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Asset allocation, diversification, and risk management in investment portfolios: evidence and limitations of modern portfolio theory.

Asset allocation, diversification and risk management in investment portfolios: evidence and limitations of modern portfolio theory

Assignment, diversification and management of risks in investment portfolios: evidence and limitations of modern portfolio theory

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SUMMARY

Asset allocation is one of the central decisions in investment management, as it translates expectations of return, risk, correlation, time horizon, and constraints into a portfolio structure. This article analyzes the fundamentals of diversification and mean-variance optimization, as well as the limitations that arise when theoretical models are applied to estimated data. A structured narrative review is adopted, based on classic literature and empirical studies on portfolio selection, estimation error, naive diversification, covariance matrices, and robustness. The analysis shows that Markowitz's contribution remains fundamental in demonstrating that the risk of a portfolio depends on the relationships between assets, and not just on the individual risk of each position.

However, subsequent literature shows that small changes in estimates of expected returns and covariances can produce unstable weights and economically fragile concentrations.
Out-of-sample studies also show that theoretically sophisticated strategies do not consistently outperform simple rules when the estimation error is high. It is concluded that risk management requires combining diversification, allocation discipline, more robust estimation techniques, economically justifiable constraints, and continuous evaluation of model assumptions.
Keywords: asset allocation; diversification; risk; modern portfolio theory; mean-variance optimization; investments.

ABSTRACT

Asset allocation is a central investment-management decision because it converts expectations about return, risk, correlation, horizon, and constraints into a portfolio structure. This article examines the foundations of diversification and mean-variance optimization, as well as limitations that arise when theoretical models are applied to estimated data. This article adopts a structured narrative review, drawing on classical literature and empirical studies on portfolio selection, estimation error, naive diversification, covariance matrices, and robustness. The analysis shows that Markowitz's contribution remains fundamental in demonstrating that portfolio risk depends on relationships among assets rather than solely on the standalone risk of each position. Subsequent literature, however, shows that small changes in expected-return and covariance estimates may generate unstable weights and economically fragile concentrations. Out-of-sample studies also indicate that theoretically sophisticated strategies do not consistently outperform simple allocation rules when estimation error is substantial. The article concludes that risk management requires combining diversification, allocation discipline, more robust estimation techniques, economically justified constraints, and continuous reassessment of model assumptions.

Keywords: asset allocation; diversification; risk; modern portfolio theory; mean-variance optimization; investments.

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1 INTRODUCTION

Portfolio selection is an economic choice problem under uncertainty. The investor distributes
Transferring resources between assets whose future returns are unknown, and this decision involves
Simultaneously, the expectation of remuneration and the exposure to losses. Markowitz's formulation.
(1952) profoundly altered investment analysis by formalizing the relationship between return
expected value and variance, and by showing that the portfolio should be evaluated as a set of positions.
interdependent.

In the mean-variance approach, portfolio risk does not result from the simple sum of the risks.
Individual. The covariances between asset returns modify the aggregate risk and allow for...
diversification. In economic terms, two risky assets can form a less profitable combination.
riskier than each position analyzed in isolation when its returns do not move in a certain way.
perfectly positive. This property constitutes the mathematical basis of the diversification proposed by
Markowitz (1952).

The efficient frontier represents combinations that, within the model's assumptions, offer the greatest
expected return for a given level of variance or the lowest variance for a given return
expected. This formulation is conceptually powerful because it forces the decision-making process to
Consider trade-offs. However, the calculated frontier depends on the parameters provided to the model.
And these parameters need to be estimated from data or expectations that involve uncertainty.
Michaud (1989) demonstrated a significant practical weakness: mean-variance optimizers.
They tend to amplify errors present in the input assumptions. A seemingly small difference.
In contrast to expected return or covariance, the algorithm may produce extreme positions. Thus,
A mathematically optimal portfolio for the estimated parameters may be economically unsuitable.
robust when these parameters do not adequately represent the future.

