# A Century of Evidence on Trend-Following Investing

**Brian Hurst**
Principal

**Yao Hua Ooi**
Principal

**Lasse H. Pedersen, Ph.D.***
Principal

**Fall 2014**

## Executive Summary

We study the performance of trend-following investing across global markets since 1880, extending the existing evidence by more than 100 years. We find that trend following has delivered strong positive returns and realized a low correlation to traditional asset classes for more than a century. We analyze trend-following returns through various economic environments and highlight the diversification benefits the strategy has historically provided in equity bear markets. Finally, we evaluate the recent environment for the strategy in the context of these long-term results.[1]

*Brian Hurst and Yao Hua Ooi are at AQR Capital Management, and Lasse Heje Pedersen is at New York University, Copenhagen Business School and AQR Capital Management. We are grateful to Cliff Asness, John Liew, and Antti Ilmanen for helpful comments, and to Ari Levine, Haitao Fu, Vineet Patil, Jusvin Dhillon, and David McDiarmid for excellent research assistance.

[1] We originally published this paper in Fall 2012, and are now releasing an update due to the availability of additional historical data, which have allowed us to extend the backtest to 1880 and increase the number of assets in the sample at every point in time.

**AQR Capital Management, LLC**
Two Greenwich Plaza
Greenwich, CT 06830

p: +1.203.742.3600
f: +1.203.742.3100
w: aqr.com

## Section 1: Introduction

As an investment style, trend following has existed for a very long time. Some 200 years ago, the classical economist David Ricardo's imperative to "cut short your losses" and "let your profits run on" suggests an attention to trends. A century later, the legendary trader Jesse Livermore stated explicitly that the "big money was not in the individual fluctuations but in … sizing up the entire market and its trend."[2]

The most basic trend-following strategy is time series momentum — going long markets with recent positive returns and shorting those with recent negative returns. Time series momentum has been profitable on average since 1985 for nearly all equity index futures, fixed income futures, commodity futures and currency forwards.[3] The strategy explains the strong performance of Managed Futures funds from the late 1980s, when fund returns and index data first becomes available.[4]

This paper seeks to establish whether the strong performance of trend following is a statistical fluke of the last few decades or a more robust phenomenon that exists over a wide range of economic conditions. Using historical data from a number of sources, we construct a time series momentum strategy all the way back to 1880 and find that the strategy has been consistently profitable throughout the past 135 years.[5] We examine the strategy's decade-by-decade performance, its correlation to major asset classes and its performance in historical equity bull and bear markets. The wealth of data also provides context for evaluating the recent environment for the strategy. We consider the effect of increased assets in the strategy as well as the increased correlations across markets since the 2008 Global Financial Crisis. We also review a number of developments that are potentially favorable for the strategy going forward, such as lower trading costs, lower fees and an increasing number of tradable markets.

## Section 2: Constructing the Time Series Momentum Strategy

Trend-following investing involves going long markets that have been rising and going short markets that have been falling, betting that those trends continue. We create a time series momentum strategy that is simple, without many of the often arbitrary choices of more complex models. Specifically, we construct an equal weighted combination of 1-month, 3-month and 12-month time series momentum strategies for 67 markets across four major asset classes — 29 commodities, 11 equity indices, 15 bond markets and 12 currency pairs — from as far back as January 1880 to December 2013. Since not all markets have return data going back to 1880, we construct the strategies using the set of assets for which return data exist at each point in time. We use futures returns when they are available. Prior to the availability of futures data, we rely on cash index returns financed at local short-term interest rates for each country. Appendix A lists the markets that we consider and the source and length of historical return data used.[6]

For each of the three time series momentum strategies, the position taken in each market is determined by assessing the past return in that market over the relevant look-back horizon. A positive past return is considered an "up" trend and leads to a long position; a negative past return is considered a "down" trend and leads to a short position. Therefore, each strategy always holds either a long or short position in every market. Each position is sized to target the same amount of volatility, both to provide diversification and to limit the portfolio risk from any one market. The positions across the three strategies are aggregated each month and scaled such that the combined portfolio has an annualized ex ante volatility target of 10%.[7] The volatility scaling procedure ensures that the combined strategy targets a consistent amount of risk over time, regardless of the number of markets that are traded at each point in time.

---

[2] Ricardo's trading rules are discussed by Grant (1838) and the quote attributed to Livermore is from Lefèvre (1923).

[3] Moskowitz, Ooi and Pedersen (2012).

[4] Hurst, Ooi and Pedersen (2012).

[5] Our century of evidence for time series momentum complements the evidence that cross-sectional momentum (a closely related strategy based on a security's performance relative to its peers) has delivered positive returns in individual equities back to 1866 (Chabot, Ghysels and Jagannathan, 2009) and has worked across asset classes (Asness, Moskowitz and Pedersen, 2012).

[6] While we have attempted to create as realistic a simulation as possible, we are not claiming that this strategy would have been implementable as described back in the 1880s. Modern day financing markets didn't exist then, nor did equity index and bond futures markets which are simulated in this study. The commodities data throughout is based on traded commodities futures prices and is therefore the most realistic, and by the 1980s most of the returns are based on futures prices. The main point of the study is to show that markets have exhibited statistically significant trends for well over a century.

Finally, we subtract transaction costs and fees. Our transaction cost estimates are based on current estimates of average transaction costs in each of the four asset classes, as well as an estimate of how much higher transaction costs were historically compared with the present, based on Jones (2002). To simulate fees, we apply a 2% management fee and a 20% performance fee subject to a high-water mark, as is typical for Managed Futures managers.[8] Details on transaction costs and fee simulations are given in Appendix B. Our methodology follows that of Moskowitz, Ooi and Pedersen (2012) and Hurst, Ooi and Pedersen (2012). These authors find that time series momentum captures well the performance of the Managed Futures indices and manager returns, including the largest funds, over the past few decades when data on such funds exists.

## Section 3: Performance Over a Century

Exhibit 1 shows the performance of the time series momentum strategy over the full sample since 1880 as well as for each decade over this time period. We report the results net of simulated transaction costs, and consider returns both before and after fees.

