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Diversification & Portfolio Optimization through Alternative Investments: Assessing Gold and Silver Mutual Funds in a Multi-Asset Portfolio through a Multi Method Approach

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KEYWORDS

Alternative investments, Portfolio Optimization, Diversification, Risk-adjusted returns, Mean-Variance Optimization, Principal Component Analysis, Rolling Beta Analysis.

ABSTRACT

The impact of gold and silver mutual funds on diversification and risk-adjusted returns is examined in this study. On the basis of data from 10 mutual funds, which have been divided into equity (small-cap, mid-cap, large-cap), debt (short-term, medium-term, long-term), and alternative (gold and silver) funds, the research utilizes Mean-Variance Optimization (MVO), Principal Component Analysis (PCA), Rolling Beta Analysis, and Correlation Matrix Analysis to measure their diversification power.

The results demonstrate that gold mutual funds increase portfolio stability, especially during times of market stress, and silver mutual funds have a greater equity correlation but still achieve diversification. MVO results suggest that a best-fit portfolio composition prefers a mix of gold and equity funds, with least dependence on debt funds and maximum dependence on gold. PCA analysis verifies that alternative investments are segregated into discrete risk clusters, affirming their effectiveness in reducing risk. Rolling Beta Analysis also illustrates the time-varying sensitivity of gold and silver mutual funds to market movements.

By including alternative mutual funds, investors can gain increased diversification advantage and enhanced risk-adjusted performance. This paper contributes empirical evidence towards asset allocation rules, stressing the significance of alternative investments within mutual fund portfolios

1. INTRODUCTION

Investors aim to maximize returns with minimum risk, and diversification of a portfolio is a fundamental tool to accomplish this. Diversification means investing in various asset classes to minimize overall portfolio volatility. (Markowitz, 1952)'s Modern Portfolio Theory formalized the idea of building efficient portfolios by having assets that are uncorrelated with each other, thus helping in maintaining an optimal trade-off between risk and return. Classically, portfolios are based on stocks

and bonds, but market volatility makes alternative investments mandatory to add diversity and optimize the risk-adjusted return.

Alternative investments can be commodities, hedge funds, private equity, real estate, and precious metals, all which have varying risk-return profiles when compared to the traditional assets. Of these, gold and silver are commonly well known for possessing safe-haven characteristics, especially in times of economic crisis. Their inflation- and financial system-hedging capabilities make them useful additions to investment portfolios. The Dot-Com Crash of 2000-2002 is a good case in point, with gold prices rising as tech stocks fell through the floor, solidifying its position as a wealth protector. Although silver has some of the characteristics of gold, it is more correlated to equities and, therefore, more volatile but still a good diversifier.

Mutual funds are an efficient means of portfolio diversification, providing access to a blend of asset classes under professional management. The analysis uses data of 10 mutual funds, grouped into equity funds (small-cap, mid-cap, large-cap), debt funds (short-term, medium-term, long-term), and alternative funds (gold and silver mutual funds). The aim is to determine if gold and silver mutual funds are beneficial in diversification within a mutual fund portfolio to minimize risk with better overall returns.

This study investigates the contribution of gold and silver to mutual fund diversification, analysing their effect on risk-adjusted returns and correlation with conventional equity and debt funds and the optimum weights of equity, debt and alternative investments in a portfolio

2. LITERATURE REVIEW

Portfolio diversification is a guiding concept in modern finance, which seeks to maximize risk-return trade-offs. The Mean-Variance Optimization (MVO) model was proposed by (Markowitz, 1952), who stressed that holding a mix of uncorrelated assets lowers the risk of the portfolio. Whereas conventional portfolios centre on equities and bonds, alternative assets like commodities, hedge funds, and precious metals are increasingly added to the portfolio because of their distinctive diversification benefits (Upson et al., 1975)

Alternative assets are added to portfolios mainly for their potential to reduce volatility and improve risk-adjusted returns. (L. Jacob, 1974) discusses limited diversification approaches, asserting alternative assets offer unique advantages that go beyond equities and bonds.

