Cross Asset Strategy

Applied Portfolio Construction Research: Can you time your optimization technique?

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This inaugural report introduces a new series of publications focused on Applied Portfolio Construction Research.

In the first part we offer an intuitive overview of the most popular cross-sectional and time-series portfolio construction frameworks. We also analyze and visualize ex-ante optimal portfolios built on traditional core risk factors i.e. Equities, Bonds, Credit and Commodities.

We then examine the results of an out-of-sample backtest over the 1975-2022 period. Risk-based models have done overall better than return-based ones but there is **no framework that consistently outperforms over time**. The VMP overlay boosted performance of both risk-based and return-based models.

Finally, we look at the issue of dynamically selecting portfolio methods. Here we employ a set of univariate and multivariate (i.e. KNN and 5-states model) regime frameworks based on growth, inflation and risk aversion.

Assuming persistence in the current regime: 1) Return headwinds for portfolios of core risk factors are likely to remain. 2) Return-based models should be slightly preferred to risk-based ones because of a structurally lower allocation to Fixed Income and higher allocation to Commodities. MSR achieved the highest risk-adjusted performance but BL had the highest Hit Ratio across return-based frameworks. Within risk-based models the preference is for EW and MDP. **3) The VMP overlay is likely to improve performance** under current market conditions.

Our analysis shows that strictly committing to one approach 'for life' implies investment decisions and consequences. At the same time, it opens the door to market-timing the different optimization models. Forming an opinion on portfolio constructions seems doable assuming regimes are well-defined, though this is subject to having a process for taking expected returns views, making calls on the business cycle, defining risk inputs etc. For this exploratory analysis, we have relied on simple CMAs but part of our future research will be on systematically forecasting expected returns, correlations and volatilities and strengthening these conclusions.

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See page 24 for analyst certification and important disclosures, including non-US analyst disclosures.

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Introduction

Asset allocation is the decision faced by an investor who must choose how to allocate their portfolio across a number of asset classes. In these respects, the goal of a portfolio optimization process is to create the best possible portfolio for a particular investment objective, given some assumptions for future asset performance. The optimization objective can be to achieve a portfolio with the lowest possible risk, highest Sharpe ratio, smallest tracking error relative to a benchmark, or other objectives specified by an investor. However, in order to obtain asset weights that will result in an optimal portfolio, an investor often needs to make assumptions on the future asset returns, volatilities and correlation between assets.

The big issue is that the forecasts for asset returns, volatilities and correlations are often not accurate and return distributions are often not normal. As a result, an expected optimal mathematical solution may not turn out to be a portfolio with the desired properties after the fact. Given that asset returns are not easy to forecast, some investors may choose to limit themselves to forecasting volatility and correlations. The rationale behind forecasting only volatility and correlations is that these measures tend to exhibit properties of persistence and mean reversion, and their average levels should be easier to estimate. In these, respects, to avoid forecasting asset returns, an investor can use simplifying assumptions such as equal expected returns, and equal asset Sharpe ratios.

This introductory report introduce a series of thematic publication focused on Portfolio Construction Research. The end goal of this series is to help investors becoming familiar with the available risk methods. Each framework will have its own benefits and drawbacks, and may work best under different market conditions. Hence, the optimal approach to manage risk will depend not only on the forecast returns and covariances, but also on the understanding of the prevailing market regime and potential tail risks. Investors who are versatile in all risk management methods can stand ready to apply a specific method when it is likely to yield the best results.

The rest of this introductory note is structured as follows. First, we provide a gentle overview of the main portfolio construction frameworks. Second, we look at the optimal ex-ante portfolios produced by each of the cross-sectional models discussed. Finally, we turn to the issue of dynamically selecting the best portfolio construction process via backtesting and regime-based frameworks.

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Portfolio construction overview

The aim of this section is to convey an overview and an intuitive understanding of the main portfolio construction tools. Our list mainly includes cross-sectional frameworks i.e. models that allocates risk across factors/asset classes. In particular we cover Mean Variance Optimization (MVO); Maximum Sharpe Ratio (MSR); Black Litterman (BL); Equal Weight (EW); Global Minimum Variance (GMV); Most Diversified Portfolio (MDP); Generic Risk budgeting (RB); Equal Marginal Volatility (EMW); Risk Parity (RP) and Hierarchical Risk Parity (HRP). We also cover one popular time-series risk allocation method i.e. the Vol Managed Portfolios (VMP). Notably, we avoid the math behind these optimization problem as we prioritize intuition. For those interested in the more technical details we suggest to look at *Risk Factor Approach to Investing and Portfolio Management*.

Table 1 illustrates the main objectives of different cross sectional portfolio construction frameworks we consider as well as conditions under which each of these methods leads to an optimal portfolio. Admittedly, while assumptions such as 'equal returns' or 'equal Sharpe ratios' may seem overly simplistic, they do relate to some realistic market regimes. For instance, in an efficient market regime one would expect assets to have similar Sharpe ratios, while in a 'Volatility Anomaly' market regime, assets may have similar returns, i.e. high volatility assets having lower Sharpe ratios than low volatility assets.

Table 1: Portfolio construction frameworks objective

Framework	Objective
Mean-Variance Optimization (MVO)	Achieve max returns for a target level of portfolio risk
Maximum Sharpe Ratio (MSR)	Achieve Maximum Portfolio Sharpe ratio
Black-Litterman (BL)	Achieve Maximum Sharpe ratio after incorporating expected return views
Equal weight (EW)	Each asset has equal weight
Global Minimum Variance (GMV)	To obtain minimum variance
Most-Diversified Portfolio (MDP)	To obtain maximum diversification ratio
Generic Risk Budgeting (RB)	Specific total risk contribution for each asset
Equal Marginal Volatility (EMV)	Each asset has equal marginal volatility
Risk Parity (RP)	Equal total risk contribution for each asset
Hierarchical Risk Parity (HRP)	Avoid the instability and concentration with highly correlated assets

Source: J.P. Morgan. See Table 23 on page 80 of *Risk Factor Approach to Investing and Portfolio Management*

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Return-based methods

We refer to the first set of cross-sectional models as return-based frameworks. The key feature is that these optimization problems require as inputs not only risk metrics (i.e. correlation matrices and volatilities) but also expected returns. Notably, the success of practical implementations of return-based models largely relies on the quality of return forecasts.

Mean Variance Optimization (MVO) & Maximum Sharpe Ratio (MSR)

The idea that financial decisions and portfolio construction should be based on the trade-off between risk and return was introduced seventy years ago by Markowitz (1952). In a MVO frameworks, returns, volatilities and correlations are assumed to be deterministic. With the risk of oversimplifying a little the description, an investor takes the inputs as given and can either solve for the portfolio with maximum return given a target level of risk (we term this approach MVO) or find the optimal portfolio with the maximum Sharpe ratio (MSR). Despite its theoretical elegance, the practical application of MVO has universally encountered problems:

First, the success of MVO is highly dependent on the accuracy of the estimated returns, volatilities and correlations. Since estimates of market parameters are subject to significant statistical errors, the portfolios obtained from MVO are often not workable from a practical point of view (Kritzman (2006) discussed this at length). A relatively small change in return and covariance inputs may result in large changes in the output weights. In these respects, assets with positive estimation error will be overweighed, while assets with negative estimation error will be underweighted; this is why MVO is sometimes referred to as an error maximizer. The potential instability of MVO weights is often quoted as the main reason against its broader usage.

