NORTHERN TRUST
ASSET MANAGEMENT

RESEARCH REPORT

LOW VOLATILITY INVESTING: AN EVOLUTION IN ALPHA

A NEW VOLATILITY REGIME HAS DELIVERED MORE RETURN FOR LESS RISK

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Greek letters are pervasive in the world of finance. They symbolize fundamental investment concepts and encapsulate common attributes of interest. The most popular symbols — alpha (α) and beta (β) — have been widely adopted throughout the industry. For the most part, the convenience they afford outweighs the potential for misunderstanding. This isn't to suggest these symbols have universal meaning. To the contrary, they represent different things to different people.

If you mention the term "alpha" to an academic, it will likely be associated with an asset pricing model such as the Capital Asset Pricing Model (Sharpe, 1964) or the Fama-French Three Factor Model (Fama and French, 1993). In this context, "alpha" represents return that cannot be attributed to a common set of risk factors. If you mention the term "alpha" to an investor, it will likely be associated with a benchmark. In this context, "alpha" represents return earned above a reference portfolio. Unfortunately, it is possible for an investment to earn positive alpha by one definition and negative alpha by another.

Low volatility equity investing has a long history of generating positive alpha from an academic perspective, reliably producing higher returns than those predicted by asset pricing models. Despite this consistent performance, low volatility investing has been an afterthought to many investors tasked with the goal of beating a benchmark. From an investor's standpoint, low volatility portfolios are expected to underperform capitalization weighted benchmarks over the long run given that they have considerably less risk than passive market portfolios.

However, the recent performance of low volatility strategies has challenged conventional wisdom as they have delivered positive alpha from both academic and investor perspectives. This type of performance contradicts one of the most basic tenets of finance — that higher risk must accompany higher return. Thus, investors are reluctant to embrace the "free lunch" that low volatility investing seemingly offers.

In this paper we analyze low volatility portfolios over the past 30 years to identify the forces behind the remarkable recent performance. We find that changes in

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the distribution of volatility provide a significant tailwind to low volatility investments by enhancing the ability of low volatility portfolios to become more defensive when it is needed (as volatility rises) and less defensive when it is not (as volatility falls). We conclude by discussing some important considerations for investors such as the desired level of volatility reduction and the tendency for low volatility portfolios to introduce excessive systematic risk. We recommend investors pursue low volatility portfolios that explicitly control for these risks while balancing the benefits of downside mitigation with upside participation.

HISTORY OF LOW VOLATILITY INVESTING

The historical performance of low volatility portfolios is commonly regarded as "the greatest anomaly in finance."

The low risk anomaly refers to the tendency for low volatility and low beta portfolios to earn higher returns than high volatility and high beta portfolios.[1] The robustness of this phenomenon across time horizons, markets, variable definitions, and asset classes has led some to consider it "the greatest anomaly in finance.[2]"

The anomaly was first documented by Friend and Blume (1970), and motivated Jensen, Black, and Scholes (1972) to challenge the assumptions of the renowned Capital Asset Pricing Model (CAPM). Haugen and Heins (1975) explored the topic thoroughly using data from 1926 to 1971 and concluded "over the long run stock portfolios with lesser variance in monthly returns have experienced greater average returns than their 'riskier' counterparts." A number of studies[3] were conducted from this point forward, each establishing the anomaly further despite the advancement of multi-factor pricing models.

Exhibit 1 shows the alpha and beta coefficients of three popular pricing models applied to low volatility portfolios formed within the Russell 1000 Index over the past 3 decades — the CAPM, the Fama-French Three Factor Model, and the Carhart Four Factor Model (Carhart, 1997). Historical volatility is computed for two popular look-back periods (1 year and 3 year), at three different frequencies (daily, weekly, and monthly).[4] Each quarter, all index constituents are sorted independently by each risk variable. The stocks in the bottom 30th percentile[5] are assigned to the corresponding low volatility portfolio and market capitalization weighted. The asset pricing model coefficients are obtained by regressing the monthly excess returns[6] of the low volatility portfolios against the excess returns of the US stock market (labeled as Mkt (β)), as well as the SMB, HML, and UMD factor returns.[7]

[1] We generally refer to low risk as low volatility from this point forward, encompassing both low volatility and low beta.
[2] Baker, Bradley, and Wurgler (2011) write "Among the many candidates for the greatest anomaly in finance, a particularly compelling one is the long-term success of low-volatility and low-beta stock portfolios."
[3] Examples include Baker and Haugen (1991), Chan, Karceski and Lakonishok (1999), Jangannathan and Ma (2003), and Clarke De Silva and Thorley, (2006).
[4] Variables are computed using equally weighted trailing total returns.
[5] The 30th percentile is commonly used to represent "high" or "low" portfolios in academic research. Similar results are obtained with quartile (25th percentile) or quintile (20th percentile) analysis.
[6] From this point forward "excess return" refers to return earned in excess of the risk-free rate of interest and "active return" refers to return earned in excess of a reference (benchmark) portfolio.
[7] For more information about the SMB, HML, and UMD factors refer to the Kenneth R. French Data Library https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

EXHIBIT 1: ASSET PRICING MODEL COEFFICIENTS AND [T-STATS] OF LOW VOLATILITY PORTFOLIOS WITHIN THE RUSSELL 1000 INDEX (12/31/1989 – 12/31/2019)

CAPM: $(R_{it} - R_{ft}) = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it}$

Fama-French 3 Factor: $(R_{it} - R_{ft}) = \alpha_i + \beta_{1i}(R_{mt} - R_{ft}) + \beta_{2i}SMB_t + \beta_{3i}HML_t + \varepsilon_{it}$

Carhart 4 Factor: $(R_{it} - R_{ft}) = \alpha_i + \beta_{1i}(R_{mt} - R_{ft}) + \beta_{2i}SMB_t + \beta_{3i}HML_t + \beta_{4i}UMD_t + \varepsilon_{it}$

Where:

- R_i is the monthly return of portfolio i
- R_f is the risk-free rate of interest
- R_m is the monthly return of the aggregate US equity market portfolio
- SMB, HML, and UMD are the small-minus-big, high-minus-low, and up-minus-down monthly factor returns, respectively

	CAPM		Fama French 3 Factor				Carhart 4 Factor				
	α	Mkt (β)	α	Mkt (β)	SMB	HML	α	Mkt (β)	SMB	HML	UMD
1-Year Daily Volatility	**2.6%**	0.64	**2.2%**	0.71	-0.30	0.16	**1.5%**	0.73	-0.30	0.18	0.07
	[2.34]	[29.9]	**[2.55]**	[42.3]	[-13.0]	[6.6]	**[1.84]**	[42.5]	[-13.5]	[7.6]	[4.3]
1-Year Weekly Volatility	**2.5%**	0.65	**2.0%**	0.72	-0.30	0.16	**1.5%**	0.74	-0.30	0.18	0.06
	[2.28]	[31.2]	**[2.49]**	[44.2]	[-13.2]	[6.8]	**[1.85]**	[44.0]	[-13.6]	[7.6]	[3.8]
3-Year Weekly Volatility	**2.2%**	0.66	**1.7%**	0.73	-0.31	0.16	**1.3%**	0.74	-0.31	0.18	0.04
	[1.96]	[30.7]	**[2.10]**	[44.4]	[-13.7]	[6.9]	**[1.61]**	[43.5]	[-14.0]	[7.4]	[2.7]
3-Year Monthly Volatility	**1.8%**	0.69	**1.4%**	0.76	-0.31	0.14	**0.9%**	0.77	-0.32	0.16	0.05
	[1.72]	[33.6]	**[1.87]**	[49.7]	[-15.1]	[6.5]	**[1.21]**	[49.4]	[-15.6]	[7.4]	[3.9]