### Exhibit 1 — Hypothetical Performance of Time Series Momentum

**Strategy performance after simulated transaction costs both gross and net of hypothetical 2-and-20 fees.**

| Time Period | Gross of Fee Returns (Annualized) | Net of 2/20 Fee Returns (Annualized) | Realized Volatility (Annualized) | Sharpe Ratio, Net of Fees | Correlation to U.S. Equity Market | Correlation to US 10-year Bond Returns |
|---|---|---|---|---|---|---|
| **Full Sample** | | | | | | |
| Jan 1880-Dec 2013 | 14.9% | 11.2% | 9.7% | 0.77 | 0.00 | -0.04 |
| **By Decade** | | | | | | |
| Jan 1880-Dec 1889 | 9.1% | 6.5% | 9.5% | 0.27 | -0.11 | -0.04 |
| Jan 1890-Dec 1899 | 14.0% | 10.4% | 8.9% | 0.73 | -0.02 | -0.15 |
| Jan 1900-Dec 1909 | 10.2% | 7.5% | 9.6% | 0.34 | 0.02 | -0.35 |
| Jan 1910-Dec 1919 | 8.3% | 5.7% | 12.6% | 0.13 | 0.12 | -0.01 |
| Jan 1920-Dec 1929 | 17.2% | 13.1% | 8.4% | 1.09 | 0.15 | 0.06 |
| Jan 1930-Dec 1939 | 10.4% | 6.9% | 8.6% | 0.74 | -0.11 | 0.20 |
| Jan 1940-Dec 1949 | 15.4% | 10.9% | 10.6% | 0.99 | 0.33 | 0.31 |
| Jan 1950-Dec 1959 | 19.6% | 15.1% | 9.0% | 1.45 | 0.23 | -0.19 |
| Jan 1960-Dec 1969 | 13.5% | 10.0% | 10.9% | 0.56 | -0.09 | -0.37 |
| Jan 1970-Dec 1979 | 26.7% | 21.3% | 9.0% | 1.70 | -0.24 | -0.25 |
| Jan 1980-Dec 1989 | 22.0% | 17.8% | 9.5% | 0.96 | 0.18 | -0.16 |
| Jan 1990-Dec 1999 | 17.2% | 13.2% | 8.5% | 0.98 | 0.01 | 0.21 |
| Jan 2000-Dec 2013 | 11.3% | 7.9% | 9.6% | 0.62 | -0.30 | 0.25 |

Source: AQR. Time Series performance is hypothetical as described above. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Past performance is not a guarantee of future performance. U.S. Equity Market: (Prior to 1926, the U.S. Equity series was constructed by adding price-weighted capital appreciation returns of NYSE stocks collected by Goetzmann, Ibbotson, and Peng to U.S. equity dividend returns recorded by the Cowles commission. The series consists of returns of the S&P 90 from 1926 to 1957 and returns of the S&P 500 from 1957 onwards.)

---

[7] A simple covariance matrix estimated using rolling 3-year (equally weighted) monthly returns is used in the portfolio volatility scaling process.

[8] While a 2/20 fee structure has been commonplace in the industry, some managers charged higher management and performance fees in earlier time periods. On the other hand, there are also managers that charge lower fees for the strategy today.

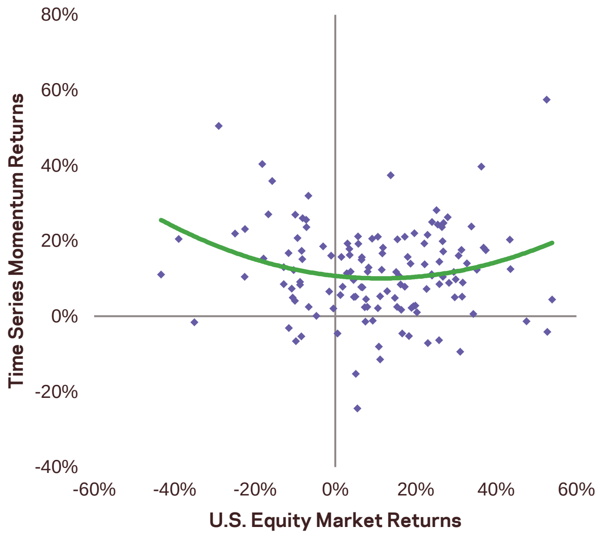
The performance has been remarkably consistent over an extensive time horizon that includes the Great Depression, multiple recessions and expansions, multiple wars, stagflation, the Global Financial Crisis and periods of rising and falling interest rates. Some skeptics argue that managed futures has benefited mainly from a long secular decline in interest rates. While the strategy did perform well over the past 30 years, the best-performing decade for the strategy was the 1970s, when U.S. 10-year Treasury yields rose from 7.8% to 11.1% with extreme volatility in between.

Our long-term out-of-sample evidence suggests that it is unlikely that such price trends are a product of statistical randomness or data mining. Indeed, the first 10 decades of data is out-of-sample evidence relative to the literature, and the performance remains strong during this period. Trends appear to be a pervasive characteristic of speculative financial markets over the long term. Trend-following strategies perform well only if prices trend more often than not. A large body of research[9] has shown that price trends exist in part due to long-standing behavioral biases exhibited by investors, such as anchoring and herding, as well as the trading activity of non-profit-seeking participants, such as central banks and corporate hedging programs. For instance, when central banks intervene to reduce currency and interest-rate volatility, they slow down the rate at which information is incorporated into prices, thus creating trends. The fact that trend-following strategies have performed well historically indicates that these behavioral biases and non-profit-seeking market participants have likely existed for a long time.

The returns to the strategy have exhibited low correlations to stocks and bonds over the full time period, as well as in most subperiods, as shown in Exhibit 1. Even more impressively, the strategy has performed best in large equity bull and bear markets. Exhibit 2 shows the annual hypothetical returns to the strategy, plotted against the returns to the U.S. equity market from 1880–2013. The "smile" shows that trend following has done particularly well in extreme up or down years for the stock market. This strong performance in bear markets over the century extends the evidence that has been documented since the 1980s, as exemplified most recently with the strong performance of trend following during the Global Financial Crisis.