The aim of this article is to critically examine the fundamentals of asset allocation and...
diversification, discussing how risk, correlation, estimation error, and constraints affect the
Portfolio construction. The guiding question is: how to preserve the analytical benefits of the theory.
How can we modernize portfolios without confusing mathematical precision with economic certainty? The answer is
developed from verifiable literature and without using non-professional results
documented by the author.

2 METHODOLOGY

The study uses a structured narrative literature review. This strategy was chosen because

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The goal is not to estimate a new econometric model or produce a meta-analysis, but to integrate.
theoretical foundations and empirical evidence that contribute to understanding the difference between the
The logic of diversification and the performance of specific optimization implementations.
Peer-reviewed articles and recognized academic and professional publications were prioritized.
which deal directly with portfolio selection, mean-variance optimization, estimation error,
diversification 1/N, covariance estimation and robustness. Markowitz's seminal work (1952) is
used as a theoretical basis; Michaud (1989), Ledoit and Wolf (2004) and DeMiguel, Garlappi and Uppal
(2009) support the discussion about empirical limitations.
The analysis was organized into six axes: fundamentals of diversification; systematic risk and
Diversifiable; correlation and covariance; parameter instability; comparison between optimization and
Simple rules and robustness mechanisms. Sources were used for affirmative action purposes only.
consistent with the results and arguments presented in their publications.
No primary data was produced; simulations were presented as empirical evidence.
Personal percentages or results attributed to Enzo Leonardo Tieppo's professional experience. A
Figure 1 is conceptual and serves only to illustrate the economic relationship between diversification and the frontier.
Risk-return analysis, without intending to replicate market data.
As a limitation, a narrative review does not offer the exhaustiveness of a systematic protocol and
It does not allow for inferring causality from the frequency of results in the literature. Its usefulness, in this context, is therefore not applicable.
The article's aim is to connect theory and evidence in a traceable way, highlighting where the conclusions are...
robust and dependent on assumptions, samples, and estimation procedures.

3 FUNDAMENTALS OF DIVERSIFICATION AND THE EFFICIENT FRONTIER

Markowitz (1952) formulated portfolio selection based on two essential properties: the
Expected return and variance of returns. The innovation did not consist simply of recommending.
many assets, but in formally demonstrating that the optimal composition depends on the structure.
The combined returns. Therefore, diversification is not synonymous with the number of positions; it depends.
how these positions interact.
When assets show a correlation of less than +1, the combination can reduce the variance of
The lower the correlation between a portfolio and a perfectly aligned risk structure, the lower the correlation.
The greater the potential for risk reduction through combination, all other conditions remaining the same, tends to be.
This does not imply that correlations are constant nor that diversification eliminates losses, but
It explains why concentration and diversification represent economically distinct choices.
The efficient frontier organizes the dominant portfolios in the mean-variance space. A portfolio

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Below the frontier is inefficient if there is another frontier that offers a higher expected return for the same investment.
The level of risk, or lower risk for the same expected return. The concept allows for separating efficiency.
Mathematics of preference: the theory identifies efficient alternatives, while the choice between them...
It depends on the investor's risk tolerance and other constraints.
This framework also reveals why analyzing each asset in isolation is insufficient. An asset of
High volatility can contribute to an efficient portfolio if its relationship with other assets is considered.
improve the overall portfolio mix. Conversely, a seemingly defensive asset can...
to offer little marginal benefit if their behavior replicates exposures already present in
portfolio.
Figure 1 summarizes this logic conceptually. The curves do not represent observed data.
They merely illustrate that distinct correlation structures can alter the set of risk combinations.
return. The economic benefit of diversification therefore stems from the interdependence between returns,
and not a promise of superior returns in any given period.