SOURCE: Northern Trust Quantitative Research, FTSE Russell, Kenneth French Data Library

The data reported in Exhibit 1 is representative of historical research findings and highlights the interest in the low volatility phenomenon from an academic point of view. All of the alpha terms are positive, with most models reporting moderate-to-strong significance.[8] This implies that low volatility investors are earning too much return for the risk they are actually bearing. The failure of asset pricing models to explain these results has led to numerous attempts to rationalize them. Most of the explanations put forth fall into three broad categories — market frictions (structural), behavioral biases, and problem misspecification. Some of the most popular theories are listed in Table 1[9].

TABLE 1: LOW VOLATILITY ANOMALY RATIONALES

Theme	Rationale
Market Frictions (Structural)	Many investors cannot use leverage, so they turn to high beta stocks in order to achieve high returns. In doing so, they bid up the price of high beta stocks until the shares are overpriced (Black, 1972, and Frazzini and Pedersen, 2011). Fixed-benchmark mandates discourage investment in low-volatility and low-beta stocks that have high marginal contributions to active risk. As a result, demand for low-beta stocks tends to lag (Baker, Bradley and Wurgler, 2011).
Behavioral Biases	Investor overconfidence and willingness to pay a premium for a small chance of earning large returns, known as the "lottery effect," leads to a demand for high volatility stocks that is not warranted by fundamentals (Kumar, 2009, and Bali, Cakici and Whitelaw, 2011).
Problem Misspecification	Evidence of the low volatility anomaly is not robust to portfolio weighting schemes or liquidity considerations (Bali and Cakici, 2008, and Han and Lesmond, 2011). Low volatility and low beta anomalies are well explained by asset pricing models that include the newer factors of profitability and investment (Novy-Marx, 2014, and Fama and French, 2016).

SOURCE: Northern Trust Asset Management

[8] As a shorthand, a |t-stat| > 1.65 is regarded to be different from zero with a 90% probability.
[9] For a comprehensive examination of low volatility explanations refer to Hou and Loh (2016).

While the interpretation of the low volatility phenomenon lacks consensus, the robustness of the anomaly is irrefutable. Evidence of the low volatility effect has been found in US stocks, international stocks, treasury bonds, corporate bonds, sovereign bonds, foreign exchange, commodities, and derivatives.[10] Although the research community remains fascinated by these findings, investors have been less than enthusiastic. Exhibit 2 shows the results of the same low volatility portfolios as reported in Exhibit 1, but this time from an investor perspective. In this context, the Russell 1000 Index represents the reference benchmark portfolio, and "Active Return" is the difference in returns between the low volatility portfolio and the benchmark (i.e. "investor alpha").

The low volatility phenomenon has been documented across time periods, geographies, and asset classes.

EXHIBIT 2: 30-YEAR PERFORMANCE DATA FOR THE RUSSELL 1000 INDEX AND LOW VOLATILITY PORTFOLIOS (12/31/1989 – 12/31/2019)

	Portfolio Return	Portfolio Volatility	Sharpe Ratio	Active Return	Tracking Error	Information Ratio
Russell 1000 Index	10.1%	14.4%	0.57			
1-Year Daily Volatility	10.2%	11.1%	0.71	0.1%	7.0%	0.02
1-Year Weekly Volatility	10.2%	11.2%	0.71	0.1%	6.8%	0.02
3-Year Weekly Volatility	9.9%	11.3%	0.67	-0.2%	6.8%	-0.03
3-Year Monthly Volatility	9.7%	11.5%	0.65	-0.4%	6.3%	-0.06

SOURCE: Northern Trust Quantitative Research, FTSE Russell

The results show that all low volatility portfolios achieved higher risk-adjusted returns than the passive capitalization weighted index (Russell 1000 Index) over this period, as evidenced by higher Sharpe Ratios.[11] However, only 2 of the 4 portfolios managed to earn positive active return, with all strategies generating considerable tracking error against the benchmark. The resulting information ratios[12] are therefore either negative or barely positive. In light of these results, it is difficult to find fault with investors who have dismissed low volatility portfolios as a means to beat their benchmarks. Yet, the recent performance of low volatility strategies has led many investors to reconsider.

RECENT PERFORMANCE REQUIRES A PARADIGM SHIFT

The performance of low volatility portfolios in the 21st century has captured the attention of investors and academics alike. Exhibit 3 reveals similar levels of volatility reduction, positive active returns, and significantly improved information ratios compared to the results shown in Exhibit 2 (for corresponding asset pricing model coefficients, refer to Appendix A).

[10] Frazzini and Pedersen (2011), and Cao and Han (2013) represent a large body of supporting research.
[11] Sharpe Ratio is the average return earned in excess of the risk-free rate per unit of excess return volatility.
[12] Information ratio is the active return per unit of tracking error.

EXHIBIT 3: 20-YEAR PERFORMANCE DATA FOR THE RUSSELL 1000 INDEX AND LOW VOLATILITY PORTFOLIOS (12/31/1999 – 12/31/2019)

	Portfolio Return	Portfolio Volatility	Sharpe Ratio	Active Return	Tracking Error	Information Ratio
Russell 1000 Index	6.3%	14.7%	0.38			
1-Year Daily Volatility	8.1%	10.8%	0.63	1.8%	7.7%	0.23
1-Year Weekly Volatility	7.7%	11.0%	0.59	1.4%	7.4%	0.19
3-Year Weekly Volatility	7.5%	11.2%	0.56	1.2%	7.4%	0.16
3-Year Monthly Volatility	7.3%	11.4%	0.54	1.0%	6.9%	0.14

SOURCE: Northern Trust Quantitative Research, FTSE Russell

Of course, this timespan prominently features the extraordinary "lost decade" of the 2000s which included two historic events — the dot-com bubble and the global financial crisis. The turbulence associated with these episodes ought to favor defensive strategies such as low volatility relative to the broader stock market, as confirmed in Exhibit 4.