**Exhibit 2 — Time Series Momentum "Smile"**

**The annual net of fee returns of a time series momentum strategy versus U.S. Equity Market Returns, 1880-2013**



Source: AQR. Time Series performance is hypothetical as described above. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Past performance is not a guarantee of future performance.

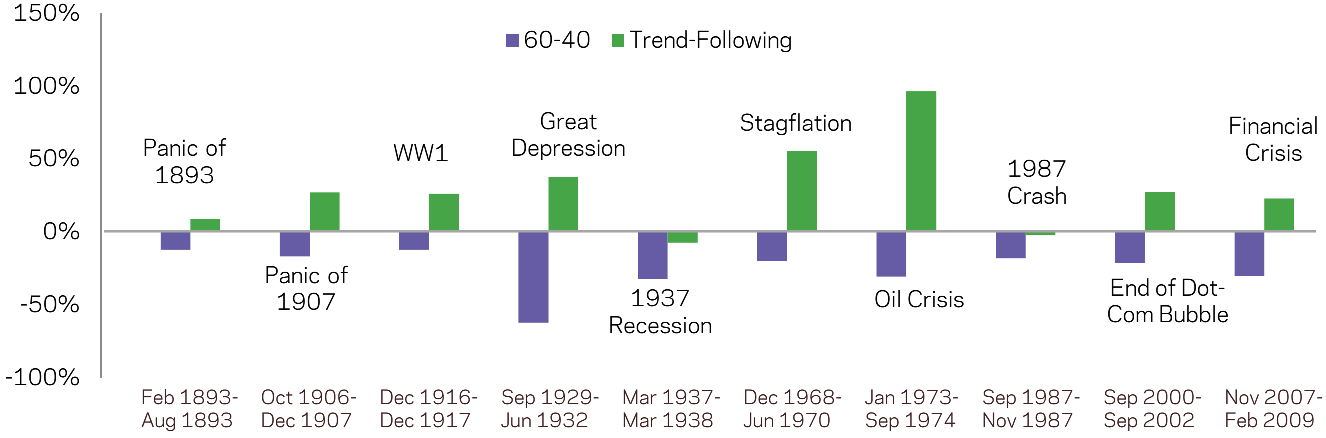
As another way to evaluate the diversifying properties of trend following during extreme events, we consider the performance during peak-to-trough drawdowns for the typical 60/40 portfolio.[10] Exhibit 3 shows the performance of the time series momentum strategy during the 10 largest

---

[9] Barberis, Shleifer and Vishny (1998), Daniel, Hirshleifer, Subrahmanyam (1998), De Long et al. (1990), Hong and Stein (1999) and Frazzini (2006) discuss a number of behavioral tendencies that lead to the existence of price trends.

[10] The 60/40 portfolio has 60% of the portfolio invested in the U.S. Equity Market and 40% invested in U.S. 10-year government bonds. The portfolio is rebalanced to the 60/40 weights at the end of each month, and no fees or transaction costs are subtracted from the portfolio returns.

## Exhibit 3 — Total Returns of U.S. 60/40 Stock/Bond Portfolio and Time Series Momentum in the 10 Worst Drawdowns for 60/40 between 1880 and 2013



Source: AQR. Time Series performance is hypothetical as described above. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. The 60/40 portfolio has 60% of the portfolio invested in the U.S. Equity Market and 40% invested in U.S. 10-year bonds. Past performance is not a guarantee of future performance.

drawdowns experienced by the traditional 60/40 portfolio over the past 135 years. We see that the time series momentum strategy experienced positive returns in 8 out of 10 of these stress periods and delivered significant positive returns during a number of these events. The valuable hedging benefits that trend-following strategies delivered during the 2007–2009 Global Financial Crisis do not look unusual when you consider how the strategy has behaved in other deep equity bear markets.

Why have trend-following strategies tended to do well in bear markets? The intuition is that most bear markets have historically occurred gradually over several months, rather than abruptly over a few days, which allows trend followers an opportunity to position themselves short after the initial market decline and profit from continued market declines. In fact, the average peak-to-trough drawdown length of the 10 largest 60/40 drawdowns between 1880 and 2014 was approximately 15 months.

Given the attractive returns and diversifying characteristics of a time series momentum strategy, allocating to one would have significantly improved a traditional portfolio's performance over the past 135 years. Specifically, Exhibit 4 shows the simulated effect of allocating 20% of the capital from a 60/40 portfolio to the time series momentum strategy. We see that such an allocation would have helped reduce the maximum portfolio drawdown, lowered portfolio volatility and increased portfolio returns.

## Exhibit 4 — Diversifying 60/40 with an Allocation to Time Series Momentum

**Performance characteristics of the 60/40 portfolio and a portfolio with 80% invested in the 60/40 portfolio and 20% invested in the time series momentum strategy, from January 1880 to December 2013**

| | Annualized Net of Fee Return | Annualized Realized Vol | Max Drawdown | Net of Fee Sharpe Ratio |
|---|---|---|---|---|
| 60/40 Portfolio | 7.8% | 10.8% | -62.3% | 0.38 |
| 80% 60/40 Portfolio, 20% Time Series Momentum Strategy | 8.5% | 8.8% | -50.2% | 0.54 |

Source: AQR. Time Series performance is hypothetical as described above. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. The 60/40 portfolio has 60% of the portfolio invested in the U.S. Equity Market and 40% invested in U.S. 10-year bonds. Past performance is not a guarantee of future performance