4. Systematic Risk, Diversifiable Risk, and Concentration

Diversification primarily reduces specific exposures when idiosyncratic shocks do not occur.
affect all positions simultaneously. In contrast, broader market factors, such as liquidity,
Credit or economic activity can affect numerous assets at the same time. Therefore, a
A portfolio with many securities can still remain concentrated in a single economic factor.
The distinction between the quantity of assets and the number of sources of risk is fundamental. A portfolio composed
Having several companies in the same sector, from the same country, or with the same style can create the appearance of dispersion.
nominal, while maintaining high common dependency. The risk analysis should consider not
not only the weights per asset, but also the aggregate exposures and the relationships between returns.
Historical correlation is an estimate, not a structural constant. Relationships between assets may
These factors can change when economic regimes, volatility, and liquidity shift. Thus, a portfolio built...
Based on past relationships, one may exhibit different behavior precisely during periods of
Stress, when the expected protection is most needed.
Managing concentration requires evaluating the marginal impact of positions and factors. Weight limits,
Diversification among classes and exposure restrictions can reduce dependence on the outcome of
a single premise. These restrictions do not eliminate risk; they transform how it is experienced.
distributed and can reduce the portfolio's sensitivity to estimation errors.
Consequently, diversification should be understood as an ongoing process. Changes in
Price factors modify weights, correlations, and risk contributions, so an initial allocation...

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Balanced can become concentrated. Rebalancing, when consistent with the objectives,
Costs and restrictions: it is a mechanism to restore the intended portfolio structure.

5. Estimation Error and Optimization Instability

Mean-variance optimization requires estimates of expected returns, variances, and covariances.
The practical problem is that expected returns are especially difficult to estimate accurately, and
Covariance matrices can become unstable when the number of assets is high relative to the number of assets.
based on the available data. The mathematical solution corresponds exactly to the numbers provided.
even when they contain noise.
Michaud (1989) argues that traditional optimization can maximize the effects of errors.
entry. The mechanism is intuitive: if an asset appears slightly superior due to a sampling error,
The optimizer may assign high weight to this apparent advantage. The result could be a portfolio
focused on estimates that are precisely the least reliable.
Ledoit and Wolf (2004) specifically address the problem of the sample covariance matrix in
Portfolio optimization. The authors propose shrinkage, combining sample information with a
A more stable structure, in order to reduce estimation error. The study shows why improving the
Estimating covariance can be just as important as improving the optimization algorithm.
The instability also has operational implications. Small changes in estimates between
Periods can generate large changes in weights, increasing turnover and costs. A portfolio
What appears superior before costs may lose some of its advantage when negotiation, taxation,
Actual spreads and restrictions are incorporated.
Therefore, robustness is a distinct objective from point optimality. A robust solution seeks
reasonable results in different parameter scenarios, rather than maximizing performance for
A single estimate. Restrictions, regulation, shrinkage, and sensitivity testing may work.
as mechanisms to reduce reliance on weak assumptions.

6. OPTIMIZATION VERSUS NAIVE DIVERSIFICATION

A central empirical question is whether the sophistication of optimization translates into performance outside of the norm.
of the sample. DeMiguel, Garlappi, and Uppal (2009) compared 14 allocation models to seven sets.
data, including the simple 1/N rule, which distributes resources equally among assets.
considered.

The authors report that none of the 14 models evaluated was consistently superior to the strategy.

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1/N in Sharpe ratio, equivalent return of certainty or turnover in the examined sets. The
The result does not demonstrate that equal weights are universally optimal; it shows that theoretical gains
The optimization's advantages can be negated by estimation errors when parameters need to be...
inferred from finite samples.
DeMiguel, Garlappi and Uppal (2009) also present analytical results and simulations that
They indicate extremely long estimation windows in certain calibrations so that strategies
mean-variance ratios exceed 1/N. These numbers refer to the specific conditions of the study and not
They should be generalized as a universal requirement for any market or universe of assets.
Comparison is important because it establishes a disciplined benchmark. A complex model.
It needs to demonstrate incremental value not only in the sample, but also after errors, costs, and...
instability. The 1/N rule has obvious limitations — it ignores differences in risk and correlation —,
However, its simplicity reduces the risk of over-adjusting the parameters.
The implication is not to abandon quantitative models. It is to demand that complexity be taken into account.
Economic justification and out-of-sample evidence. In environments where estimates are weak,
Parsimonious solutions, constraints, and combinations of methods can produce more robust decisions.
rather than unrestricted optimization.