EXHIBIT 4: ACTIVE PERFORMANCE OF LOW VOLATILITY PORTFOLIOS IN THE RUSSELL 1000 INDEX (12/31/1999 – 12/31/2019)

		Active Return vs. Russell 1000 Index				
Period	Russell 1000 Index Return	1-Year Daily Volatility	1-Year Weekly Volatility	3-Year Weekly Volatility	3-Year Monthly Volatility	Average Active Return
2000s	-0.5%	3.5%	2.7%	2.9%	2.4%	2.9%
2010s	13.5%	-0.2%	0.0%	-0.8%	-0.6%	-0.4%

SOURCE: Northern Trust Quantitative Research, FTSE Russell

Although the 2000s were responsible for the positive active return earned over the full time period, low volatility portfolios on average gave back little of the outperformance in the following decade despite strong equity market returns (13.5% annualized return). This is noteworthy given that the equity risk premium[13] itself represents the biggest headwind to a low volatility investment for benchmark-aware investors. The average market beta coefficient of the four low volatility portfolios reported over this time period is 0.68 (refer to Appendix A), implying that low volatility portfolios capture only a fraction of the equity risk premium. Therefore, the better the aggregate equity market performs, the harder it becomes for low volatility strategies to surpass the benchmark (and vice-versa). Given the stellar performance of the equity market during the past decade, it is reasonable to conclude that low volatility portfolios exceeded expectations over this time period.

When we look internationally, the relationship between the broader equity market and low volatility performance is much harder to discern. Exhibit 5 shows local active returns[14] for low volatility portfolios within the MSCI World ex US Index[15]

[13] The equity risk premium refers to the return earned by the aggregate capitalization weighted stock market over the risk-free rate of interest. It is represented in Exhibit 1 as $(R_{mt} - R_{ft})$.
[14] Local returns are shown in order to separate the low risk anomaly from currency effects. All results for the MSCI World ex US Index and the MSCI Emerging Markets Index are reported in local currency unless noted otherwise.
[15] Each risk variable is ranked within each region in order to limit the degree of bias on the analysis. Region membership is determined in accordance with Fama and French (2012).

and MSCI Emerging Markets Index over the same time period (for USD returns, refer to Appendix B).

EXHIBIT 5: ACTIVE PERFORMANCE OF LOW VOLATILITY PORTFOLIOS IN THE MSCI WORLD EX US AND MSCI EMERGING MARKET INDEXES (12/31/1999 – 12/31/2019) IN LOCAL CURRENCY

Active Return vs. MSCI World ex US Index (Local)

Period	MSCI World ex US Index Return (Local)	1-Year Daily Volatility	1-Year Weekly Volatility	3-Year Weekly Volatility	3-Year Monthly Volatility	Average Active Return
2000s	-0.3%	2.7%	3.5%	3.2%	2.5%	3.0%
2010s	7.6%	1.0%	1.2%	1.6%	1.7%	1.4%

Active Return vs. MSCI EM Index (Local)

Period	MSCI EM Index Return (Local)	1-Year Daily Volatility	1-Year Weekly Volatility	3-Year Weekly Volatility	3-Year Monthly Volatility	Average Active Return
2000s	10.2%	4.2%	2.8%	5.4%	5.4%	4.4%
2010s	6.5%	1.8%	1.1%	2.5%	0.7%	1.5%

SOURCE: Northern Trust Quantitative Research, MCSI

Low volatility portfolios performed well on a relative basis in both markets during this time period, with no negative active returns reported despite three periods of positive market return (7.6%, 10.2%, and 6.5%).

In total, the performance of low volatility over the past 20 years leads us to wonder if other systematic forces have emerged to enhance the low volatility anomaly. In the next section, we analyze the distribution of volatility over this time period and investigate its influence on low volatility portfolios.

The performance of low volatility over the past 20 years suggests new market dynamics have enhanced the anomaly.

VOLATILITY ASYMMETRY ENHANCES RETURN ASYMMETRY

Volatility asymmetry refers to the tendency for low stock returns to be associated with an increase in volatility, and vice-versa. It is well-documented[16] in financial literature and generally recognized among investors. The fact that the most popular volatility index (VIX Index[17]) is commonly referred to as the "Fear Gauge" affirms that investors view an expected increase in equity market volatility as an ominous sign for the stock market. The first two rows of Exhibit 6 seem to support this belief, as the annualized monthly volatility of the Russell 1000 Index is higher during the 2000s compared to the decades before and after. However, volatility asymmetry is generally accepted as a short-term phenomenon, given that investors can adjust their risk expectations and align their required rates of return over the long run. For this reason, volatility asymmetry is measured at shorter time horizons such as daily, weekly, or monthly holding periods. Exhibit 6 reports volatility asymmetry by comparing the average daily volatility[18] of the Russell 1000 Index in months with negative returns ("down months") to months with positive returns ("up months").

[16] For more information, refer to Bae, Kim, and Nelson (2007).
[17] The VIX Index refers to the CBOE Volatility Index. It reflects investors' consensus view of future (30-day) expected stock market volatility within the S&P 500 Index. For more information, refer to http://www.cboe.com/products/vix-index-volatility
[18] The daily volatility is computed by taking the standard deviation of total daily returns for all trading days during the month

EXHIBIT 6: RUSSELL 1000 INDEX RETURN AND VOLATILITY STATISTICS (12/31/1989 – 12/31/2019)

	Russell 1000 Index		
	1990s	2000s	2010s
Annualized Return	18.1%	-0.5%	13.5%
Annualized Monthly Volatility	13.5%	16.4%	12.6%
Negative Months (Down Months)	37	50	34
Positive Months (Up Months)	83	70	86
Average Down Month Daily Volatility	0.88%	1.48%	1.21%
Average Up Month Daily Volatility	0.75%	1.01%	0.69%
Volatility Asymmetry (Down Vol / Up Vol)	**1.17**	**1.46**	**1.77**

SOURCE: Northern Trust Quantitative Research, FTSE Russell

In each period, the average down month volatility exceeds the average up month volatility, though the difference has become more pronounced over time. During the 1990s, the average down month daily volatility was 1.17 times higher than the average up month volatility. This ratio increased to 1.46 in the 2000s and again to 1.75 in the 2010s (possible explanations for this trend will be deferred to a later section). Exhibit 7 reports similar levels of volatility asymmetry in the international markets when compared to the past two decades[19] of the Russell 1000.

The difference between "down market" volatility and "up market" volatility has become more pronounced over time.

