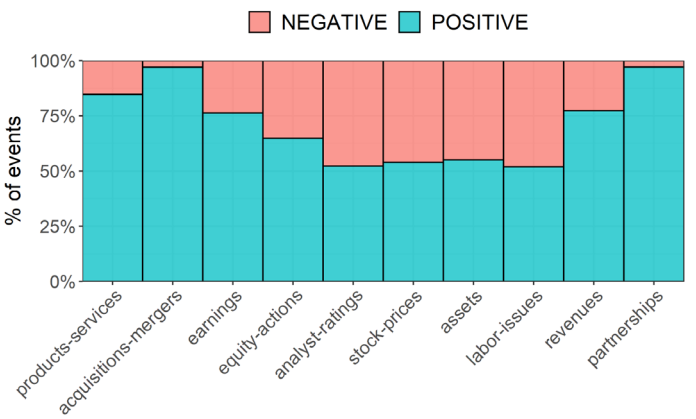


Exhibit 4: Distribution of Top 10 Event Signals Captured in the Fund's Data
Source: RavenPack, May 2019

Strategy Performance

Below, we present the performance metric from 2016-2019 for a long-only $100M portfolio, comprising of 40 stocks, and using a 3-month averaging window for our sentiment indicator. The long-only strategy produces an annualized return of 12.3% (accounting for 8bp of one-way trading costs), with an Information Ratio of 0.8 and average holding period of two to three weeks. The market-neutral strategy passively hedged via the fund's benchmark,[1] produced a 10.6% annualized return with a 1.0 Information Ratio. Exhibit 5 shows cumulative gross P&L of the strategy (before trading costs) versus the benchmark.

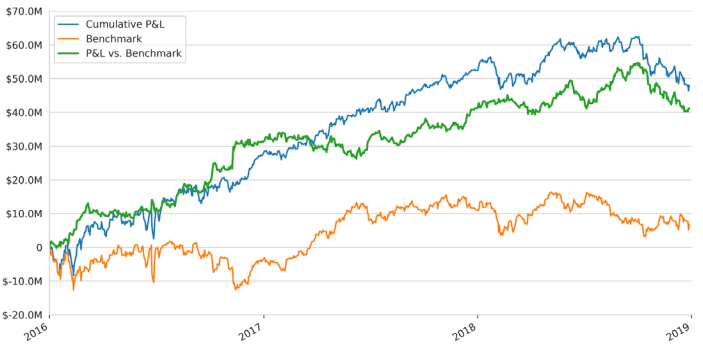


Exhibit 5: Performance of a $100M AUM Long-Only Portfolio Verses Benchmark
Source: RavenPack, May 2019

The specific return of the portfolio, or an equivalent neutral factor-hedged portfolio (assuming a perfect factor hedge), produced an annualized return of 6.4% before trading costs, with an Information Ratio of 1.6. In Exhibit 6, we isolate specific portfolio P&L (alpha) versus traditional market factors, demonstrating persistent alpha over the period.[2]

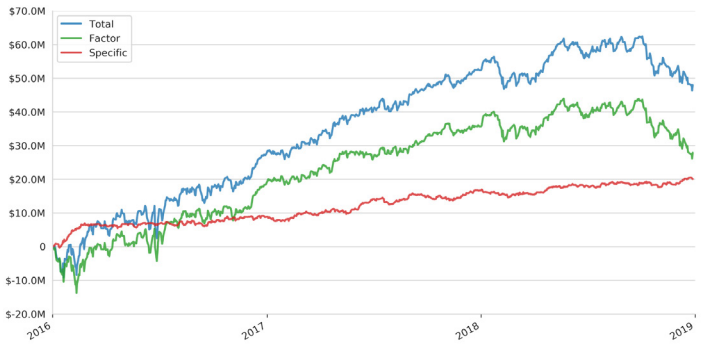


Exhibit 6: Factor Performance Breakdown of a $100M AUM Long-Only Portfolio
Source: RavenPack, May 2019

Portfolio exposures to traditional factors are relatively stable over the period - we can see from Exhibit 7 that the factor component of total portfolio risk ranges between 85-95%, which mainly comprises of broad market beta.

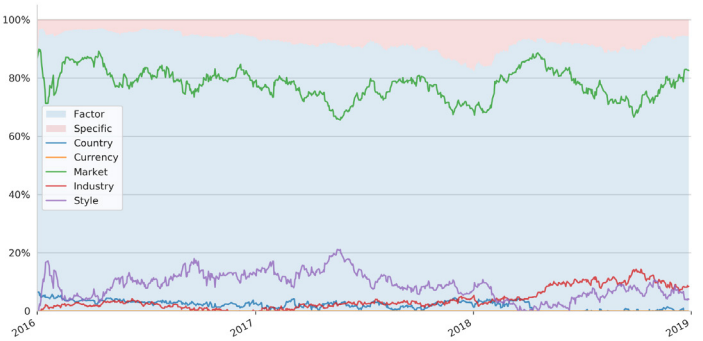


Exhibit 7: Factor Exposure Breakdown of a $100M Long-Only Portfolio
Source: RavenPack, May 2019

To get a better understanding for the high-level composition of the portfolio, we show top position concentrations in Exhibit 8. As can be observed, the portfolios are somewhat concentrated in the extremes with the Top 5 names accounting for about 25% of allocations. However, we still achieve a reasonable degree of diversification including the 40 names into our portfolio, with the Bottom 20 accounting for 30% of allocations.

