

# The Evolution of Quantitative Investment Strategies



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## Executive Summary

Quantitative equity investing has been an evolutionary process from its inception, and one whose practitioners hold certain tenets—disciplined adherence to a research-driven process, objectively engineered alpha, and awareness of systematic risks. Five years after the financial crisis, quantitative strategies are gaining investor interest precisely because the systematic application of these principles has resulted in attractive risk-adjusted returns. Contrast this view with conditions that prevailed during the crisis, which left many investors disappointed in the performance of quantitative approaches.

As investment professionals, we understand that investment strategies naturally tend to come in and out of favor. Because of changing investor perception of these strategies, we believe this is an appropriate juncture to revisit the history of quantitative equity investing and provide greater context around these approaches. We explain why quantitative equity investing is well positioned to provide attractive long-term performance.

Quantitative investing is an approach with a distinguished academic pedigree stretching back to the early 20th century. Enduring behavioral and market inefficiencies identified by academic research and investment practitioners in the years since support the notion that quantitative approaches remain compelling. We conclude that quantitative investing remains a viable, attractive approach, reflecting the fact that it is data driven, testable, and easily given to rigorous self-examination and process improvement. This natural inclination of quantitative practitioners means they are well positioned to learn prior lessons and apply them to future market environments. Significantly, we find that correlations and performance contours for various quantitative and traditional strategies suggest that quantitative portfolios can play a complementary role alongside traditional management approaches.

## Introduction

Quantitative investment management may loosely be described as the application of rigorous mathematical and statistical principles, informed by economic theory, to the study of financial markets with the primary goal of forming investment portfolios to achieve superior returns. This approach to investing has a long history and distinguished academic pedigree. So while quantitative investment strategies have gone in and out

of favor with investors, it should be clear that this is a time-tested approach based on sound economic principles, rigorous academic research, and real-world analysis. In this paper, we hope to advance the understanding of quantitative investment practices by providing a survey of the academic antecedents of these strategies, as well as more recent learnings driven by the experience of the financial crisis and its aftermath.

### Early Pioneers

Despite its more recent prominence and popularity, the field of quantitative investing is over a century old. Louis Bachelier, a French mathematician at the turn of the 20th century, is widely acknowledged as a pioneer in the application of advanced mathematical concepts to the study of financial markets. His Ph.D. thesis at the Sorbonne, titled *The Theory of Speculation*, was published in 1900 and illustrated the use of statistical techniques to study the fluctuation of stock prices. Bachelier's work was initially viewed with skepticism and the full value of his contribution was not understood or acknowledged until decades later. Therefore, it should come as no surprise that quantitative investing remained an academic discipline with no apparent real-world significance.

### Value Investing

In sharp contrast, another pioneering piece of work received critical acclaim and, decades later, had a major influence on the development of practical quantitative investment strategies. Following steep market declines in the 1930s, two professors at Columbia University, Benjamin Graham and David Dodd, published a book titled *Security Analysis* that exhorted investors to consider a disciplined framework to analyze securities. They promoted an approach that examined a company's business via the lens of its financial statements to arrive at a measure of the company's intrinsic value. Comparing the market price of a security to its intrinsic value could be used to identify under- and over-valued securities. This approach, dubbed "value investing," gained popularity among fundamental analysts. Several decades later, with the widespread availability of financial data and growth in computing, this philosophy would also find favor with quantitative investors.

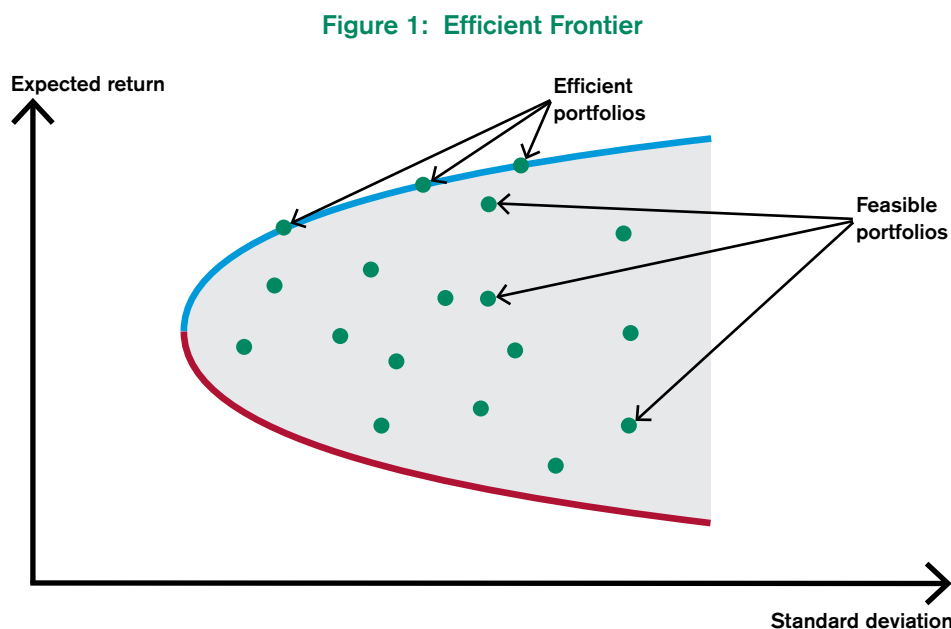
### Modern Portfolio Theory

Modern quantitative investing would not have been practical without the pioneering contribution of Harry Markowitz. His early work in this area was published in an article in the *Journal of Finance* in 1952, followed by his seminal work in the 1959 book titled *Portfolio Selection: Efficient Diversification of Investments*. The notion of diversification formalizes, in mathematical terms, the old adage: "Don't put all your eggs in one basket." It was well known that security prices fluctuated randomly and that all investors faced the possibility of losses on their investments. While several intuitive measures of the uncertain outcomes of an investment were proposed, many by Markowitz himself, his key insight was to recognize that if an investor chose to measure investment uncertainty using the standard deviation of the distribution of returns, then the investment problem becomes mathematically tractable.