EXHIBIT 7: MSCI WORLD EX US INDEX AND MSCI EMERGING MARKETS INDEX RETURN AND VOLATILITY STATISTICS (12/31/1999 – 12/31/2019)

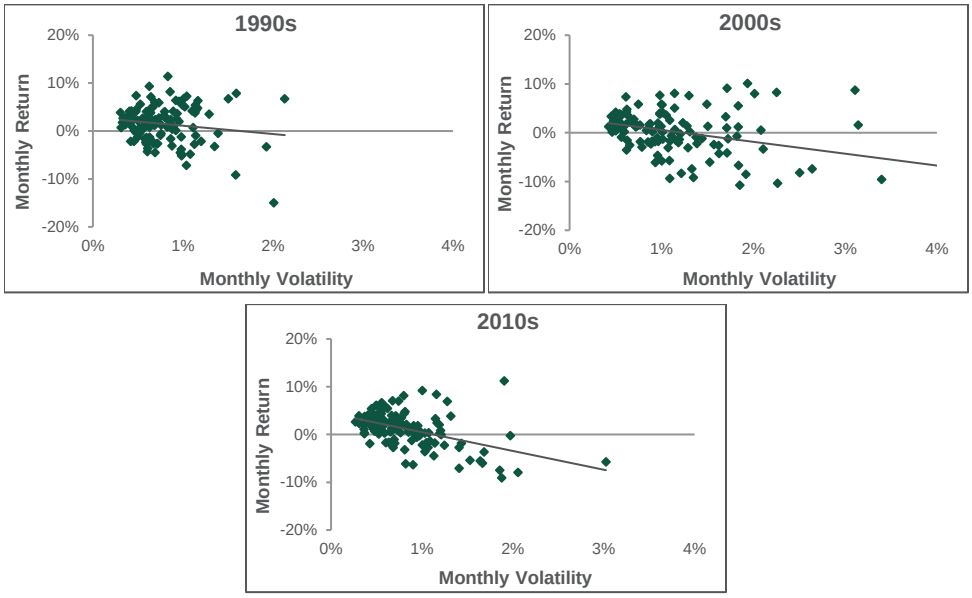
	MSCI World Ex US Index		MSCI EM Index	
	2000s	2010s	2000s	2010s
Annualized Return	-0.3%	7.6%	10.2%	6.5%
Annualized Monthly Volatility	15.6%	11.1%	20.7%	12.0%
Negative Months (Down Months)	53	41	48	54
Positive Months (Up Months)	67	79	72	66
Average Down Month Daily Volatility	1.17%	0.94%	1.21%	0.81%
Average Up Month Daily Volatility	0.77%	0.57%	0.83%	0.60%
Volatility Asymmetry (Down Vol / Up Vol)	**1.53**	**1.63**	**1.45**	**1.34**

SOURCE: Northern Trust Quantitative Research, MSCI

The increase in volatility asymmetry in the Russell 1000 Index has led to a stronger relationship between market volatility and market returns. Exhibit 8 plots the paired observations of monthly returns and volatility for each of the past three decades in the Russell 1000 Index.

[19] Daily local returns of the MSCI World ex US and MSCI Emerging Markets Indexes do not extend back to 12/31/1989. All analyses for these markets begin on 12/31/1999 for this reason.

EXHIBIT 8: RUSSELL 1000 INDEX MONTHLY RETURN AND VOLATILITY (12/31/1999 – 12/31/2019)



SOURCE: Northern Trust Quantitative Research, FTSE Russell

The trend lines fitted to the scatter plots become increasingly negative in slope[20], indicating a stronger association between increasing (decreasing) short-term market volatility and low (high) stock market returns. Exhibit 9 further corroborates this progression, as the correlations of the Russell 1000 Index become increasingly negative over this time period.

EXHIBIT 9: CORRELATIONS OF MONTHLY RETURNS TO MONTHLY VOLATILITY (12/31/1989 – 12/31/2019)

	Russell 1000 Index	MSCI World ex US Index	MSCI EM Index
1990s	-0.15		
2000s	-0.39	-0.51	-0.49
2010s	-0.47	-0.58	-0.48

Source: Northern Trust Quantitative Research, FTSE Russell, MSCI

The link between volatility asymmetry and low volatility performance lies in the connection between low volatility portfolio betas and market volatility. As we will see, this relationship plays a larger role in low volatility performance as volatility asymmetry increases. In order to understand this dynamic, we begin with a review of portfolio beta.

The link between volatility asymmetry and low volatility performance lies in the connection between portfolio beta and market volatility.

[20] Negative slopes are an expected outcome given volatility asymmetry.

The beta of any portfolio is represented as follows:

$$\boldsymbol{\beta_p = Cov(R_p, R_m) / \sigma_m^2}$$

Where:

- β_p is the beta of portfolio p
- $Cov(R_p, R_m)$ is the covariance between the portfolio returns R_p and the market returns R_m
- σ_m^2 is the variance of the market returns R_m

Recalling that covariance may be expressed in terms of correlation and volatility,

$$\boldsymbol{Cov(R_p, R_m) = \rho_{p,m}\sigma_p\sigma_m}$$

allows us to substitute and simplify our equation to yield a common alternate form of portfolio beta:

$$\boldsymbol{\beta_p = \rho_{p,m}(\sigma_p/\sigma_m)}$$

Where:

- $\rho_{p,m}$ is the correlation between the portfolio returns R_p and the market returns R_m
- σ_p is the standard deviation of the portfolio returns R_p
- σ_m is the standard deviation of the market returns R_m

Portfolio beta is therefore a product of two factors, 1) the correlation of the portfolio to the market ($\rho_{p,m}$), and 2) the ratio of portfolio volatility to market volatility (σ_p/σ_m). Equity correlations are commonly expected to rise with market volatility, so the first factor ($\rho_{p,m}$) should have an increasing influence on portfolio beta as market volatility (σ_m) increases (and vice-versa). But what contribution should be expected from the second factor (σ_p/σ_m) as market volatility changes? Though perhaps not immediately obvious, the volatility ratio of low volatility portfolios declines as market volatility increases. Exhibit 10 reports the slope coefficients obtained by regressing the monthly volatility ratio of low volatility portfolios (σ_p/σ_m) on the monthly volatility of the market index portfolio (σ_m) in the US and international markets.[21]

EXHIBIT 10: VOLATILITY RATIO SENSITIVITY TO MARKET VOLATILITY OF LOW VOLATILITY PORTFOLIOS IN THE RUSSELL 1000, MSCI WORLD EX US, AND MSCI EMERGING MARKETS INDEXES (12/31/1999 – 12/31/2019)

Slope coefficients and test statistics from regressions of the form:

$$(\sigma_{i_t}/\sigma_{m_t}) = \alpha_i + \beta_i(\sigma_{m_t}) + \varepsilon_{it}$$

Where:

- σ_i is the trailing 1-month standard deviation of the daily returns of low volatility portfolio i
- σ_m is the trailing 1-month standard deviation of the daily returns of market index portfolio m

	1-Year Daily Volatility	1-Year Weekly Volatility	3-Year Weekly Volatility	3-Year Monthly Volatility
Russell 1000	-7.84 [-5.86]	-7.16 [-5.49]	-5.94 [-4.50]	-4.66 [-3.70]
MSCI World ex US	-8.46 [-4.33]	-6.47 [-3.41]	-4.23 [-2.17]	-1.66 [-0.90]
MSCI Emerging Markets	-17.60 [-6.51]	-10.29 [-3.85]	-9.33 [-3.66]	-6.66 [-2.79]

Source: Northern Trust Quantitative Research, FTSE Russell, MSCI

[21] Market index portfolios are represented by the Russell 1000, MSCI World ex US, and MSCI Emerging Markets Indexes, respectively.