- Chopra (1993) and Frost and Savarino (1988) suggested adding **portfolio constraints** to the MVO problem so that the optimal portfolio is kept within feasible bounds. Unfortunately, the optimal portfolio tends to be sensitive to the choice of portfolio constraints, which is often quite subjective.
- Michaud (1998) proposed the use of **resampling methods** to generate different samples, each with their own mean, variances and covariances. MVO can be applied to each sample, and the final portfolio is an aggregation of the portfolios generated for each sample. Scenario-based stochastic programming methods also address the problem of uncertainty in the inputs by generating different scenarios in advance. However, these approaches are computationally intensive; they become inefficient when the number of assets grows, as discussed by Scherer (2002); and they lack any strong theoretical underpinning

Second, MVO is challenged by the non-normal properties of asset distributions. Alternative risk factor portfolios might be less vulnerable than traditional portfolio to the previous issues but this issue could be equally problematic for both.

Black Litterman (BL)

Robust estimation approaches aim to reduce the statistical error in the mean returns by using some form of **shrinkage** of the mean returns toward a sensible value. **Black and Litterman** (1991) proposed shrinking mean returns toward market-implied returns. Effectively, the BL framework uses proper statistical methods to combine information implied by the market (market portfolio) and investors' views on expected returns. Combining market information and the investor's view results in return and covariance estimates that are then fed into a standard MVO process. The idea is that these estimates will lead to more robust (stable) MVO weights.

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The first step of applying the BL framework involves reverse engineering the expected returns from current market portfolio weights. This step establishes the so called 'market prior' distribution of the expected returns. The 'market prior' and specific investor views are then combined in a Bayesian framework to produce the so-called 'posterior distribution' of portfolio returns. With investor views, the optimal portfolio (the posterior) under the BL framework reflects a combination of market portfolio ('market prior') and a portfolio reflecting optimal application of the investor's views.

The BL approach often results in more stable asset weights (as compared to traditional MVO) **because the 'posterior' expected returns are anchored to a common 'market prior' returns**. Additionally, while the 'market prior' is usually specified as a normal distribution around expected CAPM returns, the BL framework allows for other choices of a 'market prior' distribution. The BL is a flexible framework as it gives investors the ability to (1) specify the relative uncertainty of prior information e.g. uncertainty of market equilibrium versus investor views, and (2) incorporate other priors such as an EW allocation. One drawback of BL is that the additional shrinkage parameters required are not necessarily clear for estimation purposes and can have a significant impact on the optimal portfolio allocation.

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Risk-based methods

Given the potential drawbacks of MVO (and more generally return-based models) **related to the sensitivity to return forecasts**, many investors decided to turn to purely risk-based portfolio methods (see Leote de Carvalho et al (2012) for a detailed discussion). These approaches aim to increase the robustness of the optimal portfolio. The rationale behind the focus on volatility and correlations is that these measures tend to exhibit properties of persistence and mean reversion, and their average levels should be easier to estimate

Equally weighed portfolio (EW)

The EW portfolio is the simplest risk-based portfolio construction and is based on the idea of diversification, allocating the same dollar amount to each asset (for N assets, the weight of each asset is the same and equal to 1/N).

Interestingly, this strategy has been called “Talmudic rule” (Duchin and Levy 2009) since the Babylonian Talmud recommended this strategy approximately 1,500 years ago: “A man should always place his money, one third in land, a third in merchandise, and keep a third in hand.” More recently, this framework has gained much interest due to superior historical performance of equally weighted stocks ETFs vs Capitalization based analogues which has led to the emergence of several equally weighted ETFs.

Interestingly, if one assumes that all assets have the same mean-return, volatility and if all pairwise correlations are equal the EW portfolio is the MSR portfolio.

Global Minimum Variance (GMV)

GMV is a special case of MVO where an investor has very high risk aversion. In this case “risk avoidance” takes priority to “return maximization” and the optimization tries to find the weights that will result in a portfolio with the lowest possible volatility. It can be shown that the GMV approach is also equivalent to a special case of an MVO in which the investor simply assumes that the expected returns for all assets are equal.

Thus GMV may be an optimal approach for investors that are either highly risk averse, or don’t have any differentiating view on the performance of individual assets. An equal return assumption also implies that higher volatility assets have lower Sharpe ratios. While this may contrast with assumptions of efficient markets, there is some recent historical evidence that Sharpe ratios may indeed be lower for higher volatility assets. This ‘low Volatility anomaly’ has been observed empirically in the Equity (Ang et al. (2006) and Frazzini and Pedersen (2014)) and Fixed Income space (Leote de Carvalho 2014)

Most Diversified Portfolio (MDP)

MDP maximizes a measure called the ‘Diversification Ratio’ which is defined as the ratio of the weighted average asset volatility to overall portfolio volatility. In other words, the portfolio diversification is high when the relatively high volatility of component assets results in overall low portfolio volatility through the offsetting effect of correlations.

Although MDP was formally introduced by Choueifaty and Coignard (2008), the concept of maximizing diversification is hardly new. In fact, MDP is just a special case of MVO in which an investor assumes that the Sharpe ratios for all the assets are equal. In fact, if we assume the Sharpe ratios of all assets are equal, the diversification ratio is simply proportional to portfolio Sharpe ratio. In this case,

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maximizing the Sharpe ratio via MVO is the same as finding the most diversified portfolio.

Generic Risk Budgeting (RB)

In an RB framework, an investor starts with 'risk budgets' for each of the assets and then solve for portfolio weights. For instance, an investor can require that Commodities add to 10% of total portfolio risk, Equities 50%, and so on. Such risk budgets should add to 100%. Risk budgets can be based on the investor's specific view on future performance of assets, or some general principles such as to assign equal risk budget to major asset classes or factor styles.

RB can be used to avoid allocating too much risk to one asset or a group of correlated assets. An often quoted argument in support for risk budgeting is the traditional 60% Equity, 40% Bond allocation; it was argued that such a portfolio has 90% of risk in Equities and only 10% in Bonds, and is therefore prone to equities tail risk. A portfolio with more balanced risk budgets would select a lower allocation to Equities and higher allocation to Bonds. The contribution of each asset to portfolio risk is determined by the asset's volatility as well as its correlation to other assets in the portfolio. Adding an uncorrelated asset will increase the volatility of the portfolio only in proportion to the asset's weight and volatility, while adding a highly correlated asset will increase portfolio volatility largely through the correlations with other risky assets. In practice, weights are determined in an iterative numerical procedure. If an investor believes that realized (ex-post) return contributions of each asset will be in line with the predetermined risk budget profile, the risk budgeted portfolio will also have the Maximum Sharpe Ratio.

Equal Marginal Volatility (EMV)

EMV assigns portfolio weights based on to the expected volatilities of individual assets. It UW assets with higher volatility and OW those with lower volatility so as to achieve an EMV contribution for all assets. However, the EMV approach ignores the contribution to portfolio volatility coming from asset correlations. In that regards, EMV is a special case of the MDP when the average level of correlation is zero, and a special case of RP when all the correlations are zero. The weight of an asset in the EMV approach is just the inverse of expected asset volatility. Academic researchers commonly use an EMV portfolio as a simple and transparent method to allocate risk between factors. See, for example, Moskowitz et.al (2012) and Asness et.al (2013).

Risk Parity (RP)

A special case of the RB approach is to assign equal risk budgets to all assets in the portfolio. This approach is also called Equal Risk Contribution, or Risk Parity. During recent years, Risk Parity (RP) methods drew a lot of interest because of their strong performance when applied to multi-asset portfolios. Given the higher marginal volatility of stocks, commodities and credit, these models had on average higher allocation to Treasuries. The strong performance of US Treasuries over the past few decades has helped these models to outperform most other asset allocation approaches. The total risk contribution of an asset to a portfolio is equal to the corresponding portfolio weight times its beta with the portfolio (the "beta" component incorporates the correlation of an asset to the portfolio). If an investor assumes the return contribution of each asset is equal, the RP portfolio has the highest Sharpe ratio. When all the pair-wise correlations of assets are zero, the RP portfolio allocates weights just based on assets' volatility. This special case is the EMV approach we just discussed.