Gold has long been regarded as a safe-haven asset, especially in times of economic uncertainty. (Ratner & Klein, 2008) discover that gold is negatively or weakly correlated with equities and thus serves as an effective portfolio stabilizer. (Huang & Zhong, 2013) also verifies that gold's hedging power is enhanced during financial crises, lowering investors' downside risk. (Pruchnicka-Grabias, 2021) also affirms that gold is important in reducing systemic risks.

The Dot-Com Crash experienced a catastrophic fall in technology stocks, as the Nasdaq Composite Index lost almost 78% of its value between March 2000 and October 2002. During this time, gold exhibited its safe-haven characteristics by increasing in value as investors looked for stability in times of market instability. Research indicates that gold had a low correlation with equities during the crash, cementing its position as a hedge against speculative bubbles. The growing demand for gold during this time reflects its potential to maintain wealth when conventional markets experience severe declines.

Silver, though usually linked with gold, has specific traits. (Pruchnicka-Grabias, 2021) discovers that the performance of silver is significantly different depending on market conditions, rendering it an unreliable hedge but a good diversifier during bull markets. (Szulc-Janek, 2023) notes that silver correlates more with equities than gold but remains a diversification option.

(Schweizer, 2008) criticizes the conventional MVO method, noting that alternative assets tend to have non-normal return distributions, necessitating sophisticated optimization methods.

There have been some methodologies suggested for bringing alternative investments into portfolios:

- Maximum Diversification Strategy: (Theron & van Vuuren, 2018) suggest maximizing the diversification ratio of a portfolio instead of concentrating only on risk-return trade-offs as they believe this strategy yields more risk-adjusted returns.
- Principal Component Analysis (PCA): Utilized to determine the major drivers of risk, PCA indicates if alternative assets perform differently from equities and bonds, as emphasized by (Szulc-Janek, 2023) in her research on metals as investment vehicles.

(Huang & Zhong, 2013) identifies the diversification potential of REITs and commodities, where gains are market-condition dependent.

(Theron & van Vuuren, 2018) underscore maximizing diversification over Sharpe ratios alone.

Conventional mean-variance models might not be able to capture the risk-return behaviour of these assets, and hence sophisticated techniques like PCA, rolling beta analysis, and maximum diversification are required. Investors need to consider time-varying correlations and market conditions while incorporating gold and silver in their portfolios to achieve

maximum diversification benefits.

RESEARCH OBJECTIVES

- To analyse the correlation between alternative investments and traditional investments
- To understand if alternative investments help in portfolio diversification and effect on risk-adjusted returns.
- To calculate optimal weights of equity, debt and alternative funds in a portfolio.

3. RESEARCH METHODOLOGY

This research adopts a quantitative method to analyse the contribution of alternative investments in diversifying a portfolio through four top statistical methods: Mean-Variance Optimization (MVO), Principal Component Analysis (PCA), and Correlation Matrix Analysis and Rolling Beta Analysis. The sample is comprised of 10 mutual funds, which include three equity funds, three debt funds, and four alternative investment funds (2 of gold and 2 of silver). The objective is to measure how alternative funds maintain an optimal portfolio, their intrinsic risk-return traits, and the way they correlate with traditional assets. The portfolio comprises:

Table 1: Mutual Funds used in research

Equity Mutual Funds	Debt Mutual Funds	Alternative Mutual funds
Nippon India Growth Fund	HDFC Short Term Debt	Kotak Gold
ICICI Prudential Large Cap	SBI Magnum Gilt Fund	AXIS Gold
Tata Small Cap Fund	ICICI Prudential Long Term	Nippon Silver ETF
		ICICI Prudential Silver ETF

Historical data of monthly price of each fund for the year 2022-25 was collected through Yahoo Finance.

