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COMPARISON OF THE BEHAVIOR OF MARKOWITZ MODEL ACROSS THREE BROAD INDICES UNDER DIFFERENT MARKET CONDITIONS

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ABSTRACT

The Markowitz model, introduced by Harry Markowitz in 1952, forms the basis of Modern Portfolio Theory and provides a mathematical framework for investors to create well-diversified portfolios by balancing risk and return. This research investigates the performance of the Markowitz model across three major indices: Nifty 50 of India, PSEi composite of the Philippines, and Straits Times Index of Singapore, under different market conditions in different time regimes. The study covers a 15-year period starting from 2007, encompassing the global financial crisis and the COVID-19 pandemic. From each index, 20 stocks were selected based on their market capitalization. Through the application of the Markowitz mean-variance model, optimal portfolio weights were derived for different time regimes within each country. These trial period optimal weights were then applied to subsequent simulation periods for comparative analysis with the Market Capitalization Weighted Portfolio, serving as the benchmark. Performance assessments were based on the Sharpe ratio and Information ratio. Results revealed that the Markowitz model's varied performance across market conditions in India and the Philippines whereas, in Singapore, it constantly well-performed despite the market condition due to the country's relative stability than India and Philippines. These results suggested that the effectiveness of the model relies on the stability challenges that emerge in volatile and uncertain periods when the country is relatively unstable.

Keywords: Indices, Information ratio, Markowitz model, Risk and return, Sharpe ratio

1. Introduction

Portfolio optimization is an important aspect of investment management that aims to select a portfolio that provides the highest expected return while minimizing risk (Markowitz, 1952). The process entails evaluating a set of potential portfolios and selecting the one that best meets a specified objective. Portfolio optimization considers a variety of factors, including the expected return, risk, and diversification benefits of individual assets, as well as their covariance structure (Markowitz, 1952). A well-optimized portfolio is expected to provide better risk-adjusted returns than portfolios chosen otherwise (Markowitz, 1952).

One of the most widely used frameworks for portfolio construction and management is the Markowitz portfolio optimization model. The model, developed by Harry Markowitz in 1952, is based on probability theory and quantifies the expected risk and return of financial assets as a risk-return trade-off. To determine the optimal portfolio, the model takes into account the diversification (Markowitz, 1952) of the assets which is a key factor that is used to measure risk (Markowitz, 1952). The Markowitz model calculates the efficient frontier, which represents portfolios that offer the maximum expected return for a given level of risk, or the minimum risk for a given level of expected return (Markowitz, 1952).

The research begins by presenting a theoretical background of the Markowitz Model and subsequently applies it using the mean-variance approach to construct portfolios for three broad market indices. It then investigates the viability of using the trial period's optimal portfolio mix derived from the Markowitz Model for future investments by examining different market movements during the simulation period. Additionally, the study compares the optimal portfolio weights to the market capitalization-weighted portfolio from the simulation period, utilizing ratios such as the Sharpe ratio and Information ratio (Sholehah et al., 2020; Catherine & Robiyanto, 2020), to comprehensively analyze the practical implications of the findings for real-life investment activities.

2. Literature Review

Previous studies have explored portfolio optimization using Markowitz's mean-variance portfolio theory examining specific countries, international markets, and market performances.

One study examined the application of Markowitz's optimal portfolio theory on 50 stocks selected from the Bulgarian stock market during 2013-2016 to determine efficient frontiers and optimal portfolios. The study finds that the efficient portfolios formed by the Markowitz model outperformed industrial domestic securities during the period of study (Ivanova & Dospatliev, 2018).

In the Indian stock market context, 42 stocks were considered initially from the Nifty50 index, based on large trading volume and market capitalization. From the selection, the top 14 stocks were selected to construct portfolios as the weights of other stocks were insignificant after optimization. These portfolios consistently outperformed the benchmark Nifty50 portfolio, achieving higher returns with lower risk indicating that the application of the Markowitz model outperforms the benchmark portfolio consistently (Das & Mukherjee, 2012).