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Hierarchical risk parity (HRP)

The HRP framework is termed “Hierarchical” because it makes use of the hierarchical clustering algorithm to assign assets into similar groups, and then apply the (naïve) RP allocations recursively across asset groups (Lopez de Prado (2016)). Actually, rather than trying to improve upon the naïve Risk Parity approach, the idea of HRP was to improve upon the GMV strategy. The rationale behind HRP is to avoid the instability and concentration in GMV portfolios that rely on the inversion of covariance matrix, which is problematic when the matrix is close to singular – this happens when there are highly correlated assets. Furthermore, estimations of full covariance matrices could be noisy or spurious, especially when the number of assets is large and the number of observations is relatively small. HRP comes as a solution to get around the above issues by allocating to clusters of similar assets. For those interested, our colleagues looked at HRP applications in the context of allocations across risk premia.

The Hierarchical Risk Parity algorithm consists of 3 major steps: 1) computing a distance matrix among the assets based on correlations; 2) Re-ordering the assets into clusters. This will lead to a quasi-diagonalized correlation matrix with large values 'closer' to the diagonal; and 3) Allocating weights inversely proportional to the volatility of the clusters in an iterative manner (recursive bisection), starting from the largest cluster. In each iteration, the larger clusters are divided into two smaller ones and weights are re-distributed across the clusters based on their volatilities.

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Time-series risk allocation

We now briefly turn our attention to time-series risk allocation. In previous pages, we overviewed methods to allocate risk across different assets in a portfolio. These cross-sectional frameworks are designed to be repeated periodically (e.g. monthly, quarterly or even annually) as volatility, correlation and performance estimates change. In addition to cross sectional risk allocation, investors can implement time-series risk allocation. Effectively, this means continuously manage the overall portfolio risk by allocating between the factor portfolio and the risk-free asset (e.g. cash or short term bills). Usually, time-series allocation to the risk-free asset is based on specific prescription for overall portfolio risk. For example, one of the popular methods is to target a constant level of volatility (e.g., 5%, 10% etc. annualized volatility). Volatility targeting techniques essentially reduce the risky portfolio position size during volatile periods and leverages up when portfolio volatility is lower than the target (Harvey et al. (2018)).

In this paper, our reference for time-series risk allocation is the Volatility Managed Portfolio (VMP) framework introduce by Moreira and Muir (2016). Given an optimal portfolio from a cross-sectional perspective (e.g. MVO or MSR optimal), the allocation between the optimal portfolio and cash is dynamically rebalanced by scaling exposure to the risky portfolio by the inverse of its previous month's realized variance. Hence, risk exposure is decreased when recent variance is high and vice versa.

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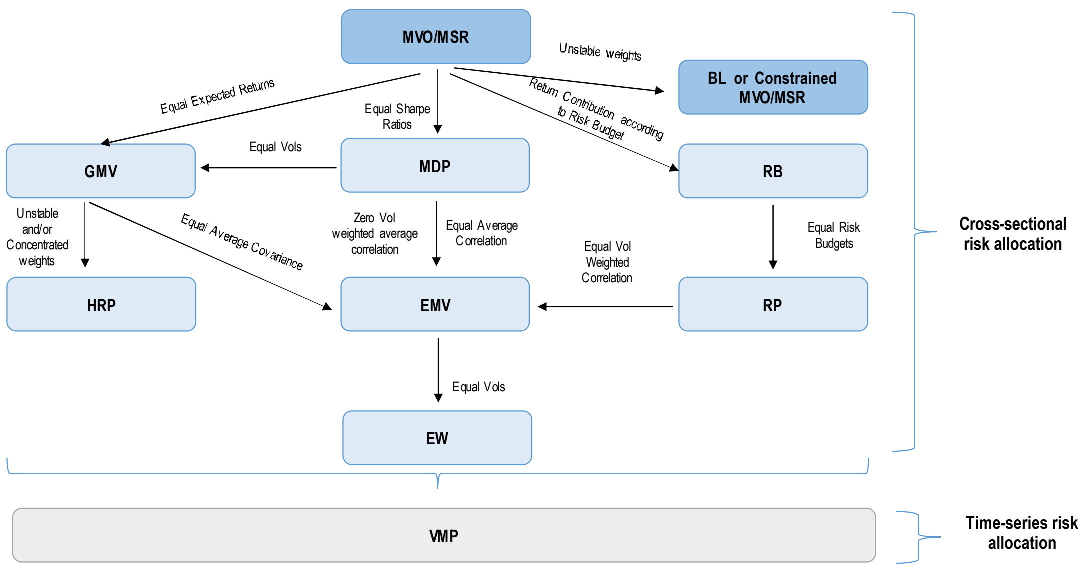
The Birds'-Eye View

The risk models we just discussed and their relationships are summarized in Chart 1. In the Figure, blue boxes refers to cross-sectional risk allocation frameworks. Here, dark blue highlights return-based models and light blue risk-based models. The wide grey box at the bottom of the table refers to VMP i.e. our preferred time series risk allocation framework. Notably, cross-sectional and time-series risk allocation methods are complementary. Once one chooses how to allocate across risk factors it can dynamically alter exposure via a time-series overlay.

Chart 1: Theoretical links between various portfolio Allocation Methods



Source: J.P. Morgan

Notably, the risk models we discussed are related to each other. Most methods discussed are an implementation of MVO under certain assumptions. Working from the bottom of the diagram, EW is an EMV if we assume equal asset volatilities; EMV is an MDP if we assume zero average correlation; and finally MDP is an MVO if we assume equal marginal Sharpe ratios. HRP can be seen as improvement on GMV when too many correlated assets caused unstable and/or concentrated weights and GMV is an MDP if the asset volatilities are the same, and it is MVO if the expected returns are the same. The condition for the equivalence of MDP and RB is more complicated: it is achieved when the portfolio weight is proportional to the ratio of risk budget to marginal volatility. RP becomes EMV for zero correlation or equal volatility weighted correlations. RP also becomes general RB for non-equal risk budgets, and it becomes MVO for equal return contributions from each asset. Finally, BL and constrained MVO optimization are forms of MVO/MSR where either reasonable constrained are added to the optimization or shrinkage is used with the aim of dealing with unstable weights.

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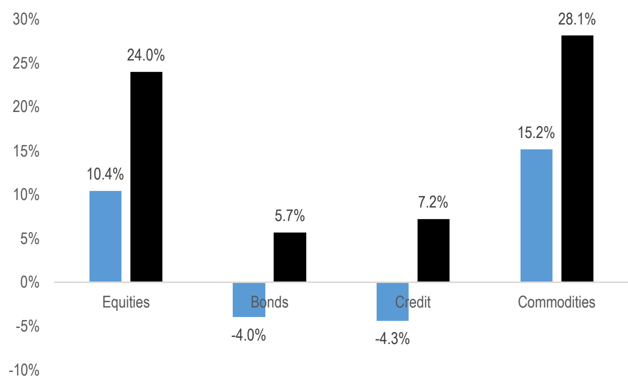
Ex-ante optimal portfolios

In this section, we look at ex-ante optimal portfolios on the 4 traditional asset classes (Equities, Bonds, Credit and Commodities) based on cross sectional risk allocation methods. Traditional asset classes represent the core risk factors of most investment portfolios and data are available for long-sample periods. Interestingly, are our key calls from a tactical asset allocation perspective (TAA) are on the same factors.

