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Financial portfolio management through the goal programming model: Current state-of-the-art

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ABSTRACT

Since Markowitz (1952) formulated the portfolio selection problem, many researchers have developed models aggregating simultaneously several conflicting attributes such as: the return on investment, risk and liquidity. The portfolio manager generally seeks the best combination of stocks/assets that meets his/her investment objectives. The Goal Programming (GP) model is widely applied to finance and portfolio management. The aim of this paper is to present the different variants of the GP model that have been applied to the financial portfolio selection problem from the 1970s to nowadays.

1. Introduction

In the current globalized economy several companies have developed their own business network which implies a portfolio approach due to the extent of vertical, horizontal or diagonal integration or due to the setting of a corporate venture capital program. This approach backs to the financial portfolio selection model developed by the American economist Harry Markowitz in 1952. His model has revolutionized the way people think about portfolios of assets and started the portfolio financial modern theory. This model is based on a simultaneous optimization of two conflicting and incommensurable criteria, namely: a) the return of the portfolio and b) the risk related to the financial losses. Hence, in order to obtain the best portfolio, the Financial Decision-Maker (FDM) is requested to make some compromises (trade-offs) among these criteria, based on his/her preferences, experience, intuition and judgement. Markowitz (1952) suggests that the FDM diversifies the portfolio components by attempting to achieve an overall balance of risk and return rather than to focus on the risk of each position. Markowitz (1952, 1959) gave the foundations of the financial portfolio selection theory and his model has been extended and applied several times within the field of finance. This decision-making process presents several steps in which the FDM could be involved. It also requires the evaluation of the stock market and the individual stocks' performance (Aouni, 2009, 2010).

Over the years we have observed a significant increase in publications related to the topic of multi-attribute portfolio selection. Most of these papers have proposed different portfolio selection formulations based on operational research models. In their papers, Elton and Gruber (1987) and Zopounidis and Doumpos (2013) present various quantitative techniques that have been applied to portfolio selection such as: stochastic dominance, multi-attribute utility models, discriminant analysis, heuristics, neural networks, optimization models, multi-criteria analysis and multi-objective programming. Zopounidis and Doumpos (2013) present an exhaustive literature review on the applications of multi-criteria decision aid tools to financial problems. They highlight the contribution of the operational research discipline to finance. The Goal Programming (GP) is one of these models that have been widely utilized for selecting financial portfolio based on several attributes. The GP model aggregates multiple objectives and allows obtaining the portfolio where the deviations between achievement and the aspirations levels of the attributes are to be minimized.

The GP model is easy to understand and to apply. This model is based on mathematical programming supported by some powerful software packages such as Lindo and CPLEX. The GP describes the spectrum of the FDM's preferences where some trade-offs can be made through a user-friendly and learning decision-making process. Such process will help generating scenarios where the FDM can interact and make changes into the model parameters in a way that improves the decision-making process. It is a progressive and evolutionary process. The investment decisions are taken by the FDM and the mathematical model is to help and not to substitute the FDM.

This paper aims at updating the literature review on application of GP models to financial portfolio management. This manuscript can be very helpful for researchers and practitioners interested in this area. The structure of the manuscript is as follows. Section 2 presents the general formulation of the portfolio selection based

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on several objectives. The general formulation of the multi-objective programming and the GP are given in Section 3, which provides the FDM with some guidelines to choose the appropriate GP variant to be utilized for financial portfolio selection among all GP variants. This paper seeks to limit its domain of coverage just to GP variants applied to the financial portfolio selection. This survey is an extension of some previous papers related to GP and portfolio management, such as Lin and O'Leary (1993), Aouni (2009, 2010), and Azmi and Tamiz (2010). We provide in Section 4 some concluding remarks.

2. General formulation of the multi-attribute portfolio selection problem

Markowitz (1952) proposed the first bi-criteria portfolio selection formulation, where two conflicting and incommensurable criteria are to be optimized simultaneously, namely: (a) the expected return and (b) the risk. He had the insight that while diversification reduces risk, it would not generally eliminate it. This model requires some compromises based on the FDM's preferences. Markowitz (1952) formulation can be summarized as follows:

$$\text{Objective 1}: \text{Max.} \sum_{j=1}^{n} E_j x_j$$

$$\text{Objective 2}: \text{Min.} \sum_{j=1}^{n}\sum_{k=1}^{n} x_j \sigma_{jk} x_k$$

Subject to:

$$\sum_{j=1}^{n} x_j = 1, \tag{1}$$

$$x \in F, \tag{2}$$

where Objective 1 is the expected return of the portfolio; Objective 2 is the variance; x_j is the proportion to be invested in the stock (security) j, E_j is the expected return of security j, σ_{jk} is the covariance of the returns of securities j and k, and F is the set of feasible solutions.