He went on to show how to use this insight to form "efficient" portfolios. The notion of efficiency, central to quantitative investing, loosely refers to the best way to achieve investment objectives. For example, if an investor has forecasts of returns on a set of stocks as well as measures of their correlation and standard deviation, then there

**Figure 1:** First proposed by Markowitz, the mean-variance frontier is a popular device used to illustrate the range of risk-return combinations. Every portfolio can be represented as a point in this two-dimensional graph. It turns out that all feasible portfolios lie in the shaded region, between the upper and lower graph. The portfolios plotted along the blue line are termed efficient portfolios, as they offer the highest expected return for a given level of risk.

is an analytically tractable way to form an efficient portfolio—the portfolio is efficient in the sense that it will achieve the highest level of expected return for a given standard deviation.



Source: American Century Investments

### A Model of Risk and Expected Returns

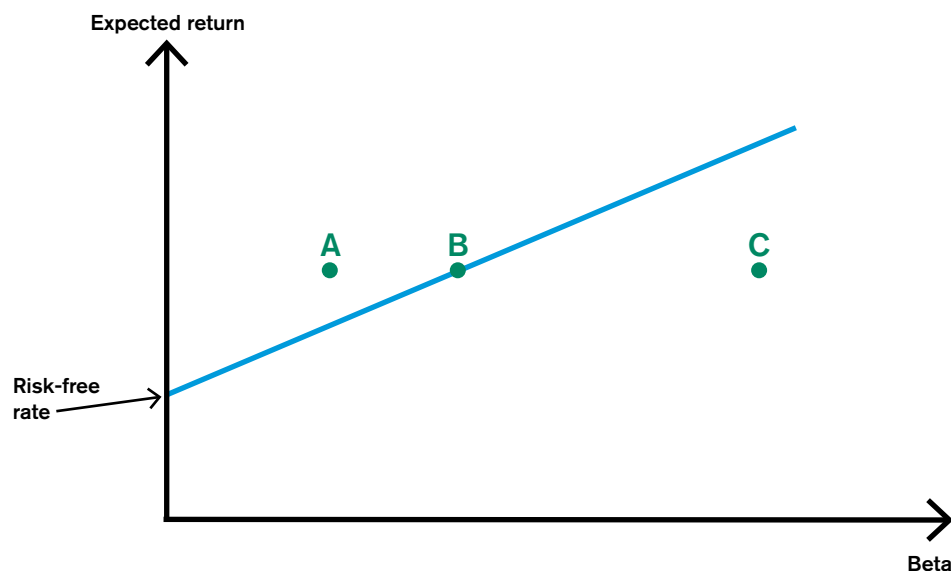
Most investors would intuitively accept the notion that a risky security should offer a higher rate of return in order to make it an attractive investment. In other words, relative to a safe investment that offers investors a return commensurate with the time value of money, a risky investment must offer them an extra reward to compensate for the likely losses they may incur.

Markowitz's successful characterization of risk using the standard deviation of returns led to the next major advance in quantitative investing in the early 1960s—the establishment of a rigorous economic model that linked the risk of a security to its expected return. This model became known as the Capital Asset Pricing Model, or CAPM. While Bill Sharpe's name is most prominently associated with the development of the CAPM, a few other economists independently derived similar models more or less contemporaneously.

The CAPM starts with the premise that all securities are exposed to fluctuations in the overall market. A security's beta is defined as the component of its risk coming from its exposure to the overall market. The CAPM argued that only this source of non-diversifiable risk should be rewarded by the market. All other fluctuations in an individual security's price, termed as diversifiable risk, will become very small if an investor holds a diversified portfolio, and should therefore not be rewarded by the market. In summary then, the CAPM predicted that the expected returns of individual securities, net of the risk-free rate, should be related linearly to their betas.

**Figure 2:** The security market line graphically shows the expected return of each security plotted against its sensitivity to the market portfolio, i.e., its beta. Its slope is the expected return on the market portfolio in excess of the risk-free rate, i.e., the market risk premium. Stocks that lie on the line, e.g., stock B, are considered fairly priced according to the CAPM. Stocks like A that lie above the line offer higher expected returns than predicted by the CAPM and are considered under-priced while those that lie below the line, like stock C in the figure, are over-priced.

**Figure 2: Security Market Line**



Source: American Century Investments

### Follow-up from the CAPM

The publication of the CAPM spawned the emphasis on indexing. The logic was straightforward: If the only component of a security's risk that is rewarded is its beta risk, then investors should hold each security in proportion to its representation in the market; any other weighting would only add risk to the portfolio without any extra reward.