## Exhibit 5 — The 10 Largest Drawdowns of Time Series Momentum between 1880 and 2013

**The 10 largest peak-to-trough drawdowns of the time series momentum strategy, calculated using net of fee returns**

| Rank | Start of Drawdown (Peak) | Lowest Point of Drawdown (Trough) | End of Drawdown (Recovery) | Size of Peak-to-Trough Drawdown | Peak-to-Trough Length (Months) | Trough-to-Recovery Length (Months) | Peak-to-Recovery Length (Months) |
|---|---|---|---|---|---|---|---|
| 1 | Aug 1947 | Dec 1948 | May 1951 | -26.3% | 16 | 29 | 45 |
| 2 | Feb 1937 | Jun 1940 | May 1943 | -25.3% | 40 | 35 | 75 |
| 3 | Apr 1912 | Jan 1913 | Aug 1914 | -23.9% | 9 | 19 | 28 |
| 4 | Mar 1918 | Feb 1919 | Mar 1920 | -21.4% | 11 | 13 | 24 |
| 5 | Jun 1964 | Aug 1965 | Dec 1965 | -17.1% | 14 | 4 | 18 |
| 6 | Aug 1966 | May 1967 | Apr 1968 | -15.2% | 9 | 11 | 20 |
| 7 | Apr 1885 | Jan 1887 | Aug 1887 | -14.9% | 21 | 7 | 28 |
| 8 | Feb 1904 | Jul 1904 | Jan 1907 | -14.7% | 5 | 30 | 35 |
| 9 | Aug 1896 | Jun 1898 | Jan 1899 | -14.6% | 22 | 7 | 29 |
| 10 | Dec 1899 | Oct 1900 | Mar 1901 | -13.5% | 10 | 5 | 15 |

Source: AQR. Time Series performance is hypothetical as described above. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix. Past performance is not a guarantee of future performance.

## Section 4: Strategy Outlook

While trend-following strategies have performed well over the past 135 years and during the Global Financial Crisis of 2008, the returns have been mixed since 2008, which raises several questions regarding the future outlook for the strategy. First, the assets under management in these strategies have grown rapidly over the past two decades and competition could potentially lower future returns. Second, over the past several years there has been a lack of clear trends — and even a number of sharp trend reversals — which raises the question of whether the current economic environment is simply worse for the strategy. We try to evaluate each of these issues in turn.

To evaluate the effect of increased assets in the strategy, consider BarclayHedge's estimate that the assets managed by systematic trend followers has grown from $22 billion in 1999 to over $280 billion in 2014.[11] While this growth is substantial, the size of the underlying markets has also grown over the past decade. We estimate that the aggregate size of positions held by trend followers remains a small fraction of the markets that they are invested in. If we assume that all trend-following managers employ the identical simple strategy we described, the average positions held would amount to approximately 0.2% of the size of the underlying equity markets, 2% of the underlying bond markets, 6% of the underlying commodity markets and 0.4% of the underlying currency markets.[12] Appendix C provides details on the data used to estimate the aggregate size of the different markets. Even with the significant growth in assets under management, trend followers appear to remain a modest fraction of the markets that they invest in.

Following very strong performance in 2008, trend-following strategies have experienced a few drawdowns since 2008. Does this recent performance imply that the environment today is meaningfully worse for trend-following investing? Exhibit 5 shows the 10 largest historical drawdowns experienced by the strategy since 1880, including the amount of time the strategy took to realize and recover from each drawdown. We compute the drawdown as the percentage loss since the strategy reached its highest-ever cumulative return (its high-water mark). When evaluated in this long-term context, the drawdowns experienced within the past several years do not look unusually large. While recent strategy performance has been disappointing, we do not find any evidence that the recent environment has been anomalously poor for the strategy relative to history.

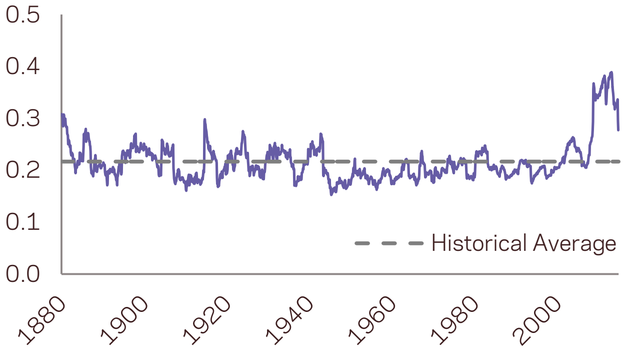
---

[11] www.barclayhedge.com.

[12] Based on correlation analysis, we estimate that only about half of the $280 billion dollars BarclayHedge attributes to systematic trend followers are in funds primarily pursuing time series momentum. For example, one company manages two funds that are not focused on trend following which represent over $100B of this AUM figure. The percentage of underlying markets occupied by trend-followers is therefore likely to be meaningfully lower than the numbers cited here.

While the performance of trend-following investing over the past few years does not appear to be outside the normal range, it is also useful to consider the potential effects the current economic environment may have on the strategy. For several years following the Global Financial Crisis, the "risk-on/risk-off" macroeconomic environment led to higher correlations both within and across asset classes. Exhibit 6 plots the average pairwise correlation across all the markets used in our strategy, showing how correlations increased meaningfully across markets after 2007, when the crisis began. As markets became more correlated, the strategy had fewer available independent trends to profit from, potentially lowering its risk-adjusted returns, as was true for many investment strategies.

**Exhibit 6 — Average Pairwise Asset Correlations**



Source: AQR. Pairwise Correlation is based on the average absolute rolling 36-month pairwise correlations for the assets used in the hypothetical Time Series Momentum Strategy. Time Series performance is hypothetical as described above. Hypothetical data has inherent limitations, some of which are disclosed in the Appendix.

However, there are a number of positive developments that could benefit the strategy going forward. First, while correlations have been high recently, they appear to be returning to more normal levels. In fact, more high-frequency estimates of correlations signal that correlations are already back in the normal range (these estimates are not shown). Second, even if the major markets remain more correlated than in the past, there are now considerably more markets to diversify among than throughout most of history, which should benefit trend following. For example, trend followers can now invest in emerging equity markets and emerging currency markets, which are much more liquid than they were in the past.

Third, more competition among market makers in the equity markets has vastly reduced transaction costs.[13] In currency and futures markets, market maker competition has increased as well. This should continue to help reduce trading costs going forward for managers willing and able to invest in the proper trading infrastructure. In addition, investors can now access these strategies at lower fees than the 2 and 20 fee structure we assumed in our strategy returns.