The negative slope coefficients reported in Exhibit 10 are evidence that the volatility ratio of low volatility portfolios declines with market volatility. The loss of diversification is one of the primary contributors[22] to these results. As noted previously, correlations tend to increase with market volatility, thereby reducing the degree of diversification in equity portfolios. However, the market portfolio loses diversification at a faster rate than low volatility portfolios on average, resulting in the denominator (σ_m) increasing at a higher rate than the numerator (σ_p). To interpret this dynamic, consider that low volatility portfolios are concentrated on the left-side of the volatility distribution[23], and therefore exclude the most volatile stocks in the market. By contrast, the market portfolio includes the full volatility distribution. Since the market portfolio loses diversification at a faster rate than low volatility portfolios, one may conclude that the correlations of high volatility stocks are more sensitive to changes in market volatility (i.e. are less stable) than the correlations of low volatility stocks (for a thorough examination of the volatility ratio please refer to our whitepaper *Low Volatility Beta Asymmetry: A Closer Look*).

The volatility ratio of low volatility portfolios *declines* with market volatility.

According to our analysis thus far, the effect of the two factors on low volatility portfolio beta is ambiguous. We expect a positive relationship between the changes in market volatility (σ_m) and correlation ($\rho_{p,m}$), and a negative relationship between the changes in market volatility (σ_m) and the volatility ratio (σ_p/σ_m). So what is the expected net impact on low volatility portfolio betas?

We explore this question empirically within the Russell 1000, MSCI World ex US, and MSCI Emerging Markets indexes by comparing correlations, volatility ratios, and portfolio betas in "High" and "Low" volatility regimes. We begin by computing the daily volatility of each index every month from January 2000 through December 2019 (240 months), as well as the daily volatility of every low volatility portfolio within the index. We then sort by index volatility to classify three volatility regimes (Low, Mid, and High) with an equal number of months (80) belonging to each classification. In order to isolate the contribution of both factors individually, the correlation of daily returns between every low volatility portfolio and the corresponding index is computed for each month, as well as the volatility ratio and resulting portfolio beta. Correlations, volatility ratios, and portfolio betas are then averaged for each volatility regime. Exhibit 11 shows the average values for the Low and High volatility regimes and reports the ratio of the two values as "Asymmetry" (High over Low).

EXHIBIT 11: BETA OF LOW VOLATILITY PORTFOLIOS IN LOW AND HIGH VOLATILITY REGIMES (12/31/1999 – 12/31/2019)

	Russell 1000 Low Volatility Portfolios								
	Avg High Vol $\rho_{p,m}$	Avg Low Vol $\rho_{p,m}$	**$\rho_{p,m}$ Asymmetry**	Avg High Vol (σ_p/σ_m)	Avg Low Vol (σ_p/σ_m)	**(σ_p/σ_m) Asymmetry**	Avg High Vol β_p	Avg Low Vol β_p	**β_p Asymmetry**
1-Year Daily Volatility	0.90	0.91	**0.99**	0.77	0.88	**0.87**	0.70	0.80	**0.87**
1-Year Weekly Volatility	0.91	0.92	**0.99**	0.77	0.88	**0.88**	0.71	0.81	**0.88**
3-Year Weekly Volatility	0.90	0.90	**1.00**	0.79	0.87	**0.90**	0.72	0.79	**0.91**
3-Year Monthly Volatility	0.92	0.91	**1.01**	0.81	0.88	**0.92**	0.76	0.80	**0.94**
Average	0.91	0.91	**1.00**	0.78	0.88	**0.89**	0.72	0.80	**0.90**

[22] Another important factor is the rate at which the dispersion of volatility increases with market volatility. As market volatility increases, the distribution of volatility widens, pushing the tails further from the mean.
[23] The volatility distribution refers to the distribution of the individual stock volatilities within the equity market. In this paper, low volatility portfolios are formed by investing in the left tail of this distribution up to 30% of the index constituents.

MSCI World ex US Low Volatility Portfolios

	Avg High Vol $\rho_{p,m}$	Avg Low Vol $\rho_{p,m}$	**$\rho_{p,m}$ Asymmetry**	Avg High Vol (σ_p/σ_m)	Avg Low Vol (σ_p/σ_m)	**(σ_p/σ_m) Asymmetry**	Avg High Vol β_p	Avg Low Vol β_p	**β_p Asymmetry**
1-Year Daily Volatility	0.93	0.92	**1.01**	0.73	0.84	**0.87**	0.69	0.78	**0.88**
1-Year Weekly Volatility	0.93	0.91	**1.01**	0.75	0.84	**0.89**	0.70	0.77	**0.91**
3-Year Weekly Volatility	0.92	0.90	**1.03**	0.77	0.83	**0.92**	0.72	0.75	**0.96**
3-Year Monthly Volatility	0.93	0.91	**1.02**	0.80	0.84	**0.95**	0.76	0.77	**0.98**
Average	0.93	0.91	**1.02**	0.76	0.84	**0.91**	0.71	0.77	**0.93**

MSCI Emerging Markets Low Volatility Portfolios

	Avg High Vol $\rho_{p,m}$	Avg Low Vol $\rho_{p,m}$	**$\rho_{p,m}$ Asymmetry**	Avg High Vol (σ_p/σ_m)	Avg Low Vol (σ_p/σ_m)	**(σ_p/σ_m) Asymmetry**	Avg High Vol β_p	Avg Low Vol β_p	**β_p Asymmetry**
1-Year Daily Volatility	0.90	0.88	**1.01**	0.70	0.87	**0.80**	0.63	0.77	**0.82**
1-Year Weekly Volatility	0.89	0.88	**1.01**	0.71	0.82	**0.86**	0.64	0.73	**0.87**
3-Year Weekly Volatility	0.92	0.88	**1.04**	0.72	0.83	**0.87**	0.66	0.73	**0.90**
3-Year Monthly Volatility	0.92	0.87	**1.06**	0.73	0.81	**0.91**	0.68	0.71	**0.96**
Average	0.91	0.88	**1.03**	0.71	0.83	**0.86**	0.65	0.73	**0.89**

Source: Northern Trust Quantitative Research, FTSE Russell, MSCI

The results reveal that the change in the volatility ratio dominates the change in correlation. In fact, there is scant evidence to suggest that correlations are meaningfully different at all across volatility regimes (the $\rho_{p,m}$ Asymmetry values are all close to 1.00). This may not be terribly surprising given that we are comparing correlations of diversified portfolios as opposed to individual stocks. On the other hand, the difference in volatility ratios between low and high volatility regimes is both material and consistent. Therefore, the betas of low volatility portfolios generally decrease (increase) as market volatility rises (falls).

This dynamic feature of low volatility betas combined with the heightened volatility asymmetry of the past 2 decades gives low volatility portfolios the attractive property of becoming more defensive when it is needed (as volatility rises) and less defensive when it is not (as volatility falls). This allows low volatility investors to capture more of the market when it advances and less of the market when it declines. Exhibit 12 shows the up/down capture for low volatility portfolios within the Russell 1000 Index over each of the past 3 decades, where “Up Capture” (“Down Capture”) represents the sum of the low volatility portfolio monthly returns divided by the sum of the Russell 1000 Index monthly returns for all months when the index was positive (negative). The “Up/Down Capture” is then reported as the ratio of up capture to down capture over the time period. The volatility asymmetry ratios originally reported in Exhibit 6 have been included for reference.