Financial economists also carried out a number of empirical studies to examine whether the data supported the theory. Of these, the works by Black, Jensen, and Scholes (1972) and Fama and MacBeth (1973) are widely cited. These papers were partially, but not fully, supportive of the theory. While they confirmed that a security's expected return was positively related to its beta, the empirical differences in expected returns between high-beta and low-beta securities did not appear to be as large as the CAPM predicted.

### Persuasive Evidence of Market Inefficiency

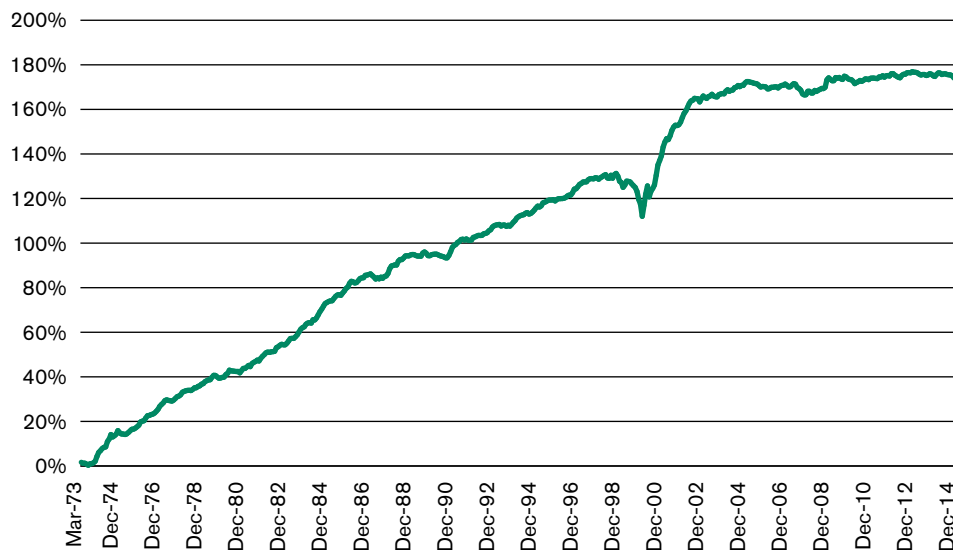
Starting in the late 1970s, a series of papers showed that there was strong evidence that the cross-sectional variation in expected returns was unrelated to beta, but expected returns appeared to be strongly correlated to other financial characteristics. Many of these studies examined the variation in expected returns along two dimensions, beta and another characteristic, some of which are discussed below. They found that the expected return variation was weak across the beta dimension, but was strong across these other dimensions.

The first of these studies was by Sanjoy Basu (1977), which showed that average returns on stocks with high earnings yield are higher than the CAPM would predict. Figure 3A depicts the cumulative returns of a portfolio of stocks characterized by high earnings yield. A second important contribution came from Rolf Banz (1981), who showed that small-cap stocks offer higher average returns than predicted by CAPM. Figure 3B depicts the size anomaly over the last 40 years. Finally, there were several papers that documented the "book-to-price effect." Stattman (1980) and Rosenberg, Reid, and Lanstein (1985) are the classic references here. Collectively, these papers showed that stocks with high book-to-price ratios had higher returns than the CAPM would predict.

**Figure 3A:** Basu (1977) showed that companies with high earnings yield offered average returns higher than predicted by CAPM. The plot shows the cumulative returns on a portfolio that tilts toward high earnings yield while remaining neutral to beta, industries, and size. Except for a pronounced drawdown in the years leading up to the internet bubble in the late 1990s, and a period of volatile performance during the 2007-09 period, this portfolio has posted positive returns on average.

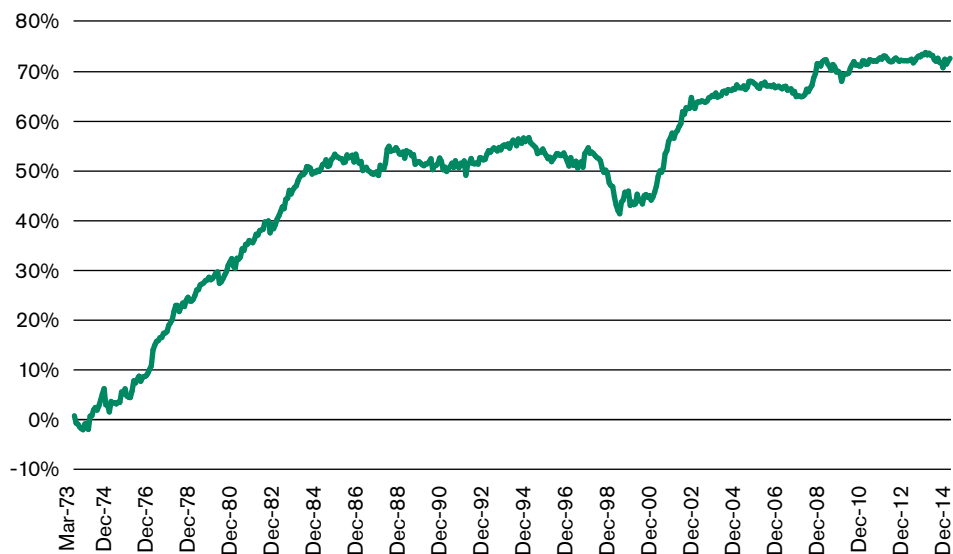
**Figure 3B:** First discovered by Banz (1981), the term “size anomaly” relates to the empirical finding that small-cap stocks yielded higher average returns than predicted by the CAPM. The plot shows cumulative returns to a portfolio that is tilted toward small-cap names and away from large-cap names while remaining neutral to beta and industries. Controlling for these factors, small-cap names offered substantial return premium through the mid-1980s. The premium vanished in the late 1980s as well as in the 1990s; indeed, there was a large-cap premium in the late 1990s. After the internet bubble burst in 2000, the small-cap premium has been pronounced.