Fourth, the strategy's attractive diversification characteristics continue to make it a potentially valuable addition to a traditional portfolio even we ignore the positive developments and assume that the future Sharpe ratio will be lower than historically observed. For instance, suppose that the strategy only realizes a Sharpe ratio of 0.4 net of fees and transaction costs, such that strategy returns are half as large as what we have observed historically. Even with this conservative assumption, allocating 20% of a 60/40 portfolio to trend-following would still be beneficial. Over the 1880 to 2013 period, such an allocation would have left portfolio returns unchanged, lowered portfolio volatility from 11% to 9%, increased the overall portfolio's Sharpe ratio from 0.38 to 0.46, and reduced the maximum drawdown from 62% to 51% relative to a 60/40 portfolio.[14]

---

[13] Weston (2000), O'Hara and Ye (2009).

Lastly, while the example above assumes that the 60/40 portfolio will perform as well as it has historically, given the current low real yield on bonds and the high valuation of stocks, there are strong reasons to believe that the 60/40 portfolio will not perform as well going forward, which further makes the case for allocating a portion of one's portfolio to trend following.

## Section 5: Conclusion

Trend-following investing has performed consistently over more than a century, as far back as we can get reliable return data for several markets. Our analysis provides significant out-of-sample evidence beyond the substantial evidence already in the literature (Moskowitz, Ooi and Pedersen, 2012). This consistent long-term evidence suggests that trends are pervasive features of global markets.

The most likely candidates to explain why markets have tended to trend more often than not include investors' behavioral biases, market frictions, hedging demands, and market interventions by central banks and governments. Such market interventions and hedging programs are still prevalent, and investors are likely to continue to suffer from the same behavioral biases that have influenced price behavior over the past century, setting the stage for trend-following investing going forward.

Despite well over a century of very strong performance for trend-following investing and the continued presence of biases and interventions, the strategy's expected return going forward may nevertheless be hurt by several factors: increased assets under management in the strategy, high fees and higher correlations across markets. However, the returns to investing in the strategy can be improved if asset managers offer lower fees, invest in trading infrastructure and strategy implementation that reduce transaction costs, and obtain broader diversification by expanding the set of tradable futures and forward contracts. The diversification benefits of the strategy remain strong and we think offer a compelling case for a modest allocation in an investor's portfolio.

---

[14] Here we assume that the return distribution of the 60/40 portfolio is as in the past century while time series momentum returns are lowered by a constant amount such that returns average half of what they actually delivered.

## Appendix A: Markets and Data Sources

We use historical returns data from the following 67 markets in order to construct the time series momentum strategy:

### Equity Indices

The universe of equity index futures consists of the following 11 developed equity markets: SPI 200 (Australia), S&P/TSE 60 (Canada), CAC 40 (France), DAX (Germany), FTSE/MIB (Italy), TOPIX (Japan), AEX (Netherlands), IBEX 35 (Spain), FTSE 100 (U.K.), Russell 2000 (U.S.) and S&P 500 (U.S). Futures returns are obtained from Datastream and Bloomberg. We use MSCI country level index returns and returns from Ibbotson, Global Financial Data (GFD) and the Yale School of Management prior to the availability of futures returns.

### Bond Indices

The universe of bond index futures consists of the following 15 developed bond markets: Australia 3-year bond, Australia 10-year bond, Euro Schatz (2-year), Euro Bobl (5-year), Euro Bund (10-year), Euro Buxl (30-year), Canada 10-year bond, Japan 10-year bond (TSE), Long Gilt, U.S. 2-year Note, Italian 10-year bond, French 10-year bond, U.S. 5-year note, U.S. 10-year note and U.S. long bond. Futures returns are obtained from Morgan Markets and Bloomberg. We use country level cash bond returns from Datastream, Ibbotson and Global Financial Data (GFD) prior to the availability of futures returns. We scale monthly returns from GFD and Ibbotson to a constant duration of 4 years, assuming a duration of 2 years for the U.S. 2-year note, 4 years for the U.S. 5-year note and German REX Index, 20 years for the U.S. long bond and 7 years for all other bonds.