For this exercise, our capital market assumptions ('CMAs') for the core risk factors are simple and based on trailing sample i.e. they don't reflect our published targets. In particular, for this exercise, we assume ex-ante expected excess returns, volatilities and correlations are equal to those estimated over the past 3Y sample (Chart 2 and Chart 3). As a result, Equities and Commodities display the highest excess returns (10.4% and 15.2%) but also the highest volatilities (24% and 28.1%) while excess returns for Bonds and Credit are negative (-4% and -4.3%) but volatility is much lower (5.7% and 7.2%). Obviously, these CMAs are unrealistic and unlikely to lead to successful implementation of Portfolio Methods. Indeed, part of our future Portfolio Research will be focused on systematically forecasting/estimating expected returns, volatilities and correlation matrices:

Chart 2: Ex-ante excess returns and volatilities

Excess returns and volatilities based on 3Y trailing sample



Source: J.P. Morgan

Chart 3: Ex-ante correlation matrix

Correlation matrix based on 3Y trailing sample

	Equities	Bonds	Credit	Commodities
Equities	1.00	0.20	0.73	0.43
Bonds	0.20	1.00	0.54	(0.41)
Credit	0.73	0.54	1.00	0.26
Commodities	0.43	(0.41)	0.26	1.00

Source: J.P. Morgan

In Table 2 below we show the resulting portfolio weights, return contribution, risk contribution as well as Sharpe/Diversification ratios for each of the risk methods. We also include some constrained versions of MVO and MSR (MVOc and MSRc). As we explained in the previous section a relatively small change in return inputs may result in large changes in the output weights so adding portfolio constraints to the MVO problem can keep the optimal portfolio within feasible bounds. To visualize the relationship between different portfolio methods, we also identify each ex-ante optimal portfolio on the risky-asset efficient frontier, shown in Chart 4. The horizontal axis in the figure is the ex-ante portfolio volatility and the vertical axis is the ex-ante portfolio expected return. Each point in the risky asset efficient frontier is achieved by minimizing portfolio volatility at a certain level of expected return (or equivalently maximizing portfolio expected return at a certain level of portfolio volatility).

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Table 2: Portfolio weights, return/risk contributions, Sharpe Ratio and Diversification Ratio

	Portfolio Weight				Return Contribution				Risk Contribution							
	Equities	Bonds	Credit	Commodities	Equities	Bonds	Credit	Commodities	Equities	Bonds	Credit	Commodities	Portfolio excess Return	Portfolio Volatility	Sharpe Ratio	Diversifcaition Ratio
MVO	8%	66%	0%	26%	40%	-119%	0%	179%	19%	7%	0%	75%	2%	8%	0.27	1.63
MSR	40%	0%	0%	60%	32%	0%	0%	68%	32%	0%	0%	68%	13%	23%	0.58	1.17
BL	27%	65%	0%	9%	181%	-167%	0%	86%	69%	19%	0%	12%	2%	9%	0.18	1.44
MVOc	10%	60%	7%	23%	55%	-125%	-15%	185%	23%	8%	4%	65%	2%	8%	0.24	1.61
MSRc	55%	10%	5%	30%	59%	-4%	-2%	47%	65%	0%	1%	34%	10%	19%	0.52	1.21
EW	25%	25%	25%	25%	60%	-23%	-25%	88%	43%	1%	11%	45%	4%	12%	0.36	1.34
GMV	0%	90%	0%	10%	0%	178%	0%	-78%	0%	90%	0%	10%	-2%	5%	(0.43)	1.70
MDP	0%	83%	0%	17%	0%	437%	0%	-337%	0%	50%	0%	50%	-1%	5%	(0.15)	1.85
RB	20%	58%	18%	5%	-588%	667%	221%	-201%	55%	25%	15%	5%	0%	8%	(0.05)	1.38
RP	8%	56%	24%	11%	-118%	311%	149%	-242%	25%	25%	25%	25%	-1%	6%	(0.11)	1.58
EMW	11%	45%	35%	9%	-133%	214%	184%	-165%	31%	18%	34%	17%	-1%	7%	(0.12)	1.46

Source: J.P. Morgan

Return-based frameworks have higher ex-ante return, volatility and Sharpe ratio but they are less diversified. By construction, the **MVO** (8% target vol) portfolio lies on the ex-ante risk asset efficient frontier while the **MSR** is by definition the tangent portfolio with maximum Sharpe ratio. MSR achieves the highest Sharpe ratio but in this case also the lowest diversification ratio given a barbell allocation to Equities and Commodities. The MVO Sharpe ratio is lower than MSR (0.27 vs 0.58) but the diversification ratio is higher (1.63 vs 1.17). The constrained versions (i.e. **MVOc** and **MSRc**) are similar (as our constraints are loose) to the respective unconstrained version but obviously less ex-ante optimal because the solutions space gets reduced by the presence of boundaries. The **BL** portfolio targets an 8% ex-ante vol in the posterior return/volatility so it lies somewhat near standard MVO. Relative to standard MVO, one of the main differences is that the market portfolio anchor keeps **BL** more highly allocated to Equities and prevent a higher allocation to Commodities.

Risk based methods are generally more diversified, less risky but ex-ante also less-optimal i.e. the Sharpe Ratios are generally lower. Although the **EW** method allocates equal dollar weights to the four assets, its return and risk contributions are predominantly from high volatility assets (Stock and Commodities > 90% of the total). As a result, the EW portfolio is not well diversified. The **GMV** portfolio resides in the far left hand side of the efficient frontier and by construction achieves minimum portfolio volatility (as well as the lowest returns) by increasing the weight in less volatile and more diversification-capable instruments (Bonds). An interesting fact about GMV is that its total risk contributions for each asset are equal to the asset portfolio weights. This fact holds in general because GMV assets' betas with respect to the portfolio are the same and equal to one. Since risk contribution is just the asset's portfolio weight times its beta, portfolio weights and asset risk contributions are the same. The **MDP** achieved (by definition) the highest diversification ratio but its ex-ante Sharpe ratio is low.

The **RB** portfolio is designed to have pre-specified risk contributions in our case we use 55% for Equities, 25% for Bonds, 15% for Credit and 5% for Commodities. Although the **EMW** portfolio is weighted to achieve equal marginal volatility – its risk contribution is not equal because of non-zero correlations. In fact, the Stock and Credits indices contributes to about 65% of the total portfolio risk because of their higher average correlation compared to Bonds and Commodities. As marginal volatilities of different assets are usually different, an EMV portfolio is usually a better benchmark than the EW. The **RP** portfolio is defined by equal total risk contributions. This is achieved by weighting each asset inversely with its beta with the portfolio. Stocks and Commodities have a higher beta, and hence receive lower weights, while Bonds and Credit have lower beta, and hence receive higher weight.

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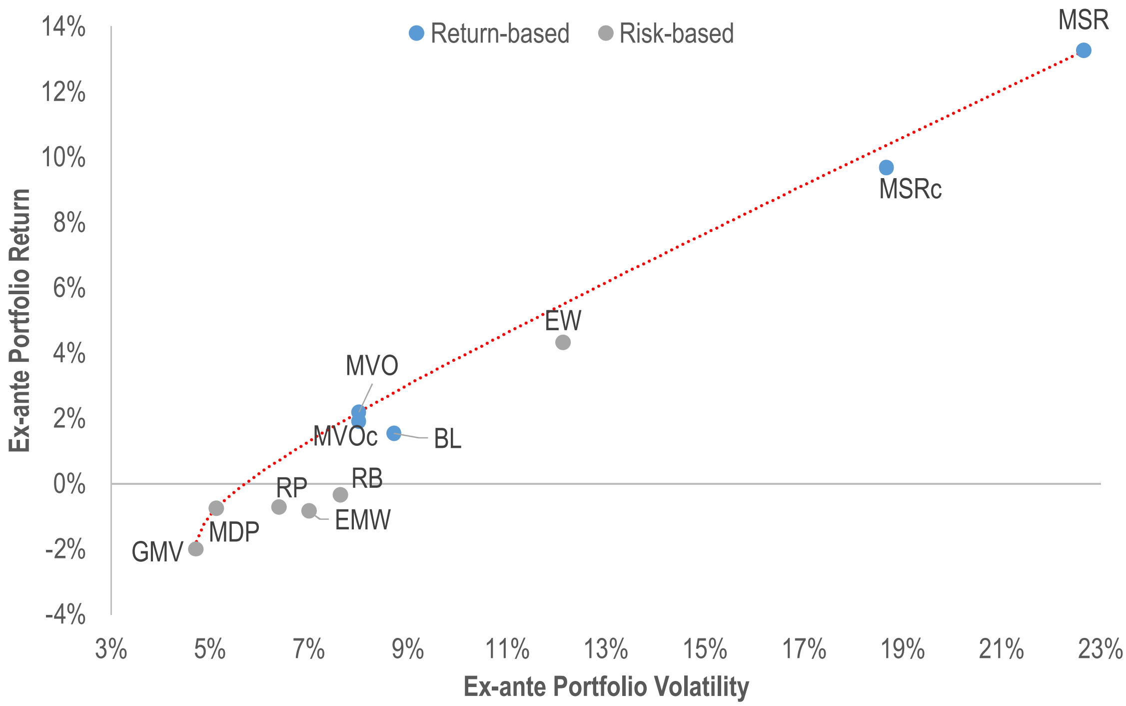
Chart 4: Risky asset "efficient frontier" of the Stock, Bond, Credit and Commodities Portfolio