7. Covariance, Shrinkage, and Robustness

The covariance matrix is central because it describes how returns vary together. In
In large universes, the number of covariances grows rapidly, increasing the demand for data.
When the sample size is limited, the estimated matrix may incorporate enough noise to distort the...
Portfolio composition.
Ledoit and Wolf (2004) propose a shrinkage estimator that shifts sample coefficients.
extremes towards a more stable target structure. The principle is to accept some bias in exchange for
a reduction in the variance of the estimate. This trade-off is common in statistics and is particularly...
This is relevant when the accuracy of the parameters affects highly sensitive decisions.
Robustness can also be increased through economically justifiable constraints. Limits
weight, prohibition or limitation of short selling, bands by asset class and penalties for
Turnover can reduce extreme solutions. However, restrictions should not be chosen solely for this reason.
To improve results retrospectively, they need to reflect realistic goals and limitations.
Sensitivity tests complement the estimation. By varying expected returns, volatilities and
By correlating factors within plausible ranges, the manager can identify positions whose presence depends on...
Based on very specific premises. Portfolios that change radically in the face of minor disturbances.

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They deserve additional caution.

Thus, the modern allocation problem is not simply about finding a point on the efficient frontier.
estimated, but also assess the reliability of that boundary. Shrinkage techniques, constraints and
Out-of-sample validation transforms optimization from a deterministic exercise into a process.
decision-making under uncertainty regarding the parameters.

8. Asset Allocation, Horizon, and Rebalancing

The appropriate composition of a portfolio depends on the time horizon and the needs of
Liquidity, loss tolerance, and economic objectives. The mean-variance theory.
It provides a language for organizing risk and return, but does not, by itself, determine those constraints.
An efficient allocation for one investor may be unsuitable for another, due to obligations, timeframes, etc.
or different risk tolerances.

The time horizon alters the relevance of liquidity and short-term volatility. Resources allocated to
Short-term commitments require different capital treatment than long-term capital.
Mixing objectives within a single role, without recognizing these differences, can produce a portfolio
Mathematically sound, but financially inadequate.
Rebalancing is the mechanism by which weights shifted due to market movements are...
redirected to a target structure. It can impose discipline against risky drift, but also
This generates costs and a potential tax impact. The appropriate frequency depends on the magnitude of the...
deviations from the costs and economic function of allocation.
Rebalancing bands offer an alternative to rigid schedules: the intervention occurs
when the weights exceed the defined limits. This procedure does not guarantee a return.
superior, but it connects negotiation to material changes in the risk structure, avoiding transactions.
Purely mechanical when the deviations are small.
Portfolio management should therefore separate strategic allocation, tactical decisions, and maintenance.
operational. This distinction reduces the risk of transforming short-term fluctuations into changes
Permanent strategy decisions facilitate subsequent evaluation of which decisions effectively contributed to the process and allow for a more thorough evaluation of which decisions were made.
for the result.

9 Contemporary Evidence and Advances Until 2025

Recent literature confirms that the central problem identified by modern portfolio theory
The following remains true: the quality of the optimization depends on the quality of the estimates used. Shkolnik

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et al. (2025) revisit portfolio selection in a high-dimensionality context and emphasize that
Estimating the inputs for mean-variance optimization remains a statistical problem.
central. The study explores factorial models, principal components, and shrinkage techniques.
reinforcing that the estimated covariance structure should be evaluated by how it affects the portfolio.
resulting, and not just from abstract measures of statistical adjustment.
Goldberg, Gurdogan, and Kercheval (2025) advance in this direction by proposing shrinkage of eigenvectors.
specifically geared towards the constraints of the investment strategy. The authors show that errors
In the estimation of eigenvectors, excess volatility can be generated in optimized portfolios and
They develop estimators to reduce this effect. The contribution is relevant because it shifts the
Discussion of a generic covariance estimate versus a problem-related estimate.
economic to be effectively optimized.