### Currencies

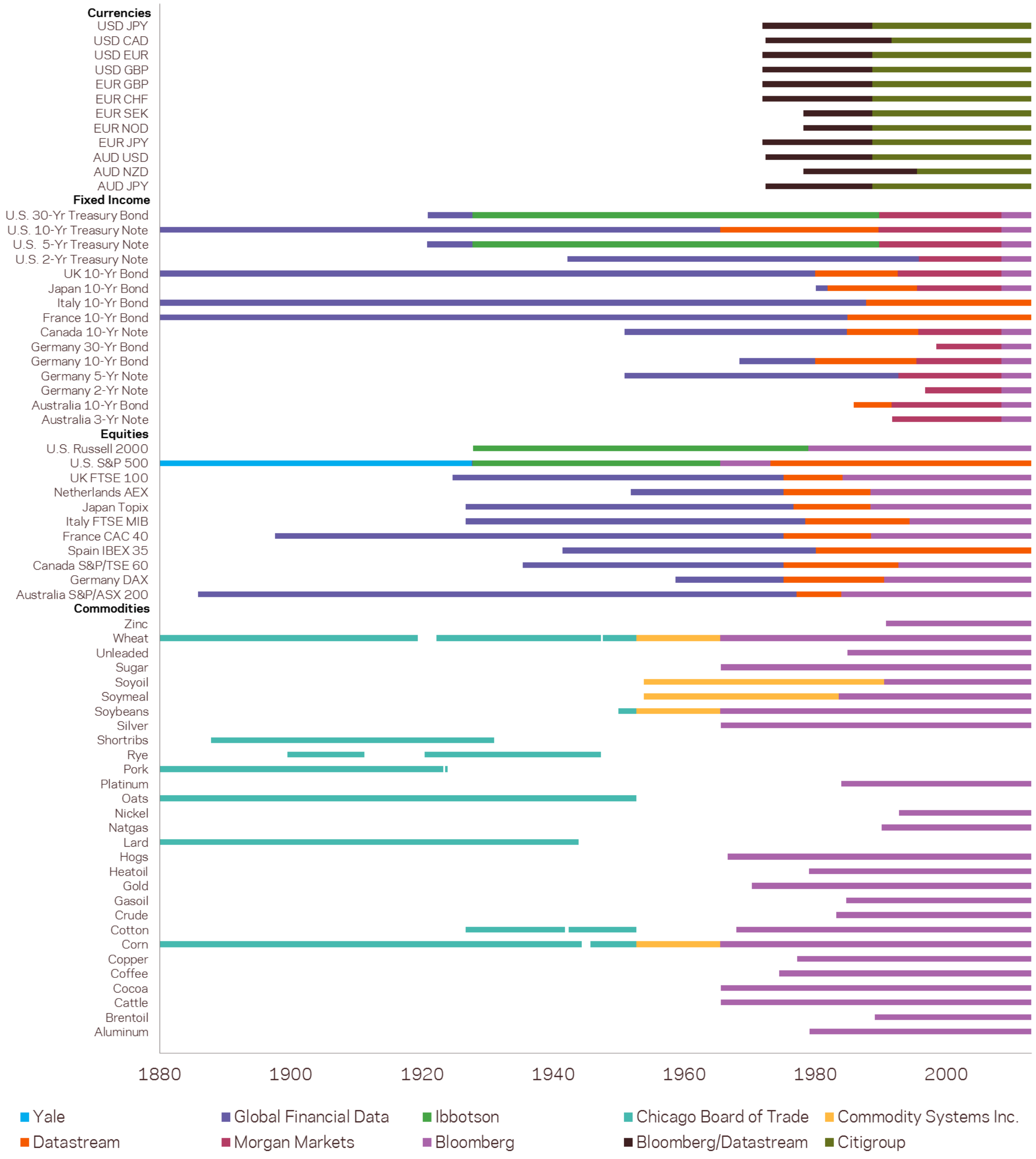
The universe of currency forwards covers the following 10 currencies: Australian dollar, Canadian dollar, German mark spliced with the euro, Japanese yen, New Zealand dollar, Norwegian krone, Swedish krona, Swiss franc, British pound and U.S. dollar. We use spot and forward interest rates from Citigroup to calculate currency returns going back to 1989 for all the currencies except for CAD and NZD, which go back to 1992 and 1996. Prior to that, we use spot exchange rates from Datastream and LIBOR short rates from Bloomberg to calculate returns.

### Commodities

We cover 29 different commodity futures. Where available, we use futures price data from Bloomberg. For periods before Bloomberg data is available, we use futures prices from Commodity Systems Inc. and historical records of the Chicago Board of Trade.

## Appendix A: Markets and Data Sources

The following chart shows the length and source of data for each individual market (1880–2013):



## Appendix B: Simulation of Fees and Transaction Costs

In order to calculate net-of-fee returns for the time series momentum strategy, we subtracted a 2% annual management fee and a 20% performance fee from the gross-of-fee returns to the strategy. The performance fee is calculated and accrued on a monthly basis, but is subject to an annual high-water mark. In other words, a performance fee is subtracted from the gross returns in a given year only if the returns in the fund are large enough that the fund's NAV at the end of the year exceeds every previous end of year NAV.

The transactions costs used in the strategy are based on AQR's 2012 estimates of average transaction costs for each of the four asset classes, including market impact and commissions. The transaction costs are assumed to be twice as high from 1993 to 2002 and six times as high from 1880-1992, based on Jones (2002). The transaction costs used are as follows:

| Asset Class | Time Period | One-Way Transaction Costs (as a % of notional traded) |
|---|---|---|
| Equities | 1880-1992 | 0.34% |
| | 1993-2002 | 0.11% |
| | 2003-2013 | 0.06% |
| Bonds | 1880-1992 | 0.06% |
| | 1993-2002 | 0.02% |
| | 2003-2013 | 0.01% |
| Commodities | 1880-1992 | 0.58% |
| | 1993-2002 | 0.19% |
| | 2003-2013 | 0.10% |
| Currencies | 1880-1992 | 0.18% |
| | 1993-2002 | 0.06% |
| | 2003-2013 | 0.03% |

## Appendix C: Estimation of the Size of Managed Futures Positions Relative to Underlying Markets

The 2014 estimate of assets under management in the BarclayHedge Systematic Traders index is $280 billion. We looked at the average monthly holdings in each asset class (calculated by summing up the absolute values of holdings in each market within an asset class) for our time series momentum strategy since 2000, run at a NAV of $280 billion, and compared them to the size of the underlying cash or derivative markets. For equities, we use the total global equity market capitalization estimate from the October 2014 World Federation of Exchanges (WFE) monthly statistics tables. For bonds, we add up the total government debt for the 15 developed countries with the largest debt using Bloomberg data. For currencies, we use the total notional outstanding amount of foreign exchange derivatives, excluding options, which are U.S. dollar denominated in the first half of 2014 from the Bank for International Settlements (BIS) November 2014 report. For commodities, we use the total notional of outstanding OTC commodities derivatives, excluding options, in the first half of 2014 from the BIS November 2014 report and add the aggregate exchange futures open interest for 31 of the most liquid commodities.

| | Average Position size in $280B Time Series Momentum Portfolio (bn) | Total Market Size (bn) | Percentage of Total Market |
|---|---|---|---|
| **Commodities** | 134 | 2,300 | 5.8% |
| **Equities** | 99 | 63,000 | 0.2% |
| **Bonds** | 758 | 33,000 | 2.3% |
| **Currencies** | 226 | 62,000 | 0.4% |

## Related Studies

Asness, Cliff, 1994, “Variables that Explain Stock Returns,” Ph.D. Dissertation, University of Chicago.

Asness, Cliff, John Liew and Ross L. Stevens, 1997, “Parallels between the cross-sectional predictability of stock and country returns,” *The Journal of Portfolio Management* 23(3), 79-87.

Asness, Cliff, Tobias Moskowitz and Lasse H. Pedersen, 2013, “Value and Momentum Everywhere,” *The Journal of Finance* 68(3), 929-985.

