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Using managed volatility in multi-asset portfolios

Invesco Investment Insights

Executive Summary:

Financial markets have become quite turbulent over the past few years. Starting with the outbreak of COVID-19 and subsequent supply shocks, followed by runaway inflation and the responses of central banks, all amidst elevated geopolitical risk, markets have been reacting forcefully and this has led to significant price swings. These intense movements have highlighted the importance of volatility management as part of the overall portfolio construction process. In this white paper we highlight how adding uncorrelated asset classes can reduce portfolio volatility. Beyond this common approach, we propose two strategies to manage risk through the utilization of our volatility forecast model. The first employs a static volatility cap, whereas the second leverages a dynamic risk target (cap) to adjust for business cycle conditions. Integrating either of these strategies into the investment process can lead to more attractive investment outcomes, particularly in volatile market conditions such as the environment we currently find ourselves in.

Modern portfolio theory and the dynamic nature of correlation among asset classes
Nobel Laureate Harry Markowitz developed Modern Portfolio Theory (MPT) in his paper entitled "Portfolio Selection" in the 1952 edition of the Journal of Finance. This paper revolutionized the investment management industry and has led risk-aware investors to manage their portfolio risk by utilizing diversification.

Correlations between various asset classes are extremely important when we think about diversification benefits for a multi-asset portfolio. The lower the correlation is between two assets, the more diversification combining them can provide. We can see that between the years 1999 and 2021, the correlation between US Equity and EM Equity was 0.45 (Figure 1). Although positive, this is still moderate in terms of overall magnitude, meaning that these two asset classes provide some level of diversification. While the correlation between US Equity and US Treasury during this period was -0.33, substantially lower than the correlation between the aforementioned pair of assets. This explains why US Treasury as an asset class can typically do a better job in decreasing portfolio volatility when combined with US Equity.

Figure 1 - Correlation between different assets

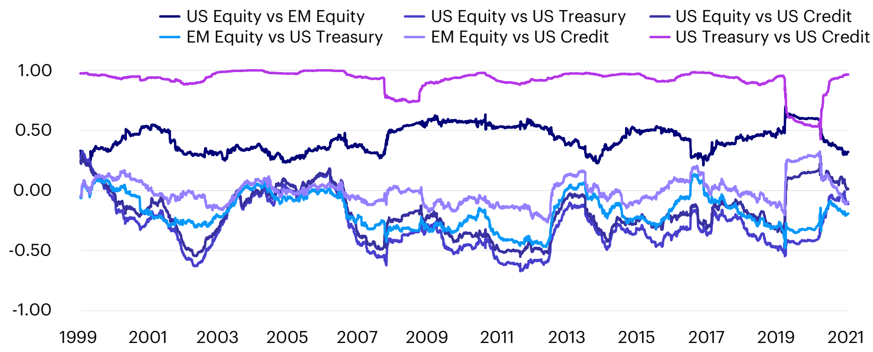
	US Equity	EM Equity	US Treasury	US Credit
US Equity	1.00	0.45	-0.33	-0.18
EM Equity	0.45	1.00	-0.23	-0.02
US Treasury	-0.33	-0.23	1.00	0.87
US Credit	-0.18	-0.02	0.87	1.00

Source: Bloomberg, data as of Dec. 31, 2021. Data range from 1999-2021. Data is represented by the S&P 500 index, MSCI Emerging Market Index, Bloomberg US Treasury Total Return Index and Bloomberg US Credit Total Return Index. An investment cannot be made in an index. Diversification does not guarantee profit or protect against loss.

When we look deeper into time series data, we find that rolling correlations can change considerably over time (Figure 2). The result points us to some important observations about correlation:

- Long-term correlations represent results over a number of years. This is an average, and like all other averages, the data may not fully capture other dynamics that are happening behind the scenes.
- Correlation is typically dynamic and changes over time. As it is often influenced by the macro environment, we could consider dividing the time period up and estimating the different correlations in each regime instead of using the same correlation figure for the entire period.

Figure 2 - Rolling one-year correlation of different assets



Source: Bloomberg, data as of Dec. 31, 2021. Data range from 1999-2021. Data is represented by the S&P 500 index, MSCI Emerging Market Index, Bloomberg US Treasury Total Return Index and Bloomberg US Credit Total Return Index. An investment cannot be made in an index.