Another study examined the association among international stock markets including BSE-Sensex, NYSE, NASDAQ, S&P500, Hang Seng, Nikkei225, SSE Composite Index, FTSEIOO, IPC, CAC 40, FTSE/JSE, DOW JONES, STI and DAX using Markowitz mean-variance approach. It analyzed data from 2007 to 2012 and constructed portfolios to find the best-performing market and its comparison to the Indian market. They also calculated the risk and correlation with various markets to determine the optimal portfolio consisting of major market indices. The results of the study revealed the existence of associations among world markets as per the correlation matrix and therefore the advantages have been diminished when diversifying investments across countries (Guha et al., 2014).

In a study evaluating financial instruments in the Romanian stock market, a portfolio with the lowest possible risk was constructed using three securities: OMV Petrom (energy, oil, and gas sector), Transgaz (energy sector), and Albalact (food sector, dairy industry). The Markowitz model was employed to analyze the profitability and risk of portfolios comprising three securities. The results indicated that the minimum variance portfolio primarily consists of Transgaz assets, offering good, expected returns, a balanced risk level, and an impressive Sharpe ratio. (Zavera, 2017).

The literature highlights the significance of the portfolio optimization model; the Markowitz Model, in constructing efficient portfolios. Researchers have demonstrated the model's effectiveness in various contexts, outperforming individual securities and offering maximum return on investment while managing risk.

Despite the widespread use of Markowitz mean-variance models in different contexts, there is a gap in the literature regarding the comparison of their applicability across Broad Indices under different market conditions. This study aims to fill this gap by applying the Markowitz Model to three broad market indices and comparing the effectiveness of the derived optimal portfolio weights under different market conditions.

3. Methodology

3.1. Data set

Three Asian countries and their main stock indices were selected to analyze the performance of the optimization models under different market conditions and market movements. The chosen countries and their respective main indices are as follows:

- India – Nifty 50
- Philippines – PSEi Composite
- Singapore – STI (Straight Time Index)

The study's time period starts from 1st December 2007 to 31st December 2021, encompassing significant global events like the global financial crisis in 2008 and the covid 19 pandemic. The entire period was then segmented into distinct time regimes using a moving average analysis, considering the index behavior, reflecting market movements including bullish and bearish trends, and significant global and local market conditions.

These time periods are referred to as "trial periods," during which the optimization models were applied to derive the optimal portfolios. Then the immediate one-year period following each trial is designated as the "simulation period," during which the optimal portfolio derived from the trial period was applied to check the performance. The performance of the optimal portfolio during the simulation period was then compared to the performance of the market-cap-weighted portfolio, considering it as the benchmark. Tables 1, 2, and 3 show the time regimes and selection criteria of each country.

Table 1. Time regimes – India.

Regime	Time Period	Selection Criteria
01	2007/12/01 – 2009/05/15	Global Financial Crisis
02	2009/05/16 - 2014/01/31	Highly Volatile Period
03	2014/02/01 – 2016/12/31	Erratic Movements in Index
04	2017/01/01 – 2020/01/29	Gradual Bull Trend
05	2020/01/30 – 2021/12/31	COVID-19 Pandemic

Table 2. Time regimes – Philippines.

Regime	Time Period	Selection Criteria
01	2007/12/01 – 2009/05/31	Global Financial Crisis
02	2009/06/01 – 2013/05/12	Long Bull Market
03	2013/05/13 – 2018/01/31	Highly Volatile Bull Market
04	2018/02/01 – 2020/01/31	Highly Volatile Period
05	2020/02/01 – 2021/12/31	COVID-19 Pandemic

Table 3. Time regimes – Singapore.

Regime	Time Period	Selection Criteria
01	2007/12/03 – 2009/02/20	Global Financial Crisis
02	2009/02/20 - 2015/04/15	Highly Volatile Period
03	2015/04/15 – 2019/12/31	Erratic Movements in Index
04	2017/01/01 – 2020/01/29	COVID-19 Pandemic

Historic data for each time regime was obtained from the top 20 companies based on market capitalization for each time period.

3.2. Markowitz model

Using the historical stock data, individual returns, volatility and covariances were calculated for each stock. Subsequently, 50,000 distinct portfolio combinations were randomly generated, and the return, risk, and Sharpe ratio of each portfolio were calculated.