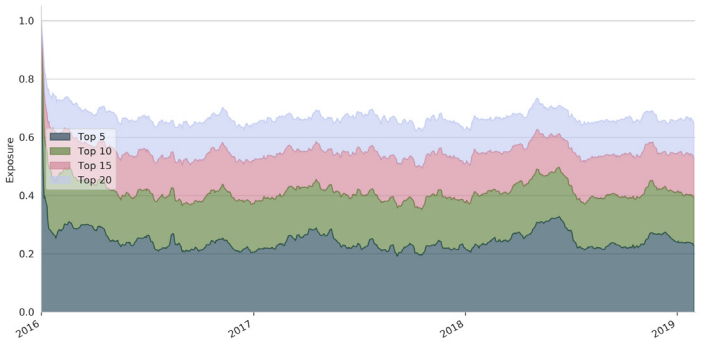


Exhibit 8: Top Position Concentrations Over Time
Source: RavenPack, May 2019

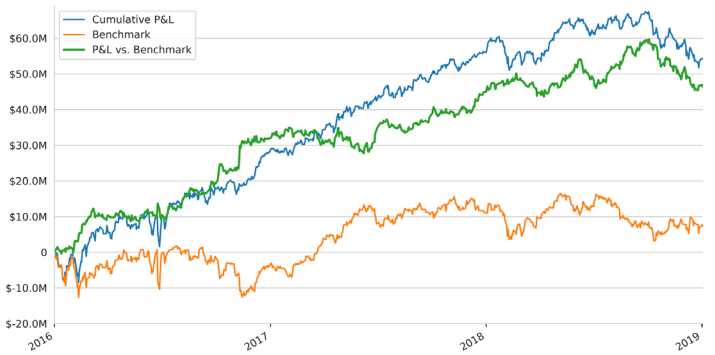


Exhibit 9: Performance of a $100M AUM Long-Only Portfolio with a 3-Day Liquidity Window.
Source: RavenPack, May 2019

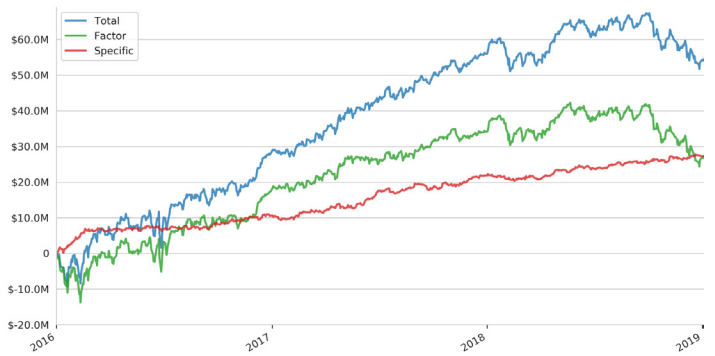


Exhibit 10: Factor Performance Breakdown of a %100M AUM Long-Only Portfolio with a 3-Day Liquidity Window.
Source: RavenPack, May 2019

In an effort to relax some of the liquidity constraints on the portfolio, we decided to examine what happens to performance if we increase the maximum allocation limit to 30% of the 21-day average trading volume from the initial 10%, while still limiting daily trading to 10% of the daily volume. This effectively allows for a 3-day liquidity window. The resulting long-only strategy produced an annualized return of 17.2% (accounting for 8bp one-way trading costs), with an Information Ratio of 1.2 and average holding period of close to three weeks. The market-neutral strategy, passively hedged via the fund's benchmark, produced a 12.9% annualized return with a 1.2 Information Ratio. Exhibit 8 shows cumulative gross P&L of the strategy (before trading costs) versus the benchmark.

The resulting specific return for this strategy was 8.8% before trading costs, with an Information Ratio of 2.2. Exhibit 10 shows the breakdown of factor and specific P&L, demonstrating a more robust alpha over time compared to the original strategy.

Exhibit 11 details the performance metrics for both strategies. Overall, expanding the liquidity window allow us to achieve not only higher returns, but also an improved risk-return trade-off, with the added benefit of reduced turnover.

Conclusion

In this paper, we highlight and uncover the hidden value within the private data assets of a fundamental hedge fund. We demonstrated that there is alpha to be captured in the sea of internal digital content by systematically extracting, structuring and enriching the fund's own content in real time to generate a tradeable investment strategy. The study found strong long-only signals that persist for several weeks, offering fundamental investors a reasonable time frame to act on them. Portfolio risk factor analysis shows stable P&L coming from idiosyncratic price moves, demonstrating persistent alpha generation from a traditional factor model perspective.

The scale of unstructured digital assets across organizations is immense and growing exponentially. Transforming this mountain of data into actionable insights is a real challenge, requiring a combination of reliable technological solutions and sound data science practices. The uniqueness of internal digital footprint within each organization provides an attractive way to harvest differentiated information not available elsewhere and capture incremental alpha that otherwise remains untapped.

Portfolio	Liquidity Window	Information Ratio	Cumulative P&L	Annualized Return (%)	Turnover (%)	Average Holding Period
Long-Only	1-day	0.8	$41.6M	12.3	10.3	~2-3 weeks
	3-day	1.2	$58.3M	17.2	6.8	~3 weeks
Long-Short	1-day	1.0	$34.8M	10.6	10.3	~2-3 weeks
	3-days	1.2	$43.3M	12.9	6.8	~3 weeks
Factor Hedged	1-day	1.6	$20.1M	6.4	-	-
	3-day	2.2	$27.2M	8.8	-	-
Benchmark	-	0.26	$6.8M	3.8	-	-

Exhibit 11: Performance Metric for a $100M Portfolio
Source: RavenPack, May 2019

Disclosure

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Endnotes

1. The fund uses a blend of 70% MSCI European Utilities Index and 30% MSCI European Transport and Infrastructure Index as a benchmark.
2. Using the Axioma European Medium-Term Factor Model.
3. Based on a constant $100M AUM and using trading costs of 16bp (two-way)
4. Zero trading costs and assuming a "perfect" factor hedge.

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"Peter is the head of data science at RavenPack. Since joining RavenPack in 2008, he's been a pioneer in the field of applied news analytics bringing alternative data insights to the world's top banks and hedge funds. Peter has more than 15 years of experience in quantitative finance with companies such as Standard & Poor's, Credit Suisse First Boston, and Saxo Bank.

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Gender Lens Investing

Julia Enyart
Glenmede

Gender lens investing can meet risk and return objectives and fiduciary duties of care and diligence. Several reports and studies highlight data that underpins the value of investing with diversity in mind, including:

- A 2017 study looked at executive team diversity in the teams of the S&P 1500 companies between 2001 and 2014 to find that diverse executive teams "dramatically outperform" firms with homogenous teams.
- A 2016 Credit Suisse study of over 3000 firms found that sales growth, EPS growth, and return on assets were all higher in companies where women occupied 50% or more of leadership positions.[1]
- In a study of Russell 1000 companies, we found that firms with greater gender diversity[2] outperformed with greater return and less risk.[3]
- Investors are increasingly considering gender diverse criteria as material in their investment analysis: asset managers representing $8 trillion in AUM supported several shareholder proposals on board diversity and voted against the re-election of a chair of a board's nominating committee with men-only boards.[4]

Institutional investors are more and more commonly looking at gender and diversity in the context of environmental, social, and governance (ESG) criteria. The 2018 US SIF trends report noted an increase of 8% in educational institutional assets that were subject to various ESG criteria from 2016 to 2018. The 2018 US SIF survey cites that the most prevalent social issue considered by educational institutions after conflict risk is equal opportunity and diversity, affecting $109 billion AUM, an 849% increase since 2016.5

One reason for this increased focus may be the increase in understanding by colleges and universities of the connections between their role as leaders in society, educators of the world's future leaders, and investors of endowment funds. As educational institutions, colleges, and universities are particularly well-suited to play a leading role in the gender lens investing space, especially given the power of higher education to create a necessary change in mindset, skills and values of government, business and other professional leaders.

