PORTFOLIO OPTIMIZATION IN THE LIGHT OF SUSTAINABILITY CONSTRAINT: EVIDENCE FROM INDIAN CAPITAL MARKET

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ABSTRACT

For the past few years, it is seen that most of the companies are facing the pressure to provide the information regarding their performance based on environmental, social and governance (ESG) issues. Although there are very limited studies which has focused on the optimal ways to construct sustainability-based portfolios. This papertries to reduce this gap by incorporating the ESG constraint in portfolio optimization. The objective of the study is to construct an optimum portfolio by using the basic Markowitz mean-variance optimization model and the modified mean variance model with sustainability constraint in order to make a comparative evaluation of basic Markowitz model and proposed mean variance optimization model with ESG constraint in Indian Capital Market. The study shows that the modified mean variance model with sustainability constraint is very much effective in the Indian capital market rather than the basic Markowitz optimization model.

Keywords: *Portfolio optimization, Markowitz model, Sustainability-based portfolios, NLP.*

INTRODUCTION

Determining the optimum allocation of securities is the main theme of portfolio optimizationand this set of assets with the respective weights must able to satisfy the investors preferences in relation to the risk return combination.The quantification of return and investment risks through the variance and expected return of individual securities works as the basic framework of Markowitz (1952) model (Zhang et al., 2018). Maximization of portfolio return and minimization of portfolio risks are the basic pillars of Portfolio theory and to meet this purpose various assets allocations issues and related various studies regarding diversification measures have been adopted by Lintner (1965), Latane and Tuttle (1966), Hennessy and Lapan (2003), Ivkovicet al. (2008) and Cesaroneet al. (2020).

It is observed that over past twenty years the companies are not only responsible for financial disclosure but also, they are accountable for environmental and social sustainability issues (see Branke et al. 2009; Bruni et al. 2016; De Long et al. 1990). From the recent literatures on portfolio optimization, very few studies have been made regarding ESG based portfolio (see Oikonomou et al. 2018, Gangi andVarrone 2018). Although most of the extensions and developments regarding portfolio optimization are based on Basic Markowitz model but most of the studies used the technical constraints rather than the fundamental and sustainability constraints (see Konno and Yamazaki (1991), Konno and Suzuki (1995), Rockafellar et al., 2000, Mansini et al., 2007,Benati, 2015, Sharma &Banerjee, 2015, Mishra et al., 2016, Bensaida et al.,2018, and Cesarone et al., (2020). Very few empirical evidences regarding accommodation of multiple constraints, and modelling phase by phase optimization by considering sustainability issues are not found in Indian Capital Market.

The goal of this paper is to find out the optimum portfolio by following the basic Markowitz mean-variance model and the modified Markowitz model with ESG constraint in order to compare and evaluate the two optimization models in context of Indian Capital Market.