Ex-ante optimal portfolios vs ex-ante efficient frontier



Source: J.P. Morgan

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How could CMAs be improved?

As mentioned, our CMAs are unrealistic and unlikely to lead to successful implementation of Portfolio Methods. Indeed, part of our future Portfolio Research will be focused on systematically forecasting/estimating expected returns, volatilities and correlation matrices to obtain improved CMAs. Even if CMAs are not the focus of this report we think it is worthwhile to include some considerations on how one could make some improvements:

- There are three general types of systematic models used to estimate e**xpected returns**. Economic/Market Models use economic/market-based variables such as GDP growth, unemployment, PMI, yield curve, dividend yield, etc to forecast asset/factor returns (See Ilmanen (2011)). Alternatives could be to apply Fundamental bottom-up or Technical Models (based on momentum, reversion, seasonality etc...) on market indices.

- As **cross asset volatilities** display short-term persistence, their near-term levels are relatively easier to forecast than returns. There are three popular types of models in forecasting volatility: (1) one could directly use historical volatility; (2) implied volatility (if available); or (3) various extensions of Generalized autoregressive conditional heteroscedasticity (GARCH).

- The last element is the **correlation matrix** of the assets. While simultaneous estimation of volatilities and the correlation matrix is possible through multivariate GARCH models such as Orthogonal GARCH discussed in Kariya (1988) and Alexander and Chibumba (1997), there are usually too many model parameters to obtain robust results. Instead, there are three general empirical treatments of correlation matrices: (1) historical correlation or implied correlations (if available); (2) dynamic models (such as auto-regressive) could be used to capture the time-series dependence structure of correlation; or (3) Eigenvalue methods.

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Which framework should you use?

In the previous section we looked at ex-ante optimal portfolios. Now, the focus will be on analyzing ex-post realized performance of ex-ante optimal portfolios. Our sample covers 1975 to 2022 and we use a rolling 3Y lookback for estimating expected returns, volatilities and correlations in the out-of-sample backtesting. We focus mainly only on cross-sectional allocation across core risk factors (Equities, Bonds, Credit and Commodities) but we also show the performance of adding time-series risk allocation via VMP. The methods we use are the following:

1. Unconstrained Mean Variance Optimized Portfolio (**MVO**) with an 8% vol target
2. Unconstrained Maximum Sharpe Ratio (**MSR**)
3. Constrained MVO and MSR (**MVOc** and **MSRc**) with the following loose ranges: 10%-90% for Equities, 10%-60% for Bonds, 5%-30% for Credit and 5%-30% for Commodities
4. Black-Litterman portfolio (**BL**) with ex-ante equilibrium weights set a the market portfolio and 8% vol target
5. Equally weighted portfolio (**EW**)
6. Global Minimum Variance portfolio (**GMV**)
7. Most Diversified Portfolio (**MDP**)
8. Risk budgeting (**RB**) with the following allocation (55% to Equities, 25% to Bonds, 15% to Credit and 5% to Commodities)
9. Equal marginal volatility portfolio (**EMV**)
10. Risk Parity (**RP**)
11. Vol-managed portfolios (**VMP**) applied to MSR and RP i.e. **VMP(MSR)** and **VMP(RP)**

Returns for various portfolio construction frameworks are highly correlated but return-based and risk-based approaches form two distinct clusters. The correlation matrix in Chart 5 shows that the performance of different methods is closely correlated (average correlation coefficient of 0.78). The Chart also shows that return-based and risk-based frameworks form two distinct clusters. The average correlation coefficient across return-based frameworks is high (0.83) and this gets even higher (0.89) across risk-based models.

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Chart 5: Correlation matrix shows return-based and risk-based strategies form two clusters

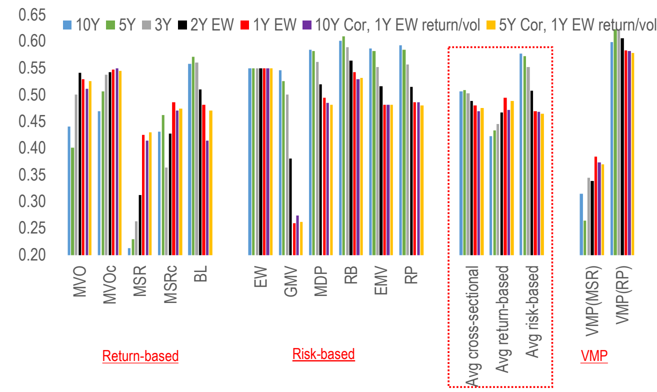
Full-sample correlation matrix of monthly out-of-sample returns

	MVO	MVOc	MSR	MSRc	BL	EW	GMV	MDP	RB	EMV	RP	VMP(MSR)	VMP(RP)
MVO	1.0	0.9	0.8	0.9	0.8	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.6
MVOc	0.9	1.0	0.8	0.9	0.9	0.8	0.6	0.8	0.8	0.8	0.8	0.6	0.7
MSR	0.8	0.8	1.0	0.8	0.7	0.6	0.5	0.6	0.5	0.6	0.6	0.7	0.5
MSRc	0.9	0.9	0.8	1.0	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.6	0.7
BL	0.8	0.9	0.7	0.8	1.0	0.7	0.6	0.8	0.8	0.8	0.8	0.5	0.7
EW	0.7	0.8	0.6	0.8	0.7	1.0	0.7	0.9	0.8	0.9	0.9	0.4	0.8
GMV	0.6	0.6	0.5	0.7	0.6	0.7	1.0	0.9	0.9	0.9	0.9	0.4	0.7
MDP	0.7	0.8	0.6	0.8	0.8	0.9	0.9	1.0	0.9	1.0	1.0	0.4	0.8
RB	0.7	0.8	0.5	0.8	0.8	0.8	0.9	0.9	1.0	0.9	0.9	0.4	0.8
EMV	0.7	0.8	0.6	0.8	0.8	0.9	0.9	1.0	0.9	1.0	1.0	0.4	0.8
RP	0.7	0.8	0.6	0.8	0.8	0.9	0.9	1.0	0.9	1.0	1.0	0.5	0.8
VMP(MSR)	0.7	0.6	0.7	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.5	1.0	0.6
VMP(RP)	0.6	0.7	0.5	0.7	0.7	0.8	0.7	0.8	0.8	0.8	0.8	0.6	1.0

Source: J.P. Morgan

Chart 6: Optimal lookback for return-based and risk-based models go in opposite directions

Full-sample Sharpe ratio vs different lookback periods



Source: J.P. Morgan

We find that optimal lookbacks for risk-based and return-based frameworks move in opposite direction. Before presenting the results for our 3Y baseline we consider performance sensitivity across a series of different lookbacks for estimating returns, volatilities and correlations. In particular, we consider: a) simple 10Y, 5Y and 3Y cases; b) 10Y sample with exponentially weighted ('EW') return/risk metrics with 1Y or 2Y half-life (1Y EW and 2Y EW); and c) mixed case with 10Y/5Y sample for correlations and 10Y/5Y EW return/volatilities with 1Y half-life. The average full-sample Sharpe ratios of each models under the different options are shown in Chart 6. It emerges that shorter samples tend to improve return based models. The average Sharpe ratio across return-based models is lowest for the 10Y case (0.42) and highest when using 10Y sample with 1Y EW (0.49). In our view, this could come from the ability of a shorter lookback to pick up cross-sectional momentum at the core risk factors level. In contrast, risk-based models seems adversely impacted by a shorter lookback as average ratio Sharpe Ratio falls from 0.58 in the 10Y case to 0.46 in the mixed case with 5Y sample and 1Y EW return/volatility. One reason for this could be that excessively shortening the trailing sample could makes estimates of the covariance matrix less efficient.