Colleges and universities can leverage several tools and resources as they explore a gender lens investing approach to their investment strategies, including updating the investment policy statement, entering a dialogue with the investment consultant, investing and engaging across the landscape of gender lens products, and communicating progress. By doing so, colleges and universities can potentially drive corporate performance, downgrade investment risk, and reinvigorate a donor base by signaling to alumni, donors, students and faculty that the school fully embraces its educational mission.

Gender lens investing, a term first coined in 2009, recognizes the business dividend of paying attention to gender while meeting the risk and return objectives appropriate for an institutional portfolio.[6] Broadly speaking, gender lens investing integrates gender into financial analysis to get a better outcome.[7] In practice, gender lens, or gender smart investing, can be applied across a range of outcomes, including increasing women's access to capital, developing products and services beneficial to women and girls, and promoting diversity and equality throughout the workplace and value chain.

Increasingly, college and university endowments are exploring and implementing strategies for endowment portfolios to more closely align their investments with institutional mission and sustainability goals. One strategy to do so is to invest with a gender lens-- overlaying rigorous financial analysis with gender diverse characteristics, while still meeting the risk and return objectives appropriate for an institutional portfolio.

This primer explores the link between value creation and gender diverse companies; highlights the rising trend of colleges and universities moving towards mission aligned investing; and, outlines a diverse range of tools and investment strategies available to decision makers as they consider the integration of gender smart products in endowments. Finally, this primer acknowledges the branding and storytelling value of gender lens investing as colleges and universities continuously iterate on how to best grow their endowments and their positive impact.

Gender Lens Investing in the Context of Fiduciary Duty and Today's Capital Markets

Can gender lens investing meet performance requirements and the risk and return objectives of an institutional investor?

Several recent studies show that diverse teams deliver better results and can have a positive impact on financial performance. Companies with three or more female board members demonstrate a higher return on equity;[8] companies with more women in the C-suite are correlated with higher profitability;[9] and, the top third[10] of gender diverse companies have been associated with higher than average relative returns.[11] Given the performance benefits associated with gender diverse teams, it appears that companies who fail to integrate gender components into their investment decisions may risk losing financial value.

Additional reports and studies highlight data that underpins the value of investing with diversity in mind, reinforcing the merit of gender lens investing from several angles.

- **Diversity and team performance.** Incorporating more women increases the collective intelligence of a team. As more perspectives are included, more blind spots are avoided.[12] A 2017 study looked at executive team diversity in the teams of the S&P 1500 companies between 2001 and 2014 to find that diverse executive teams "dramatically outperform" firms with homogenous teams. Investing in diverse teams and divesting from companies with homogenous teams delivered a cumulative risk-adjusted return of 60%, yielding a Sharpe ratio[13] that dominated all other investment strategies considered.[14]
- **Diversity and financial performance.** Greater diversity has been shown to deliver stronger financial performance. A 2016 Credit Suisse study of over 3000 firms found that sales growth, EPS growth, and return on assets were all higher in companies where women occupied 50% or more of leadership positions.[15]
- **Gender and investing risk.** Gender-balanced teams are also associated with lower levels of risk. In a study of Russell 1000 companies, we found that firms with greater gender diversity[16] exhibited higher average return and less average risk than companies lacking diversity.[17] Credit Suisse found that women manage more for downside risk, rather than focusing more narrowly on absolute return like their male peers.[18]

More work to be done on the availability of gender equity data. Not all studies illustrate that outperformance can be achieved through gender diversity.[19] It is important to note that many financial studies have not been peer reviewed, but do employ replicable and reliable methodologies that will continue to be tested over time. Outside of these studies, academics and authors of financial literature can agree that the drivers of gender equity are more complex than simply board and management diversity, and we can expect to see a growing sophistication and depth of data collecting that will inform additional key parameters (e.g., pay parity, parental leave, total workforce diversity) in years to come.

Exhibit 1: U.S. Large Cap Stocks: Firms with Greater Gender Diversity Outperformed with Less Risk
Source: Glenmede Data through 12/31/2018
*Within the Russell 1000, we compare the companies with women in leadership attributes relative to the companies without women in leadership attributes from July 2009 through December 2017. If a company has any one of the following characteristics, they will be in the women in leadership universe: (1) Female CEO or Chair, (2) Greater than 20% women on board, and (3) Greater than 25% women in management. This is historical performance which may not be repeated. Actual results may differ materially. Although the information contained herein has been obtained from sources believed to be reliable, accuracy and completeness cannot be guaranteed.

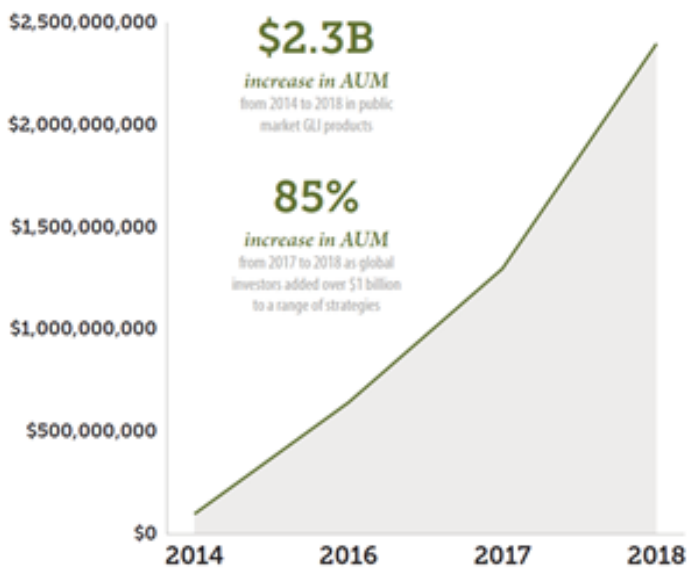


Exhibit 2: Public Market Gender Lens Investing Strategies Assets Under Management (AUM) as of June 30th
Source: Gender Lens Investing: Bending the Arc of Finance for Women and Girls," Veris Wealth Partners, 2018.

