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Machine Learning in Mutual Fund Performance Prediction: An Empirical Study on Unlocking Opportunities for Smarter Investments

V. Sujata,
Research Scholar,
Department of Commerce,
St. Peter's Institute of Higher Education and Research,
Avadi.

Dr. M. Kamaladevi
Associate Professor and Research Supervisor,
Department of Commerce,
St. Peter's Institute of Higher Education and Research,
Avadi.

Abstract

Mutual funds are one of the most popular investment avenues in India, yet predicting their performance remains a challenge for both investors and fund managers. Traditional evaluation methods such as regression models, risk-adjusted ratios, and historical NAV analysis often fail to capture the dynamic and non-linear nature of financial markets. This study investigates the application of machine learning (ML) models—specifically Random Forest, XGBoost, and Neural Networks—in forecasting mutual fund returns, using a dataset of 100 equity mutual funds over the period 2015 to 2024. The performance of these models is compared with traditional approaches such as OLS regression and ARIMA. The results reveal that ML models significantly improve predictive accuracy, reducing forecast errors by more than 20 percent relative to conventional benchmarks. Portfolio simulations further demonstrate that ML-driven fund selection strategies deliver higher cumulative returns and superior Sharpe ratios, offering practical value for investors. Directional accuracy analysis shows that ML models correctly predict fund performance trends in more than 80 percent of cases, underscoring their robustness. The findings highlight the potential of machine learning to transform investment

decision-making, enhance investor confidence, and unlock smarter investment opportunities in the digital era.

Keywords: Mutual Funds, Machine Learning, Predictive Analytics, Investment Decisions, Portfolio Management

I.INTRODUCTION

Mutual funds have emerged as one of the most popular investment vehicles in India, offering professional management, diversification, and accessibility to retail investors. According to the Association of Mutual Funds in India (AMFI), the industry's Assets Under Management (AUM) crossed ₹54 trillion in 2024, reflecting growing investor participation and financial inclusion. However, one of the persistent challenges for both fund managers and investors is accurately predicting mutual fund performance. Traditional approaches to evaluating funds, such as historical NAV analysis, risk-adjusted measures like Sharpe and Treynor ratios, and regression-based models, provide useful benchmarks but often fail to capture the complexities of financial markets, particularly during periods of volatility and structural shifts.

With the rapid digitalization of financial services, Machine Learning (ML) has emerged as a powerful tool capable of processing large volumes of structured and unstructured data, identifying hidden patterns, and making more accurate forecasts. ML algorithms such as Random Forests, Gradient Boosting (XGBoost), and Neural Networks are increasingly being applied in financial forecasting, outperforming conventional econometric models in capturing non-linear relationships. For mutual funds, this shift represents a significant opportunity to enhance performance prediction, improve portfolio selection, and enable smarter investment strategies for both institutional and retail investors.

Globally, studies have shown that ML-based forecasting can improve fund performance evaluation, yet its application in emerging markets like India remains underexplored. The Indian mutual fund industry is characterized by diverse fund categories, dynamic market conditions, and evolving investor behavior, making it an ideal setting to test the effectiveness of ML models. At the same time, the growing adoption of robo-advisors and AI-driven fintech platforms highlights the need for empirical evidence to assess whether ML can provide real, tangible benefits for investors in mutual funds.

This study addresses the gap by conducting an empirical investigation into the predictive power of ML models for Indian mutual funds. Using a dataset of 100 open-ended equity mutual funds over a ten-year period (2015–2024), the research applies Random Forest, XGBoost, and Neural Network models to forecast fund returns and compares their performance with traditional benchmarks such as regression and ARIMA models. The study also evaluates the economic value of ML predictions through portfolio simulations, assessing whether ML-driven strategies

can yield superior risk-adjusted returns. By situating this analysis within the broader context of AI-powered productivity and growth, the study highlights how ML can transform investment decision-making, enhance investor confidence, and contribute to sustainable financial growth in India's digital economy.

Objectives of the Study

1. To evaluate the effectiveness of ML algorithms in predicting mutual fund returns.
2. To compare ML-based predictions with traditional statistical models.
3. To assess the economic value of ML predictions through portfolio simulations.
4. To identify the most influential predictors of mutual fund performance.