Sharpe ratio indicates the risk-adjusted return of the portfolio, which shows the return for each additional unit of risk. The risk-free rate considered for the Sharpe ratio calculation was the 10-year government bond rate. The portfolio with the highest Sharpe ratio was determined as the optimal portfolio for each trial period. The formula for the Sharpe ratio is given in Equation 1.

Equation 1: Sharpe ratio formula

$$Sharpe\ ratio = \frac{E(R_p)\ -\ R_f}{\sigma_p}$$

$E(R_p)$ – Expected return of the portfolio
R_f – Risk-free rate
σ_p – Risk of the portfolio

3.3. Performance analysis

As the next step, the optimal weights derived for each trial period were applied to the simulation period. The performance of the optimal portfolio during the simulation period was then compared with the market-cap weighted portfolio of the simulation period, considering the market-cap weighted portfolio as the benchmark.

The following measures were used to compare the performance of both portfolios during the simulation period. These measures enable investors to assess the performance of the optimal portfolio concerning risk adjustment and its relative performance.

- **Sharpe ratio**

The risk-adjusted performance of an investment is measured by considering the excess return generated over the risk-free rate relative to the additional unit of risk taken. This is given in Equation 1.

- **Information ratio**

Assess the risk-adjusted performance of a portfolio in comparison to its benchmark. It is calculated as in Equation 2.

Equation 2: Information ratio formula

$$Information\ Ratio = \frac{R_p\ -\ R_b}{SD\ of\ daiy\ excess\ returns}$$

R_p – Return of the portfolio
R_b – Return of the benchmark
$SD\ of\ Daily\ Excess\ Returns$ – Standard deviation of the daily excess returns

A higher and positive information ratio suggests that the trial period optimal portfolio has outperformed the benchmark portfolio while a negative value suggests it has under-performed the market-cap weighted portfolio (benchmark).

4. Results and Discussion

The fundamental procedure of the study starts with the division of time regimes for the trial period using market movements and special market conditions of each country's indices for the selected period of 15 years starting from 2007 as given in Table 1, Table 2 and Table 3.

4.1. Application of Markowitz model

Markowitz's mean-variance model is applied to derive trial period optimal weights for each time regime, for all three countries separately.

Since the objective of this study is to check whether the optimal portfolio weights obtained from the trial period can be used in the immediate next one-year period of time (i.e.: simulation period), derived trial period optimal weights were applied to the simulation period. Subsequently, a comparative analysis was conducted with the market-cap-weighted Portfolio of the simulation period. The performance of the portfolios was assessed and compared based on the Sharpe ratio and Information ratio.

4.2. Illustration of results

An explanation for the aforementioned methodology can be elaborated using the following results obtained for three countries India, the Philippines, and Singapore.

The results in Table 4 can be examined and discussed by considering the time regimes separately for India as follows.

Table 4. Results of India.

India	Sharpe Ratio		Information Ratio (IR)
	Derived MV Portfolio	MCW Portfolio	
Regime 01	-4.7111	-6.7336	6.6898
Regime 02	0.7927	-7.02697	15.6525
Regime 03	-6.0215	-0.4506	-11.2403
Regime 04	-4.2912	-1.5853	-10.8760
Regime 05	-6.1898	-5.5654	-3.0289

Regime 01: Although negative values are observed in both figures, the market-cap-weighted (MCW) portfolio has a smaller negative Sharpe ratio compared to the optimized (MV) portfolio with trial weights. It has indicated an outperformed Derived MV portfolio, and the results were further validated by a positive value of Information Ratio (IR).

Regime 02: A significant difference between the Sharpe ratios of the two portfolios indicated that the derived portfolio from trial period weights outperformed compared to the benchmark portfolio (MCW) while having a highly positive IR value.

Regime 03: Sharpe ratios are negative in both portfolios. However, the existing notable difference helps investors to make a choice of investment decision. The MCW portfolio performed well compared to the Derived MV portfolio. The higher negative IR implied a higher downward shift in the mean return of MV than MCW.

Regime 04: Negative Sharpe ratios and IR value implied that the Derived MV portfolio from trial period weights has underperformed the benchmark on a risk-adjusted basis.

