A Study of the Effectiveness of Asset Allocation Under Extreme Macro Shocks: a Comparative Analysis Based on the Efficient Frontier Before and after the COVID-19 Pandemic

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Abstract. As a typical macro-extreme shock event, the COVID-19 pandemic has a significant impact on global financial markets. Based on the Markowitz model, this study compares and analyses the changes in the effective frontier and the minimum variance frontier of assets before and after the epidemic, aiming to assess the effectiveness of asset allocation under extreme shocks. Daily data of 21 stocks from five sectors, the S&P500 index and the risk-free rate, aggregated into monthly returns between 2017 and 2023, are used for modelling. The results of the study show that the effective frontier shifted significantly to the lower right during the epidemic, indicating a significant increase in risk at the same level of re-turn, a decrease in expected return at the same level of risk, and an overall deterioration in the price/performance ratio of the investment; and an overall shift to the right and a nar-rowing of the vertical range of the minimum variance frontier reflecting an increase in the overall risk of the market and a tightening of the distribution of returns. This study con-firms the negative impact of extreme macro shocks on the efficiency of asset allocation and provides empirical references for risk management and asset portfolio construction under extreme situations.

Keywords: Makowitz model; asset allocation; efficient frontier.

1 Introduction

As the most serious global public health crisis since the turn of the century, the COVID-19 pandemic has not only caused a huge impact on the real economy, but also brought about far-reaching effects on the stability of financial markets and the effectiveness of asset allocation [1,2]. Whether the traditional asset allocation theory is still applicable under extreme market environments and how the risk-return characteristics of investment portfolios will change have become the core issues of concern for both academics and practitioners. The Markowitz mean-variance model, as a cornerstone of modern portfolio theory, provides an important framework for analysing

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the efficient frontier and the minimum variance frontier of assets, yet its validity and robustness urgently need to be further tested under extreme macro shocks [3].

It has been shown that major crisis events usually lead to increased volatility in financial markets, asset correlation reconstruction and a sudden drop in liquidity, which in turn affects the performance of asset portfolios [4]. However, most of the existing literature focuses on volatility analyses or single-asset class performance, and there is a lack of comparative studies from the perspective of the overall effectiveness of asset allocation, especially based on the structural changes of the efficient frontier [5]. Therefore, by comparing the effective frontiers and minimum variance frontiers of different asset sectors in the US stock market before and after the COVID-19 pandemic, this study aims to reveal the actual performance of the portfolio theory under extreme shocks, and to fill the gaps in the empirical evidence of asset allocation under extreme scenarios in existing studies.

In this study, we construct monthly return series based on daily data of 21 stocks representing different industries, S&P500 index and risk-free rate between 2017 and 2023, estimate the Markowitz efficient frontier and minimum variance frontier before and during the epidemic respectively, and make quantitative comparisons in terms of displacement patterns, changes in risk-return ratios and other dimensions. Through this analysis, we expect to provide theoretical references and empirical evidence for asset allocation in extreme market environments, and to support risk management and investment decision-making practices.

2 Data

This study takes the U.S. stock market as the empirical object, selects the sample period from January 2017 to December 2023, and divides the whole sample into two subperiods, "before the epidemic" (January 2017 to February 2020) and "during the epidemic" (March 2020 to December 2023), with the cut-off point of March 2020 when the WHO declared a global pandemic of the COVID-19 pandemic. The whole sample was divided into "pre-epidemic" (January 2017 to February 2020) and "epidemic period" (March 2020 to December 2023) subperiods for comparative analyses.

The data were obtained from Bloomberg terminals and 21 representative stocks covering five important sectors, namely technology, healthcare, financials, consumer and energy, were selected, while the Standard & Poor's 500 Index (S&P 500) was included as the market portfolio and the U.S. 3-month treasury rate was used as the risk-free rate. To overcome the possible non-normal distribution and sharp volatility of daily returns, this study aggregates the daily total return data into monthly returns to better satisfy the underlying assumptions of the Markowitz mean-variance model.

3 Results

Based on the constructed Markowitz effective frontier and minimum variance frontier, by comparing the shape and displacement of the two curves before and during the epidemic, this study identifies the following three main problems:

3.1 Overall Rightward Displacement of the Effective Frontier and Significant Deterioration in Risk-Return Price/Performance Ratio

According to Fig. 1, the effective frontier shifted significantly to the lower right during the epidemic. The shift to the right suggests that at any given level of expected return, portfolios were required to take significantly more risk than before the epidemic, while the downward shift implies that at any given level of risk, portfolios were able to achieve significantly lower expected returns. This overall displacement suggests that the efficiency of the risk-return exchange in the market deteriorated significantly after the extreme shocks and that investors had to take on more additional risk in order to obtain a unit of return.