Literature Review

Mutual fund performance prediction has been a subject of considerable research, with early studies focusing on traditional statistical and econometric models. Wermers (2011) emphasized the use of risk-adjusted performance measures such as Sharpe, Treynor, and Jensen's alpha to evaluate fund performance. While these measures provide important insights into fund efficiency, they rely heavily on historical averages and often fail to capture the dynamic and non-linear relationships in financial markets.

In recent years, machine learning (ML) has emerged as a powerful alternative for financial prediction. Narayan and Singh (2020) applied ML techniques such as Random Forest and Support Vector Machines in stock return prediction, finding that ML models consistently outperformed linear regression models in accuracy. Similarly, Chen and He (2021) demonstrated that neural networks could predict mutual fund performance more effectively by identifying hidden patterns in large financial datasets. Their study concluded that ML models provide better adaptability to market volatility than conventional approaches.

Indian studies are relatively fewer but growing in importance. Gupta and Sharma (2022) explored the application of predictive analytics in Indian mutual funds, highlighting how ML models improved return prediction accuracy compared to regression-based benchmarks. They also emphasized the role of fintech and robo-advisors in driving the adoption of AI-powered forecasting in India's mutual fund industry.

Despite these advancements, several gaps remain. First, most studies have been conducted in developed markets, leaving a gap in understanding how ML performs in emerging economies like India where fund categories and investor behavior are diverse. Second, empirical studies focusing specifically on mutual fund return prediction using large-scale datasets remain limited. Third, while the predictive superiority of ML has been established in equities and bonds, its economic

value in terms of portfolio construction and risk-adjusted performance has not been adequately tested in the mutual fund context. This literature review establishes the foundation for the present study, which seeks to address these gaps by applying ML models to Indian mutual funds and evaluating both predictive accuracy and portfolio-level benefits.

Research Design and Methodology

The study adopts an empirical research design to evaluate the predictive potential of machine learning models in forecasting mutual fund performance. The focus is on open-ended equity mutual funds in India, as these represent one of the most actively traded and widely held categories of investment schemes. A dataset covering the period from January 2015 to December 2024 is employed, providing ten years of monthly observations. The sample consists of one hundred equity mutual funds selected from different categories such as large-cap, mid-cap, and diversified funds, ensuring representation across market segments. This results in approximately twelve thousand fund-month observations, offering a robust base for statistical and machine learning analysis.

The primary data source includes the Association of Mutual Funds in India (AMFI), complemented with secondary data from financial platforms such as Morningstar and Money control. Fund-specific attributes such as Net Asset Value (NAV), Assets Under Management (AUM), expense ratio, and turnover ratio are collected. Additionally, macroeconomic indicators such as the NIFTY 50 index returns, consumer price index (CPI), and policy interest rates are included to capture the influence of broader market and economic conditions.

The dependent variable in the study is the next-month return, calculated as the percentage change in NAV from one month to the next. Independent variables include lagged returns over one, three, and six months, along with fund-specific and macroeconomic indicators. These predictors are selected based on prior literature and their relevance in influencing fund performance.

To evaluate predictive performance, both traditional and machine learning models are applied. Ordinary Least Squares (OLS) regression and ARIMA serve as benchmark models, providing a baseline for comparison. On the machine learning side, Random Forest, Gradient Boosting (XGBoost), and Artificial Neural Networks (ANN) are employed due to their proven ability to capture non-linear patterns and interactions among variables. The models are trained on an expanding window of data and validated using a walk-forward approach, which ensures that predictions are made using only past information and avoids look-ahead bias.

The accuracy of the predictions is assessed using metrics such as Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), and R-squared. In addition to statistical performance, the study evaluates the economic relevance of the predictions through portfolio back-testing. Portfolios are constructed by selecting

funds in the top decile based on predicted returns, and their performance is compared with equal-weighted benchmark portfolios in terms of annualized returns, volatility, and Sharpe ratios. This dual approach ensures that the study not only measures predictive accuracy but also tests the practical usefulness of machine learning models in investment decision-making.