LITERATURE REVIEW

Rational behaviour of investors is better reflected from the traditional theory of portfolio optimization (Markowitz 1952, 1991) which often tells the story of maximizing return at a given level of risk or minimizing the variance at a given level of return while the safety theory given by Roy (1952) and the two-fund separation theorem by Tobin (1958) provides immense help to assets allocation problem. To remove the complexities in calculation much more balanced approach is given by Sharpe (1964) and Lintner (1965). However, regarding the forecasting ability of portfolio manager and the higher order moments incorporation to the portfolio construction process by Jensen (1968) and Samuelson (1970) added the boost to the mean variance approach of optimization. The broader insight of empirical mean-variance optimization is better reflected from the studies ofKazemi (1988), Lee and Chang (1995), Ballestero (1998), Fletcher and Hillier (2001), Steinbach (2001), Zhou and Yin (2003), Leibowitz and Bova (2005) and Post and Levy (2005) and more robust structure is given to mean variance optimization by Calafiore (2007) and Lucas and Siegmann (2008). In India most of the researches has been conducted on CAPM models and portfolio management while very limited empirical investigation has been conducted on portfolio optimization. This scenario is evident from Gupta and Sehgal (1993), Gupta (1997), Bansal and Gupta (2000), Manjunatha et al. (2006), Mehta and Chander (2010), Taneja (2010), Vij and Tamimi (2010) and Raj and Murugan (2011).Limited studies have empirically investigated the optimum portfolio construction by considering socially responsible portfolios but there are some major literatures found in this context of portfolio optimization by considering sustainability issues like Ballestero et al. (2012), Dorfleitner and Utz (2012), Utz et al. (2015), Alvarez et al. (2017), Oikonomou et al. (2018), Perez Odeh et al. (2018)and Qi (2018). There are some studies which reflects that the portfolio optimization considering high ESG or low ESG does not improve portfolio performance like Schroder (2007), Renneboog et al. (2008), Statman and Glushkov (2009) and Halbritter and Dorfleitner (2015) while some studies just reflects the opposite scenario, i.e., portfolio optimization considering ESG factors improves the portfolio performance like Bauer et al. (2005), Kempf and Osthoff(2007), Gil-bazo et al. (2010), Edmans (2011) and Henke (2016). From all the above studies one major research gap arises and thereby the research question is: To what extent does the sustainability based constrained Markowitz optimization approach helps to enhance the investment results in relation to Indian Capital Market and this paper makes an attempt to answer this question.

OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

1. To find out the optimum portfolio by following basic Markowitz model.
2. To find out the optimum portfolio by following modified Markowitz model with ESG constraint.
3. To compare and evaluate the discussed two optimization models in the light of Indian Capital market.

DATA BASE & METHODOLOGY

The concerned study of portfolio optimization has considered the stock return of the 30 listed companies in Nifty 50 (on monthly basis depending on higher market capitalization) and the yearly ESG score. The stock price data have been collected from Capitaline database while the ESG score has been taken from CRISIL data base. The span of the study is taken from 1st April 2008 to 31st March 2022.

Assuming no short sales and no riskless lending and borrowing the following Non-Linear Programming (NLP) model is used in order to find out the optimum portfolio weights in the Markowitz Model

Minimize $\Sigma^{n}_{i=1} \Sigma^{n}_{j=1} W_i W_j Cov_{ij}$

Subject to

$$\sum_{i=1}^{n} W_i R_i \geq \rho$$

$$\sum_{i=1}^{n} W_i \geq 1$$

$$0 \leq w_i \leq 1; i=1 \text{ to } n$$

To fulfil the sustainability requirement of the investors, the ESG constraint along with the upper bound constraint is incorporated with in the basic Markowitz model. Here the upper bound constraint implies the maximum limit on the amount invested in the portfolio, Accordingly, the modified Markowitz model with ESG constraint is presented as follows:

Minimize $\Sigma^{n}_{i=1} \Sigma^{n}_{j=1} W_i W_j Cov_{ij}$

Subject to

$$\sum_{i=1}^{n} W_i R_i \geq \rho$$

$$\sum_{i=1}^{n} W_i \geq 1$$

$$0 \leq w_i \leq 1; i=1 \text{ to } n$$

$W_i \leq U_i$, (Upper Bound Constraint)

$ESG_i \geq Q_{esg3}$ (Sustainability Constraint)

where W_i = Weight of i^{th} security in the portfolio

W_j = Weight of j^{th} security in the portfolio

Cov_{ij} = the covariance between the rates of return for securities i and j

R_i= Rate of return on i[th] security
ρ= Required rate of return on the portfolio which is assumed to be the upper quartile level (Q3) of the distribution of return
U_i=15%
Q_{esg3}=Upper quartile of ESG score distribution
ESG_i = ESG score.