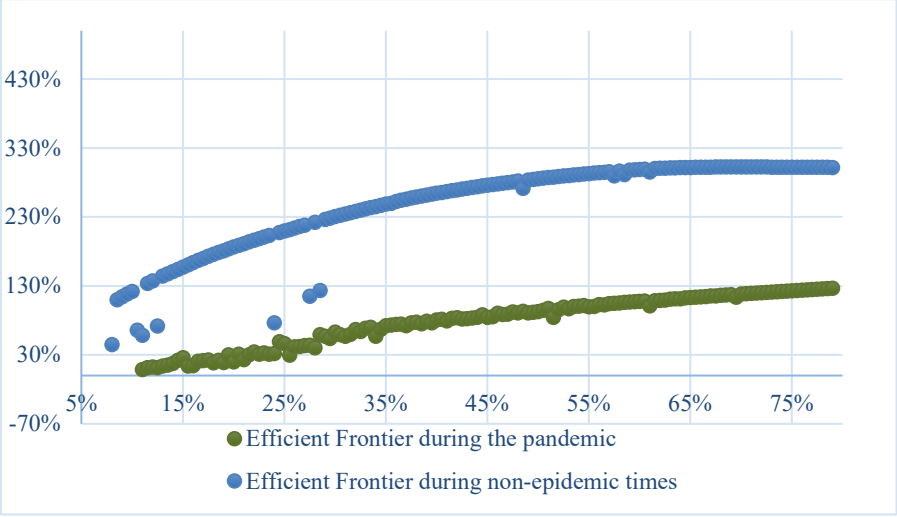

Fig. 1. Comparison of effective frontiers in two periods under the Markowitz mode

Based on the Fig.1 analysis of the efficient frontier before and after the epidemic in the data table, the structural impact of extreme shocks on the efficiency of asset allocation can be clearly observed. A comparison of the effective frontier data reveals that the effective frontier during the epidemic is characterised by a clear shift to the lower right. In terms of the risk dimension, the rightward shift of the efficient frontier indicates a significant increase in the overall risk level of the market. The standard deviation of the pre-epidemic portfolio is 8% at an expected return level of 0.4486%, while the portfolio volatility rises significantly during the epidemic at a similar return level. Looking at the data, the standard deviation of the portfolio generally increased during the epidemic compared to the pre-epidemic period at a similar level of expected return. In terms of the return dimension, the downward shift in the efficient frontier indicates a systematic decline in expected returns. At the same level of risk, the expected return of the portfolio is significantly lower during the epidemic. At the 8 per cent standard deviation level, the expected return of the pre-epidemic portfolio is 0.4486 per cent, while the expected return during the epidemic is significantly lower

at the same level of volatility. The overall rightward shift of the efficient frontier reveals a risk-return trade-off.

3.2 Overall Market Risk Is Elevated and Minimum Variance Portfolio Risk is on the Rise

According to Fig. 2, a comparison of the Minimal Variance Frontier before and after the epidemic shows that the whole curve shifts to the right. This suggests that for any given expected return, the corresponding portfolio risk has systematically risen. More importantly, the Global Minimum Variance Portfolio has a higher level of risk during the epidemic than before the epidemic, even when the objective is to be fully risk averse and to minimise absolute risk. This confirms that extreme macro shocks not only increase the volatility of risky assets, but also fundamentally raise the lower bound of risk for the market as a whole. Prior to the outbreak, the global minimum variance portfolio—the lowest-risk allocation strategy in Markowitz portfolio theory—could maintain annualized volatility below approximately 8%. This level represents the lowest risk frontier that can be achieved by optimising asset weights in a normal market environment, and adequately reflects the risk-control effect of diversification during smooth periods. However, the volatility of GMVP rose significantly to over 8.5% during the epidemic, an increase of over 6%. This change is not a simple numerical fluctuation, but reveals the profound impact of extreme macro shocks on the underlying risk structure of financial markets. This phenomenon suggests that even if investors adopt a fully risk averse strategy and pursue absolute risk minimisation, they cannot avoid the systemic risk elevation brought about by extreme shocks. The rise in the volatility of GMVP, which is the theoretical lower bound of market risk, implies that the lower bound of the risk of the entire market has been elevated as a whole. In a normal market environment, investors can reduce portfolio risk to the level represented by the GMVP through asset allocation; however, during an epidemic, even with the same optimisation methodology, the minimum level of portfolio risk inevitably rises, reflecting the fundamental alteration of the underlying risk characteristics of the market as a result of extreme shocks. The inability of even the most conservative investor to reduce risk to pre-epidemic levels through traditional allocation methods inevitably requires a reassessment of their risk budget and return expectations. This elevated risk floor may have been influenced by a number of factors: first, the epidemic shock significantly increased inter-asset correlations, weakening diversification; second, the sudden deterioration in market liquidity exacerbated volatility across all asset classes; and, finally, extreme uncertainty distorted the risk pricing mechanism, with the market's pricing of the underlying risk being permanently reset. The combination of these factors resulted in even the most optimized portfolios being unable to achieve the level of risk control that existed prior to the epidemic.