Chabot, Benjamin, Eric Ghysels and Ravi Jagannathan, 2009, “Momentum Cycles and Limits to Arbitrage: Evidence from Victorian England and Post-Depression U.S. Stock Markets,” working paper, Yale University.

Cutler, David M., James M. Poterba and Lawrence H. Summers, 1991, “Speculative dynamics,” *The Review of Economic Studies* 58(3), 529-546.

Erb, Claude B., and Campbell R. Harvey, 2006, “The tactical and strategic value of commodity futures,” *Financial Analysts Journal* 62(2), 69-97.

Fung, William, and David A. Hsieh, 2001, “The Risk in Hedge Fund Strategies: Theory and Evidence From Trend Followers,” *Review of Financial Studies* 14(2), 313-341.

Goetzmann, William, Roger G. Ibbotson and Liang Peng, 2000, “A New Historical Database for the NYSE 1815 to 1925: Performance and Predictability,” unpublished working paper, Yale ICF.

Gorton, Gary B., Funio Hayashi and K. Geert Rouwenhorst, 2008, “The Fundamentals of Commodity Futures Returns,” unpublished working paper, Yale ICF.

Grant, James, 1838, The Great Metropolis, vol. II (Philadelphia: E.L. Carey & A. Hart).

Hurst, Brian, Yao Hua Ooi and Lasse H. Pedersen, 2012, “Demystifying Managed Futures,” working paper, AQR Capital Management and New York University.

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

Jones, Charles M., 2002, “A Century of Stock Market Liquidity and Trading Costs,” working paper, Columbia Business School.

Moskowitz, Tobias, Yao Hua Ooi and Lasse H. Pedersen, 2012, “Time Series Momentum,” *Journal of Financial Economics*, 104(2), 228-250.

Rouwenhorst, K. Geert, 1998, “International Momentum Strategies,” *The Journal of Finance* 53(1), 267-284.

Shleifer, Andrei, and Lawrence H. Summers, 1990, “The Noise Trader Approach to Finance,” *Journal of Economic Perspectives* 4(2), 19-33.

## Disclosures

The information set forth herein has been obtained or derived from sources believed by the authors and AQR Capital Management, LLC ("AQR") to be reliable. However, the authors and AQR do not make any representation or warranty, express or implied, as to the information's accuracy or completeness, nor does AQR recommend that the attached information serve as the basis of any investment decision. This document has been provided to you solely for information purposes and does not constitute an offer or solicitation of an offer, or any advice or recommendation, to purchase any securities or other financial instruments, and may not be construed as such. This document is intended exclusively for the use of the person to whom it has been delivered by AQR and it is not to be reproduced or redistributed to any other person. AQR hereby disclaims any duty to provide any updates or changes to the analyses contained in this presentation**. This document is subject to further review and revision.**

This document is not research and should not be treated as research. This document does not represent valuation judgments with respect to any financial instrument, issuer, security or sector that may be described or referenced herein and does not represent a formal or official view of AQR.

The views expressed reflect the current views as of the date hereof and neither the author nor AQR undertakes to advise you of any changes in the views expressed herein. It should not be assumed that the author or AQR will make investment recommendations in the future that are consistent with the views expressed herein, or use any or all of the techniques or methods of analysis described herein in managing client accounts. AQR and its affiliates may have positions (long or short) or engage in securities transactions that are not consistent with the information and views expressed in this document.

The information contained herein is only as current as of the date indicated, and may be superseded by subsequent market events or for other reasons. Charts and graphs provided herein are for illustrative purposes only. The information in this document has been developed internally and/or obtained from sources believed to be reliable; however, neither AQR nor the author guarantees the accuracy, adequacy or completeness of such information. Nothing contained herein constitutes investment, legal, tax or other advice nor is it to be relied on in making an investment or other decision.

There can be no assurance that an investment strategy will be successful. Historic market trends are not reliable indicators of actual future market behavior or future performance of any particular investment which may differ materially, and should not be relied upon as such. Target allocations contained herein are subject to change. There is no assurance that the target allocations will be achieved, and actual allocations may be significantly different than that shown here. This document should not be viewed as a current or past recommendation or a solicitation of an offer to buy or sell any securities or to adopt any investment strategy.

The information in this document may contain projections or other forward-looking statements regarding future events, targets, forecasts or expectations regarding the strategies described herein, and is only current as of the date indicated. There is no assurance that such events or targets will be achieved, and may be significantly different from that shown here. The information in this document, including statements concerning financial market trends, is based on current market conditions, which will fluctuate and may be superseded by subsequent market events or for other reasons. Performance of all cited indices is calculated on a total return basis with dividends reinvested.

The investment strategy and themes discussed herein may be unsuitable for investors depending on their specific investment objectives and financial situation. Please note that changes in the rate of exchange of a currency may affect the value, price or income of an investment adversely.