Availability of products with a gender mandate. Twenty years ago, products with an explicit gender mandate were almost nonexistent. In the period between 1993-2012, only five gender lens strategies existed in the public markets. From 2013 to 2018, at least 30 strategies have launched in the public markets, according to the 2018 Veris Wealth Partners report. That's, on average, five new investment options added per year, bringing the total value of investments in gender lens products in the public market to $2.4 billion.[20] Likewise, the growth of private market products with a gender mandate has been staggering. The 2019 Project Sage report estimates investment in gender lens products in the private markets amounted to a total value of $2.2 billion.[21] In 2018 alone, over $1 billion have been directed into gender lens funds, nearly doubling the amount of capital invested in gender lens products over the last 20 years combined.[22]

Can Gender Lens Investing Meet Fiduciary Duties of Care and Diligence?

Gender as a component of fiduciary duty. Given the potential materiality of a gender lens, large and small asset managers[23] are increasingly recognizing gender as a component of their fiduciary duty. In 2017, State Street and BlackRock, cumulatively representing $8 trillion in assets under management (AUM) supported several shareholder proposals on board diversity and voted against the re-election of board members responsible for appointing the members of all-male boards at companies they own shares of.[24] Positioning gender as a key component of sustainable investing, BlackRock asserts that more diverse teams draw upon alternative solutions, which "can ultimately lead to sustained value creation."[25]

Growth of robust data. As investors press for greater corporate disclosures and companies become more transparent, gender related data is increasingly available. This is evidenced by the surge in gender-specific data collected on publicly owned companies. One data provider ranks over 3000 companies not just by women in leadership, but also by gender pay parity, parental leave policies, and reports of sexual harassment.[26] To date, this data has informed and enabled the creation of over $600 million in investment products whose investable universe is defined by these specific, outcome-based data points.

Gender lens investing as a tool in portfolio construction. In addition to taking advantage of a strategy that research supports as prudent, colleges and universities that incorporate gender into their investment portfolios can also benefit from:

- **Diversification.** Endowments can mitigate risk by investing in gender diverse teams, shifting away from an investment portfolio dominated by companies with solely male boards and male dominated leadership.[27]
- **Transparency.** Implementing gender lens investing offers an opportunity to for greater transparency and thereby stronger governance practices in managing the endowment. Aligning endowments to the mission of the school helps to facilitate conversations between trustees, their financial advisors, and the school's community about the kinds of companies the school chooses to invest in, enabling a more transparent investment analysis process.
- **Fundraising.** Linking college and universities' endowments with their core mission can reinvigorate alumni communities and expand the donor base.

Is this consistent with what my peers are doing?

Higher education endowments are increasingly examining how their investments align with their institutional mission, values, and sustainability goals. College and university endowments in the United States have approximately $550 billion in AUM.[28] The 2018 US SIF trends report noted an increase of 8% in educational institutional assets that were subject to various ESG criteria from 2016 to 2018.[29] Of the ESG criteria considered by colleges and universities, diversity and inclusion issues are increasingly viewed as material. The 2018 US SIF survey cites that the most prevalent social issue considered by educational institutions after conflict risk is equal employment opportunity and diversity, affecting $109 billion AUM, an 849% increase since 2016.[30] Additionally, in 2018, more than 80 educational institutions had established committees on investor responsibility, compared to 40 in 2016.[31]

While 16% of the 809 participants in the 2017 NACUBO-Commonfund Study of Endowments reported including investments that rank high on ESG criteria,[32] higher education endowments are not yet actively investing their portfolios with a gender lens.

Integrating a gender lens into endowment strategies offers an opportunity to achieve competitive returns; invigorate the donor base; and not only educate women, but invest in them as well.

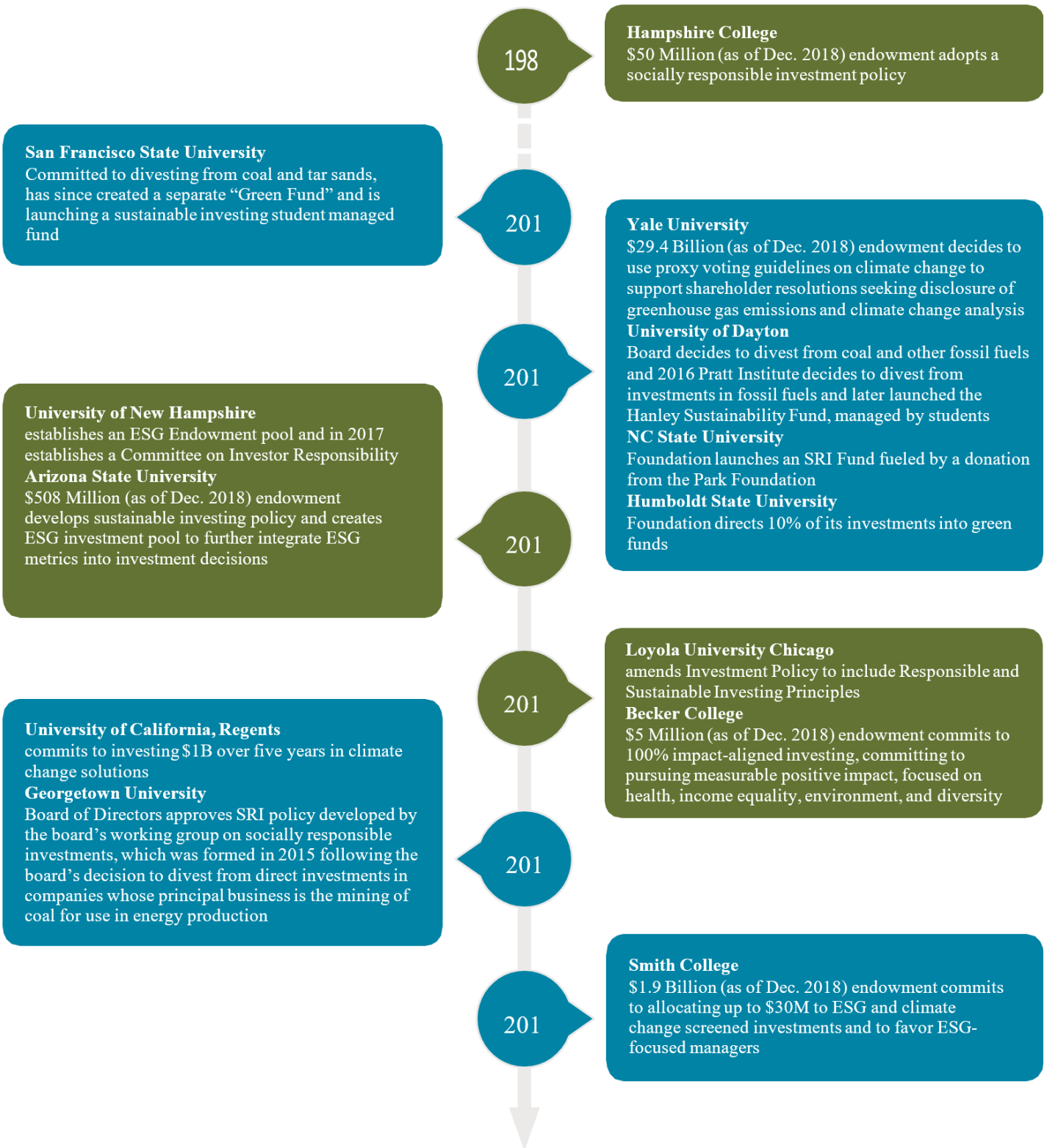
Gender Lens Investing in the Context of Higher Education's Mission

