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# A fuzzy rule based expert system for stock evaluation and portfolio construction: An application to Istanbul Stock Exchange

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ABSTRACT

The aim of this study is to construct appropriate portfolios by taking investor's preferences and risk profile into account in a realistic, flexible and practical manner. In this concern, a fuzzy rule based expert system is developed to support portfolio managers in their middle term investment decisions. The proposed expert system is validated by using the data of 61 stocks that publicly traded in Istanbul Stock Exchange National-100 Index from the years 2002 through 2010. The performance of the proposed system is analyzed in comparison with the benchmark index, Istanbul Stock Exchange National-30 Index, in terms of different risk profiles and investment period lengths. The results reveal that the performance of the proposed expert system is superior relative to the benchmark index in most cases. Additionally, in parallel to our expectations, the performance of the expert system is relatively higher in case of risk-averse investor profile and middle term investment period than the performance observed in the other cases.



## 1. Introduction

Portfolio management process is an integrated set of steps undertaken in a consistent manner to create and maintain an appropriate portfolio to meet clients' goals (Maginn, Tuttle, McLeavey, & Pinto, 2007). The aim of this study is constructing appropriate portfolios that meet investor's risk profile and specific preferences, rather than constructing an optimal portfolio that is just a collection of individual assets having desirable risk-return characteristics. Accordingly, a fuzzy rule based expert system (ES) is developed in this study to support portfolio managers in their middle term stock evaluation and portfolio construction decisions.

Modern Portfolio Theory (MPT), as an important research area of modern finance theory, has born from the study of Markowitz published in 1952. Markowitz (1952) showed that the variance of the rate of return was a meaningful measure of portfolio risk under a set of assumptions, and he derived the formula for computing the variance of a portfolio.

MPT has been widely accepted and studied by researchers. However, in recent years, criticism on the assumptions of MPT is increasing. The basic assumption of MPT is the efficiency of markets. However, Grossman and Stiglitz (1980) asserted that obtaining information about markets is costly and it is impossible to get whole information about each individual stock. Therefore, prices cannot perfectly reflect the information and markets cannot be efficient. Hence, it is very important to identify the undervalued stocks for investment.

Another criticism on MPT is the computational burden caused by the quadratic utility functions and covariance matrix. This burden causes challenging difficulties in real life applications due to the high number of stocks. That is why investors prefer to use simplified investment rules instead of the models in the field of MPT. However, the portfolio management process is divided into two stages in recent studies to reduce the initial number of stocks and consequently reduce the computational difficulty. In the first stage, appropriate stocks for portfolio construction are selected. In the second stage, the amount of capital to be invested in each selected stock is specified. The study of Xidonas, Askounis, and Psarras (2009) is an example to this two-stage process.

Finally, it is widely criticized that MPT disregards real investor's preferences. Moreover, it is often found in portfolio optimization that investors prefer portfolios that lie behind the efficient frontier of the Markowitz model even though they are dominated by other portfolios with respect to the two criteria, expected return and risk. This observation can be explained by the fact that not all the relevant information for an investment decision can be captured in terms of explicit return and risk. Therefore, some additional criteria must be added to the classical risk-return criteria. By considering additional and/or alternative decision criteria, a portfolio that is dominated with respect to expected return and risk may make up for the deficit in these two criteria by a very good performance in

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one or several other criteria and thus be non-dominated in a multi-criteria setting (Ehrgott, Klamroth, & Schwehm, 2004).

As a result, portfolio management is a multidimensional problem and multi-criteria decision making (MCDM) approach provides the methodological basis to resolve the inherent multi-criteria nature of the problem. MCDM approach builds realistic models by taking into account, apart from the two basic criteria; return and risk, a number of important other criteria, i.e. additional statistical measures of the variation of return, criteria that are founded in the theory of fundamental analysis, or criteria related to the stock market characteristics and behavior of securities, etc. (Xidonas, Mavrotas, Zopounidis, & Psarras, 2011). Additionally, MCDM have the advantage of taking into account the preferences of any particular investor. Furthermore, these methods do not impose any norm to the investor's behavior. The use of MCDM methods allows synthesizing in a single procedure the theoretical and practical aspects of portfolio management, and then it allows a non-normative use of theory (Xidonas & Psarras, 2009).

Portfolio management is a complex, subjective and generally unstructured process. Additionally, decision makers have partial information about the market and have to deal with high level of uncertainty. Moreover, the interaction between fundamental and technical criteria is uncertain. Due to the complex, uncertain and unstructured nature of the problem, there is a growing interest in artificial intelligence (AI) techniques recently. The readers who are interested in more details regarding AI applications on portfolio management may refer to Bahrammirzaee (2010). Among these techniques, a fuzzy rule based ES is thought to be an appropriate framework for the solution due to the characteristics of the problem.