Modeling Portfolio Volatility

In our previous paper on managing volatility [1], we outlined the key properties of asset volatility. These include persistence, mean-reversion, and asymmetry. These statistical properties can be modeled using approaches such as Moving Average, ARMA (Autoregressive Moving Average), ARCH (Autoregressive Conditional Heteroskedasticity) and GARCH (Generalized Autoregressive Conditional Heteroskedasticity). Regarding volatility forecasting, some practitioners focus on univariate approaches. Even though univariate models are more straight forward, one potential issue is that they overlook the covariance structure between financial assets in the portfolio, and thus may cause investors to overestimate the portfolio volatility.

In contrast, multivariate models consider all individual assets within a portfolio as well as their relationships with each other. One such model is Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH), which is an extension of GARCH. Different MGARCH models have been proposed, and they can generally be divided into the following subgroups [2]:

- **Factor Models:** Factor models assume that observations are driven by some conditionally heteroskedastic underlying factors. The advantage of factor models is dimensionality reduction. Because the number of factors relative to the parameters of the return vector is quite small, it is more feasible to model portfolios with a large number of assets.
- **Semiparametric and Nonparametric Approaches:** Semiparametric models and nonparametric models do not assign a distribution or structure to the input data, so there is no chance of misspecification. However, compared to fully parametric multivariate GARCH models, these approaches lack details on the dynamic structure of model statistics.

1. Nguyen D., J. Borbidge and M. Shwarzman (2016), Seeking Better Investment Outcome by Managing Volatility, Invesco.
2. Silvennoinen, A. and T. Terasvirta (2008), Multivariate GARCH models, Handbook of Financial Time Series, pp 201-229.

- **Models of Conditional Covariance Matrices:** Models of conditional covariance matrices were the earliest multivariate approaches. Examples of these models include the Vector Error Correction (VEC)-GARCH model developed by Bollerslev, Engle, and Wooldridge (1988) and Baba-Engle-Kraft-Kroner (BEKK) model. The latter is a restricted version of an earlier version of the VEC model developed by Engle and Kroner (1995). One of the major drawbacks of conditional covariance matrix models is that they require a large number of parameters to create the model.
- **Models of Conditional Variances and Correlations:** Correlation models break down the conditional covariance matrix into conditional standard deviations and correlations. The Constant Conditional Correlation (CCC) model of Bollerslev (1990) is the simplest multivariate correlation model. Engle (2002) introduced a Dynamic Conditional Correlation (DCC) model with a time-varying conditional correlation matrix.

After weighing the advantages and disadvantages of each subgroup, we chose the conditional variances and correlations approach to model volatility. We chose this instead of the conditional covariance matrix model because estimating the covariance matrix could be very challenging due to potential dimensionality issues and the requirement of positive definiteness of the covariance matrix.

Factor models and nonparametric approaches were not selected because they do not offer a natural interpretation of their parameters (correlations) while conditional variances and correlations models do, thus their economic implications are very intuitive.

We chose the DCC GARCH model as our primary framework. Although CCC GARCH has attractive parameterization in many ways, empirical studies have shown that the assumption of constant conditional correlations for different assets may be too restrictive and unrealistic. The DCC GARCH model retains CCC GARCH's decomposition but relaxes the time-invariant assumption of the conditional correlation matrix.

There is a two-step algorithm to estimate the parameters of DCC GARCH model. In the first step, a univariate GARCH model is used to estimate the conditional variances for respective assets. In the second step, the parameters from the first step are applied to the conditional correlation estimators [3]. This approach is not only relatively easy to use in practice but also paves the way for estimating covariance for as many as hundreds of assets using a manageable computation.