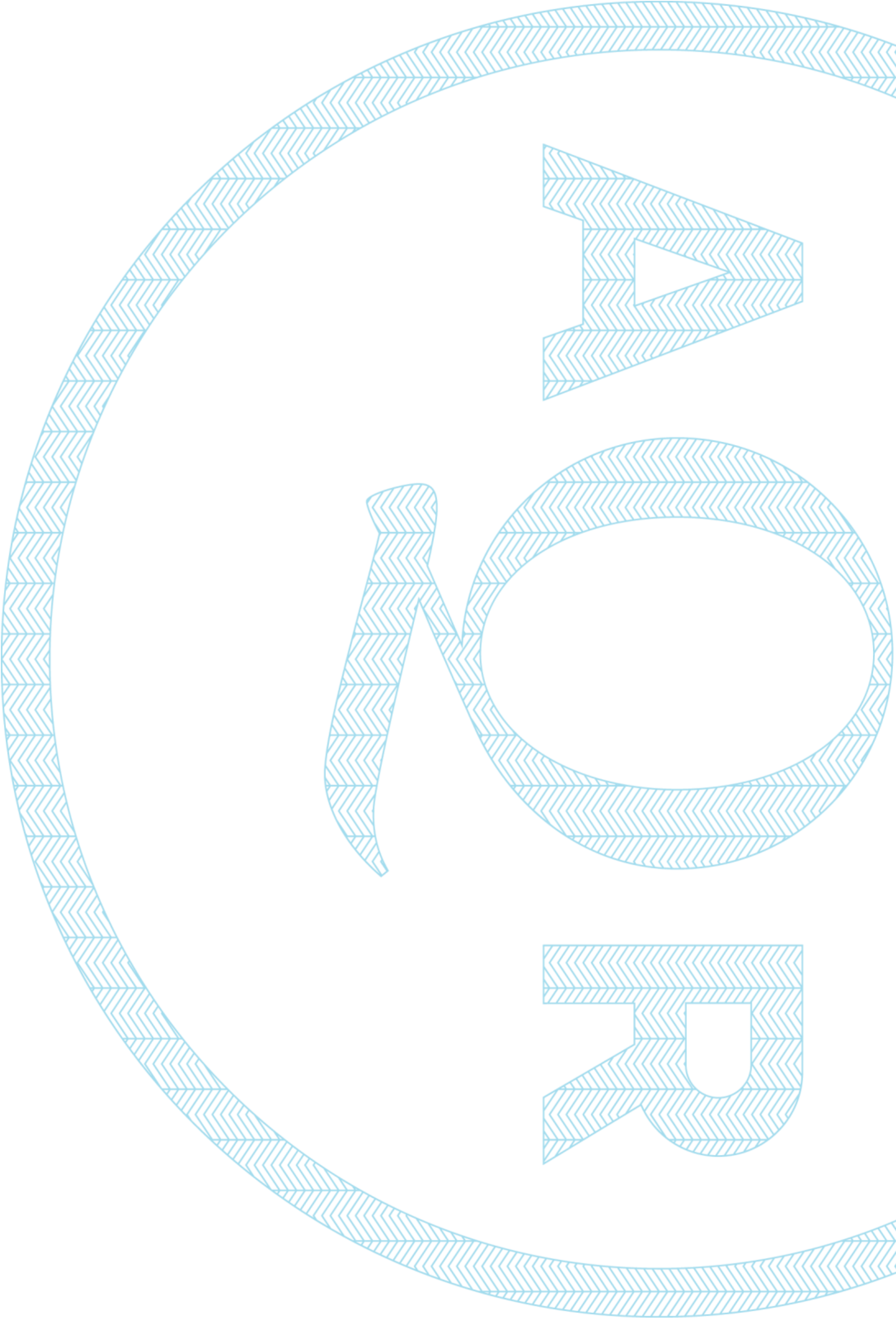
Neither AQR nor the author assumes any duty to, nor undertakes to update forward looking statements. No representation or warranty, express or implied, is made or given by or on behalf of AQR, the author or any other person as to the accuracy and completeness or fairness of the information contained in this document, and no responsibility or liability is accepted for any such information. By accepting this document in its entirety, the recipient acknowledges its understanding and acceptance of the foregoing statement.

The data and analysis contained herein are based on theoretical and model portfolios and are not representative of the performance of funds or portfolios that AQR currently manages. There is no guarantee, express or implied, that long-term volatility targets will be achieved. Realized volatility may come in higher or lower than expected. **Past performance is not a guarantee of future performance.** Diversification does not eliminate the risk of experiencing investment loss.

Hypothetical performance results (e.g., quantitative backtests) have many inherent limitations, some of which, but not all, are described herein. No representation is being made that any fund or account will or is likely to achieve profits or losses similar to those shown herein. In fact, there are frequently sharp differences between hypothetical performance results and the actual results subsequently realized by any particular trading program. One of the limitations of hypothetical performance results is that they are generally prepared with the benefit of hindsight. In addition, hypothetical trading does not involve financial risk, and no hypothetical trading record can completely account for the impact of financial risk in actual trading. For example, the ability to withstand losses or adhere to a particular trading program in spite of trading losses are material points which can adversely affect actual trading results. The hypothetical performance results contained herein represent the application of the quantitative models as currently in effect on the date first written above and there can be no assurance that the models will remain the same in the future or that an application of the current models in the future will produce similar results because the relevant market and economic conditions that prevailed during the hypothetical performance period will not necessarily recur. There are numerous other factors related to the markets in general or to the implementation of any specific trading program which cannot be fully accounted for in the preparation of hypothetical performance results, all of which can adversely affect actual trading results. Discounting factors may be applied to reduce suspected anomalies. This backtest's return, for this period, may vary depending on the date it is run. Hypothetical performance results are presented for illustrative purposes only. In addition, our transaction cost assumptions utilized in backtests, where noted, are based on AQR's historical realized transaction costs and market data. Certain of the assumptions have been made for modeling purposes and are unlikely to be realized. No representation or warranty is made as to the reasonableness of the assumptions made or that all assumptions used in achieving the returns have been stated or fully considered. Changes in the assumptions may have a material impact on the hypothetical returns presented. Hypothetical performance is gross of advisory fees, net of transaction costs, and includes the reinvestment of dividends. If the expenses were reflected, the performance shown would be lower. Where noted, the hypothetical net performance data presented reflects the deduction of a model advisory fee and does not account for administrative expenses a fund or managed account may incur. Actual advisory fees for products offering this strategy may vary.

Broad-based securities indices are unmanaged and are not subject to fees and expenses typically associated with managed accounts or investment funds. Investments cannot be made directly in an index.

There is a risk of substantial loss associated with trading commodities, futures, options, derivatives and other financial instruments. Before trading, investors should carefully consider their financial position and risk tolerance to determine if the proposed trading style is appropriate. Investors should realize that when trading futures, commodities, options, derivatives and other financial instruments one could lose the full balance of their account. It is also possible to lose more than the initial deposit when trading derivatives or using leverage. All funds committed to such a trading strategy should be purely risk capital.



**AQR Capital Management, LLC**
Two Greenwich Plaza, Greenwich, CT 06830
p: +1.203.742.3600 I f: +1.203.742.3100 I w: aqr.com