Decision Support Systems 51 (2011) 549–561

Contents lists available at ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

A decision support system for strategic asset allocation ☆

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ARTICLE INFO

Article history:
Received 18 February 2010
Received in revised form 13 December 2010
Accepted 27 February 2011
Available online 11 March 2011

Keyword:
Strategic asset allocation
Risk management
Stochastic programming

ABSTRACT

Strategic asset allocation is a crucial activity for any institutional or individual investor. Given a set of asset classes, the problem concerns the definition and management over time of the best asset mix to achieve favorable returns subject to various uncertainties, policy and legal constraints, and other requirements. Although a considerable attention has been placed by the scientific community to address this problem by proposing sophisticated optimization models, limited effort has been devoted to the design of integrated framework that can be systematically used by financial operators. The paper presents a decision support system which integrates simulation techniques for forecasting future uncertain market conditions and sophisticated optimization models based on the stochastic programming paradigm. The system has been designed to be accessed via web and takes advantages of the increased computational power offered by high performance computing platforms. Real-world instances have been used to assess the performance of the decision support system also in comparison with more traditional portfolio optimization strategies.

1. Introduction

Optimization-based decision support systems (DSS) provide a powerful tool in many industrial and operative contexts. By the formulation of optimization models it is possible to mathematically represent complex decision making problems and control, by the corresponding solutions, critical issues such as cost, risk, performance indexes and so forth. When encapsulated in decision support systems, the advantage related to the adoption of quantitative methodologies is further enhanced by the recent advances in computer science and information technology. The impact deriving from the adoption of DSS becomes even more evident in all those operative contexts characterized by a high level of complexity due, for example, to the presence of uncertainty, to the need to analyze huge amount of data and to operate in a short time. All these features are dominant in the field of financial management where the adoption of efficient and effective DSS can assist the complex decision making process by improving the quality and the effectiveness of provided solutions. Nevertheless, recent global crisis and spectacular breakdowns have further emphasized the need to complement expertise and experience with the suggestions provided by advanced systems based on the integration of decision models and algorithms.

The paper contributes in this direction by proposing a system designed to support financial operators in portfolio management activities. Different applications, from personal financial planning, to pension fund management, to strategic and tactical asset allocation can be casted as Asset–Liability Management problems (ALM) (see the contributions in [12,14,33,38]). In this paper, the attention is focused on the strategic asset allocation problem (SAA, for short). Given a time horizon, the problem refers to the allocation and management of a portfolio of asset classes with the aim of maximizing the portfolio return while controlling the risk exposure.

SAA is a crucial problem that every investor (at individual or institutional level) has to deal with. Its practical relevance is the motivation behind the considerable attention devoted to this topic by the scientific community. Starting from the Markowitz's seminal contribution [27] based on a static buy and hold portfolio strategy, other modeling frameworks [6,9,26,28,29,32] have been proposed and deeply investigated in the last decades. A special attention deserves the stochastic programming framework (SP, for short) [8,22] because of its high modeling power stemming from the integration of dynamic and uncertain aspects also accounting for the possibility to accommodate specific requirements (policy restrictions, trading constraints, and so forth). On the other hand, the complexity of the SP methodology has limited its wide diffusion in the non-academic environment.

The considerations reported above represent the main motivation of the present contribution aimed at proposing a user-friendly DSS relying on the integration of SP as decision engine with simulation techniques for the generation of future uncertain market conditions and solution algorithms powered by the adoption of advanced computing platforms.

Other DSS designed for financial management problems have been proposed in the last decade. A system which integrates multi-dimension databases, on-line analytical processing (OLAP) tools, procedural and

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doi:10.1016/j.dss.2011.02.017

declarative modeling languages has been proposed in [15]. In [30] the authors have proposed DSSALM, a tool to simulate interest rate risk and forecast the amounts of future assets and liabilities. Another contribution is [16], where the authors propose a web-based DSS which integrates portfolio management models with OLAP tools to handle multidimensional data structures and PVM network environment as high-performance computational framework.

The proposed DSS differs from other systems for the following features:

- the system core relies on innovative methodologies for the SAA problem and takes advantage of the computational power offered by high-performance computing environment. This last feature is particularly important for applications which are "space"-sensitive: a huge amount of data should be stored, managed and analyzed in order to get robust recommendations. In addition "time" can play a key role in terms of competitive advantage;
- the DSS provides a tool for risk management and allows benchmark analysis with other portfolio strategies;
- the system can be easily extended to other problems and functionalities, thanks to its modular structure;
- customers can access the system by a user-friendly interface and can easily modify parameters and settings;
- no investment or maintenance cost for final users is required because of the web technology used.