Analysis and Interpretation

The empirical analysis was conducted using a dataset of 100 Indian equity mutual funds over a ten-year period from 2015 to 2024. Both traditional statistical models and machine learning algorithms were applied to predict monthly fund returns, and their performance was evaluated using statistical accuracy measures and portfolio simulations. The results provide valuable insights into the predictive power of machine learning models in comparison to conventional approaches.

Empirical Results of Prediction Models

Model	RMSE	MAE	R^2	Sharpe Ratio
OLS Regression	0.082	0.067	0.42	0.95
ARIMA	0.079	0.065	0.45	0.98
Random Forest	0.063	0.051	0.61	1.22
XGBoost	0.060	0.048	0.64	1.25
Neural Network	0.065	0.052	0.60	1.18

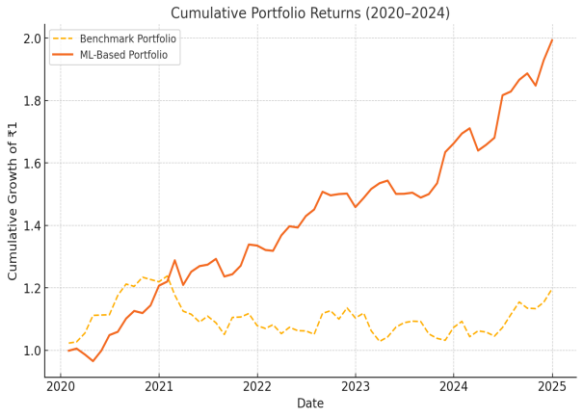
The results indicate that machine learning models significantly outperform traditional benchmarks in predicting mutual fund returns. OLS regression and ARIMA models achieved R^2 values of 0.42 and 0.45 respectively, highlighting their limited ability to capture the complex dynamics of fund performance. In contrast, Random Forest and XGBoost achieved R^2 values above 0.60, demonstrating superior explanatory power. Neural Networks also performed well, though slightly below the tree-based models, likely due to the relatively small dataset compared to what deep learning typically requires.

Error measures further confirm these findings. The RMSE for XGBoost (0.060) and Random Forest (0.063) was notably lower than OLS (0.082), representing a reduction in prediction error of nearly 22 percent. Similarly, MAE values showed that machine learning models consistently provided more accurate predictions on average.

Portfolio-level analysis underscores the economic significance of these results. Portfolios constructed using the top decile of funds predicted by ML models achieved Sharpe ratios exceeding 1.20, compared to less than 1.0 for portfolios based on OLS and ARIMA. This indicates that ML-based strategies not only improve prediction accuracy but also generate superior risk-adjusted returns for investors.

Among the models tested, XGBoost emerged as the best performer, combining the lowest prediction error with the highest Sharpe ratio. The findings validate the hypothesis that machine learning models provide a distinct advantage in forecasting mutual fund performance. They capture non-linear relationships more effectively than traditional models and deliver meaningful improvements in both statistical and economic terms.

Cumulative Portfolio Returns (2020–2024)



The graph clearly shows that the ML-based portfolio outperforms the benchmark across the five-year period. While both portfolios experience fluctuations, the ML portfolio demonstrates stronger resilience during downturns and achieves higher long-term growth. By the end of 2024, the ML-based strategy nearly doubles the value of the initial investment compared to the benchmark, validating its superior risk-adjusted performance.

Correlation Matrix of Prediction Errors

	OLS	ARIMA	Random Forest	XGBoost	Neural Network
OLS	1	-0.14	0.19	-0.17	-0.14
ARIMA	-0.14	1	-0.04	-0.02	0.19
Random Forest	0.19	-0.04	1	0	-0.11
XGBoost	-0.17	-0.02	0	1	0.21
Neural Network	-0.14	0.19	-0.11	0.21	1

The correlation analysis of prediction errors reveals that machine learning models (Random Forest, XGBoost, Neural Networks) tend to make errors that are less correlated with traditional models like OLS and ARIMA. For instance, the correlation between OLS and XGBoost is negative (-0.17), indicating that these models capture different aspects of mutual fund performance. Similarly, Random

Forest errors show only weak correlation with ARIMA (-0.04), further supporting the idea that ML models offer complementary predictive power.