**Figure 3A: Anomalies – Earnings Yield**



Source: MSCI Barra, American Century Investments. Data from 3/31/1973 to 12/31/2014.

**Figure 3B: Anomalies – Size**



Source: MSCI Barra, American Century Investments. Data from 3/31/1973 to 12/31/2014.

### Origins of Quantitative Active Management

The finding that stocks with high book-to-price ratios or high earnings yield were attractive investments was not a surprise to fundamental analysts, especially to those steeped in the Graham-Dodd tradition. Indeed, these variables were natural starting points for richer valuation models that they had designed. The compelling evidence of market inefficiency documented in these studies, along with the widening availability of financial market data in machine-readable form, spurred the launch of quantitative active strategies starting in the mid-1980s.

Several practitioners, notably Barr Rosenberg and Richard Grinold, made important contributions to the growth and success of these strategies. Rosenberg was instrumental in the establishment of Barra Inc., a financial software firm in Berkeley, California, whose pioneering research led to forecasts of stock-level variances and correlations, a crucial ingredient in building quantitative portfolios that efficiently traded off risk and expected return. Grinold published several articles that showed how to adapt the key insights of Markowitz and Sharpe to the world of active portfolio management. See for example Grinold (1989, 1994).

### Intuitive Description of Quantitative Portfolio Construction

Quantitative investment strategies have several distinguishing features. The first is that such strategies formally quantify forecasts of expected return, standard deviations, and correlations of securities. The second is the use of an optimizer to construct portfolios. Modern optimizers are extremely sophisticated in their ability to handle complex objectives and constraints; professionals who work on building or enhancing these tools usually have advanced training in mathematics or allied fields. Vendors of optimizers provide easy-to-use interfaces that do not require a user to necessarily know its inner workings. As a result, it is common practice to view the optimizer as a “black box.” This view has served to obscure the role of an optimizer in the process and has detracted from an intuitive understanding of how they work. Below, we provide an intuitive interpretation of quantitative portfolio construction by drawing a strong parallel with the heuristic approach used by traditional managers.

Let’s start by describing a hypothetical traditional manager’s approach to building portfolios. Suppose their research leads them to conclude that XYZ Inc., an energy company, has superior management quality and that, as a result, the fundamentals of the company will remain stronger than its peers. They will want to overweight the stock to reflect this view. Notice, however, that a simple purchase of XYZ Inc. will expose them to risks coming from the broader market as well as fluctuations in energy prices; from their perspective, these are incidental risks, not intentional risks. They should hedge their overweight in XYZ Inc. by underweighting one or more names that have similar exposures to the market as well as to energy prices. In other words, their insight about XYZ Inc. is represented in the portfolio via a basket of stocks—overweight XYZ and underweight one or more hedging positions.

What about the size of the bet on XYZ? Traditional managers usually approach this decision via heuristics that account for the level of conviction in their insight as well as the riskiness of the stock. In short, then, a traditional manager’s process uses baskets of stocks to represent each insight, hedges out incidental risks, and sizes the bet based on level of conviction and risk.

A quantitative investment process, via the use of an optimizer, uses exactly the same principles to construct portfolios. Quantitative managers commonly describe their return forecasts through the use of multiple factors, e.g., earnings yield, book-to-price, size, etc. Each factor is represented via a basket of securities that maximizes exposure to the factor while hedging out incidental risks. So, for example, the earnings yield basket will overweight cheap stocks and underweight expensive ones. Typically, however, low-growth sectors tend to have lower P/E multiples than high-growth ones. The earnings yield basket will attempt to hedge out these sector biases by choosing to overweight names that are cheap relative to their sector and underweighting names expensive within their sector.

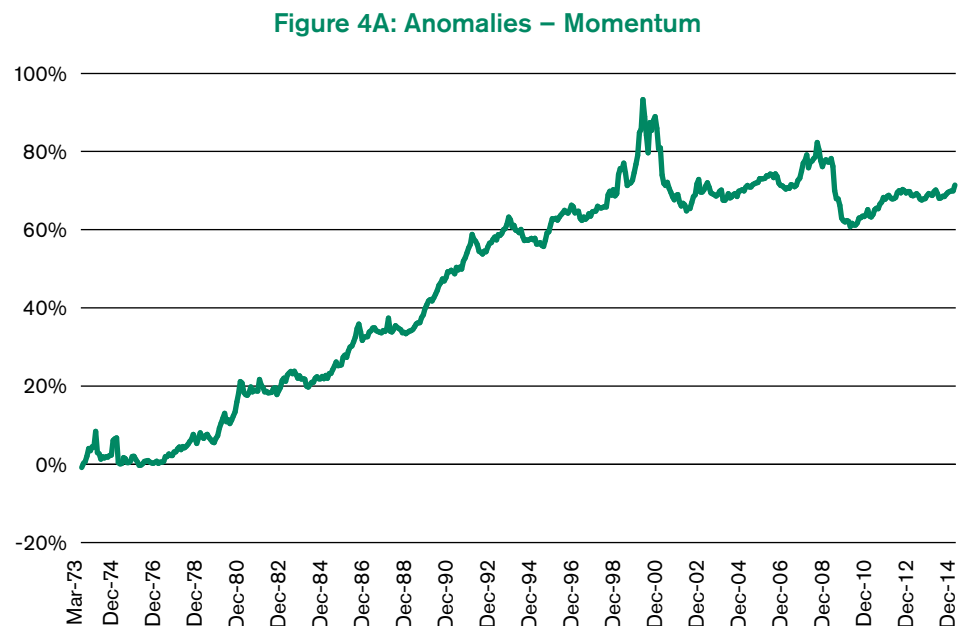
What about the size of the bet on each factor? The relative proportions of different factors in a quantitative portfolio are chosen based on the relative levels of conviction about the outperformance of these factors while also being mindful of their riskiness.