Shi et al. (2025) analyze global minimum variance portfolios and propose selecting the intensity
shrinkage through minimization of a negative log-likelihood function validated by
Cross-validation. The reported empirical results indicate more covariance estimators.
stable and improvements in out-of-sample metrics, including variance, turnover, and Sharpe ratio, with
The particularly favorable performance of certain linear shrinkage estimators. These
The findings reinforce the importance of evaluating methods based on portfolio behavior outside of the
sample.

Mattera (2025) addresses the problem using the precision matrix, proposing a new estimator of
shrinkage, whose optimal intensity is defined by maximizing the investor's utility.
This approach highlights that recent advances do not abandon the mean-variance structure; they seek
to reduce errors that occur when unknown population parameters need to be inferred.
from finite samples.
Taken together, the literature of 2025 reinforces a more careful interpretation of modern theory of
wallets. The contemporary problem is not choosing between accepting or rejecting Markowitz, but
to determine how to implement its principles when the number of assets is high, the data is
Limited resources and investment constraints are real. This supports the conclusion of this article that
diversification, statistical robustness, economically justified constraints, and validation outside of
Samples should be treated as complementary components of risk management.

10 DISCUSSION

The literature reviewed supports a twofold conclusion. First, the diversification of Markowitz (1952)
This remains a fundamental contribution, as it establishes that risk must be analyzed at the level of

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portfolio and incorporates covariance into the decision problem. Secondly, the implementation
The quantitative analysis of this idea involves substantial uncertainty, since the relevant parameters are not...
known and need to be estimated.

Michaud (1989) and DeMiguel, Garlappi and Uppal (2009) converge in showing, through different paths,
that mathematical precision does not eliminate estimation error. The first emphasizes the amplification of

The second shows that, outside the sample, sophisticated strategies may not be able to identify errors by optimizers; the second shows that, outside the sample, sophisticated strategies may not be effective.

to consistently outperform a simple benchmark.

Ledoit and Wolf (2004) offer a statistical response to part of the problem by improving the estimation.
from the covariance matrix through shrinkage. The relevance of this contribution lies in recognizing
explicitly stating that extreme estimates can be unreliable. The method does not predict the future.
Predictable; it only reduces a measurable component of statistical instability.

These results favor a robustness-oriented allocation approach. Instead of looking for weights
supposedly perfect, the process must assess whether the portfolio remains defensible when the assumptions
They change. This shifts the focus from point optimization to risk governance, data quality,
Economic sensitivity and coherence.

For finance and investment professionals, the main implication is methodological: the models
They are decision-making tools, not substitutes for judgment. The value of a portfolio does not derive from...
The complexity of the algorithm lies not in the consistency between objectives, data, assumptions, constraints, and costs.
and the ability to remain on track when market conditions change.