EMPIRICAL ANALYSIS AND INTERPRETATION

Analysis from basic Markowitz optimization model

To derive the annual mean return, the individual mean return is calculated first on monthly basis. Similarly, the variance and standard deviation of the thirty securities are calculated on the basis of highest market capitalization. By using lingo software command, the variance of the basic Markowitz model has been minimized. By solving the quadratic equation, it has been found that all the constraints goal has been achieved without any surpluses and the variance of the portfolio is minimized at 0.0584. Negative duality for funds exhaustion constraint amounts to -0.093 which implies unit increase in the risk of portfolio for one unit increase in constraint. A slack value of 5.357 per cent is observed in return constraintwhich interprets that if this slack value is subtracted from the targeted value of return value (31.739 per cent),then the all-total estimated portfolio return will be 26.38 per cent. The results are shown in Table 1.

TABLE 1: Results of Basic Markowitz Portfolio Optimization Model.

Infeasibilities: 0.000000 Model Class: NLP Total solver iterations: 73			
Variables	Targets	Slack or Surplus	Dual Price
Variance	Minimise	0.05843	-1.000000
Budget	1	0.000000	-0.093085
Returns	0.31739	-0.053574	0.000000

The optimal weightsof basic Markowitz model have been allocated among 14 companies belonging to five industriesnamely consumer goods, automobile, pharmaceuticals, energy & IT and the optimum portfolio is formulated which are displayed in Table 2. Here the average weight of securities within the portfolio is 7.14 per cent while the average weight of industries within the portfolio is 20 per cent. Maximum proportion of weight has been given to Bosch Ltd (17.25 per cent) while the second highest weight of 14.86 per cent is scored by Asian Paints. Substantial amount of funds is also invested in Hero Moto Corp Ltd and Infosys Ltd whereas the lowest proportion of weights are allocated to Hindustan Unilever Ltd, ITC Ltd and Indian Oil Corporation Ltd. The portfolio variance (σp2) in this basic Markowitz model is 5.84 per cent and the return of the portfolio E(Rp) is 26.38 per cent, while the variance of the benchmark portfolio nifty fifty is 8.43 (per cent)2 and the benchmark return is 18.67 per cent.

TABLE 2: Optimal Weights and Expected return of Basic Markowitz Optimization Portfolio.

Company Name	Weights	Expected Return
Asian Paints Ltd	14.86%	41.47%
Bosch Ltd.	17.25%	30.15%
Bharat Petroleum Corporation Ltd.	4.63%	21.27%
Cipla Ltd.	5.82%	21.33%
Dr. Reddy's Laboratories Ltd.	4.93%	28.05%
GAIL (India) Ltd.	5.33%	10.93%
Hero MotoCorp Ltd.	8.51%	22.73%
Hindustan Unilever Ltd.	4.71%	24.16%
Infosys Ltd.	9.03%	19.83%
Indian Oil Corporation Ltd	3.13%	7.89%
I T C Ltd.	4.19%	27.94%
Lupin Ltd.	5.77%	43.67%
NTPC Ltd.	7.83%	5.43%
Sun Pharmaceutical Industries Ltd.	4.01%	39.93%

ANALYSIS FROM MODIFIED MEAN VARIANCE MODEL WITH ESG CONSTRAINT

By considering the ESG constraint, upper bound and the return constraint, the variance is minimized and by solving the quadratic programming, it is found from Table 3 that the return derived from the portfolio of 11 securities amounts to 31.739 per cent and 4.47 per cent is the risk of portfolio, while the risk of the benchmark portfolio nifty fifty is 8.43 per cent and the benchmark return is 18.67 per cent. No surplus ESG output is observed and no surplus return exists. The sustainability output from the portfolio amounts to 68.

TABLE 3: Results of Modified mean variance model with ESG constraint.

Infeasibilities: 0.000000 Model Class: NLP Total solver iterations: 51			
Variables	Targets	Slack or Surplus	Dual Price
Variance	Minimise	0.0447061	-1.000000
Budget	1	0.000000	-0.0010531
Returns	0.31739	0.000000	-0.0013095
Portfolio ESG	68	0.000000	-0.000031

Modified mean-variance model with ESG constraint portfolio encompasseseleven companies belonging to five industrial sectors, namely automobile, banking, consumer goods, pharmaceuticals, and IT.