### Growth of Quantitative Strategies

Early versions of quantitative strategies were launched in the mid-1980s. These strategies typically employed factors like size, earnings yield, and book-to-price, all of which had recently been discovered by academics as deviations from CAPM. The next 20 years saw an exponential growth in assets in these strategies, along with an increase in the breadth of offerings—long-only, long-short, and partial-short strategies were all launched, investing in U.S., EAFE, Asia, EM, etc.

Alongside this growth, academics continued to publish more deviations from CAPM. Two notable papers were those by Jegadeesh and Titman (1993) and Sloan (1996). Jegadeesh and Titman documented the striking anomaly that recent winners, i.e., stocks that had outperformed over the prior six-to-12-month period, continued to trend upward for the subsequent six to 12 months and, conversely, recent losers continued to trend downward. Moreover, they showed that the returns to a momentum portfolio, that is long winners and short losers, offered returns above what the CAPM would predict. This is depicted in Figure 4A.

**Figure 4A:** Jegadeesh and Titman (1993) showed that a portfolio of stocks that over-weighted recent winners and under-weighted recent losers offered excess returns unexplained by CAPM. They termed this the “momentum effect.” As Figure 4A shows, the momentum effect was very strong until the turn of the century. Over the past 15 years, performance has been volatile with two episodes of strong drawdowns, first after the internet bubble burst and again in the aftermath of the strong junk rally starting in March 2009.



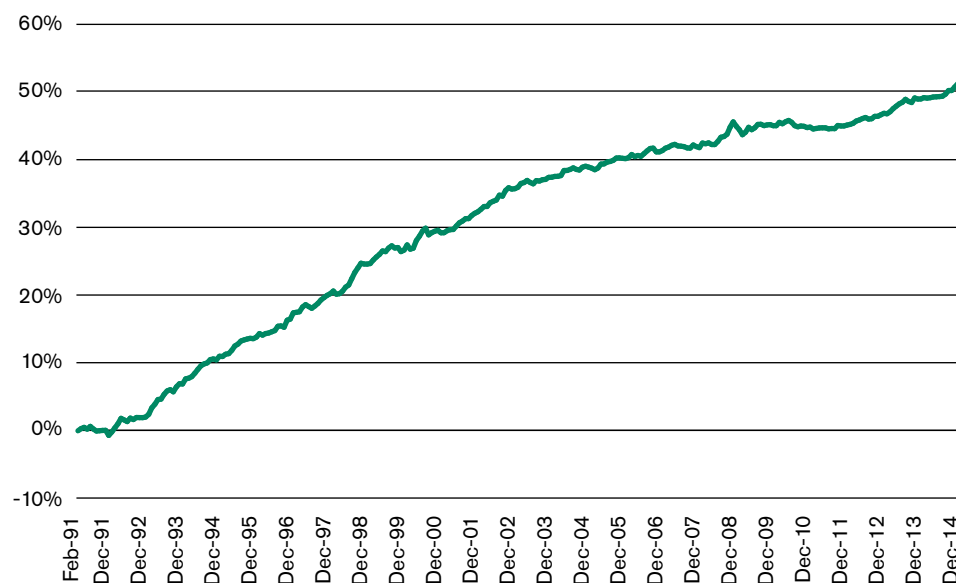
Source: MSCI Barra, American Century Investments. Data from 3/31/1973 to 12/31/2014.

In their 1934 book, Graham and Dodd argued that investors seemed to fixate on earnings and tended to ignore the importance of cash flows, and had illustrated their hypothesis with a few examples. The widespread availability of machine-readable financial statement data led Richard Sloan to test this hypothesis systematically across a much larger universe. His 1996 paper showed strong evidence that investors continued to fixate on earnings and ignore cash flows. Accountants refer to the gap between earnings and cash flows as accruals. Sloan showed that an investment portfolio formed by overweighting companies with low accruals and underweighting those with high accruals yielded returns in excess of those predicted by the CAPM. Figure 4B displays the prevalence of this accrual anomaly over the last 25 years. Needless to say, quantitative investors quickly implemented these ideas in their models; by the turn of the century, momentum and accruals were staples of quantitative models along with factors like earnings yield, book-to-price, and size.

As a result of the efficacy and rapid implementation of these ideas, quantitative strategies experienced a “golden age” from 2000 to 2007. During this period, quantitative managers were heavily favored by the gate keepers of asset management. And for good reason—these strategies featured heavy research, moderate active risk, disciplined processes, and solid risk-adjusted returns that were supported by a long history of academic theory, borrowing from both behavioralists and efficient-market proponents.