First, Mean-Variance Optimization (MVO) is used to generate the best portfolio which would reduce the risk for a given level of return. Past nav data of said 10 funds are used to estimate expected returns, monthly returns and standard deviation of each of the funds. Covariance matrix of whole 10 funds is used to determine portfolio variance and overall standard deviation of portfolio, and Sharpe ratios are calculated to receive the risk adjusted return. Sharpe Ratios are calculated using 0.56% (monthly) as risk-free rate to calculate the Sharpe Ratios. Optimal asset weights are calculated by using Excel Solver to receive the optimal risk-return trade-off varying weights which were taken equal initially. Efficient Frontier is drawn, showing various portfolio combinations and indicating the best portfolio allocation. This helps in finding out if the introduction of alternative funds improves the overall risk-adjusted return of the portfolio.

Then PCA Analysis is done to identify underlying common risk drivers between asset classes using actual stats excel add-in tool. Principal Component Analysis (PCA) tries to find a set of fewer, but more significant dimensions (or components) to capture the variation of the larger set of original variables. Standardized historical returns of all the 10 funds have been used for this analysis. A correlation matrix was first calculated to examine the relationship between the funds. Principal Component Analysis (PCA) was carried out to identify important principal factors explaining the prevailing variance in fund returns using eigenvalues and eigenvectors. Eigenvalues are employed to indicate the proportion of variance each principal component represents. Factor loadings are examined to determine whether alternative funds exhibit unique risk-return behaviour in comparison to debt and equity funds. A scree plot was utilized to help decide the number of principal components to keep by visually searching for an "elbow" where the remaining components contribute very little to explaining variance. A rotated Varimax factor matrix was computed which showed the manner in which each variable loads onto the underlying principal components following an orthogonal Varimax rotation so that this rotation redistributes the variance in a way which maximizes interpretability and shows clear clusters. This step facilitates the revelation of whether alternative investments offer unique diversification value by having different behaviour in comparison to traditional funds. This interpretation is highly significant for uses such as portfolio diversification, where it helps to cluster funds with similar risk-return profiles.

In the current research study, Rolling Beta Analysis has been applied for analysing time-variant sensitivity of alternative investments compared to a base (Sensex 30). Rolling Beta permits one to make allowance for long-term changes over time, and these offer insight into the underlying behaviour of alternative investments in states of the markets. A 12-month moving window is considered to compute the beta dynamically within the study timeframe in this research. Monthly returns history of the 4 alternate mutual funds is obtained and utilized in averages. Rolling Beta is computed as the slope coefficient of linear regression of average return against the benchmark index (Sensex 30) with the help of Excel's =SLOPE () function over moving time windows. The result of the current research study helps in determining if alternative funds are exhibiting

permanent diversification advantages or if their exposure to risk changes with the market cycle.

Finally, a Correlation Matrix Analysis is done to determine the correlation of alternative funds with equity and debt funds. Using pairwise correlation coefficients calculation, this research examines whether alternative funds correlate with conventional asset classes at low or negative levels, thereby implying potential diversification benefits. A lower correlation

means that including alternative funds in a portfolio can result in higher diversification.Using a multi-method approach, the current study measures the effect of alternative investments on portfolio diversification from various perspectives—optimal blend, intrinsic drivers of risk, and interactions among assets. The results add insight to the role of alternative funds in the diversified mutual fund portfolio, and the results are relevant to the investor who aims to optimize risk-adjusted return based on strategic asset allocation.

FINDINGS

1) Interpretation of the Correlation Matrix

The provided correlation matrix provides valuable information regarding the interdependence of different funds (F1–F10) in the portfolio and the role of alternative investments to diversification. Correlation coefficients range from -1 to 1; values close to 1 indicate a strong positive relationship (in the same direction), values close to -1 indicate a strong negative relationship (in opposite directions), and values close to 0 indicate little or no relationship.