Table 3 summarizes the performance and risk metrics for the eleven cross-sectional methods and the two applications of VMP. The Table consider absolute returns, volatility Sharpe Ratios, Hit Ratios and maximum drawdowns over the full sample for the 3Y lookback case. In the lower part of the Table we also calculate Sharpe Ratios on consecutive 5-year sub-periods.

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Table 3: Return/Risk metrics (full sample and overtime)

Risk/Return metrics (full-sample)

	MVO	MVOc	MSR	MSRc	BL	EW	GMV	MDP	RB	EMV	RP	Avg cross-sectional	Avg return-based	Avg risk-based	VMP(MSR)	VMP(RP)
Return	4.2%	4.3%	2.5%	2.6%	4.5%	4.0%	2.4%	3.1%	3.5%	3.0%	3.1%	3.4%	3.6%	3.2%	2.4%	3.2%
Vol	8.3%	8.0%	9.5%	7.2%	8.0%	7.6%	4.76%	5.6%	6.0%	5.5%	5.6%	6.9%	8.2%	5.8%	7.1%	5.2%
Sharpe	0.50	0.538	0.26	0.36	0.56	0.53	0.50	0.56	0.59	0.55	0.56	0.50	0.45	0.55	0.34	0.62
Hit Ratio	60%	63%	58%	61%	62%	61%	60%	62%	61%	61%	62%	61%	61%	61%	57%	61%
Max DD	-39%	-38%	-47%	-31%	-33%	-30%	-29%	-28%	-31%	-30%	-29%	-33%	-38%	-29%	-40%	-22%

Sharpe Ratios (full-sample and breakdown by periods)

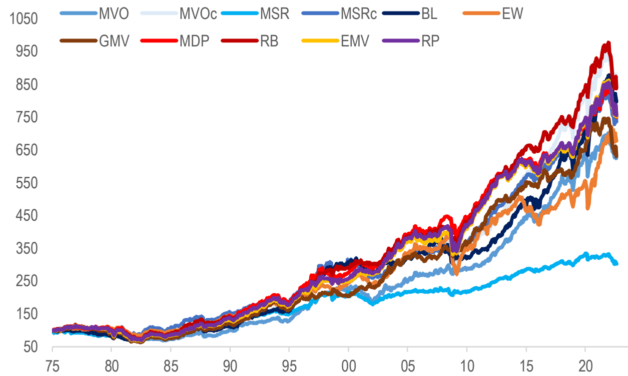
Start	End	MVO	MVOc	MSR	MSRc	BL	EW	GMV	MDP	RB	EMV	RP	Avg cross-sectional	Avg return-based	Avg risk-based	VMP(MSR)	VMP(RP)
1975	2022	0.50	0.54	0.26	0.36	0.56	0.53	0.50	0.56	0.59	0.55	0.56	0.50	0.45	0.55	0.34	0.62
1975	1980	(0.45)	(0.45)	(0.26)	(0.42)	(0.65)	0.25	(0.19)	0.18	0.09	0.02	0.10	(0.16)	(0.45)	0.08	(0.51)	0.01
1980	1985	(0.40)	(0.27)	(0.25)	(0.15)	0.05	(0.17)	(0.20)	(0.21)	(0.07)	(0.16)	(0.19)	(0.18)	(0.20)	(0.17)	(0.33)	(0.67)
1985	1990	0.88	0.86	0.96	0.95	0.84	1.31	1.04	1.19	1.00	1.18	1.20	1.04	0.90	1.15	0.97	1.31
1990	1995	0.57	0.69	0.67	0.70	0.76	0.54	0.74	0.72	0.66	0.76	0.74	0.69	0.68	0.69	0.92	0.84
1995	2000	1.46	1.48	0.98	1.10	1.63	1.05	0.68	0.95	1.37	1.05	1.01	1.16	1.33	1.02	1.32	0.81
2000	2005	0.22	0.33	0.01	0.19	0.28	0.85	1.28	1.06	0.97	1.21	1.19	0.69	0.21	1.09	0.13	1.10
2005	2010	0.45	0.36	0.02	(0.17)	0.12	0.18	0.32	0.36	0.29	0.30	0.27	0.23	0.15	0.29	0.12	(0.04)
2010	2015	2.02	2.12	1.88	2.05	1.92	0.80	1.95	1.82	2.22	1.58	1.62	1.82	2.00	1.67	1.86	1.41
2015	2020	1.01	0.94	0.85	0.51	0.93	0.57	0.79	0.82	1.10	0.88	0.88	0.84	0.85	0.84	0.92	0.77
2020	2022	(0.25)	(0.08)	(0.77)	(0.39)	(0.06)	0.42	(0.38)	(0.11)	(0.21)	(0.13)	(0.16)	(0.19)	(0.31)	(0.09)	(0.57)	(0.33)

Source: J.P. Morgan

Over the full sample, return-based frameworks do worse than risk-based ones across all metrics but absolute returns, which might reflect the bond-heavy allocations of risk-based methods during decades of falling yields. The full-sample Sharpe ratio for return-based models is below that of risk-based models (0.45 vs 0.55) but there is substantial variation within the two clusters. Within return based models, BL do better than MVO and MSR. Interestingly, MSR, i.e. the portfolio with the ex-ante highest Sharpe ratio, actually records the lowest risk-adjusted performance across all models (0.26). Adding constraints to both MVO and MSR improves performance in both cases and across all metrics. Within risk-based models performance dispersion is lower. The best performing framework is RB (0.59) and the worst is GMV (Sharpe 0.5). The VMP overlay clearly boost performance for both MSR (0.34 vs 0.26) and RP (0.62 vs 0.56). Looking at sub-periods reveal there is no portfolio construction framework that consistently outperforms. Chart 7 and 8 help plot CAGR help visualizing these conclusions. In this case, we re-scale returns to have an equal full-sample volatility of 8% before plotting the data. In this way, charts better reflect risk adjusted performance.

Chart 7: In risk-adjusted terms, MSR was the worst performing cross-sectional framework

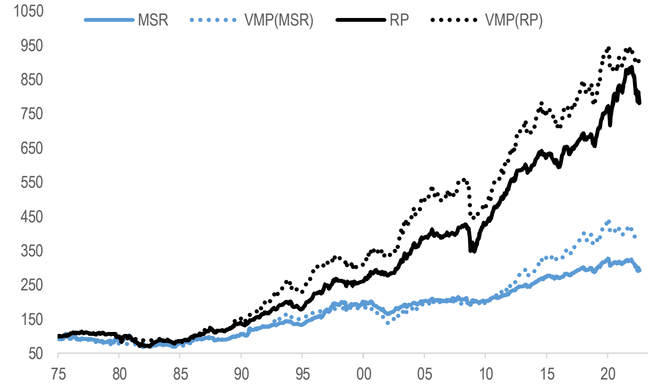
P&L of investing US$100 into each cross-sectional method 1975. Returns scaled to 8% vol.



