Risk Budgeted Portfolio Optimization Using an Extended Ant Colony Optimization Metaheuristic

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ABSTRACT

Risk Budgeted portfolio optimization problem centering on the twin objectives of maximizing expected portfolio return and minimizing portfolio risk and incorporating the risk budgeting investment strategy, turns complex for direct solving by classical methods triggering the need to look for metaheuristic solutions. This work explores the application of an extended Ant Colony Optimization algorithm that borrows concepts from evolution theory, for the solution of the problem and proceeds to compare the experimental results with those obtained by two other Metaheuristic optimization methods belonging to two different genres viz., Evolution Strategy with Hall of Fame and Differential Evolution, obtained in an earlier investigation. The experimental studies have been undertaken over Bombay Stock Exchange data set (BSE200: July 2001-July 2006) and Tokyo Stock Exchange data set (Nikkei225: July 2001-July 2006). Data Envelopment Analysis has also been undertaken to compare the performance of the technical efficiencies of the optimal risk budgeted portfolios obtained by the three approaches.

Keywords: Ant Colony Optimization, Data Envelopment Analysis, Differential Evolution, Evolution Strategy, Portfolio Optimization, Risk Budgeting

1. INTRODUCTION

A portfolio is an assortment of tradable assets such as bonds, stocks etc. The problem of portfolio optimization deals with the bi-criterion objective function of maximizing portfolio return and minimizing portfolio risk. According to Modern Portfolio Theory (Markowitz, 1952) the mean returns of the assets define expected portfolio return and the covariance of returns of the assets define portfolio risk. The proportion of capital invested in each of the assets in the portfolio are termed weights. Put simply, the problem of portfolio optimization targets obtaining that set of optimal weights satisfying the twin objectives of maximum portfolio return and minimum portfolio risk. The optimal weights together with the mean and covariance

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of returns serve to yield the expected portfolio return and risk of the portfolio. An efficient frontier is a graph of the risk-return couples of the portfolio for various choices of the risk aversion measure made by the investor. Thus an efficient frontier is a risk-return trade off curve which can help determine the least risk portfolios for an expected level of return and vice-versa. A portfolio optimization problem is considered solved when the efficient frontier can be graphed for the problem model.

The Markowitz model (Markowitz, 1952) was naïve in that it did not take into account market frictions and disallowed short sales, transaction costs, taxes etc. But in reality, the portfolio optimization problem model can turn complex when constraints reflecting investor preferences, market norms and investment strategies etc., are included in it. Besides, the inclusion of such constraints in many cases have rendered the problem model difficult for solving using traditional methods such as Quadratic Programming thus paving way for the exploration of Metaheuristic approaches such as Genetic Algorithms, Evolution Strategies, Differential Evolution, Simulated Annealing and Swarm Intelligence, besides Neural Networks (Chang et al., 2000; Kendall & Su, 2005; Maringer, 2005; Pai & Michel, 2009, 2010, 2011b, 2012; Streichert et al., 2003; Thomaidis et al., 2008) for the solution of complex problems in portfolio optimization.

In this work, the solution of the portfolio optimization problem model when the portfolios are risk budgeted besides being governed by other constraints reflective of investor preferences is discussed. Polak et al. (2010) measured risk as the worst case return and a portfolio from maximizing returns subject to a risk threshold was constructed using minimax linear programming approaches. Golmohammadi and Pajoutan (2011) discussed a new heuristic portfolio selection model which considers cost relation and stochastic revenue for projects and included risk as a threshold. However, these models took a different view of risk budgeting. Risk budgeting is a popular investment strategy where a ceiling is imposed on the risk limits of the assets or asset classes that comprise the portfolio. Typically it is common for investment managers to impose such a limit on high risk assets or as the case may be, on all assets in the portfolio. Though risk budgeting in its practical form could be implemented using simplified thumb rules, the strategy in its idealistic form could turn the portfolio optimization model difficult for direct solving using traditional methods such as Quadratic programming. Hence the need for Metaheuristic optimization approaches, where large search spaces of candidate solutions are searched, yielding acceptable, if not optimal solutions.

Pai and Michel (2010, 2011a) investigated risk budgeted portfolios using Metaheuristic approaches. One branch of their investigation concerned penalty function based metaheuristic optimization of portfolios on which risk budget was imposed on the combined risk of the high risk assets. The other branch dealt with a metaheuristic optimization of portfolios on which risk budget was imposed on the individual high risk assets only. In the absence of reported work, for both the problem models investigated, two strategies from different genres viz., an Evolution Strategy with Hall of Fame (ES HOF) and Differential Evolution (rand/1/bin) were employed as the core search strategies to effect a comparison and validation of results.

Ant Colony Optimization (ACO) is a swarm intelligence technique that was originally developed to solve discrete optimization problems and later improved to tackle continuous optimization problems (Wodrich & Bilchev, 1997). Socha and Dorigo (2008) proposed an extended ACO model termed $ACO_r$ which adopted ideas similar to the Population based ACO (PB-ACO) proposed by Guntsch and Middendorf (2002) and discussed how ACO for combinatorial optimization problems is similar to Evolutionary Algorithms (EAs) in many respects. However, with regard to portfolio optimization problems, which are continuous constrained optimization problems, Zhu et al. (2010) asserted that normal ACO cannot
Supply Chain Design Including Quality Considerations: Modeling and Solution Approaches based on Metaheuristics
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