From the table, we can see that there are some funds with high correlation, which are marked in green (>0.5) and indicate that these funds move extremely closely together. This means that the funds could be from the same asset class, for instance, equities or bonds, and therefore are not able to diversify their holding when put together as a portfolio. All the assets within a single class in this study have high correlations with one another that suggest that they have common factors of risk and market exposure.

Table 2: Correlation Matrix

	F1	F2	F3	F4
F1	**1**	**0.987573237**	**0.726937964**	**0.736631784**
F2	**0.987573237**	**1**	**0.720344975**	**0.726791083**
F3	**0.726937964**	**0.720344975**	**1**	**0.997954627**
F4	**0.736631784**	**0.726791083**	**0.997954627**	**1**

But the existence of low and negative correlations, as represented by red, is a very important sign of diversification potential. These low or negative correlations indicate that some funds may operate independently or even in a contradictory manner, which is important to hedge risks and minimize portfolio overall volatility. In this study, alternative investment mutual funds and equity mutual funds are negatively correlated with one another and alternative investment mutual fund and debt mutual fund have low correlation with one another. The low correlations found in this matrix confirm the notion that adding alternative investments to a portfolio helps diversify by lessening systematic risk exposure. In general, the correlation matrix highlights the significance of alternative investments in diversification. The combination of strongly correlated traditional funds and poorly correlated alternative funds indicates that a well-diversified portfolio incorporating alternative assets can improve risk-adjusted returns, reduce extreme losses, and exhibit resilience in declining markets.

Table 3: Correlation Matrix

	F5	F6	F7	F8	F9	F10
F1	**-0.305827294**	**-0.18055454**	**-0.183273325**	**0.142049402**	**0.037105119**	**0.063715976**
F2	**-0.294659806**	**-0.19381422**	**-0.171804297**	**0.157674358**	**0.055173355**	**0.079198434**
F3	**-0.163896985**	**-0.11840037**	**-0.080170839**	**0.27121333**	**0.265729471**	**0.153212727**
F4	**-0.175467902**	**-0.11495179**	**-0.078227032**	**0.272785216**	**0.275081735**	**0.157334833**

2) Interpretation of Mean-Variance Optimization (MVO)

In this research, Mean-Variance Optimization (MVO) was utilized to build an optimal portfolio through maximizing the Sharpe Ratio, a risk-adjusted return metric. The Solver tool in Excel was utilized to find the optimal weights for each of the ten funds (F1-F10) regarding expected returns, standard deviation (risk), and the covariance among assets. The risk-free rate of 0.56% was established, which is in line with realistic risk-free investment options.Applying the Sharpe Ratio over Standard Deviation for optimizing weight guarantees an improved risk-reward trade-off since it maximizes excess return relative to each unit of risk. While the former is concerned merely with minimizing risk, the Sharpe Ratio also takes return into account and therefore is a more realistic measure to use when optimizing portfolio. Moreover, the risk-free rate is also factored in to make sure the optimized portfolio is always better than the risk-free asset. This strategy results in a more effective portfolio, allocating high return with low risk, instead of mere minimization of fluctuations. The covariance matrix plays a critical role in Mean-Variance Optimization (MVO) in that it measures the correlation between returns on assets, and it can be used to test for diversification and calculate portfolio risk. Through the inclusion of asset correlations, it optimizes the process of weight allocation so that it minimizes risk at maximum Sharpe Ratio. This assists in building an optimally diversified portfolio with the best risk-reward balance.

In this research paper, we have first found the average return for each fund. Fund 7 (TATA equity mutual fund) has the highest average return, followed by fund 5 (Nippon India Growth Fund). Next, Standard deviation of each fund was found. Making use of the covariance matrix, portfolio standard deviation and portfolio return was found assuming equal weights. Sharpe Ratio was calculated, using which the optimal fund weights for the portfolio were calculated.