Source: J.P. Morgan

Chart 8: VMP improved performance of both MSR and RP

P&L of investing US$100 into MSR, RP with and without VMP overlay since 1975. Returns scaled to 8% vol.



Source: J.P. Morgan

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Market Regimes and dynamic selection of portfolio methods

We now turn to the issue of dynamically selecting portfolio methods. To achieve this task, we turn to regime-based frameworks. A core belief behind our tactical asset allocation approach is that some of the most consistent drivers of core risk factors are business cycle momentum, inflation and risk aversion and one of the most effective ways of thinking about these is via regimes. To some extent, if macro regimes explain the dispersion of returns for core risk factors they could also influence portfolio methods and their ranking. In that case, investors that are versatile in all risk management methods could dynamically shift to a specific method when it is likely to yield the best results and generate some alpha.

We first consider three univariate regimes focused on growth, inflation and volatility/risk aversion which we proxy with LEI Index, headline CPI and realized 22d volatility for the S&P500. We use very simple and intuitive thresholds. For each metric we have a High, Medium and Low regime based on the 33% and 67% full-sample percentiles. Table 4, show the unconditional probabilities, transition matrices, and Sharpe ratios in each regime for cross-sectional and time-series models.

Table 4: Univariate Macro-Financial Regimes

Volatility, Growth and Inflation regimes unconditional probabilities and transition matrices. Red border highlight current states

Volatility			
	High Vol	Medium vol	Low Vol
Unconditional	34%	34%	32%
Transiton matrix			
	High Vol	Medium vol	Low Vol
High Vol	71%	21%	8%
Medium vol	23%	47%	30%
Low Vol	6%	34%	59%
	High Vol	Medium vol	Low Vol
MVO	(0.14)	0.66	1.63
MVOc	(0.17)	0.73	1.73
MSR	(0.22)	0.54	1.10
MSRc	(0.19)	0.58	1.49
BL	(0.08)	0.73	1.61
EW	0.03	0.59	1.60
GMV	0.49	0.30	0.96
MDP	0.26	0.52	1.28
RB	0.21	0.64	1.36
EMV	0.31	0.46	1.30
RP	0.24	0.51	1.38
Median cross-sectional	0.03	0.58	1.38
Median return-based	(0.17)	0.66	1.61
Median risk-based	0.25	0.51	1.33
VMP (MSR)	(0.11)	0.49	1.09
VMP (RP)	0.02	0.69	1.39

Growth			
	High Growth	Medium Growth	Low Growth
Unconditional	34%	34%	32%
Transiton matrix			
	High Growth	Medium Growth	Low Growth
High Growth	83%	17%	0%
Medium Growth	16%	71%	13%
Low Growth	1%	13%	86%
	High Growth	Medium Growth	Low Growth
MVO	0.91	0.65	0.20
MVOc	1.20	0.65	0.07
MSR	0.55	0.56	0.03
MSRc	0.82	0.66	(0.08)
BL	0.96	0.62	0.30
MVP			
EW	1.08	0.64	0.15
GMV	0.62	0.66	0.35
MDP	0.89	0.71	0.27
RB	0.93	0.75	0.24
EMV	0.88	0.72	0.26
RP	0.94	0.71	0.24
Median cross-sectional	0.91	0.66	0.24
Median return-based	0.91	0.65	0.07
Median risk-based	0.89	0.71	0.25
	0.53	0.53	0.15
	0.82	0.66	0.40

Inflation			
	High Inflation	Medium Inflation	Low Inflation
Unconditional	33%	34%	33%
Transiton matrix			
	High Inflation	Medium Inflation	Low Inflation
High Inflation	92%	8%	0%
Medium Inflation	8%	84%	8%
Low Inflation	0%	8%	92%
	High Inflation	Medium Inflation	Low Inflation
MVO	(0.16)	0.89	0.85
MVOc	(0.22)	0.86	0.94
MSR	(0.16)	0.82	0.60
MSRc	(0.19)	0.65	0.69
BL	(0.13)	0.92	0.90
MVP			
EW	0.04	0.76	0.79
GMV	(0.04)	0.80	0.88
MDP	0.05	0.87	0.90
RB	(0.07)	0.87	1.09
EMV	(0.08)	0.83	1.06
RP	(0.06)	0.84	1.02
Median cross-sectional	(0.08)	0.84	0.90
Median return-based	(0.16)	0.86	0.85
Median risk-based	(0.05)	0.83	0.96
	(0.13)	0.66	0.76
	(0.02)	0.82	0.88

Source: J.P. Morgan

The first observation is that in all three cases, regimes tend to persists (i.e. probability of remaining in the same states is always the highest) which is a desirable features if one can establish that they affect performance of portfolio construction processes. Relatedly, the second observation is that Sharpe ratios for the two clusters (risk-based vs return-based) are affected by regimes. Notably, return-based models

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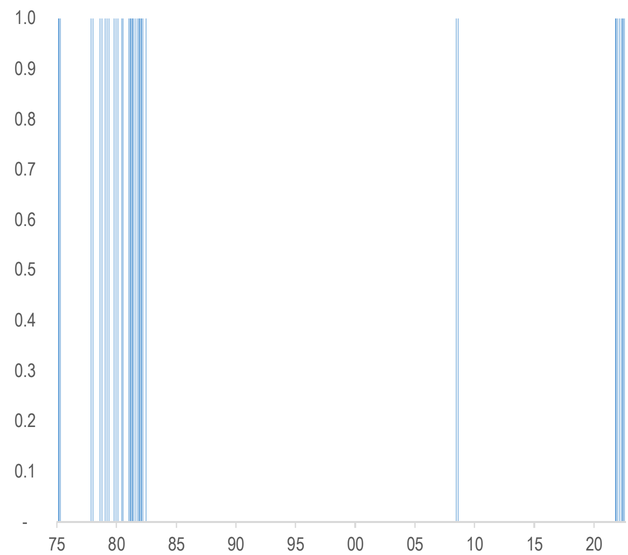
underperform when volatility is high (-0.17 vs 0.25), growth is low (0.07 vs 0.25) or inflation is high (-0.16 vs -0.05). However, the VMP tends to improve performance in each of these three cases. Hence, if the current environment of high-vol, low-growth and high-inflation persists, the message from univariate frameworks is to follow a risk-based method with a VMP overlay.

We then turn to multivariate regime-frameworks. Univariate regimes help and give insights, but they might be a bit too simple as they are unable of combining the correlation across states variables which are obviously not orthogonal (e.g. vol tends to be high when growth is low). Hence, the need for multivariate frameworks.

Chart 9: KNN identifies the late 70's/early 80's and pre GFC

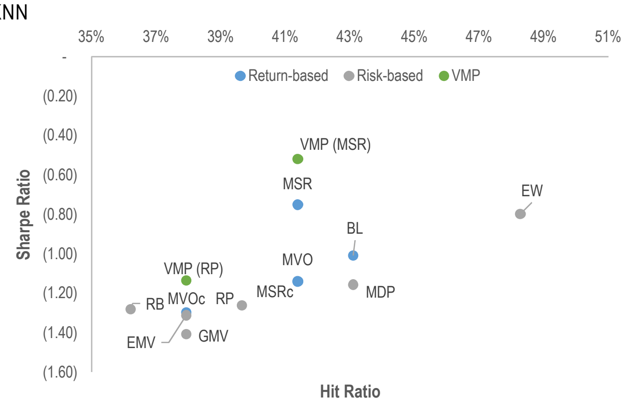
60 months more similar to August 2022 based on growth, inflation and volatility



Source: J.P. Morgan

Chart 10: Return-based and EW have done better than risk-based models in similar periods"

Sharpe Ratio and Hit Ratio for each portfolio method in months identified by KNN



Source: J.P. Morgan

The KNN suggest a slight preference for return-based models followed by EW and MDP. The first model we consider is a simple KNN algorithm. The model is based on the same regime variables we used in the univariate case i.e. growth, inflation and volatility and essentially looks for the most similar historical periods to the latest month based on Euclidean distance. There is no obvious rule for choosing the number of "nearest neighbors" so to keep things simple we only look at the most comparable 60 months (equivalent to 5 years). Chart 9 shows the 60 most similar historical periods identified by this method. Notably, these correspond to the late 70s/early 80s, the high inflation years preceding GFC and the first 8 months of 2022. Chart 10 shows the combination of Hit Ratio and Sharpe Ratio calculated over these 60 most similar months. The message is that returns are generally challenged in these periods as evidence by negative Sharpe ratios for all portfolio methods. That said, return-based model tended to do better than risk-based frameworks. MSR did best within return-based models but BL had a higher Hit Ratio. EW and MDP did better in the risk-based cluster. Quite interestingly GMV offered one of the worst combination of Hit Ratio and Sharpe Ratio. Finally, VMP overlay improved both MSR and RP performance.