Low volatility portfolios have become more defensive when it is needed (as volatility rises) and less defensive when it is not (as volatility falls).

EXHIBIT 12: UP/DOWN CAPTURE OF LOW VOLATILITY PORTFOLIOS WITHIN THE RUSSELL 1000 INDEX (12/31/1989 – 12/31/2019)

Russell 1000 Up/Down Capture

	1990s			2000s			2010s		
	Up Capture	Down Capture	**Up/Down Capture**	Up Capture	Down Capture	**Up/Down Capture**	Up Capture	Down Capture	**Up/Down Capture**
1-Year Daily Volatility	81%	80%	**1.01**	66%	51%	**1.28**	83%	67%	**1.24**
1-Year Weekly Volatility	82%	78%	**1.06**	66%	55%	**1.20**	84%	68%	**1.23**
3-Year Weekly Volatility	81%	79%	**1.03**	69%	57%	**1.21**	83%	70%	**1.18**
3-Year Monthly Volatility	82%	82%	**1.01**	70%	61%	**1.16**	84%	72%	**1.17**
Average	82%	80%	**1.03**	68%	56%	**1.21**	84%	69%	**1.20**
Volatility Asymmetry (Exhibit 6)			**1.17**			**1.46**			**1.77**

Source: Northern Trust Quantitative Research, FTSE Russell

We observe from Exhibit 12 that the average up/down capture is lowest in the 1990s (1.03) and note it is also the time period of the weakest volatility asymmetry (1.17). Both volatility asymmetry (1.46) and up/down capture (1.21) increased in the 2000s, though the subsequent increase in volatility asymmetry (1.77) did not correspond to an increase in up/down capture (1.20) in the 2010s. The up/down capture of the international low volatility portfolios are reported in Exhibit 13 for comparison (as well as the volatility asymmetry ratios from Exhibit 7).

EXHIBIT 13: UP/DOWN CAPTURE OF LOW VOLATILITY PORTFOLIOS WITHIN THE MSCI WORLD EX US AND MSCI EMERGING MARKETS INDEXES (12/31/1999 – 12/31/2019)

MSCI World ex US Low Volatility Portfolios

	2000s			2010s		
	Up Capture	Down Capture	**Up/Down Capture**	Up Capture	Down Capture	**Up/Down Capture**
1-Year Daily Volatility	72%	61%	**1.19**	81%	63%	**1.29**
1-Year Weekly Volatility	71%	56%	**1.28**	82%	62%	**1.32**
3-Year Weekly Volatility	72%	58%	**1.24**	81%	58%	**1.40**
3-Year Monthly Volatility	73%	62%	**1.17**	83%	61%	**1.36**
Average	72%	59%	**1.22**	82%	61%	**1.34**
Volatility Asymmetry (Exhibit 7)			**1.53**			**1.63**

MSCI Emerging Markets Low Volatility Portfolios

	2000s			2010s		
	Up Capture	Down Capture	**Up/Down Capture**	Up Capture	Down Capture	**Up/Down Capture**
1-Year Daily Volatility	76%	52%	**1.46**	81%	60%	**1.35**
1-Year Weekly Volatility	71%	50%	**1.41**	76%	58%	**1.31**
3-Year Weekly Volatility	79%	52%	**1.53**	80%	54%	**1.49**
3-Year Monthly Volatility	79%	52%	**1.52**	77%	62%	**1.24**
Average	76%	52%	**1.48**	79%	59%	**1.35**
Volatility Asymmetry (Exhibit 7)			**1.45**			**1.34**

Source: Northern Trust Quantitative Research, MSCI

Similar to the US, both international markets report volatility asymmetry and up/down capture ratios well above 1 in each of the past two decades. Though there are only two time periods reported, higher volatility asymmetry is

associated with higher average up/down capture within each market, as we might expect.

It is worth noting that any investment strategy that outperforms the market in either absolute or risk-adjusted (Sharpe Ratio) terms must exhibit an up/down capture greater than 1. In other words, it must be the case that such a strategy either earns more than the market when the market advances or loses less than the market when it declines (or both). Therefore, it is difficult if not impossible to attribute the up/down capture impact of beta asymmetry from the low risk anomaly itself, or any other indirect exposures that impacted low volatility portfolio performance over the reported time period (e.g. country, industry, or idiosyncratic risk). This confluence of factors may also explain the less-than-perfect alignment between the beta asymmetry ratios reported in Exhibit 11 and the up/down capture ratios reported in Exhibits 12 and 13. In light of these considerations, we conclude that higher volatility asymmetry amplifies the effects of beta asymmetry to enhance up/down capture but is not the sole determinant of it.

We conclude that higher volatility asymmetry has contributed to higher up/down capture.

VOLATILITY OF VOLATILITY DRIVES OUTPERFORMANCE

While an up/down capture greater than 1 is necessary to generate positive active return, it does not guarantee it. The average up capture of the low volatility portfolios presented in Exhibits 12 and 13 is only 81% in the most recent time period. This represents a significant headwind to low volatility investors hoping to beat the market. Exhibit 14 shows a simple two-period example[24] of how positive active return is possible when the market advances despite capturing only 81% of the upside.[25]

EXHIBIT 14: HYPOTHETICAL LOW VOLATILITY INVESTMENT

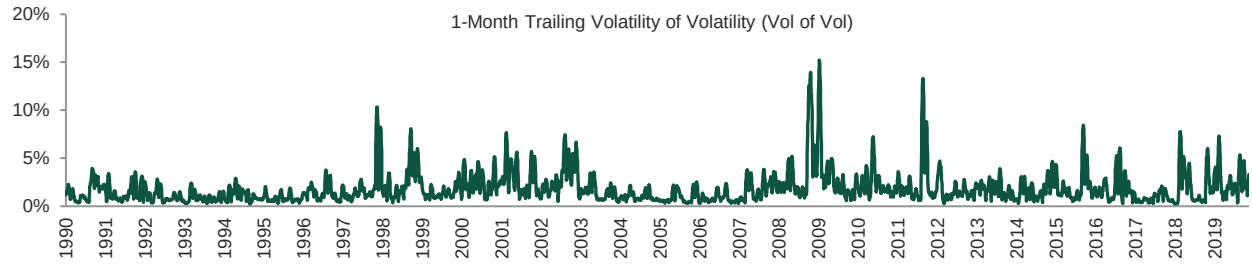
		Market Investor			Low Volatility Investor		
	Market Return	Capture	Portfolio Return	Investment	Capture	Portfolio Return	Investment
				$ 100.00			$ 100.00
Period 1 (Down Market)	-3.0%	100%	-3.0%	$ 97.00	63%	-1.9%	$ 98.11
Period 2 (Up Market)	4.0%	100%	4.0%	$ 100.88	81%	3.3%	$ 101.30
Return				**0.88%**			**1.30%**