Regime 05: According to Sharpe ratios, the MCW portfolio performed better compared to the optimized portfolio derived from trial weights. Further validating the observation, it has recorded a negative IR figure.

The results in Table 5 can be discussed comprehensively by examining the time regimes separately for the Philippines as follows.

Table 5. Results of Philippines.

Philippines	Sharpe Ratio		Information Ratio (IR)
	Derived MV Portfolio	MCW Portfolio	
Regime 02	7.9906	7.5304	0.6171
Regime 03	-1.1220	-2.0736	3.9942
Regime 04	-4.9119	-4.5018	-2.3435
Regime 05	-13.8346	-11.2867	-5.5946

**Regime 01: Dropped due to unavailability of data*

Regime 02: The Sharpe ratio of the derived portfolio from trial period optimized weights records a higher figure than the MCW portfolio. It implied that in this time regime, the Derived MV portfolio has a high probability of making higher returns than the benchmark portfolio and it has been proven by the positive IR value.

Regime 03: Although the Sharpe ratios are negative, the comparative analysis of Sharpe ratios showed an outperformed optimized portfolio derived with trial period weights relative to the benchmark portfolio (MCW) during this period. That has been proven by a highly positive IR figure.

Regime 04: Since the Derived MV portfolio has the highest negative Sharpe ratio, it has under-performed the benchmark portfolio indicating that the investment has not generated sufficient returns to compensate for the level of risk taken. That is further validated by the negative IR value.

Regime 05: The measures calculated showed that the derived portfolio from trial period weights has under-performed the MCW portfolio, as evidenced by its comparatively lower negative value of the Sharpe ratio. That is supported by the negative figure of IR.

The results in Table 6 can be discussed by analyzing the time regimes separately for Singapore as follows.

Table 6. Results of Singapore.

Singapore	Sharpe Ratio		Information Ratio (IR)
	Derived MV Portfolio	MCW Portfolio	
Regime 01	-0.1040	-1.1259	2.3367
Regime 02	-1.3125	-2.4508	3.1990
Regime 03	-2.2579	-2.6141	0.9382
Regime 04	0.0696	-0.6510	1.7091

Regime 01: The derived portfolio from optimal weights of the trial period recorded a comparatively lower negative Sharpe ratio which indicated the portfolio has

outperformed compared to the benchmark (MCW) portfolio as the positive IR value proved the same result.

Regime 02: The portfolio derived from trial period optimal weights has performed better than the benchmark portfolio since the Derived MV portfolio has a lower negative Sharpe ratio compared to the MCW portfolio. It has been validated by the positive IR.

Regime 03: The derived portfolio with trial period optimal weights performed better and indicated an outperforming portfolio from its benchmark. The positive sign IR showed excess returns were generated above the benchmark.

Regime 04: The optimized portfolio derived from trial weights has outperformed relative to the benchmark by having a significantly higher Sharpe ratio while positive IR justified the observation.

4.3. Insights on common observations

A detailed illustration is provided in this section using the results obtained by considering the common global market condition, the COVID-19 pandemic during the trial period for all three countries.

Figure 1, Figure 2, and Figure 3 show the performance comparison plots obtained for the countries India, Philippines, and Singapore respectively.

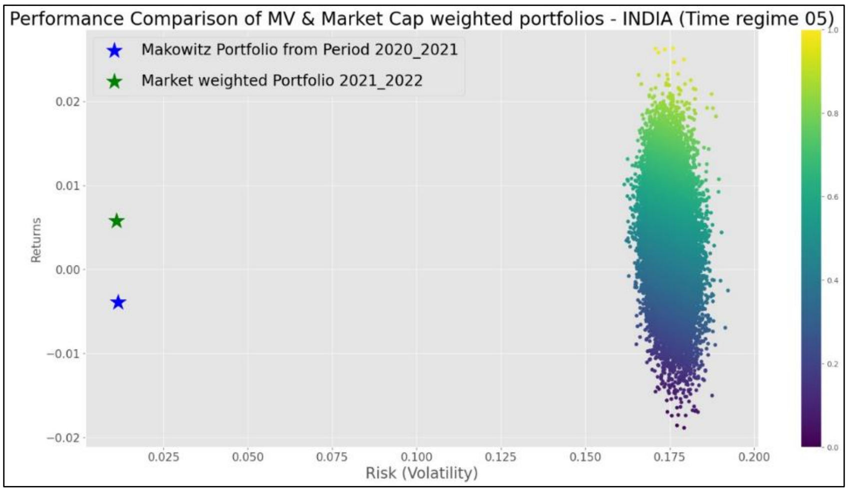

Figure 1. Portfolio comparison plot of India.