**Figure 4B:** Sloan (1996) systematically tested a hypothesis first proposed by Graham and Dodd, namely, that companies with high levels of current accruals tend to underperform. Nearly a decade later, Richardson, Sloan, Soliman, and Tuna (2005) showed that using a more comprehensive measure of accruals, dubbed “total accruals,” showed even stronger performance. The accompanying graphic shows the cumulative performance of a portfolio that bets against companies with high levels of total accruals, while controlling for beta, industries, and size.

**Figure 4B: Anomalies – Accruals**



Source: MSCI Barra, American Century Investments. Data from 2/28/1991 to 12/31/2014.



## Crowding and Its Aftermath

The week of August 6, 2007, was rather uneventful in broader equity markets. The S&P 500® Index opened the week at around 1433 and closed at about 1453. However, this apparent calm in broader markets masked the start of a tumultuous period for quantitative investment strategies. That week, a number of quantitative equity long-short portfolios experienced extremely large losses, most likely driven by sudden liquidation due to margin calls or deleveraging. These losses spiraled out to other quantitative equity strategies, resulting in catastrophic outcomes for many such portfolios. On August 10, many of these strategies rebounded strongly, indirectly confirming that the original losses were triggered by liquidity demands rather than by fundamental news.

Asset owners that had invested in droves into quantitative equity strategies were forced to rethink their allocations. The events of August 2007 led them to conclude that these strategies were more highly correlated than they had assumed. Furthermore, the massive growth in AUM led them to infer that this space had become crowded. After August 2007, these strategies faced strong headwinds from massive, continuous redemptions that accelerated as the great financial crisis wore on and increased volatility buffeted financial markets through 2008 and 2009.

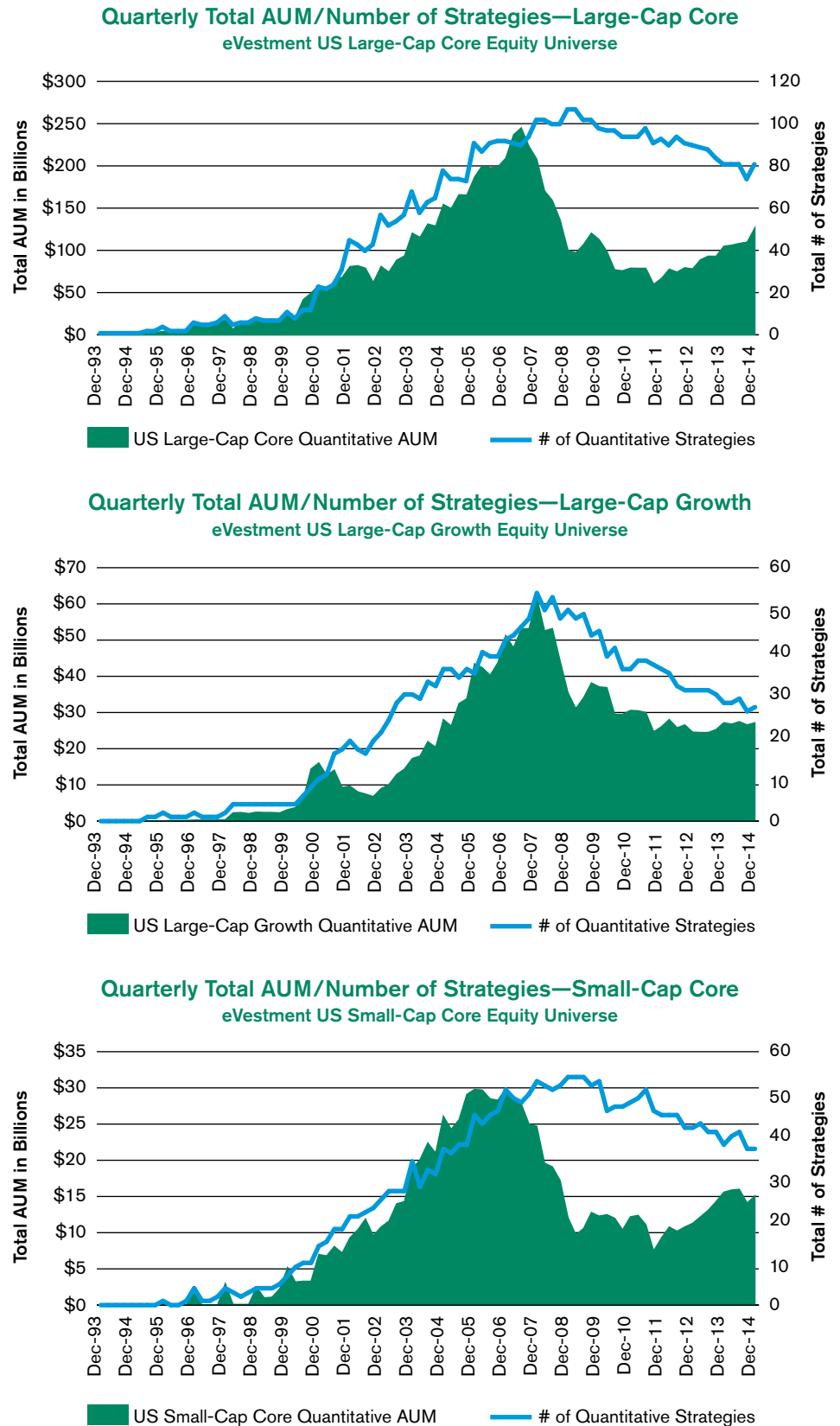
As a consequence of sustained outflows, the aggregate investment in quantitative active strategies has shrunk to a small fraction of its peak value. We depict changes in assets under management and the number of quantitative practitioners for large-cap core, large-cap growth, and small-cap core strategies in Figure 5. Although the outflows in the 2007-09 period were unprecedented and severely impacted their performance, one reason to view quantitative strategies favorably today is that there is far less competition to arbitrage away market inefficiencies that continue to persist. Indeed, starting in 2010, as some semblance of calm returned to financial markets, quantitative equity strategies have gradually recovered and the past few years have seen good performance.