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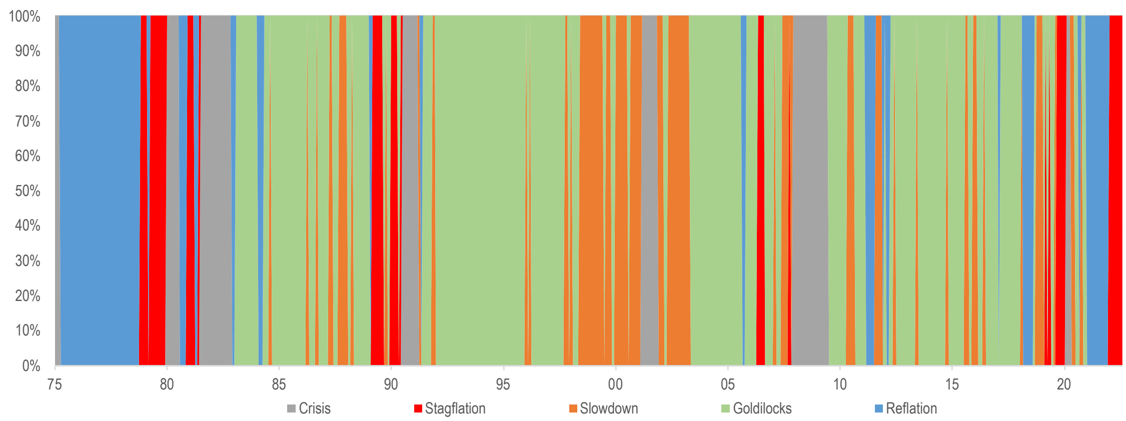
The second framework we consider has 5 states. This simple framework is a mixture of discretionary choices and GMM insights and it remains based on our 3 variables i.e. growth, inflation and volatility. To identify the 5 regimes of the model we first run a GMM algorithm over our three state variables. This model suggest a five states characterization is reasonable and provides coordinates for the centroids. One of the identified states resembles US recessions so we call this regime "Crisis" and use NBER dates for US recessions to identify this regime. For the remaining four, we make some discretionary adjustment to GMM centroids and attempt the following taxonomy: Stagflation (low growth, high inflation & high vol), Slowdown (low growth, low inflation & high vol)), Goldilocks (high growth, low inflation and low vol) and Reflation (high growth, high inflation and low vol). The 5 states are shown in Chart 11 while Chart 12 shows the unconditional probabilities and the transition matrix. Notably, the transition matrix reveals substantial persistence in each regimes and highlight the current state implied by the model i.e. Stagflation.

Chart 11: 5 states regime framework



Source: J.P. Morgan

Interestingly, the 5-states framework support KNN conclusions. In these respects, Chart 13 shows the Hit Ratio and Sharpe ratio for each portfolio in Stagflation. Notably, the conclusions are in line with those obtained from KNN. Portfolios of core risk factors generally faced headwinds in Stagflation while return-based models tended to do better than risk-based ones. Across return-based models MSR and MVO earned higher Sharpe ratios than BL but they achieved quite lower Hit ratios. Across risk-based models EW and MDP did better than others while GMV remained one of the worst performing portfolio methods. The VMP overlay improved performance for both RP and MSR and yielded the best Sharpe ratios.

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Chart 12: Transition matrix reveal some persistence

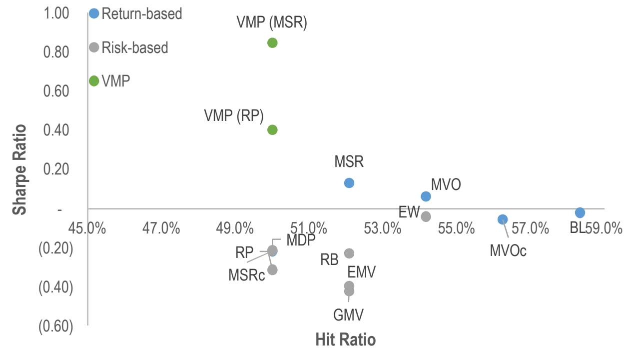
Unconditional probability and transition matrix for the 5-states framework

	Crisis	Stagflation	Slowdown	Goldilocks	Reflation
Unconditional	12%	9%	17%	48%	15%
	Crisis	**Stagflation**	**Slowdown**	**Goldilocks**	**Reflation**
Crisis	89.6%	0.0%	4.5%	1.5%	4.5%
Stagflation	8.3%	75.0%	2.1%	10.4%	4.2%
Slowdown	2.1%	2.1%	63.5%	29.2%	3.1%
Goldilocks	0.0%	1.8%	10.6%	84.6%	2.9%
Reflation	0.0%	6.9%	2.3%	9.2%	81.6%

Source: J.P. Morgan

Chart 13: The 5-states regimes and KNN give a similar message

Sharpe Ratio and Hit Ratio for each portfolio method in Stagflation



Source: J.P. Morgan

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Conclusions

This inaugural report introduced a new series of thematic publications focused on Portfolio Construction Research.

In the first part of this study, we offered an overview and intuitive explanation of the most popular cross-sectional and time-series portfolio construction frameworks. We also analyzed and visualized optimal ex-ante portfolios of traditional core risk factors i.e. Equities, Bonds, Credit and Commodities.

We then examined the results of an out-of-sample backtest over the 1975-2022 period. Risk-based models have done overall better than return-based ones but there is no framework that consistently outperforms overtime. The VMP overlay boosted performance of both risk-based and return-based models.

Finally, we looked at the issue of dynamically selecting portfolio methods. Here we employed a set of univariate and multivariate (i.e. KNN and 5-states model) regime frameworks based on growth, inflation and risk aversion.

Assuming persistence in the current regime we reached the following conclusions: **1) Return headwinds for portfolios of core risk factors are likely to remain. 2) Return-based models should be slightly preferred to risk-based ones** because of a structurally lower allocation to Fixed Income and higher allocation to Commodities. MSR achieved the highest risk-adjusted performance but BL had the highest Hit Ratio across return-based frameworks. Within risk-based models the preference is for EW and MDP. **3) The VMP overlay is likely to improve performance** under current market conditions.

One approach for many investors is to sign on with a portfolio construction 'for life' on the assumption they have committed to the best one. In many cases, what is considered the best one across the industry is a reflection of what has outperformed in recent years. We have attempted to survey what was worked better or worse in recent regimes to document the pros and cons of each approach in a given environment. For this exploratory analysis, we have relied on simple CMAs but part of our future research will be on systematically forecasting expected returns, correlations and volatilities and strengthening these conclusions. In future, we will revisit today's conclusions around the possibility of market timing the choice of portfolio construction, as **strictly committing to one approach implies investment decisions and consequences as well**.

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