Table 4 : Optimum Weights for each fund using Solver in Excel

Fund	**Weight**
Kotak Gold	**57.62%**
Axis Gold	0%
Nippon Silver	0%
ICICI Prudence Silver	0%
Nippon Equity	**8.78%**
ICICI equity	**2.36%**
TATA Equity	**31.24%**
HDFC Debt	0%
SBI Debt	0%
ICICI Debt	0%

By using solver, the optimal portfolio should include, 57.62% of Kotak Gold Alternative Investment Mutual Fund, 8.78% of Nippon equity mutual fund, 2.36% of ICICI Equity Mutual Fund and 31.24% of TATA equity mutual fund. This research indicates that the portfolio should give maximum weightage to Alternative Investment Fund and not include any Debt Mutual Fund to maximise risk adjusted return.

3) Interpretation of Rolling Beta

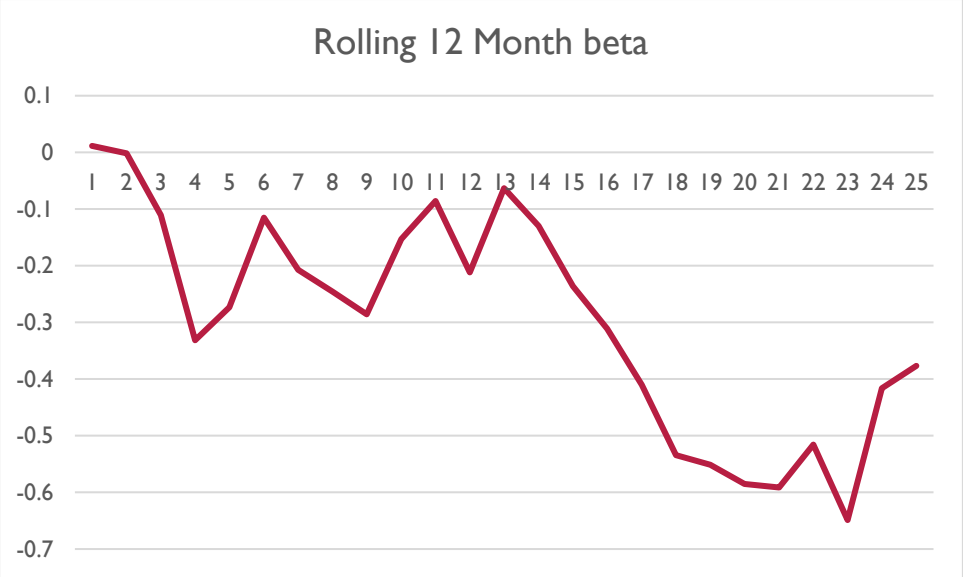

Chart 1: Rolling 12 Month Beta

The slope values in Rolling Beta Analysis represent the rate of change in beta over time. A negative slope indicates that the beta is declining, suggesting that the alternative investment is becoming less correlated with the benchmark, reinforcing its role as a diversifier. However, a rising slope indicates rising correlation, and that the alternative investment is acting more like the benchmark. The 12-month rolling beta begins on 1 March 2023 through to 1 March 2025 and consists of 25 time periods.

At first, for the first 2 months of 2023, a positive slope means an upward beta. This means that the correlation of the alternative investment with its benchmark is rising, diminishing its diversification advantage. Moving higher up the table, we see a decrease in the slope, reflecting less correlated alternative investments to its benchmark. A sharp decline in 2024 (-0.1 to 0.6 range), reflect a quick weakening of the fund's correlation with the market. This could point towards a change in investment strategy, sector exposure, or macroeconomic conditions driving the fund's behaviour. To the investor, this might mean that the alternative asset is providing increased protection against risk in relation to the traditional asset classes.