**Figure 5:** Quantitative strategies gained assets at an accelerating pace in the late 1990s and early 2000s. The quant crisis in 2007 was followed by significant volatility in financial markets, leading to severe drawdowns in the returns of such strategies and massive outflows.

To understand the magnitude of flows into and out of quantitative strategies, we looked at assets under management and number of quantitative practitioners over the last 20 years. We identified these managers by screening eVestment on the following criteria: 1) self-described quant manager in the primary investment process field of the database and 2) appropriate peer group as designated by eVestment.

We find that for the large-core and large-growth strategies, assets under management peaked in mid-2007, and were subject to sharp drawdowns thereafter. The peak in small-cap core assets occurred slightly earlier, but the general pattern holds. Only in the last several years have assets under management begun to increase again. At the same time, the number of quant practitioners declined notably in all strategy groupings.

**Figure 5: Crowding**



Source: American Century Investments and eVestment. Data from 12/1993 to 12/2014.

## Quantitative Investing 2.0

In the aftermath of the turbulent period from 2007-09, the quantitative investing landscape has become much more heterogeneous. For the most part, quantitative investors reacted to the severe performance challenges over this period by researching and emphasizing unique features of their investment process while reducing their reliance on generic aspects. For example, there is a noticeable trend to invest in the discovery of proprietary alpha ideas beyond the careful analysis of balance sheets and income statements. Today quantitative practitioners are using unstructured data, niche data sources, dynamic factor rotation, news-based analytics, credit-based factors, short-interest factors, and sector-specific factors, among others. Quantitative managers' ability to systematically evaluate and incorporate past experience and learnings into their investment processes in an objective way bodes well for such strategies in the future.

There is also an increasing emphasis on formal risk management. Although quantitative processes may be described as risk-aware as they use a risk model and an optimizer to guide portfolio construction, there is a realization that these processes can benefit from an overlay of risk management that seeks to identify and insulate the process from non-model risks. In particular, quantitative managers have typically been paying more attention to portfolio sensitivity to different macroeconomic regimes in the wake of the financial crisis. A select few managers, for example, are running stress tests under different economic and market assumptions to better understand portfolio risks and exposures.

## Where Would Quantitative Strategies Fit in a Portfolio?

Despite the changes in quantitative processes noted above, their basic investment philosophy has remained unchanged. These processes continue to select stocks in an objective and systematic manner using a range of quantifiable indicators to measure the relative attractiveness of each stock in their universe. They also typically use a risk model to guide the relative emphasis on different factors, both intentional and incidental, as well as on individual names. In contrast, the investment process of a traditional manager tends to be unique and specialized, with the use of various heuristics that have been honed through years of real-world experience. A traditional manager typically will have greater insight about any single name in their portfolio, but will own far fewer names than a quantitative investor.

These contrasting approaches have resulted in differentiated return contours for quantitative and traditional managers over time, as depicted in Figure 6 for the large-cap core, large-cap growth, and small-cap core universes. The return pattern demonstrates that quantitative and traditional managers possess differentiated holdings and generate differentiated returns, presumably because of dissimilar risk and alpha factor exposures. For these and other reasons, we believe that well-chosen quantitative strategies can offer return streams that are uncorrelated with traditional managers' returns.

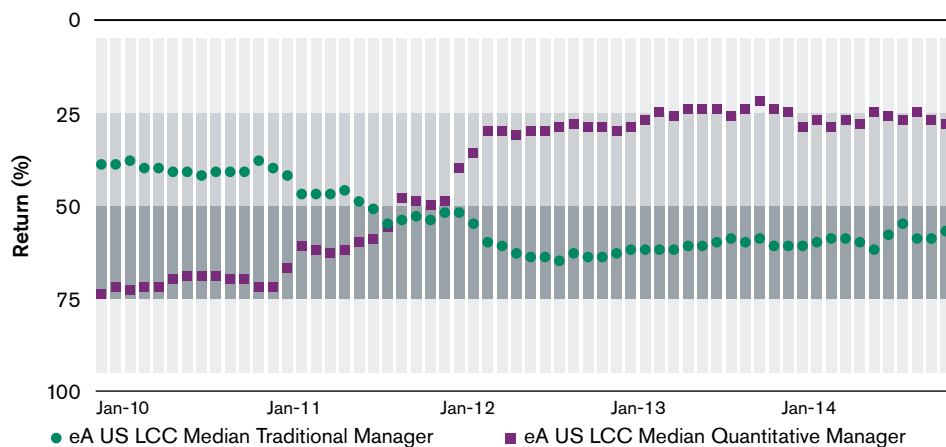
**Figure 6:** We looked at the performance contours for quantitative and traditional managers to better understand the complementary natures of these two approaches. We were particularly interested in the period since the financial crisis, which has been challenging for active management amid low volatility and rising cross-sectional correlations.

