

Swarm optimization algorithms for sustainable investing

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This is a summary of the author's PhD thesis supervised by Massimiliano Kaucic, co-supervised by Paola Rossi and defended on March 21, 2025, at the University of Trieste. The thesis is written in english and is available from the author upon request at filippo.piccotto@deams.units.it and from <https://hdl.handle.net/11368/3107018>.

In this thesis, I explore various aspects of the topic of portfolio management by analyzing several asset allocation problems with the presence of real-world constraints. The primary literature contribution of this work is twofold. On the one hand, the aim is to propose novel swarm-based procedures for addressing non-convex constrained portfolio optimisation problems. Despite their notable computing power and convergence speed, these solvers are often blind to the constraints imposed on the optimization problem. Thus, they need to be equipped with some constraint-handling techniques. In addition, realistic considerations in optimal portfolio selection models impose that certain constraints must be exactly satisfied, and constraint-handling approaches that accept tolerance violations are not always suitable. In this context, the present work proposes an innovative hybrid approach that exploits both repair schemes and penalty function methods. On the other hand, this thesis offers investors and practitioners a plethora of illustrations of equity portfolio management applications, particularly in the European stock market. Furthermore, it also considers some portfolio selection models that incorporate sustainability issues, thus addressing the recent market demand for new types of investment products.

In the first part of the thesis, after a concise illustration of the basics of the particle swarm optimizer (shortly, PSO), I introduce three single-objective portfolio selection models where the objective function to maximize extends the classical Sharpe ratio performance measure. These extensions aim to: i) overcome the issue that the Sharpe ratio is not coherent with rational investors' preferences in the periods of market downturns, and ii) include in the objective function the information obtained from the third- and fourth-order moments of the distribution of financial returns. In consideration of the great interest of institutions, managers, and investors in these models, I introduce some real-world limitations to increase the practical applicability of the proposed portfolio problems, which are box, budget, cardinality, and turnover constraints. To solve the resulting non-smooth and non-convex problems, a version of the level-based learning swarm optimizer (shortly LLSO, a recently proposed extension of the PSO algorithm) equipped with an ad-hoc ensemble of constraint handling procedures, is proposed. The general idea of the LLSO is to sort the swarm individuals in ascending order of fitness and separate them into different levels, which are treated differently.

Then, unlike PSO, instead of using the historically best positions to update particles, LLSO utilizes two predominant particles in the current swarm to guide the learning of each particle and enhance the swarm diversity. Subsequently, I conduct experimental analyses using real-world data sets from European and World equity market indexes. Firstly, I analyze the capability of the proposed algorithm to find optimal feasible solutions, assessing its superiority in comparison to some state-of-the-art competitors. On the other hand, I carry out an in-depth profitability analysis of the proposed investment strategies, considering several ex-post performance metrics.

In the second part, the emphasis shifts towards incorporating ESG (environmental, social, and governance) information within specific instances of traditional asset allocation models. Firstly, to extend the classical mean-risk framework, I consider a tri-objective optimization model that maximizes portfolio expected return and ESG score whilst minimising a risk measure (i.e., variance or conditional value-at-risk). In the empirical section, employing data from the constituents of the STOXX Europe 600 Index, the ε -constraint method is used to find optimal solutions for the previously described portfolio model. This method allows us to compute a dotted representation of the efficient frontiers on the three-dimensional surface. Moreover, I illustrate the results of an ex-post analysis, in which I choose some superior portfolios from the efficient frontiers using a multi-criteria decision-making approach. Finally, I expand my interest in the topic of behavioral finance, with a particular focus on integrating the concept of sustainable investing within the behavioral finance paradigm. More precisely, I consider a portfolio selection model based on the Kahneman and Tversky's cumulative prospect theory and I introduce a bi-objective optimization problem that considers two *s*-shaped utility functions as objectives. The primary innovation of this model is that, in contrast to the utilisation of a deterministic score for considering ESG information, it incorporates the concept of sustainability gross returns as the counterpart of financial returns on the sustainability side. The concluding computational analyses demonstrate that incorporating ESG information modifies the ex-post performance of the prospect theory-based portfolio strategies, with a particular emphasis on the potential enhancement of risk control during periods of heightened market volatility.

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