Women and girls represent half of the world's population, and yet gender inequality persists globally. Advancing gender equality is critical to all areas of a healthy society, from reducing poverty to promoting the health, education, protection and the well-being of girls and boys.[33] According to Project Drawdown, a book that identifies 100 substantive ways to reduce the pace of global warming over the next 30 years, one of the top 10 most impactful ways to reduce carbon globally is to educate girls.[34]

In 2016 women comprised more than 56 percent of students on campuses in the U.S., according to the U.S. Department of Education. Yet those female students will enter a workforce in which women earn approximately 80 cents on the dollar compared to men.[35] In the U.S. women are underrepresented on the boards of companies as well as the C-suite. In 2015, women and people of color constituted nearly 36 percent of the average board among the richest 100 companies by market cap, whereas they made up only 28 percent of executive officers.[36]

Colleges and universities can leverage their role as leaders in society, educators of the world's future leaders, and investors of non-taxed endowment funds to lead by example and not only educate, but invest in the 11.3 million female students they enroll in the U.S. each year.[37] As educational institutions, colleges and universities are particularly well-suited to play a leading role in the gender lens investing space, especially given the power of higher education to create a necessary change in mindset, skills and values of government, business and other professional leaders.

Higher Education Investment in Impact



How Can Colleges and Universities Invest with a Gender Lens?

Colleges and universities can leverage the tools and resources outlined below as they explore a gender smart approach to their investment strategies.

Update the Investment Policy Statement

The investment policy serves as a guideline for those responsible for managing the endowment assets, and sets clear goals and objectives related to sustainable investing. An investment policy statement that articulates the importance of gender lens investing and diversity can impact the types of investment vehicles considered by the endowment manager. For more information on articulating purpose in an investment policy, see Considerations for ESG Policy Development.[38]

Enter a Dialogue with Your Investment Consultant

Investment consultants can play a central role in incorporating gender lens investing into an endowment's investment strategy. In the 2017 Investment Consultant Services Review, the Principles for Responsible Investment (PRI) concluded that "investment consultants are unlikely to take action on ESG issues without stronger incentives to do so from their asset owner clients." For guidance on working with your investment consultant, see Hiring an Investment Consultant.[39]

Invest and Engage Across the Landscape of Gender Lens Products

Gender lens investing products continue to emerge, offering a viable and desirable investment strategy. Though some of the investable universe is constrained by a limited track record, major pension funds, banks, investment banks, endowments, and public sector actors are shifting capital in this direction. In 2019, a number of products with a gender lens mandate are available, spanning both the public and private markets.

Public Markets. In the public markets, gender lens investing vehicles exist across equity and fixed income. The 2018 Veris Wealth report identifies seven mutual funds, nine exchange traded fund (ETFs), three gender equality bond issues, one exchange traded note, and one certificate of deposit (CD) that employed one or more of the following gender lens investing strategies.[40]

- **Screening.** Within public equities, data is typically used to screen the universe of investable stocks to promote workplace equity across the portfolio.[41] Funds might employ positive screening, which involves investing in companies that meet certain environmental, social, and governance (ESG) criteria as determined by the investor, often looking to find "best in class" companies within a sector.[42] In the case of gender lens products, a portfolio might positively screen for companies meeting a quantified threshold of gender-related metrics. Another construction technique used in gender lens investing is negative screening, which excludes companies that do not meet a certain threshold set by the strategy. For example, a portfolio might exclude companies that don't have at least one woman on the board and at least one female executive.
- **Shareholder Engagement.** Active engagement via shareholder resolutions can promote workplace equity, pay transparency, and women on boards.

  In one example, active investor, Arjuna Capital, successfully pressed for gender pay disclosures at over 2 dozen US companies;[43] likewise, Pax World Votes voted against 170 board slates in the most recent proxy voting season due to insufficient gender diversity.[44]
- **Proxy Voting.** Proxy voting also serves an important tool in amplifying a shareholder's voice. Notably, in 2017 the proportion of shareholders voting in favor of board diversity resolutions averaged 31%, up from 26% in 2016.[45] A 2018 survey of corporate directors confirms gender diversity as a key board focus for the coming year.[46]

Private Markets. Private markets also carry an array of products with a gender mandate, spanning private equity and venture capital, debt, and angel funds. In some instances, private market vehicles can target higher impact and higher returns for investors with a longer time horizon, but are also defined by less liquidity, less transparency, and higher risk. Many college and university endowments hold private equity and venture capital in their portfolios as part of a diversification strategy, an opportunity to see more upside than one might find in public markets, and a recognition of the role of college and universities to fund innovation generated by on-campus incubators and research.