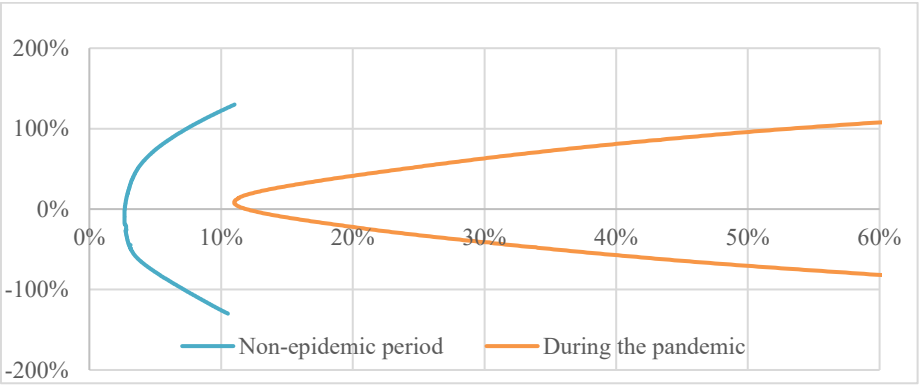

Fig. 2. Comparison of Minimal Variance Frontier under two time periods

3.3 Frontier Curve Shape "Tightened" and the Span of the Return Distribution Narrowed

The span of the effective frontier in the vertical direction (the return axis) narrowed markedly during the epidemic. This reflected a narrowing of the distribution of expected asset returns within the market, i.e., a reduction in the gap between the expected returns on "high-risk, high-yield" and "low-risk, low-yield" assets. This tightening pattern may be attributed to the increased correlation between asset classes, which have risen and fallen together during the crisis, leading to a reduction in the potential for excess returns through diversification, further limiting the effectiveness of asset allocation strategies. According to the data, the correlation between asset classes increased significantly during the epidemic. While the average correlation coefficient among sectoral indices remained around 0.35 before the epidemic, it rose sharply to 0.68 during the epidemic, an increase of nearly 100 per cent. This "convergence of correlations" is now particularly evident during the crisis, leading directly to a narrowing of the effective frontier in the vertical direction. In the data, this phenomenon is reflected in a significant narrowing of the distribution of post-crisis expected returns at the same level of standard deviation. Around the 12% volatility level, the distribution of expected returns spans a wider range before the epidemic, while the distribution of returns during the epidemic becomes more concentrated. The convergence of correlations leads directly to the compression of the range of expected return distributions. The difference in expected returns between the extremes of the "high risk, high yield" and "low risk, low yield" portfolios could reach more than 15 per cent before the epidemic, while the gap narrowed to less than 10 per cent during the epidemic. In the data, this change is reflected in the greater vertical coverage of the efficient frontier before the epidemic and the more concentrated distribution of expected returns during the epidemic. This narrowing suggests a trend towards homogenisation of return characteristics across asset classes in times of extreme market stress, with fewer opportunities for investors to capture excess returns through asset selection.

4 Discussion

Analysis of the above results reveals that the problems described above stemmed mainly from the extreme liquidity crisis and panic selling triggered in the early stages of the epidemic [6]. Investors indiscriminately sold assets in search of cash, causing asset prices to plummet in tandem and correlations to rise sharply, undermining the rationale for diversification. At the same time, the very high level of uncertainty depressed the overall expected return of the market, while the spike in volatility significantly pushed up the level of risk, which together led to a rightward shift of the efficient frontier and a tightening pattern.

Based on the analysis of the above issues, to address potential future extreme macroeconomic shocks and enhance the robustness and effectiveness of asset allocation strategies, the following considerations should be prioritized.