3. Please refer to Engle (2002)'s paper for detailed formula.

Using managed volatility in multi-asset portfolios

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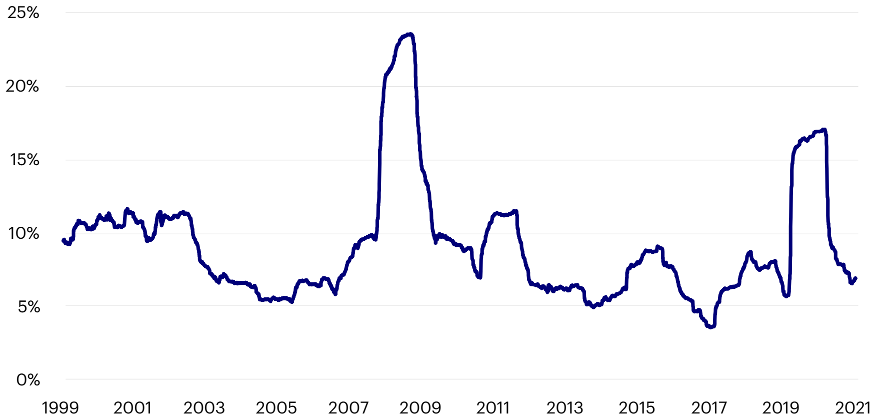
Outcome-oriented Managed Volatility Strategy
How can investors use managed volatility in their portfolio and what is the likely outcome of this? Considering the needs of different clients (investors), we have designed two managed volatility mechanisms using our volatility forecasting capabilities: namely managed volatility using a static volatility threshold (Static ManVol) and managed volatility based on dynamic volatility targeting (Dynamic ManVol). To examine the effectiveness of our two approaches, we use a well-diversified hypothetical portfolio of 40% US Equity, 20% EM Equity, 25% US Treasury and 15% US Credit (our Benchmark Portfolio) as an example. The one-year rolling realized volatility of this portfolio and its basic statistics are shown in the charts below (Figures 3, 4).

Figure 3 - One-year rolling realized volatility of benchmark portfolio



Source: Bloomberg, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. An investment cannot be made in an index.

Figure 4 - Volatility statistics of benchmark portfolio

	One-Year Rolling Realized Volatility of Benchmark Portfolio
Minimum	3.50%
1st Quartile	6.33%
Median	7.92%
Mean	9.01%
3rd Quartile	10.53%
Maximum	23.46%

Source: Bloomberg, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. An investment cannot be made in an index.

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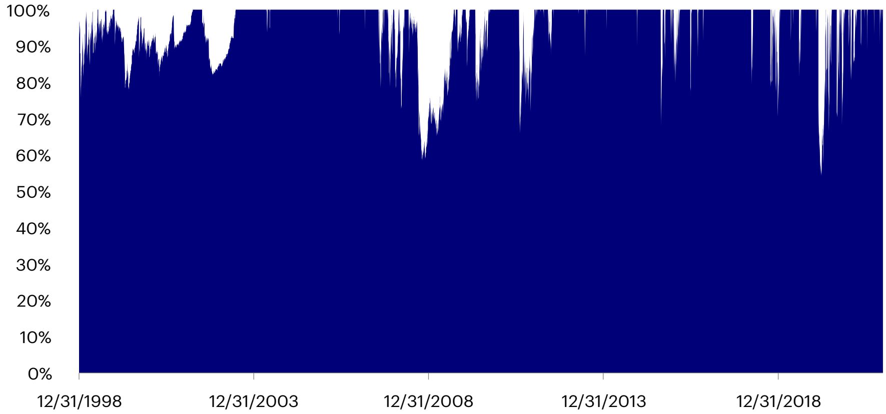
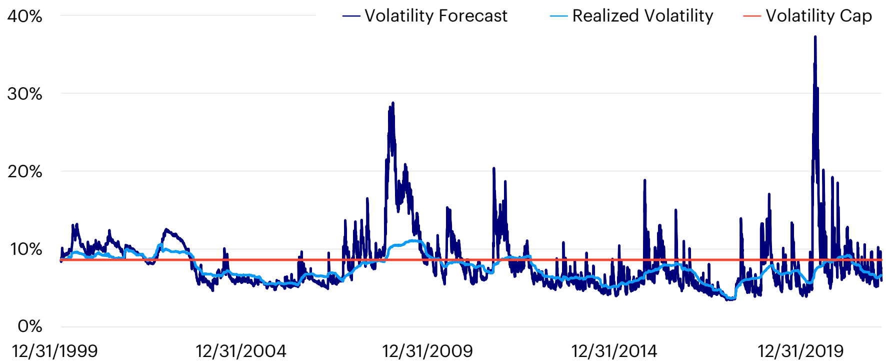
Managed Volatility using a Static Volatility Threshold (Cap)
When the volatility forecast using DCC GARCH Model is higher than the threshold level, we can bring portfolio volatility down to the threshold by reducing the exposure to risky assets (Figure 5). To do this, we use a static volatility threshold where the word "static" refers to a pre-defined volatility cap for volatility control that does not change. This approach can meet the needs of investors who prefer to keep volatility under a certain level. We can see that the overall realized volatility of the portfolio usually stays around or below the threshold level of 8.5% after implementing this mechanism (Figure 6). Backtesting shows that even though the annualized return is slightly lower using this approach, the Sharpe ratio tends to improve substantially due to the reduction in the realized volatility (Figure 7).