In the private markets, gender lens investing has been defined by three distinct approaches:

- **Funding access to capital.** A common strategy is funding female entrepreneurs or managers of investment funds to combat the structural challenges women face when seeking capital. Access to capital remains limited, despite evidence suggesting on par or better performance of women-owned businesses.[47]
- **Investing in women leaders.** A second approach is investing in companies with women leaders, or human resources benefits that enable greater female workforce participation.
- **Investing in women focused products and services.** A third angle is capitalizing on women's disproportionate share of consumer spending. This approach invests in products and services that target previously ignored needs of and enhance the quality of life for women (and often, correspondingly, for men.)[48]

Communicate Your Progress

Sharing progress publicly on gender lens investing activities can signal to alumni, donors, students and faculty that the school fully embraces its institutional mission. There are many ways to tell a positive investment story, including creating a case study, participating in an industry publication or event, reporting progress on the institution's website, earning recognition for the school and receiving guidance from organizations with expertise in sustainability, and joining investor initiatives. For additional guidance on how to communicate progress, see the last step in The Roadmap for Endowments.[49]

Conclusion

Colleges and universities are uniquely positioned to apply gender lens investing to their endowment portfolios, whether as one component of a broader sustainability strategy or employing a focused strategy around investing in companies with gender diverse characteristics. This primer has offered an overview of how gender lens investing meets the risk and return requirements- as well as standard of fiduciary care- for institutional investors, illustrated the central role that colleges and universities have played for decades in mission-aligned investing, and identified several tools and strategies across public and private markets where colleges and universities are particularly suited to lead.

As the investment committees of endowments are increasingly exposed to gender lens investing, they can consider a range of approaches to implementation.

By becoming a pioneer in gender lens investing now, colleges and universities can avoid potential investment risk and emerge as a leader in the field, presenting an institutional competitive edge when engaging with donors and applicants. Any college or university can begin to build traction by investing a sub-component of their endowment with a gender lens. Women's colleges, as well as schools with a sustainability-driven mission and who already recognize the risks and benefits of applying an ESG lens, could serve as pioneers in gender lens investing. ESG strategies with a strong gender focus can help to spark a longer-term conversation with the board, administration, students, and alumni as they engage stakeholders in a continuous learning process. Sharing progress publicly on gender lens investing can signal to alumni, donors, students and faculty that the school fully embraces its educational mission.

Endnotes

1. Julia Dawson, Richard Kersley, and Stefano Natella. "The CS Gender 3000: The Reward for Change."
2. Defined as 1) Female CEO or Chair, 2) greater than 20% women on the board, and 3) greater than 25% women in management.
3. Glenmede Investment Management, LLC. The Russell 1000 Index is an index of approximately 1,000 of the largest companies in the U.S. equity market.
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5. 2018 US SIF Report, p. 59.
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18. "The CS Gender 3000: The Reward for Change." Credit Suisse Research Institute, September 2016.
19. One Wharton meta-analysis of over 100 studies ("Does Gender Diversity on Boards Really Boost Company Performance?" by Katherine Klein) asserts that companies do not perform better when women are on the board, nor do they perform worse, arguing that evidence linking female representation and financial performance is not statistically significant. The Wharton study does recognize a small but positive link between female representation in leadership roles and long-term financial value creation.
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25. 2018 Annual Report. BlackRock Investment Stewardship. August 30, 2018. https:// www.blackrock.com/corporate/ literature/ publication/blk-annual-stewardship-report-2018.pdf.
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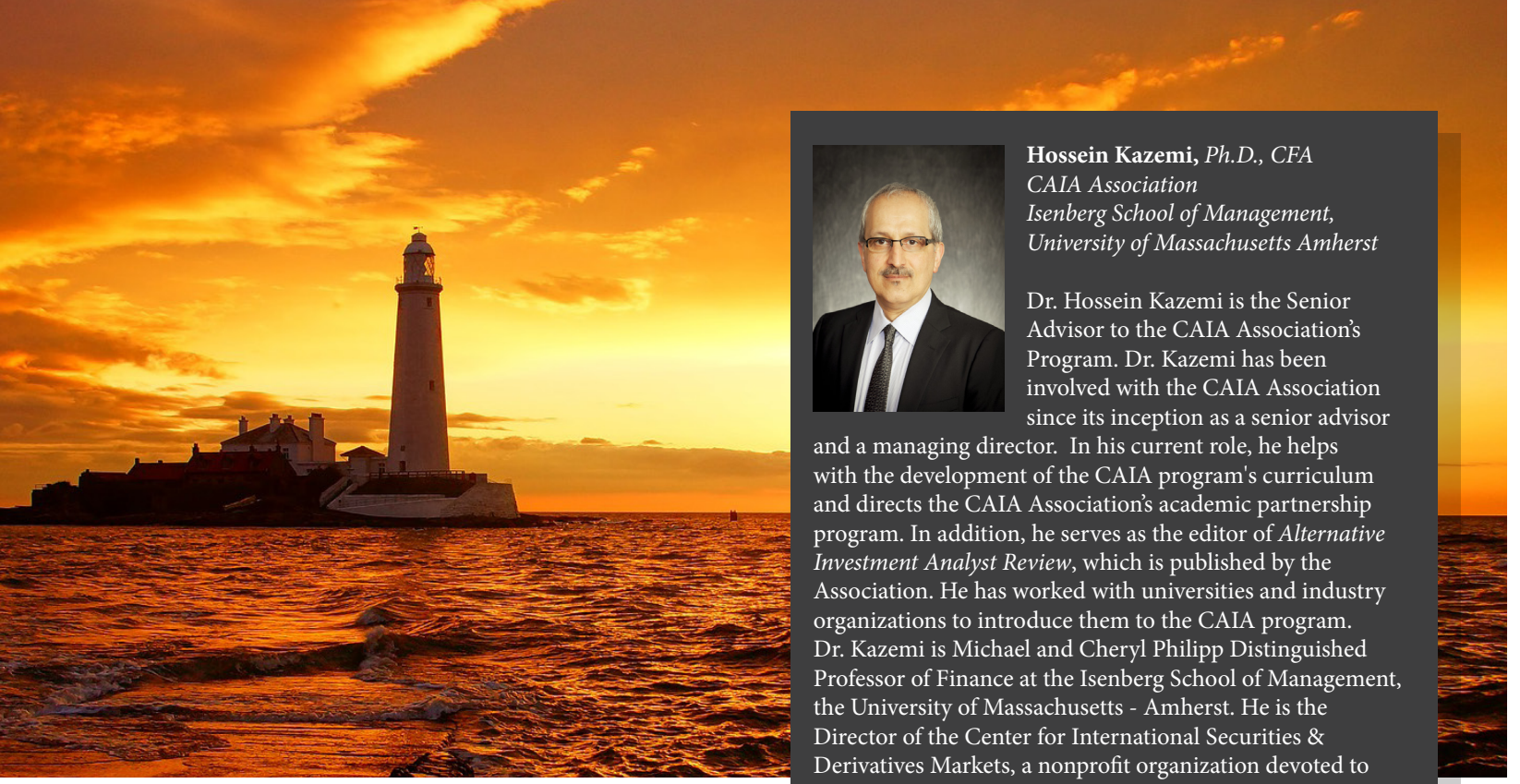