As this hypothetical example shows, outperformance is possible when market gains are accompanied by market declines. The market investor earns 88 basis points over this investment horizon while the low volatility investor earns 42 basis points more. This outcome is accentuated with larger market movements — increasing the pullback to -6% and recovery to 8% results in 96 basis points of active return under the same up/down capture assumptions. Of course, the more opportunities the low volatility investor has to "harvest" return asymmetry, the better the likelihood of outperformance. Recall that beta asymmetry is realized

[24] The scenario depicted here is entirely hypothetical and does not correspond to any historical performance period. It is meant to illustrate how a representative low volatility up/down capture profile may result in positive active return despite positive market performance.
[25] The example uses the average down capture (63%) and up capture (81%) of the reported Russell1000, MSCI World ex US, and MSCI Emerging Markets low volatility portfolios in the 2010s.

when volatility changes. Therefore, the greater the volatility of volatility[26] (vol of vol) in the market, the larger the contribution beta asymmetry has on returns. Exhibit 15 shows that the volatility of volatility increased considerably in the late 1990s, abated in the mid-2000s, and then increased again during the global financial crisis. Interestingly, the volatility of volatility has remained elevated after the global financial crisis despite the absence of an economic contraction.

EXHIBIT 15: RUSSELL 1000 INDEX VOLATILITY OF VOLATILITY (12/31/1989 – 12/31/2019)

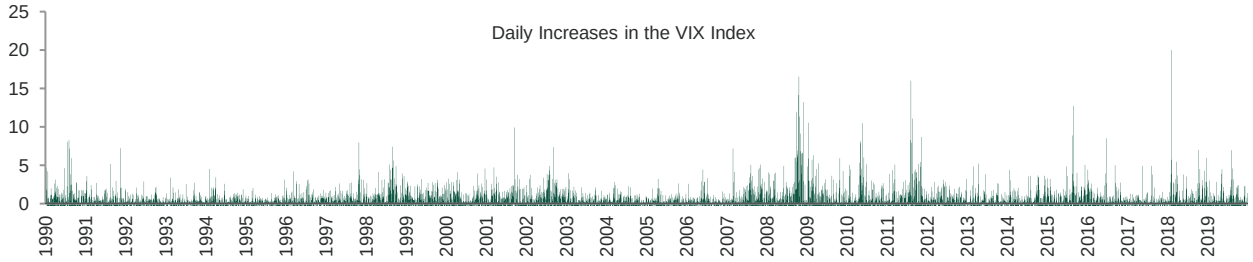


	Average 1-Month Trailing Vol of Vol	Average 3-Month Trailing Vol of Vol
1990s	1.5%	1.2%
2000s	2.2%	2.2%
2010s	2.0%	1.9%

Source: Northern Trust Quantitative Research, FTSE Russell

All of the volatility measures reported thus far have been computed with daily total returns but return asymmetry may be captured at any investment horizon. The greater the volatility change, the more pronounced beta asymmetry becomes. Large increases in volatility can be very acute and typically coincide with market selloffs, providing low volatility investors opportunities to realize up/down capture. Exhibit 16 plots daily increases in the CBOE Volatility Index (VIX)[27] and summarizes the number of volatility spikes in the corresponding table. As the data shows, volatility spikes have become more severe and more frequent in the past 20 years. This type of volatility environment is quite constructive for low volatility portfolios.

EXHIBIT 16: DAILY INCREASES IN THE CBOE VOLATILITY INDEX (12/31/1989 – 12/31/2019)



[26] Computed by taking the trailing 21-day standard deviation of the trailing 21-day standard deviation of total returns.
[27] Although the VIX Index is forward looking, it is commonly used as a measure of current short-term volatility and investor sentiment. The correlation of daily changes in the VIX Index and daily total returns of the Russell 1000 is -0.81 from 2000-2020.

Number of Daily VIX Increases

	> 1	> 2	> 3	> 4	> 5	> 6	> 7	> 8	> 9	> 10
1990s	329	114	43	21	10	6	6	2	0	0
2000s	421	166	84	43	28	19	10	8	8	6
2010s	385	171	84	46	26	15	13	10	5	5

Source: Northern Trust Quantitative Research, Chicago Board Options Exchange (CBOE)

CONSIDERATIONS FOR INVESTORS

The increase in volatility asymmetry coupled with the rise in the volatility of volatility has created a fertile environment for low volatility investments. Whether or not these changes endure will influence the ability of low volatility portfolios to outperform the market. Investors must therefore formulate a view for the ongoing distribution of volatility in order to develop forward-looking return expectations. While a thorough treatment of this topic is beyond the scope of this paper, a few common interpretations are listed in Table 2.

Low volatility investors have benefitted from the increase in volatility asymmetry and the rise in the volatility of volatility.

TABLE 2: VOLATILITY REGIME INTERPRETATIONS

Recent Regime Shift	Rationale

Increased volatility asymmetry	• Policy has become far more aggressive and proactive over the past 20 years.
	  ○ Investors have come to expect monetary and fiscal stimulus in response to economic risks, preventing them from materializing. Recurring periods of extremely low volatility[28] are reflective of investors' belief that economic expansions will be engineered to last indefinitely.
	• The low interest rate environment exacerbates volatility. When risks arise that are outside the influence of policy makers, the response becomes more extreme.
	  ○ Low interest rates have induced higher leverage[29]. Volatility increases with financial leverage (Christie, 1982, and Schwert, 1989) and leads to volatility feedback effects (Pindyck, 1984, and French, Schwert and Stambaugh, 1987).
	  ○ The lower the discount rate, the more sensitive corporate valuations are to changes in earnings projections.

Increased volatility of volatility	• More information is being priced more quickly. ○ Algorithmic trading and big data have led to immediate processing and pricing of information, resulting in volatility spikes and shorter volatility regime durations. • The global economy has become more interconnected, such that risks are no longer insulated within a particular country or region. • The prolonged low yield environment has drawn a number of market participants into non-traditional investment strategies which essentially sell financial insurance (Bhansali and Harris, 2018). Though seemingly disparate in nature these strategies are all short market volatility, which can lead to large, self-reinforcing selloffs.

SOURCE: Northern Trust Asset Management

[28] As a point of reference the VIX Index has closed under 10 a total of 59 trading days since 2010, compared to just 9 occurrences from 1990 through 2010.
[29] According to the Federal Reserve Bank of St Louis, total credit to non-financial corporations in the US reached the highest level on record in 2017, eclipsing previous highs of the global financial crisis.

Another critical factor investors must consider is the level of defensiveness they seek from their low volatility portfolio. As noted previously, the equity risk premium itself represents the biggest headwind to a low volatility investment for benchmark-aware investors, given that the equity market goes up far more often than it goes down (e.g. the Russell 1000 Index has had a positive total return in 66% of the calendar months since 1990). The more defensive the portfolio becomes, the more susceptible it is to prolonged periods of low volatility and strong equity market performance. Therefore, while up/down capture is of paramount importance to low volatility investors, they must also separately consider the upside participation if their goal is to outperform a benchmark. If the upside participation is too low, it may lead to a large performance gap, which will be difficult to close without a sizable pullback in the market.