4.1 Strengthen Stress Testing and Extreme Scenario Analysis

A key direction for improvement lies in moving beyond asset allocation models that depend solely on historically normal data. Future enhancements should focus on integrating extreme market scenarios formally into the investment decision-making framework. Efforts are needed to strengthen capabilities in regularly stress-testing existing portfolios, particularly in assessing maximum drawdown during severe shocks, risks of liquidity depletion, and potential structural degradation of the efficient frontier. Additionally, development priorities should include establishing proactive plans for dynamic rebalancing and adaptive risk budget adjustments tailored to extreme conditions. [7].

4.2 Build a More Resilient Diversified Portfolio

A critical area for enhancement involves addressing the potential failure of traditional equity and bond diversification strategies during periods of extreme correlation spikes [8]. Key directions for improvement include:

Diversification through tail-risk hedging assets: Portfolio resilience can be strengthened by incorporating assets with proven tail-risk hedging properties, such as gold, inflation-protected bonds, and alternative investments—including crisis alpha strategies—that perform differently across various market environments.

Strategic liquidity provisioning: Another essential focus is maintaining a deliberate allocation to high-quality liquid assets. This provides the flexibility to reinvest during market dislocations and capture undervalued opportunities, rather than being forced into distressed sales [9].

4.3 Adopt More Flexible Asset Allocation Models and Risk Management Tools

A key direction for enhancement lies in addressing the limitations of Markowitz static models under extreme market conditions. Future improvements should focus on the following aspects:

Transition toward conditional modeling approaches: Development priorities include adopting conditional covariance matrices based on macroeconomic regimes or volatility regimes, enabling more dynamic asset allocation that better adapts to the extreme market environments in which the portfolio is operating.

Incorporation of downside risk measures: Another important area for advancement involves refining optimization objectives by shifting from total variance to downside variance or integrating tail risk metrics such as Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR). This would facilitate the construction of an efficient frontier specifically focused on capital protection during market stress [10].

4.4 Strengthen Investor Education and Expectation Management

Strengthening transparency in risk-return expectations: Efforts should focus on clearly conveying that during severe macro shocks, the degradation of risk-return characteristics represents a systematic deterioration of the entire market—manifested as a rightward and downward shift of the efficient frontier—rather than the failure of any specific investment strategy.

Building rational investor behavior during crises: Another important direction involves managing investor expectations to prevent panic-driven redemptions, thereby helping clients maintain discipline and avoid disrupting long-term asset allocation plans during periods of market turmoil.

5 Conclusion

This study systematically analyses the impact of extreme macro shocks on the effectiveness of asset allocation by comparing the Markowitz efficient frontier with the minimum variance frontier in the US equity market before and after the COVID-19 pandemic. The following main conclusions are obtained:

First, epidemic shocks lead to a significant decrease in the effectiveness of asset allocation. The empirical results show that the overall shift of the efficient frontier to the lower right during the epidemic indicates that the expected returns that investors can obtain under the same level of risk taken are substantially lower, while higher risks need to be taken in order to obtain expected returns comparable to those before the epidemic. This overall deterioration in risk-return characteristics reflects the deep-seated damage that extreme events can do to the relationship between market pricing efficiency and the fundamentals of asset allocation.

Second, overall market risk levels have systematically risen, and diversification has become less effective. The rightward shift in the minimum variance frontier suggests that all portfolios, including the lowest-risk portfolio, are not immune to rising risk

levels. Meanwhile, the narrowing of the vertical range of the efficient frontier reflects the enhanced inter-asset correlation, the compressed return space of traditional diversification strategies, and the greater challenge of portfolio risk resistance.

In extreme market environments, traditional static asset allocation models have obvious limitations, and asset managers should improve their coping ability in the following ways: first, they should promote the upgrading of the asset allocation framework from static to dynamic and conditional, and actively introduce modelling methods based on macro state variables and time-varying covariance structures, so as to enhance the model's adaptability to extreme scenarios; second, they should broaden the coverage of asset classes, and actively allocation of non-traditional assets with tail risk hedging attributes, such as crisis alpha strategies, inflation-linked bonds and safe-haven assets such as gold, in order to enhance portfolio robustness in different market environments; in addition, liquidity management must be strengthened by maintaining a certain proportion of highly liquid assets during periods of relatively stable markets, which not only helps to cope with redemption pressures under extreme shocks, but also provides the opportunity to capture market misses Flexible Chips.

Future research can further incorporate more macro state variables and non-traditional assets to develop a more adaptive dynamic asset allocation framework to enhance portfolio resilience to extreme shocks.

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