Figure 5 - Weight of risky assets (equity) using managed volatility with static threshold



Source: Bloomberg and Invesco, data as of Dec. 31, 2021. Data range from 1999-2021.

Figure 6 - Volatility forecast and one-year rolling realized volatility using static managed volatility



Source: Bloomberg and Invesco, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. The volatility forecast is based on the unhedged benchmark portfolio. The realized volatility of the portfolio is calculated after applying the managed volatility process. An investment cannot be made in an index.

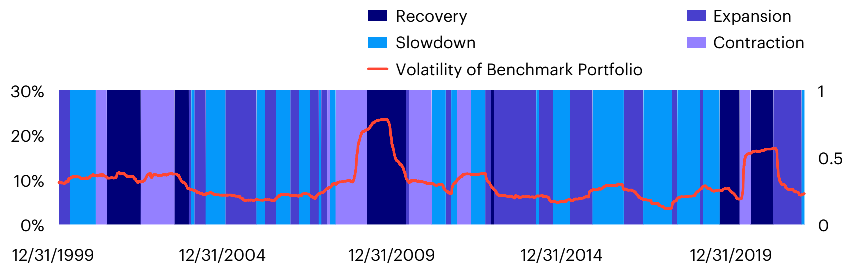
Figure 7 - Performance of static managed volatility strategy

	Benchmark Portfolio	Static ManVol
Annualized Return	7.67%	7.19%
Annualized Volatility	9.78%	7.54%
Sharpe Ratio (Rf=0%)	0.78	0.95

Source: Bloomberg and Invesco, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. Past performance is no guarantee of future results. An investment cannot be made in an index.

Managed Volatility based on Dynamic Volatility Targeting (Cap)
Dynamic volatility targeting is where the volatility cap can be adjusted depending on the market conditions. This strategy is intended for investors who are willing to tolerate higher risk during risk-on market conditions in the hopes of potentially achieving higher returns. In our approach, the market conditions are defined by our macro-regime model which combines leading economic indicators with a proprietary global risk appetite indicator [4]. Based on the level and possible changes in economic growth expectations, we define four regimes: Recovery, Expansion, Slowdown and Contraction. By observing realized volatility in each of these macro regimes, we find that the volatility level varies considerably (Figure 8). Furthermore, given market performance differs from one regime to another, having an adjustable volatility cap may better meet the needs of investors with different risk profiles.

Figure 8 - Average one-year rolling annualized volatility and annualized return in various regimes

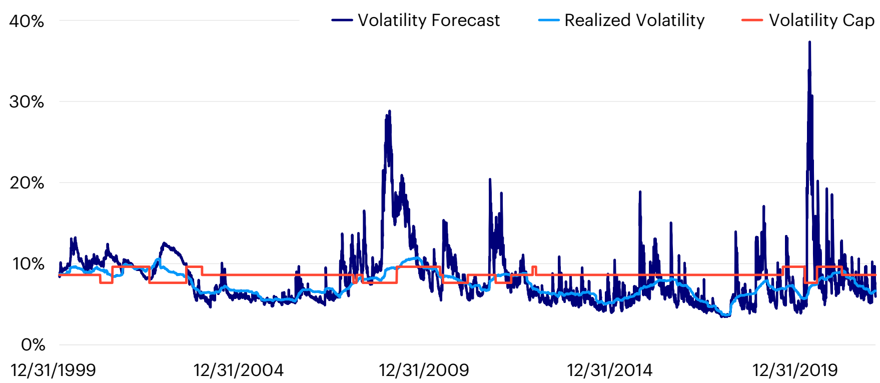


	Recovery	Expansion	Slowdown	Contraction
Annualized Return	16.56%	4.56%	10.32%	-2.40%
Average Volatility	13.58%	6.95%	7.44%	11.18%

Source: Bloomberg and Invesco, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. Past performance is no guarantee of future results. An investment cannot be made in an index.