Investors wishing to outperform a benchmark must consider upside participation as well as up/down capture.

Related to this decision is the amount of indirect systematic risk investors are willing to accept in their low volatility portfolios. Naive low volatility portfolios may carry excessive sector (industry), region (country), or currency risk in pursuit of deep volatility (beta) reduction. These exposures can introduce unintended macroeconomic risks, which may or may not be desired. The best example is the utilities sector, which is a common stalwart in most defensive strategies. The utilities sector is generally one of the highest dividend-paying sectors, making it attractive for income seeking investors — especially in a historically low interest rate environment. Utility companies also operate with high debt levels relative to other sectors, making them more sensitive to increased borrowing costs. Therefore, the amount of interest rate risk embedded in a utilities investment is non-trivial. These systematic risks often generate high levels of tracking error against a benchmark and can dominate the active risk of a low volatility portfolio. It is prudent to note that some degree of unintended systematic risk must be accepted in order to form a long-only low volatility portfolio. However, the extent to which low volatility investors are willing to expose themselves to such risks represents a key decision point.

CONCLUSION

Low volatility investing has a long history of generating superior Sharpe Ratios than passive cap-weighted indexes but has traditionally been expected to fall short in terms of total return. However, recent performance of low volatility strategies has captured the attention of investors by outperforming cap-weighted benchmarks in spite of strong equity market returns. This has led many investors to reevaluate low volatility both strategically and tactically. Strategic investors are enticed by the possibility of outpacing benchmark returns for a lower level of risk within their equity allocation, thereby increasing the efficiency of the aggregate portfolio. Tactical investors worried about heightened economic risks are looking to low volatility portfolios to offer downside mitigation without sacrificing upside potential.

Before reallocating their equity portfolios, it is essential for investors to understand the market dynamics responsible for the recent improvement in low volatility strategies. Changes in the distribution of volatility have provided a significant tailwind to low volatility investments due to the beta asymmetry inherent in low volatility portfolios. Both volatility asymmetry and the volatility of volatility have increased over the past 20 years, resulting in more frequent and more severe volatility spikes. If these changes reflect the “new normal,” it is

reasonable to expect beta asymmetry to continue to be incremental to the low risk anomaly, enhancing both risk-adjusted and total returns.

Investors must be cognizant of the trade-offs associated with low volatility investing, and look beyond typical defensive statistics, such as market beta and historical volatility. Deep volatility reduction often comes with lower upside participation and excessive systematic risk. Failure to account for such consequences may lead to superior Sharpe Ratios at the expense of active return. Given these considerations, we recommend balancing the benefits of up/down capture and downside mitigation with upside participation while controlling unintended systematic risks as much as possible. We believe this approach to low volatility investing is capable of delivering alpha from both an academic and investor point of view.

We recommend balancing the benefits of downside mitigation and upside participation in a risk-controlled manner.

APPENDIX A: ASSET PRICING MODEL COEFFICIENTS AND [T-STATS] OF LOW VOLATILITY PORTFOLIOS WITHIN THE RUSSELL 1000 INDEX (12/31/1999 – 12/31/2019)

CAPM: $(R_{it} - R_{ft}) = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it}$

Fama-French 3 Factor: $(R_{it} - R_{ft}) = \alpha_i + \beta_{1i}(R_{mt} - R_{ft}) + \beta_{2i}SMB_t + \beta_{3i}HML_t + \varepsilon_{it}$

Carhart 4 Factor: $(R_{it} - R_{ft}) = \alpha_i + \beta_{1i}(R_{mt} - R_{ft}) + \beta_{2i}SMB_t + \beta_{3i}HML_t + \beta_{4i}UMD_t + \varepsilon_{it}$

Where:

- R_i is the monthly return of portfolio i
- R_f is the risk-free rate of interest
- R_m is the monthly return of the aggregate US equity market portfolio
- SMB, HML, and UMD are the small-minus-big, high-minus-low, and up-minus-down monthly factor returns, respectively

	CAPM		Fama French 3 Factor				Carhart 4 Factor				
	α	Mkt (β)	α	Mkt (β)	SMB	HML	α	Mkt (β)	SMB	HML	UMD
1-Year Daily Volatility	**3.4%**	0.60	**3.5%**	0.66	-0.30	0.16	**3.0%**	0.71	-0.33	0.19	0.08
	[2.44]	[22.6]	**[3.29]**	[32.5]	[-10.8]	[5.7]	**[2.99]**	[33.0]	[-12.0]	[6.8]	[4.9]
1-Year Weekly Volatility	**3.0%**	0.62	**3.0%**	0.68	-0.30	0.16	**2.6%**	0.72	-0.32	0.18	0.07
	[2.16]	[23.7]	**[2.94]**	[34.2]	[-11.0]	[5.9]	**[2.65]**	[34.0]	[-12.0]	[6.8]	[4.3]
3-Year Weekly Volatility	**2.7%**	0.62	**2.7%**	0.69	-0.31	0.18	**2.4%**	0.72	-0.33	0.20	0.06
	[1.91]	[23.2]	**[2.61]**	[34.0]	[-11.1]	[6.4]	**[2.36]**	[32.9]	[-11.7]	[7.0]	[3.2]
3-Year Monthly Volatility	**2.4%**	0.65	**2.5%**	0.72	-0.31	0.16	**2.1%**	0.75	-0.32	0.18	0.06
	[1.80]	[25.5]	**[2.55]**	[38.0]	[-11.9]	[6.3]	**[2.27]**	[37.0]	[-12.7]	[7.1]	[3.7]

SOURCE: Northern Trust Quantitative Research, FTSE Russell, Kenneth French Data Library

APPENDIX B: ACTIVE PERFORMANCE OF LOW VOLATILITY PORTFOLIOS IN THE MSCI WORLD EX US AND MSCI EMERGING MARKET INDEXES (12/31/1999 – 12/31/2019) IN USD

Active Return vs. MSCI World ex US Index (USD)

Period	MSCI World ex US Index Return (USD)	1-Year Daily Volatility	1-Year Weekly Volatility	3-Year Weekly Volatility	3-Year Monthly Volatility	Average Active Return
2000s	2.0%	2.7%	3.4%	3.4%	2.6%	3.0%
2010s	5.8%	0.9%	1.0%	1.7%	1.7%	1.3%

Active Return vs. MSCI EM Index (USD)

Period	MSCI EM Index Return (USD)	1-Year Daily Volatility	1-Year Weekly Volatility	3-Year Weekly Volatility	3-Year Monthly Volatility	Average Active Return
2000s	10.1%	2.4%	1.1%	4.2%	4.2%	3.0%
2010s	4.0%	1.1%	0.5%	1.8%	0.2%	0.9%

SOURCE: Northern Trust Quantitative Research, MCSI

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I-102324-3957541-102325