The rest of the paper is organized as follows. Section 2 describes the SAA problem and provides a high level snapshot of the methodological framework. Section 3 presents the system architecture, by illustrating the main technical choices and the functional modules which implement the proposed methodological steps. Section 5 presents a system demo from an end-user perspective. Computational experiments are reported in Section 6: extensive numerical tests have been carried out in order to assess the performance of the proposed system also in comparison with other approaches. Some concluding remarks end the paper.

2. The SAA problem and proposed approach

The SAA problem concerns the definition of a medium–long term allocation among a given set of "asset classes", i.e. macro-sets of financial instruments identified by a common reference index. The goal is to achieve the maximum portfolio return within a user-defined risk level and according to specific requirements. This is a classical planning problem that financial management typically faces at "strategic" level, since decisions concern classes of assets rather than single instruments whose choice is, on the contrary, performed at a tactical level, eventually according to some specific policies of the financial institute. The problem at hand belongs to the more general class of ALM problems and presents several critical features difficult to deal with, even separately. The problem is dynamic since decisions (portfolio allocation) are taken all over the planning period and are strictly connected to market evolution. It is intrinsically stochastic since optimization should be carried out without the knowledge of the uncertain future evolution of market conditions. In addition, the problem is highly constrained, since a large number of regulatory, strategic and risk aversion constraints should be considered in order to mathematically represent end-user concerns. The SP framework allows to jointly accommodate all these features, providing more robust recommendations with respect to other modeling approaches [36]. This motivates the large stream of literature on SP for ALM problems [10,11,13,17,19,25,31,37]. Differently from other frameworks, within multistage SP the portfolio allocation problem is formulated so to consider the possibility to revise initial decisions concerning the portfolio composition. As time progresses and new information about market conditions become available, asset allocation can be revised by means of buying/selling decisions, also taking into account the possibility to have additional cash inflows. The complete mathematical model of the SAA problem formulated according to the multistage paradigm is introduced in Appendix B.

SP relies on the explicit accounting of the uncertainty surrounding the market conditions by the introduction of random variables defined on a given probability space. In the case of discrete distributions, a scenario tree is used to represent the dynamic uncertain evolution of the random parameters. Fig. 1 shows a scenario tree for a planning horizon of length 3.

The root node (denoted by 0) represents the initial state. A scenario is a path from the root to a leaf node. Each intermediate node at a given level contains a realization of the uncertain parameters (assets values, risk-free rate, etc.) at that corresponding time stage. Probability is associated with each node so to satisfy the fundamental axioms of the probability theory.

The scenario tree provides the input parameters for multistage models. Here decisions are associated with each node. In the case of the SAA problem, first stage decisions (associated with the root) concern the selection of the initial portfolio composition. At successive stages, according to the specific scenario, portfolio is rebalanced in such a way to achieve maximum performance satisfying risk constraints and other requirements. Additional constraints, known as non anticipativity restrictions assure consistency of the decisions with the tree structure [8].

Our DSS has been designed according to the adopted methodological framework. Fig. 2 shows the main steps and their interactions. The decision approach is based on the availability of historical data related to asset class indexes, interest rates, macroeconomic variables and so forth. These data are stored in a consistent database and are statistically analyzed in order to determine parameters to use in the scenario generation step. According to the scenario tree and the user requirements and settings a dynamic optimization model, representing the SAA decision problem, is created and solved. Solutions are then analyzed and elaborated in order to provide the end-user with reports and statistics easily accessible. Refinements and further evaluations can be carried out by feed-back processes.

3. System design

A prototypal DSS has been designed to support the main steps of the framework introduced above. The resulting architecture presents a three-tier structure as illustrated in Fig. 3. The front-end exposes a user-friendly web-based interface that provides the access to applications and functionalities of the system. The middle layer is composed of modules and tools to efficiently balance computational workload among available computing resources and to manage requests assignment. The third layer includes computing nodes, each one with an application kernel instance, a local resources manager and a

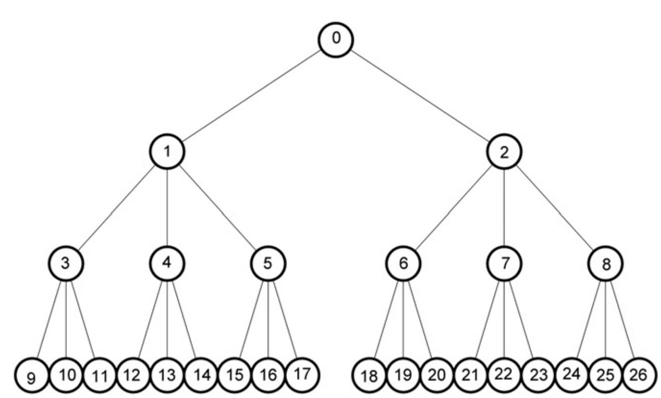

Fig. 1. Four-stages scenario tree.