The CAIA Endowment Investable Index

Hossein Kazemi

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Pearl Quest

We present the historical weights, allocation as of month-end June 2019, and historical performance to the replication portfolio that was introduced in our AIAR publication Volume 6 Issue 1.

The graph on the following page shows the exposures of the Multi-Asset ETF portfolio through time. It is important to note that the volatility displayed by these exposures does not imply that endowments alter their asset allocations as frequently as the Multi-Asset ETF portfolio. While an endowment may hold a fixed allocation to various asset classes, the underlying assets/manager may display time-varying exposures to different sources of risk. For instance, a hedge fund manager may decide to increase her fund's exposure to energy stocks while reducing the fund's exposure to healthcare stocks. Though the endowment's allocation to that manager has remained unchanged, its exposures to energy and healthcare sectors have changed. Also, if returns on two asset classes are highly correlated, then the algorithm will pick the one that is less volatile. For instance, if returns on venture capital and small cap stocks are highly correlated, then the program will pick the small cap index if it turns out to be less volatile.

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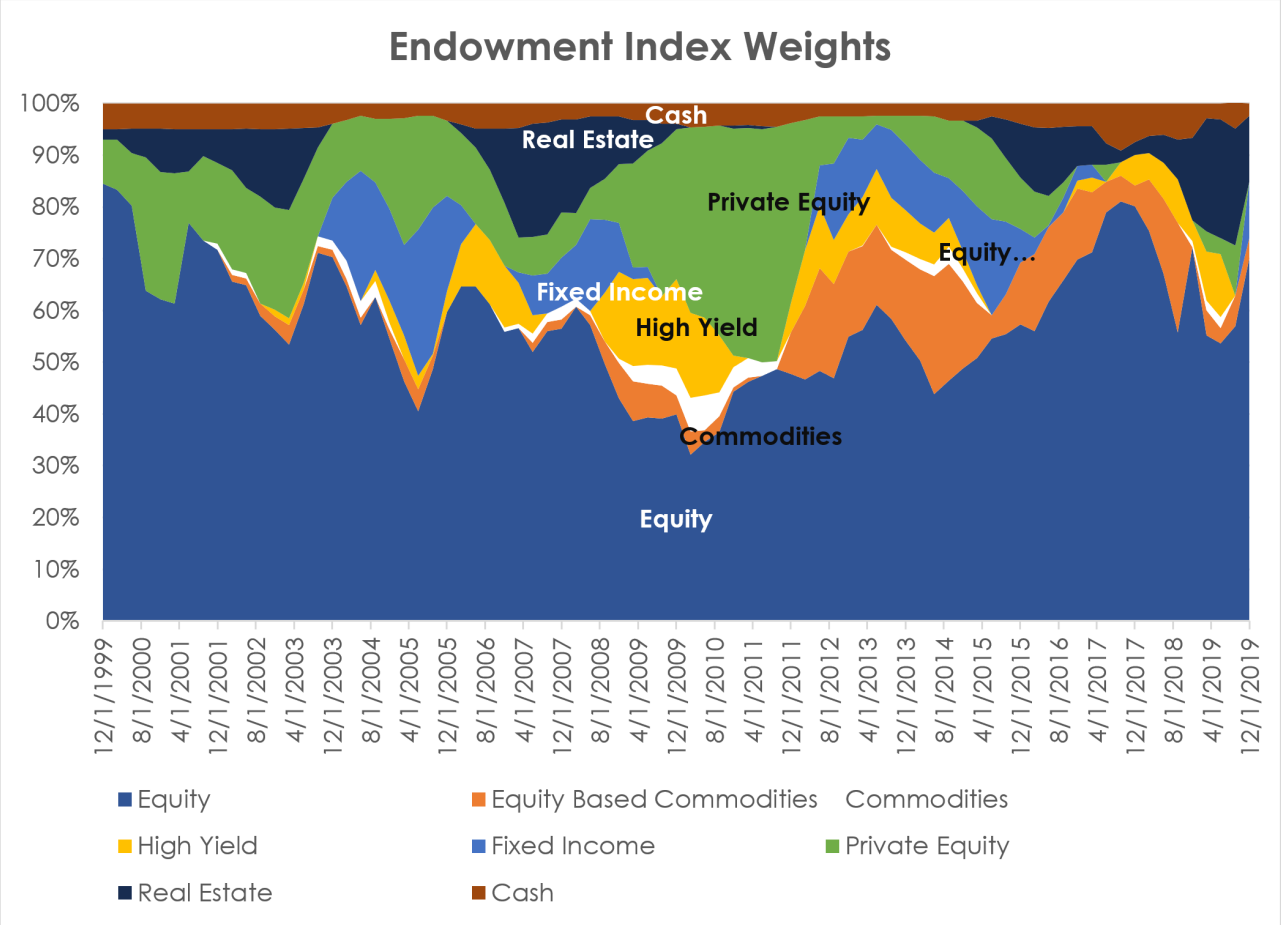
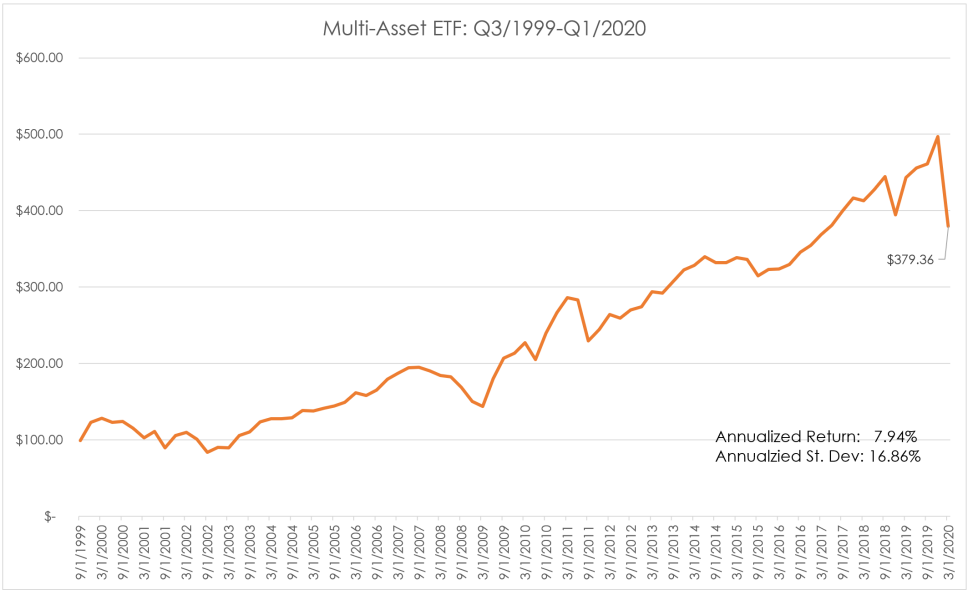