This analysis of returns compares the relative ranking of quantitative and traditional managers over time in the large-cap growth, large-cap core, and small-cap core segments. Specifically, we provide the rolling 36-month return rankings for the median eA U.S. LCC, LCG, and SCC fundamental manager and the median eA U.S. LCC, LCG, and SCC quantitative manager for the last five years relative to their respective universes.

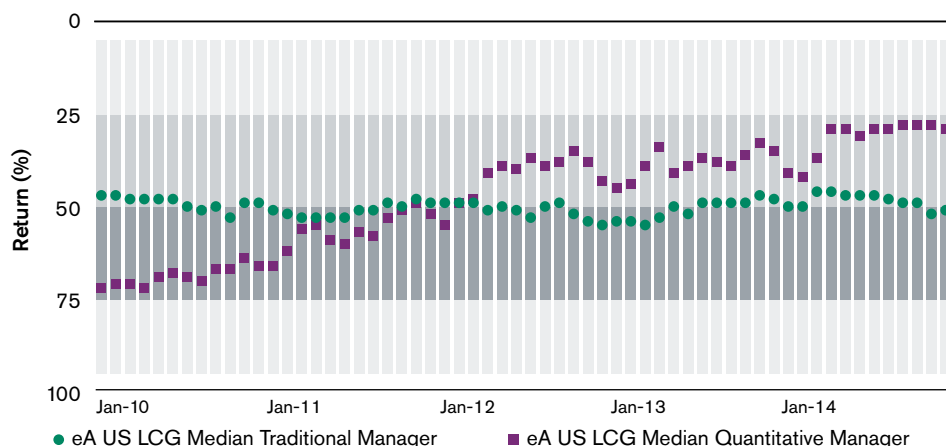
The return patterns for these differing approaches complement one another nicely in the period since the financial crisis. Indeed, beginning in late 2011 and early 2012, quantitative managers started outperforming their traditional counterparts. The difference has been significant in recent years, with the median quantitative manager consistently ranking in or near the top quartile, while the median traditional manager has been below median.

**Figure 6: Complementary Performance Contours**

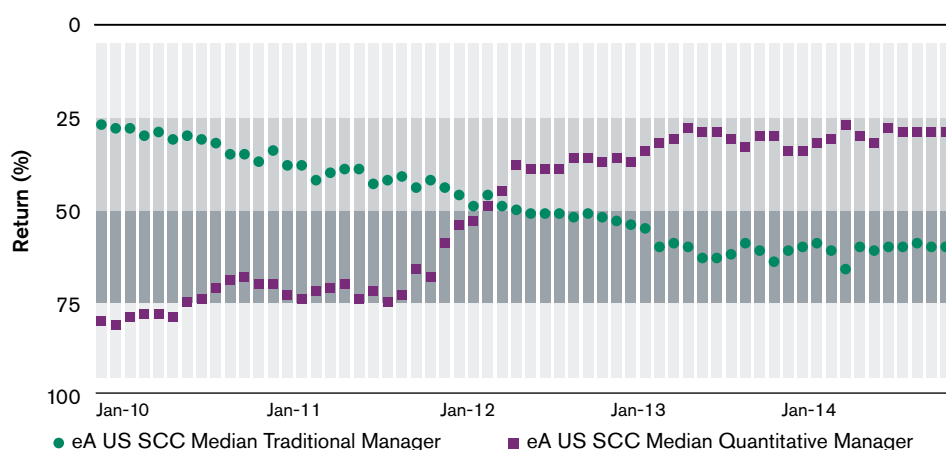
**Rolling Three-Year Returns Relative to eA US Large-Cap Core Universe**  
eA US LCC Median Traditional Manager vs. eA US LCC Median Quantitative Manager



**Rolling Three-Year Returns Relative to eA US Large-Cap Growth Universe**  
eA US LCG Median Traditional Manager vs. eA US LCG Median Quantitative Manager



**Rolling Three-Year Returns Relative to eA US Small-Cap Core Universe**  
eA US SCC Median Traditional Manager vs. eA US SCC Median Quantitative Manager



Source: American Century Investments and eVestment. Data from 1/31/2010 to 12/31/2014.

## Summary

Quantitative strategies feature several distinguishing traits—disciplined practitioners with market savvy developed from a systematic and long-running analysis of asset mis-valuation. Reflecting its academic roots, quantitative investing has been a dynamic, evolutionary process from its inception. Our belief is that quantitative strategies will continue to evolve along the lines of proprietary research and insights, and away from some of the more well-known, generic sources of alpha. Differentiation among quantitative practitioners argues for greater diversity among alpha and risk factors and lower correlation of returns. In addition, the sharp reduction in the number of such strategies in the wake of the financial crisis suggests that inefficiencies identified by practitioners are likely to endure in ways that would not have been possible at the height of the discipline's "golden age." Finally, the performance characteristics of quantitative strategies relative to traditional approaches suggest that quantitative strategies can play a meaningful, complementary role in a larger equity portfolio.

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