It is clearly evident from Table 4 that the highest weight of fifteen per cent is given to Infosys Ltd and Asian Paints Ltd. Major amount has been invested inHindustan Unilever Ltd (14.25%), HDFC Bank Ltd (13.72%) and Dr. Reddy's Laboratories Ltd (11.38%).Besides, substantial proportion of weights has been allocated to Cipla Ltd, Lupin Ltd and Tata Consultancy Services Ltd. The lowest weights have been allocated to Eicher Motors Ltd (3.35%) followed by Hero MotoCorp Ltd (3.75 %). Here the average weight of securities within the portfolio is 9.09 per cent.

TABLE 4: Optimal weights and expected return of Mean Variance Model with ESG Constraint portfolio.

Company Name	Weights	Expected Return
Asian Paints Ltd.	15.00%	41.47%
Bosch Ltd.	4.67%	30.15%
Cipla Ltd.	7.05%	21.33%
Dr. Reddy's Laboratories Ltd.	11.38%	28.05%
Eicher Motors Ltd.	3.35%	56.94%
HDFC Bank Ltd.	13.72%	39.98%
Hero MotoCorp Ltd.	3.75%	22.73%
Hindustan Unilever Ltd.	14.25%	24.16%
Infosys Ltd.	15.00%	19.83%
Lupin Ltd.	6.45%	43.67%
Tata Consultancy Services Ltd.	5.39%	35.99%

Comparing to the previous Basic Markowitz model, it is found that the energy sector from the optimum portfolio composition has been replaced by the banking sector in this modified mean variance model with ESG constraint. At the same time, only 11 securities in this proposed modified model earning a portfolio return of 31.739 per cent which is comparatively high in comparison to return from basic Markowitz portfolio of 14 securities which is 26.78 per cent. If the risk level is analysed, it is interpreted that the level of risk in modified mean-variance model with ESG constraint (4.47 per cent) is quite lower than the basic Markowitz optimization model (5.84 per cent) and this is pretty glaring from Table 5.

TABLE 5: Mean Difference Analysis between Basic Markowitz Optimization Model and Modified Mean Variance model with ESG Constraint.

Mean Difference test between Basic Markowitz Optimization Model and Modified Mean Variance model with ESG constraint	$t = \| 2.533 \|^{**}$

Note: ** implies significant at 5% level

FINDINGS OF THE STUDY

Sustainability based constrained Markowitz optimization approach helps to enhance the investment results in comparison to the Basic Markowitz model. The solver results are found to be more accurate in the modified Mean Variance model with ESG constraint since the iterations are much lower in comparison to basic Markowitz model. The optimum portfolio is formulated by using these two models and the findings are summarized below:

1. Security composition number is much lesser in the sustainability-based model in comparison to basic mean-variance model.
2. The portfolio return from the modified Markowitz model with ESG constraint is higher than the returnfrom basic Markowitz model.
3. The risk level of the modified model is also lower in comparison to basic Markowitz model.
4. The sustainability based modified model is statically much more significant in Indian Capital market rather than basic mean-variance model.

SUMMARY AND CONCLUSION

This paper finally answers the research question that in Indian Capital market, the stocks with high ESG score are enable to improve the portfolio performance and for this reason the modified Markowitz model with sustainability constraint is giving better results than the basic mean variance model in terms of portfolio return and portfolio variance. Throughout the study it is seen that both the models outperform the benchmark return and variance of Nifty Fifty, so it can easily be said that the sustainability approach towards the modified Markowitz optimization model does not disregard the basic mean variance model, rather the proposed model complements the embedded basic literature within it. So, it may be concluded that the modified mean variance model with sustainability constraint is very much effective in the Indian capital market rather than the basic mean-variance optimization model.

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