Allocations Suggested by Algorithm

iShares Russell 2000 ETF	MSCI World	Vanguard FTSE Emerging Markets ETF	Energy Select Sector SPDR® ETF	Financial Select Sector SPDR® ETF	Technology Select Sector SPDR® ETF	Health Care Select Sector SPDR® ETF	iShares Core US Aggregate Bond ETF	SPDR® Dow Jones Global Real Estate ETF	Cash
14%	35%	8%	4%	2%	7%	4%	11%	13%	2%

Historical Performance



The List: Alternative Indices

The performance table, on the following page, is a collection of both traditional and alternative indices for the 1, 5, and 10-year period annualized through June 2019. Both the annualized volatility and draw-down figures are calculated using a 10 year quarterly return series.

Alternative investments have been growing markedly over the past few years, creating a multitude of opportunities for owners and allocators alike. As the number and type of alternative asset classes continue to proliferate, we believe they are playing a more unique role in assisting investors achieve their desired investment outcomes. As we expect this trend to continue, we found it necessary to structure a pure alternative assets portfolio to have visibility in this exciting marketplace.

We set out to strike a balance between available assets in proportion to their market value, and to reflect the average "alternative investor". We defined the investment opportunity to simply be the following three assets classes: Real Asset, Private Equity/Venture Capital, and Hedge Funds. Real assets are comprised of real estate, commodities, timberland, farmland, and infrastructure; within real asset the weights were structured to reflect the market portfolio[1] within that universe. To arrive at our weight's, we researched various endowments and foundations, as well as surveys conducted by Willis Towers Watson and Russell Investments. Based on our research, alternative historical allocations have not had material deviation and therefore we decided to implement a market weight of 1/3 across each of those asset classes. A few of the constituents are not investable, and some may be reported gross or net of fee.

Ending December 2019

	Annualized Returns				Volatility	Max Drawdown	
	1 Yr	5 Yr	10 Yr	July 2008	10 Yr	10 Yr Max Drawdown	July 2008
MSCI World Free	27.67%	8.74%	9.47%	6.79%	13.01%	-16.61%	-41.61%
Barclays Global Aggregate	6.84%	2.31%	2.48%	2.86%	4.62%	-7.17%	-7.17%
MSCI Emerging Markets	18.42%	5.61%	3.68%	2.68%	17.16%	-23.90%	-47.11%
Barclays Global High Yield	12.56%	5.80%	7.26%	7.80%	6.82%	-8.27%	-26.20%
CISDM Equal-Weight Hedge Fund	11.37%	4.38%	4.62%	4.31%	4.92%	-7.84%	-17.95%
CISDM Equal-Weight CTA	16.87%	3.87%	4.31%	4.25%	7.67%	-7.94%	-7.94%
CISDM Distressed Securities	3.81%	2.59%	5.12%	4.59%	4.04%	-7.08%	-17.97%
CISDM Equity Long/Short	11.71%	4.09%	5.07%	4.68%	5.54%	-8.79%	-11.90%
Cambridge Associates US Private Equity*	17.82%	14.09%	15.07%	12.27%	4.77%	-5.10%	-30.79%
Cambridge Associates US Venture Capital*	29.14%	21.10%	24.83%	19.07%	15.26%	-5.10%	-30.79%
LPX Mezzanine Listed Private Equity	29.14%	7.23%	9.40%	2.50%	15.93%	-40.57%	-74.37%
FTSE NAREIT All Equity REITs	28.66%	8.43%	12.59%	9.04%	14.77%	-31.87%	-58.31%
NCREIF Property	6.42%	8.25%	10.17%	6.24%	1.67%	-16.86%	-23.88%
S&P Global Property	22.96%	6.87%	9.19%	6.59%	13.80%	-19.81%	-50.90%
S&P Global Infrastructure	26.99%	6.57%	7.73%	5.06%	12.10%	-15.95%	-43.75%
Bloomberg Commodity	7.69%	-3.92%	-4.73%	-8.27%	13.64%	-53.55%	-65.91%
NCREIF Timberland	1.29%	3.13%	4.44%	3.75%	3.03%	-5.69%	-5.69%
NCREIF Farmland	4.82%	7.02%	11.01%	10.97%	4.66%	0.00%	0.00%
Alternative Assets Portfolio	**13.02%**	**8.38%**	**10.03%**	**7.93%**	**4.39%**	**-3.56%**	**-17.18%**
Global 60/40 Portfolio	**18.02%**	**6.42%**	**7.04%**	**6.07%**	**8.41%**	**-9.52%**	**-21.96%**
60% Alternative / 40% Global 60/40	**15.02%**	**7.59%**	**8.83%**	**7.19%**	**5.49%**	**-5.95%**	**-21.20%**

NOTE: All returns are calculated using arithmetic mean

*Return Information Is Preliminary Reporting

Source: CAIA, CISDM, HFRI, Cambridge Associates and Bloomberg

1. Global Investment Capital Market by Hewitt EnnisKnupp, an Aon Company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