FIGURE 1 – CONCEPTUAL REPRESENTATION OF DIVERSIFICATION

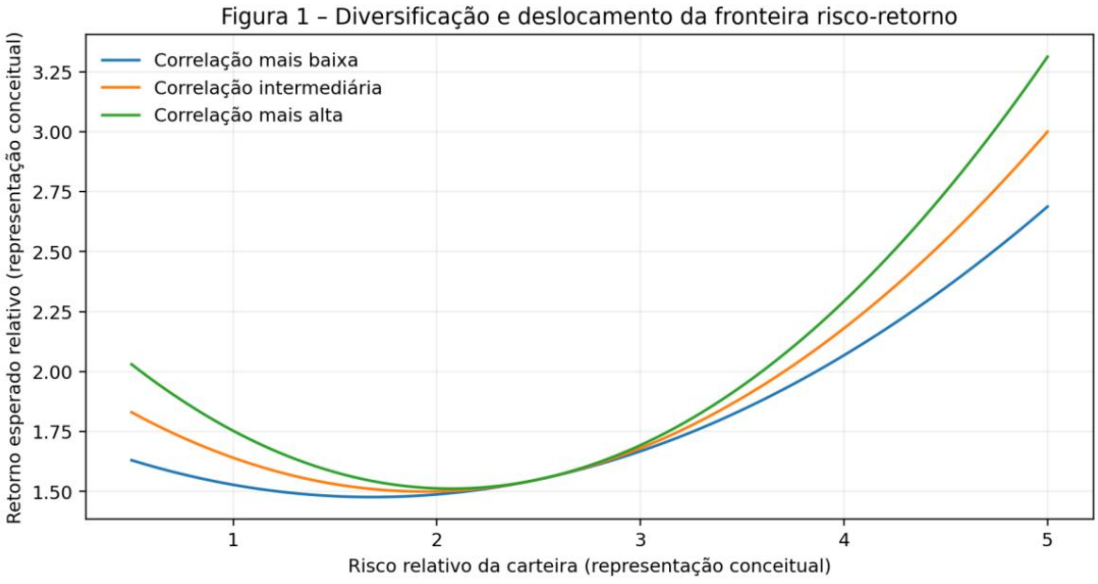


Figure 1 – Conceptual representation of how distinct correlation structures can alter

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Risk-return combinations. Does not use empirical data.

Source: author's elaboration based on Markowitz's (1952) principle of diversification.

CONCLUSION

Modern portfolio theory established a principle that remains central to portfolio management.
Investments: assets should be evaluated based on the contributions they make to the portfolio, and not just...
due to their isolated characteristics. Markowitz (1952) formally demonstrated that the covariances and
Correlations alter aggregate risk and make diversification a measurable economic decision.
This principle, however, does not transform portfolio construction into a problem with an exact solution.
Expected returns, volatilities, and covariances are unknown and need to be estimated.
When these estimates are in error, the optimizer can convert small inaccuracies into large ones.
differences in allocation.
Michaud's (1989) critique remains relevant because it highlights that fragility is not
Not necessarily in the mathematics of optimization, but in the confidence placed on the parameters. One
The solution may be excellent for a specific set of inputs, but simultaneously not very robust.
Given minor changes in these entries.
The evidence from DeMiguel, Garlappi, and Uppal (2009) reinforces the need for validation outside of
sample. The fact that none of the 14 models evaluated consistently exceeded 1/N in the metrics.
The findings do not invalidate portfolio theory; they show that the cost of estimation error can exceed...
The theoretical benefit of optimized weights under specific conditions.
Techniques such as shrinkage, exemplified by Ledoit and Wolf (2004), offer pathways to
To improve the stability of the parameters. Weight restrictions, turnover control, and testing of
Sensitivity can also reduce reliance on extreme estimates, provided they are
economically justifiable and not adopted solely to improve retrospective results.
Risk management must also recognize that nominal diversification does not equate to diversification.
Economic. Many assets may share the same risk factors, and historical relationships
These factors can change during periods of stress. Therefore, aggregate exposures, liquidity, concentration, and...
Interdependencies between assets need to be monitored over time.
Strategic allocation and rebalancing complete this process. A portfolio should reflect the
Rebalancing: horizon, objectives, liquidity needs, and loss tolerance.
It's not about predicting the market, but about restoring the risk structure when price movements deviate from the norm.
wallet with the desired design.
It can be concluded that the most lasting contribution of modern portfolio theory is not the promise of

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Not a mathematically perfect portfolio, but rather a discipline of decision-making: making objectives explicit, to measure interdependencies, acknowledge uncertainty, compare alternatives, and test the robustness of choices. Professional investment management is strengthened when quantitative sophistication is... accompanied by prudence, governance, and awareness of data limitations.

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