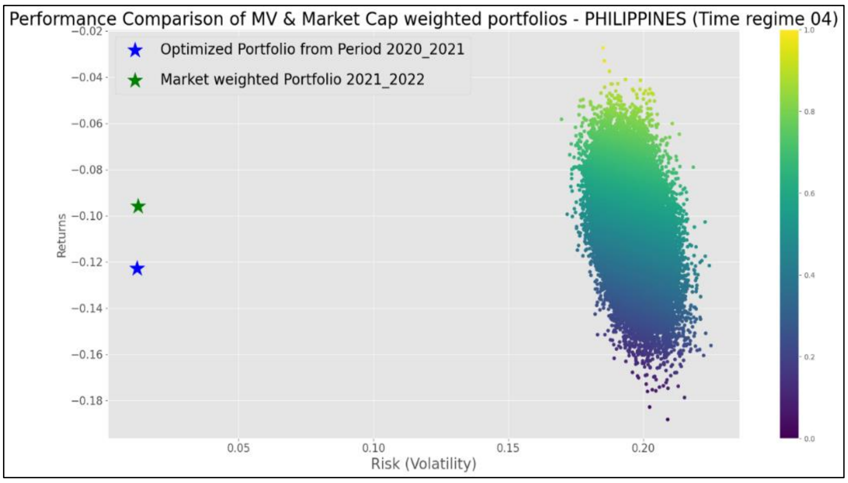

Figure 2. Portfolio comparison plot of the Philippines.

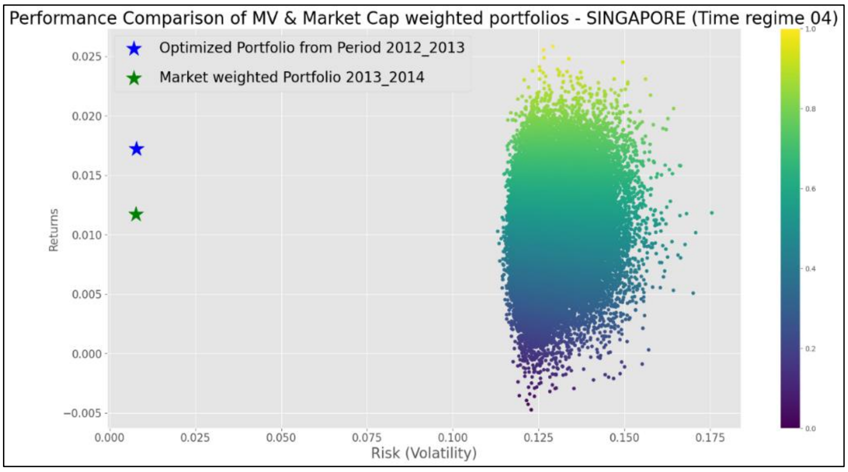

Figure 3. Portfolio comparison plot of Singapore.

Note that the blue star represents the Simulation period optimal portfolio obtained by applying trial period weights and the green star represents the Market Weighted portfolio of the Simulation period.

As per Figure 1 and Figure 2, it can be identified that the trial period optimized weights applied portfolio (denoted by the blue star) has a lesser return than the market-cap-weighted portfolio (denoted by the green star) with a similar level of risk exposure in the simulation period. Based on the results presented, investors can determine which portfolio provides better performance for allocating their investments. These observations implied that because of the COVID-19 Pandemic period, the Markowitz model did not perform well when trial period weights were applied to the simulation period in the context of India and the Philippines. According to the comparison measures calculated (Table IV and Table V), it ensured that the Derived MV portfolio has under-performed compared to the benchmark portfolio with less potential for higher returns. In brief, it is observable that the portfolio built during the pandemic has not performed well in the immediate next period for the two countries, India and the Philippines.