In this study, a fuzzy rule based expert system is developed to support portfolio managers in their middle term investment decisions. The proposed expert system is validated by using the data of Istanbul Stock Exchange (ISE) National-100 Index (XU100).

The remainder of this study is organized as follows: In Section 2, previous studies in which ES technique is used to solve stock evaluation and portfolio construction problem are presented. In Section 3, structure of the proposed ES is explained. In Section 4, performance of the proposed ES is analyzed by using the historical data obtained from ISE in cases of different risk profiles and investment period lengths. In Section 5, the performance evaluation results are discussed. Finally, concluding remarks are presented in Section 6.

## 2. Expert systems in portfolio management

An ES is a computer system, which contains a well-organized body of knowledge that imitates experts' problem-solving skills to solve complex decision problems in a specific domain. An ES is not based on black-box formulation and it is easier for users to understand its structure. By using ES technology, it becomes possible to obtain more realistic, flexible and practical solutions to the stock evaluation and portfolio construction problem. In addition, an ES reduce the time required by portfolio managers for decision-making, and standardize the decision making process. Consequently, the quality of the decision can be improved. The readers who are interested in ES applications in finance may refer to Bahrammirzaee (2010), Rada (2008), and Nedović and Devedžić (2002).

Due to the characteristics of the problem handled in this study, a fuzzy rule-based ES is considered as an appropriate solution approach. The number of studies that use rule-based ESs in portfolio management is scarce. The ES applications in portfolio management are introduced in the following.

The earliest study in this domain is the development of Port-Man (Chan, Dillon, & Saw, 1989) that is an ES for portfolio management in banking system. The main goal of this ES is to give advices to personal investment in a bank. In general, the consultation process of Port-Man is consisted of four stages; information acquisition, product selection, choice refinement and explanation (Bahrammirzaee, 2010). In Port-Man, frames are the major components of knowledge representation, while production rules are used to represent the control knowledge of product selection. Rules are used to guide the system selection of the investment products and are attached to various slots in the frames. Hence, the control becomes modular and local to the frames (Nedović & Devedžić, 2002).

Another study is conducted by Mogharreban and Zargham (2005) where they develop an ES, called PORSEL (PORtfolio SELection system), which uses a small set of rules to select stocks. This ES includes three parts; first, the information center which provides representation of several technical indicators such as price trends, second, the fuzzy stock selector which evaluates the listed stocks and then assigns a mixed score to each stock and finally the portfolio constructor which generates the optimal portfolios for the selected stocks. PORSEL also includes a user-friendly interface to change the rules during the run time. The results of the study reveal that PORSEL outperforms the market almost every year during the testing period. The authors compare their system with S&P 500 Index and conclude that the portfolios constructed by their system consistently outperform S&P 500 Index (Bahrammirzaee, 2010). However, the performance of the system is analyzed only by means of returns. There is no information about risk level and risk adjusted returns of the portfolios constructed by PORSEL.

Recently, Xidonas et al. (2009) develop a rule-based ES for selection of the securities. The ES uses the criteria based solely on fundamental analysis techniques for making rational and non-speculative investment decisions within a long-term horizon. One of the main features of the methodology is that the firms that participate in the evaluation process are categorized in classes with respect to their corresponding industry. Each of the selected criteria is modeled using a three-point scale: very satisfactory, satisfactory and non-satisfactory. The thresholds for the financial ratios are determined by the experts, in such a way as to represent their practical implementation. After the determination of the threshold values for all criteria sets, detailed hierarchical decision trees are constructed for each security class. Finally, a set of 1406 production rules are constructed in total. The validity of the ES is tested on the data concerning firms whose equities are traded in the Athens Stock Exchange leveraging from the opinion of experts.

Dymova, Sevastianov, and Bartosiewicz (2010) propose a new approach to rule base evidential reasoning and develop a stock trading ES. They integrate fuzzy sets and Dempster – Shafer theory and propose a new approach to be able to assign a belief mass to a group of events, and aggregate different sources of evidence using Dempster's rule of combination. They optimize and test their ES on the real data from Warsaw Stock Exchange. It is shown in the study that this system provides high returns with smooth profit curve and high percentage of winning trades when trading the futures contract on the main index of Warsaw Stock Exchange (WIG20).

In a recent work, Fasanghari and Montazer (2010) develop a fuzzy rule-based ES for portfolio recommendation. The stocks are ranked by a fuzzy rule-based ES considering a few criteria specified by experts. Each input of the system is modeled using three linguistic variables (low, medium, and high) by triangular membership functions (MF). The parameters of MFs and number of production rules in knowledge base are determined by fuzzy Delphi method that integrates knowledge of multiple experts. The ES is implemented on ten stocks traded on Tehran Stock Exchange. Then, portfolios are constructed by selecting the stocks recommended by the ES that takes into account the preferences and risk profile of investors. The ES is validated by interviewing with experts and users.