For example, during a Contraction regime, the economic environment is deteriorating and the outlook is quite uncertain. In this case, we set a lower threshold level so that the portfolio is more defensive and hence can weather a potential market downturn. On the contrary, under a Recovery regime, economic growth expectations are improving and the outlook is more promising. In this case, we set a higher threshold level, particularly so that we can capture the equity market's upside even in a volatile market environment (Figure 9). As an example, in this exercise we use volatility cap of 9.5% for Recovery, 8.5% for Expansion and Slowdown, and 7.5% for Contraction regimes.

Figure 9 - Volatility forecast and one-year rolling realized volatility using dynamic managed volatility



Source: Bloomberg and Invesco, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. The volatility forecast is based on the unhedged benchmark portfolio. The realized volatility of the portfolio is calculated after applying the managed volatility process. An investment cannot be made in an index.

4. de Longis, A. and D. Ellis (2019), Market Sentiment and the Business Cycle: Identifying Macro Regimes Through Investor Risk Appetite, Invesco.

Compared to the benchmark portfolio, volatility using Dynamic Volatility Targeting also drops more than 20%, which is similar to the result achieved using the Static Volatility Threshold (Figure 10).

Figure 10 - Performance of managed volatility strategies

	Benchmark Port	Static ManVol	Dynamic ManVol
Annualized Return	7.67%	7.19%	7.38%
Annualized Volatility	9.78%	7.54%	7.43%
Sharpe Ratio (Rf=0%)	0.78	0.95	0.99

Source: Bloomberg and Invesco, data as of Dec. 31, 2021. Data range from 1999-2021. The benchmark portfolio is represented by a 40% allocation to the S&P 500 index, a 20% allocation to MSCI Emerging Market Index, a 25% allocation to Bloomberg US Treasury Total Return Index and a 15% allocation to Bloomberg US Credit Total Return Index. Past performance is no guarantee of future results. The results shown are hypothetical, for illustrative purposes only and are based on index returns. An investment cannot be made in an index. Index returns do not reflect the deduction of fees which would be applied to an investment.

Conclusion

There are several techniques available to manage volatility in portfolios in order to improve risk-adjusted returns. While we have identified several of these, we chose the DCC GARCH framework to model volatility due to its relatively small number of parameter estimators and time varying covariances. This model can be implemented with a static volatility threshold if the goal is to put a cap on volatility. Alternatively, if the investor has insight into business cycle conditions, their performance can be improved by dynamically changing this threshold. This allows the investor to take on more risk during risk-on market conditions, should they be willing to tolerate this level of risk exposure. Either way, these two approaches can improve portfolio performance on a risk-reward basis and provide more efficient outcomes for investors.

In our next whitepaper on Outcome Oriented Strategies, we plan to explore Option Based Portfolio Insurance (OPBI) strategies. We will review how these strategies differ from Managed Volatility strategies and evaluate the advantages of each.

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References

Bollerslev, T. (1990), Modelling the Coherence in Short-run Nominal Exchange Rates: A Multivariate Generalized ARCH Model, The Review of Economics and Statistics, Volume 72, Issue 3, pp. 498-505.

Bollerslev, T., R. Engle, and J. Wooldridge (1988), A Capital Asset Pricing Model with Time Varying Covariances, Journal of Political Economy, Volume 96, No 1, pp. 116-131.

de Longis, A. and D. Ellis (2019), Market Sentiment and the Business Cycle: Identifying Macro Regimes Through Investor Risk Appetite, Invesco.

de Longis, A. and D. Ellis (2023), Tactical Asset Allocation, Risk Premia, and the Business Cycle: A Macro Regime Approach, The Journal of Portfolio Management, Multi-Asset Special Issue, forthcoming.

Engle, R. (2002), Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models, Journal of Business & Economic Statistics, Volume 20, pp. 339-350.

Engle R., and K. Kroner (1995), Multivariate Simultaneous Generalized Arch, Econometric Theory, Volume 11, No 1, pp. 122-150.

Markowitz, H. (1952), Portfolio Selection, The Journal of Finance, Volume 7, No 1, pp. 77-91.

Nguyen D., J. Borbidge and M. Shwarzman (2016), Seeking Better Investment Outcome by Managing Volatility, Invesco.

Silvennoinen, A. and T. Terasvirta (2008), Multivariate GARCH models, Handbook of Financial Time Series, pp. 201-229.

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