Figure 3 provides a comparison of the results of Singapore during the period when the whole world was influenced by the COVID-19 pandemic. The plot indicated that the Derived MV portfolio from the trial period weights has higher returns than the market-cap-weighted portfolio at a similar level of risk exposure. The results implied that the portfolio built during the pandemic performed well in the immediate next period as per the results recorded in Table VI. Since the Derived MV portfolio has outperformed despite of COVID-19 pandemic season, the existing and potential equity market investors may identify that the market of Singapore is more stable than India and the Philippines.

5. Conclusion and Implications

This paper investigated the performance and applicability of the optimal portfolio derived using the Markowitz mean-variance model under different market movements and different time regimes for India, the Philippines, and Singapore from 2007 to 2021. The performance of the trial period optimal portfolio weights was assessed based on its performance during the simulation period compared to the market-cap-weighted portfolio using performance measures such as the Sharpe ratio and information ratio.

Throughout this exploration, insights emerged from the analysis of five distinct market conditions: Global Financial Crisis, high volatility period, erratic movement, bullish condition, and COVID-19 pandemic period. During the Global Financial Crisis, the optimal portfolio derived from the Markowitz Model offered a desirable choice for investors in India and Singapore by outperforming the market-cap-weighted portfolio. India's large and diverse economy and Singapore's sophisticated financial system likely contributed to their market stability and the success of the Markowitz mean-variance model.

During the highly volatile period, the optimal portfolio weights derived from the Markowitz model can be used as a favourable alternative that outperformed the market cap-weighted portfolio in India and Singapore. However, in the Philippines, the Markowitz mean-variance model underperformed, possibly due to policy changes and economic unpredictability, which impacted the market's stability (National Economic and Development Authority, 2017), thus affecting the efficacy of the Markowitz model in a highly volatile period.

In an erratic period, the optimal portfolio derived from the Markowitz model of Singapore outperformed the market-cap-weighted portfolio while the situation was reversed for India. Singapore's stability in the economy and well-established government policies could have contributed to the relatively better performance of the Markowitz model. In contrast, India's experience of significant economic events, demonetization, and devaluation of the Chinese Yuan created uncertainty (Deva, 2021), making it challenging for the Markowitz model to accurately capture market dynamics.

In the Bullish market condition, the Philippines suggested that the optimal portfolio derived using the Markowitz model performed well and the weights were applicable for the future period whereas in India it was determined that the application of weights was not feasible for the future period. The PSEi Composite index reached its highest value during this period, reflecting investor optimism and positive market sentiment, which could be the reason for the better performance of the Markowitz model. However, India faced economic hurdles during this time (Pettinger, 2022), which affected the model's ability to predict optimal portfolio weights.

The optimal portfolio derived from the Markowitz model has not provided a favourable outcome for India and the Philippines during the COVID-19 pandemic period. Exceptional events like a pandemic challenge the assumptions of the model, which relies on market stability. On the other hand, the Markowitz model has outperformed against the benchmark in Singapore suggesting that Singapore experienced lesser contraction and made a swift recovery compared to the other two countries which were heavily impacted due to the pandemic.

As the results highlighted, positive Information Ratios in all four-time regimes of Singapore implied that despite the market condition, the derived Markowitz model has performed well suggesting that Singapore is a relatively stable market than India and the Philippines.

This study serves as a reminder that, while models offer useful frameworks, effective portfolio management necessitates a combination of quantitative analysis, knowledge of global dynamics, and the flexibility to adapt strategies in response to changing circumstances. By combining theoretical wisdom with real-world adaptability, investors can navigate the complexities of the investment landscape and aim for optimal risk-adjusted returns.

It is recommended for future studies to delve into alternative portfolio optimization methodologies. Models such as the Black-Litterman model, which incorporates investor views, as well as unsupervised machine learning approaches like Eigen portfolios, could offer novel insights into portfolio optimization, enriching the realm of investment strategies.

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