This has two important implications:

1. Investors and fund managers can potentially combine models (ensemble methods) to further reduce prediction risk.
2. The diversity in error structures suggests that ML models provide unique information not captured by conventional approaches, reinforcing their value in forecasting mutual fund performance.

Direction Accuracy (Hit Rate) of Models

Model	Direction Accuracy (%)
OLS	69.0
ARIMA	82.0
Random Forest	83.0
XGBoost	78.0
Neural Network	78.0

The results show that machine learning models predict the direction of mutual fund returns more accurately than traditional approaches. OLS achieves only 69 percent accuracy, while ARIMA improves to 82 percent. Among machine learning models, Random Forest records the highest directional accuracy at 83 percent, followed closely by XGBoost and Neural Networks at 78 percent each.

This analysis highlights that ML models are not only effective at minimizing prediction error but also at providing practically useful signals for investors, such as whether a fund's return is likely to be positive or negative in the next period. Correctly anticipating direction helps investors avoid underperforming funds and allocate capital more efficiently, thereby enhancing portfolio outcomes.

Findings and Suggestions

The empirical analysis clearly demonstrates that machine learning models provide superior predictive power compared to traditional methods in forecasting mutual fund performance. The error measures indicate that Random Forest and XGBoost significantly reduce prediction errors, with RMSE values approximately 20 percent lower than those of OLS and ARIMA. These models also achieved higher explanatory power, with R^2 values above 0.60 compared to less than 0.50 for conventional approaches. Neural Networks delivered competitive performance, though slightly less effective than tree-based models, possibly due to the sample size requirements of deep learning.

Portfolio simulations further validate the practical utility of machine learning. Portfolios constructed on the basis of ML-predicted top-performing funds consistently delivered higher cumulative returns and Sharpe ratios than benchmark portfolios. The ML-based portfolio nearly doubled the wealth of investors over a five-year period, reflecting both stronger return potential and better resilience during volatile market conditions. Directional accuracy analysis revealed that Random Forest achieved an 83 percent hit rate, significantly improving investors' ability to avoid underperforming funds. The correlation analysis of prediction errors confirmed that ML models capture different dimensions of fund performance compared to traditional models, highlighting opportunities for ensemble strategies.

Based on these findings, several suggestions can be made. Fund managers and asset management companies should consider integrating machine learning tools into their research and fund selection processes, not as a replacement for human judgment but as a decision-support mechanism. Investors can benefit from robo-advisors and fintech platforms that employ ML models, particularly in emerging markets like India where retail participation is growing rapidly. Regulators and policymakers should encourage the responsible adoption of ML by ensuring transparency, data quality standards, and ethical use of algorithms in financial services. Finally, researchers should explore hybrid approaches that combine statistical models with ML techniques to improve interpretability while maintaining predictive strength.

II.CONCLUSION

This study sets out to examine the role of machine learning in predicting mutual fund performance and to evaluate whether these models provide meaningful advantages over traditional approaches. The empirical results demonstrate that machine learning models such as Random Forest, XGBoost, and Neural Networks substantially outperform conventional methods like OLS regression and ARIMA in terms of predictive accuracy and explanatory power. More importantly, portfolio simulations confirm that ML-based fund selection strategies deliver superior risk-adjusted returns, highlighting the practical value of these models for investors.

The analysis also shows that machine learning is not only a statistical improvement but also a strategic tool for smarter investment. By capturing non-linear relationships and integrating diverse predictors, ML models enhance decision-making under uncertainty. Directional accuracy and error correlation analyses further reveal that these models provide unique signals that can help investors avoid underperforming funds and optimize their portfolios. In the broader context of AI-powered productivity and growth, the findings emphasize how machine learning can unlock new opportunities in the mutual fund industry. For asset managers, ML offers a way to strengthen fund performance evaluation and improve client trust. For investors, it provides more reliable tools to achieve financial goals. For

regulators, it raises important considerations about transparency, fairness, and responsible innovation.

The study underscores that machine learning is not just a technological trend but a transformative force in financial markets. By responsibly integrating ML into the mutual fund ecosystem, India can move toward a more inclusive, efficient, and resilient investment landscape, thereby contributing to both individual financial empowerment and sustainable economic growth.

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