All but two of the values in the table are negative, which means the beta of the alternative fund is decreasing over time. This means that the fund is deviating from benchmark behaviour, and the fund is an effective diversifier. A permanently negative slope implies the fund is lowering systematic risk exposure, something that may prove useful in highly volatile markets.

4) Interpretation of PCA analysis

The dataset consists of standardized return data for 10 funds: 4 alternative investment funds, 3 equity funds, and 3 debt funds and then PCA was conducted using the real stat software. The key outputs analysed include eigenvalues, explained variance, principal component loadings, and rotated Varimax factor matrix. The eigenvalues of the first 10 principal components are as follows:

Table 5: Eigenvalues, Variance & Cumulative Variance

Eigenvalue	Variance	Cumulative Variance
3.766845	37.67%	37.67%
3.567081	35.67%	73.34%
1.324666	13.25%	86.59%
0.551304	5.51%	92.10%
0.292573	2.93%	95.02%
0.252577	2.53%	97.55%
0.142242	1.42%	98.97%
0.090422	0.90%	99.88%

0.011066	0.11%	99.99%
0.001223	0.01%	100.00%

PC1 (37.67%) and PC2 (35.67%) together explain 73.34% of the total variance.

PC3 (13.25%) adds significant variance, bringing cumulative variance to 86.81%.

The remaining seven components contribute less than 14% of the variance combined. PC4 to PC10 individually explain less than 5% variance each, meaning their contribution to fund differentiation is minimal.

Dominance of PC1 and PC2 account for most variation among the funds indicates that most funds share common risk-return characteristics and are highly correlated. PC3 to PC5 capture additional diversification potential by highlighting differences not explained by PC1 and PC2. PC6 to PC10 Capture Minor Unique Risks since these components contribute marginal variance (≤3%), they mostly reflect niche investment features or residual variations that don't significantly impact overall portfolio diversification.

Since PC1 and PC2 dominate, choosing multiple funds from the same component may not add significant diversification since they exhibit similar return patterns. Instead, selecting funds that load differently across PC3, PC4, and PC5 can enhance portfolio resilience by providing better diversification benefits as they introduce distinct risk-return characteristics.

By looking at eigenvector we can find out what type of funds contribute max to PC3, PC4 and PC5.

Below is the table regarding the same:

Table 6: Eigenvectors

	PC3	PC4	PC5
Fund 1	0.200288	-0.45558	-0.01642
Fund 2	0.189788	-0.46621	-0.09967
Fund 3	0.151941	0.475702	0.087985
Fund 4	0.148286	0.462281	0.091971
Fund 5	0.370376	0.039282	-0.12436
Fund 6	0.28566	-0.16585	0.788883
Fund 7	0.522245	0.073374	-0.53094
Fund 8	-0.30374	-0.15435	0.007367
Fund 9	-0.39604	0.207036	-0.02437
Fund 10	-0.3717	-0.18434	-0.23076

For PC 3 Equity (5–7) and Alternative (1–4) funds lean positive, while Debt (8–10) funds cluster on the negative side. This suggests PC3 captures a broad contrast between equity/alternative strategies and debt instruments. Talking about diversification, alternative funds will offer when it comes to comparing those with debt. Including funds from opposite sides of PC3 can enhance diversification.

PC4 separates funds within each asset class, suggesting different styles or risk profiles within alternatives, equity, and debt. For instance, Funds 1 & 2 may be more growth-oriented alternatives, while Funds 3 & 4 may have different volatility or market sensitivity. Since higher contribution is of alternative funds in both correlations, this suggests that they offer diversification benefits.

PC5 is heavily influenced by the contrast between Equity Fund 6 and Equity Fund 7, indicating these two funds have very different return patterns. The remaining funds show only minor involvement in this component, suggesting that PC5 primarily captures a specific internal differentiation among the equity group. Debt funds do not offer any differentiation at all while alternative funds do offer diversification between its asset class of gold and silver, giving moderate differentiation.