When a multinormal distribution of return on assets is assumed, it affects the probability of extreme events and argues that the dependence between assets does not vary during market downturns or upturns. However, under normality assumption, the mean, the variances and the correlations can be easily constructed from historical data. Through the constraint (1), the sum of the proportions to be invested in stocks should to be equal to 1. In other words, the total investment amount has to be allocated. The set of constraints (2) are restrictions related to the portfolio including the diversification conditions. In order to manage the investment risk, the FDM may diversify the portfolio by investing in different securities. Both constraints determine the efficient portfolios. Markowitz (1952) model allows obtaining the best portfolio that may increase the FDM earning and minimizes at the same time the risk of financial losses. The aggregation of these two attributes can be done as follows:

$$\text{Min.} \sum_{i=1}^{n}\sum_{j=1}^{n} x_i \sigma_{ij} x_j$$

$$\text{Subject to}:$$

$$\sum_{i=1}^{n} E_i x_i = E^*$$

$$\sum_{i=1}^{n} x_i = 1,$$

$$x \in F,$$

where E^* is the target value of the return.

The objective function of this model is quadratic and the constraints are linear. Solving this model allows finding the efficient frontier of portfolios among which the FDM will make a choice based on his/her preferences regarding the attributes of return and risk. Indeed, the FDM needs to make a compromise between an acceptable level of risk and a desired return. This formulation is known, in the literature, as the mean-variance model. However, the portfolio selection problem cannot be limited to only two attributes as pointed out by Ferretti (1970) who introduced two categories of objectives: (a) objectives related to the shareholders and (b) performance objectives.

In the literature, researchers have considered different attributes in the portfolio selection problem. Levy and Sarnat (1972) extended the number of attributes by considering the following objectives: (a) the value of the stocks, (b) the present value of the stock return, (c) the share price-return ratio, (d) the dividend, and (e) the income per share and the growth value of stocks. Lee and Lerro (1973) established a GP portfolio selection model with four levels of priorities and the six following types of objectives: (a) expected portfolio return, (b) portfolio variance, (c) covariance, (d) dividend yield, (e) unexplained price variance, and (f) investment budget. Moreover, Lee and Chesser (1980), Zopounidis, Doumpos, and Zanakis (1999) and Zopounidis and Doumpos (2002) proposed fifteen objectives which can be summarized into the three following categories: (a) the corporate validity, (b) the stocks acceptability by the FDM, and (c) the financial vigor. The complete list of the objectives as proposed by Zopounidis et al. (1999) is as follows: (*i*) gross book value per share, (*ii*) capitalization ratio, (*iii*) stock market value of each firm, (*iv*) the marketability of each share, (*v*) financial position progress, (*vi*) dividend yield, (*vii*) capital gain, (*viii*) exchange flow ratio, (*ix*) round lots traded per day, (*x*) transaction value per day, (*xi*) equity ratio, (*xii*) price/earning ratio, (*xiii*) structure ratio, (*xix*) equity/debt ratio, and (*xv*) return on equity.

As the bi-criteria model proposed by Markowitz (1952) does not reflect the complexity and the multi-dimensionality of the decision-making process in the financial portfolio selection problem, the issue of considering several criteria in the portfolio selection problem is now a reality (Aouni, 2009, 2010). Several multi-dimensional approaches have been proposed in the literature in order to aggregate conflicting and incommensurables attributes, such as: Multi-Attribute Utility, Outranking Methods, Multi-Objective Programming, and GP. In their paper, Zopounidis and Doumpos (2013) provide a complete and commented literature review of the different multi-criteria aggregating procedures applied to financial portfolio selection and corporate performance evaluation. Since the 1970s, the GP has been applied to portfolio management. In the 2000s, the higher levels of computerized automation of the solution and modeling process brought a wider use of the GP model within the field of financial portfolio management (Azmi & Tamiz, 2010; Tamiz & Jones, 1998).

Table 1 shows that during the last five decades, the GP model has been widely applied to the portfolio management problem. The highest number of applications of GP to portfolio selection was observed during the 2000s. Moreover, the most popular variant is the Weighted GP.

3. Goal programming model for portfolio selection

GP was first introduced by Charnes, Cooper, and Ferguson (1955) and Charnes and Cooper (1961). The main idea behind this model is the determination of the aspiration levels of an objective function and the minimization of any (positive or negative) deviations from these levels. Over the years, the GP model has become the most popular model within the field of Multi-Objective