It can be concluded that alternative investments do help in high to moderate diversification of portfolio in both ways: by providing internal diversification and by acting in a different fashion as compared to traditional asset class of debt-equity.

Chart 2 : Scree Plot

This is the scree plot which displays the percentage of total variance by each PC in descending order with PC1 on the left and subsequent PCs to the right. A steep decline after the first few PCs (1-3) indicates those components capture most of the data's variation. The "elbow" point often guides how many PCs to keep (till 4 where additional PCs add diminishing explanatory power). Beyond the elbow, each PC (5-10) contributes relatively little variance, representing more nuanced or residual factors.

Since that significant principal components are PC 1 to PC 3, factor loadings are analysed of only these components which would provide the information regarding what kind of funds are dominated in each PC. The rotated Varimax factor matrix reveals three major clusters of funds:

Table 7 : Rotated Varimax Factor Matrix

	PC1	PC2	PC3
F1	0.925717	-0.00383703	-0.13669
F2	0.920068	0.01237047	-0.13657
F3	0.913375	0.17304211	-0.05044
F4	0.917191	0.17813645	-0.0538
F5	-0.18702	0.21700478	0.904043
F6	-0.11548	0.3204102	0.821373
F7	-0.04376	0.04760932	0.930317
F8	0.169028	0.88139078	0.209859
F9	0.093685	0.91032078	0.120977
F10	0.052712	0.93278379	0.202232

In these results, the first principal component has positive & strong correlations with Alternate Funds. The second component has positive correlations with Debt mutual funds and the third one has strong negative correlations with equity. These funds move in the same direction in the returns, reflecting a shared risk-return profile. This means there are only 3 independent original variables that move in the same way.

Thus, to minimize correlation risk portfolio a single fund of each class will also suffice due to their high correlation. This analysis is further useful for having knowledge about hybrid mutual fund's trend as well because factor loadings will be able to say if it is behaving like debt or equity. As the alternative funds are acting in totally different manner compared to

traditional asset class, their inclusion in portfolio will provide diversification advantage.

LIMITATIONS

While their results are significant, no study is perfect. Correlation analysis has linear assumptions and does not consider dynamic market conditions, which may be simplifying diversification advantages too much. Mean-Variance Optimization (MVO) is based on historical data and normal distribution assumptions and hence prone to outliers and shifts in market conditions. Rolling beta analysis, although helpful for monitoring market responsiveness, may result in noisy estimations as it is based on short-term periods and detecting the long-term direction is difficult. PCA method is just based on returns of funds ignoring other risk metrics which could have helped for knowing the potential risk factors affecting each category of fund. These shortcomings suggest that although useful information is made available through such methods, a combination with additional risk measurement methodologies is essential in order to ensure efficient portfolio building.

4. CONCLUSION

The result of the analysis highlights the importance of alternative investments in portfolio diversification. The PCA results indicate that funds with similar risk-return profiles cluster together in specific principal components. These findings suggest that selecting funds across different principal components can enhance portfolio diversification by minimizing exposure to correlated risks. In some cases, Alternative investments and equities contribute significantly to the first few PCs in eigenvector matrix, whereas debt funds emerge as distinct components whereby they lose their diversification features. However, looking at overall picture, it can be concluded that alternative investments do help in high to moderate diversification of portfolio in both ways: by providing internal diversification and by acting in a different fashion as compared to traditional asset class of debt-equity. The correlation matrix also confirms that alternatives are less correlated with equity and debt funds, validating their role in risk reduction. The MVO results, optimized through the Sharpe Ratio, demonstrate that an optimal portfolio allocation maximizes risk-adjusted returns considerably, with the given optimal mix of equity and alternative assets with maximum allocation to alternative investments. Lastly, rolling beta analysis reveals fluctuation in market sensitivity over time, confirming the need for dynamic risk assessment. Overall, the findings support maintaining alternative investments within a diversified portfolio to maximize returns and provide stability

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