Investment Portfolio Selection
Using Goal Programming

Investment Portfolio Selection Using Goal Programming: An Approach to Making Investment Decisions

By

Dr. Rania Ahmed Azmi

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This book is dedicated to my mom and dad:
Mrs. Fadia Abdel Salam
Eng. Ahmed Azmi

Their unconditional love, understanding and support in all that I have done are the keys of all my achievements and they are responsible for every good thing I have ever done.

“He that wants money, means, and content, is without three good friends.”
—William Shakespeare (1564-1616)

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PREFACE

This book suggests new scientific frameworks for investment decision making and portfolio selection and analysis that can be utilised equally by practitioners and academics. The main contributions here proposed are the application of Goal Programming to portfolio selection, the development and testing of new weighting schemes and a novel approach in extending Goal Programming models to incorporate several factors for global portfolio selection and analysis.

This book is thus intended to contribute to the theory of portfolio selection by using Goal Programming and its variants. In particular, it aims at providing the decision maker (whether an individual or institutional investor, policy maker, etc.), who is usually burdened with achieving multiple (often conflicting) objectives under complex environmental constraints, with a new scientific framework to accomplish goals and satisfy preferences.

Accordingly, this book is structured as follows:

Following the first chapter, which introduces Goal Programming for real-world decision making, chapter two presents a thorough literature review of Goal Programming for Portfolio Selection. The chapter starts with overviews of the use of multi-criteria decision analysis in portfolio selection and the importance of Goal Programming. The chapter also discusses portfolio selection using Goal Programming in the light of various theoretical and practical developments.

With these themes as a background, chapter three provides a general overview of the main methodologies used in this book; namely, Goal Programming, Markowitz, Konno's model, Sharpe and Treynor methodologies. Illustrations are provided throughout this chapter for convenience and ease of use regarding the mathematical models.

This leads on to chapter four, where the first experiments are framed in order to select a portfolio of mutual funds from two different markets—developed and emerging—with two different time periods, using Goal Programming, Sharpe and Treynor methods. The chapter's results have certain implications for the Goal Programming methodology as it is utilised in crisis time (the experiment in the UK market) and in regular time (the experiment in Egypt's market).

Chapter five builds on chapter four in terms of applying the same methodologies, but in selecting a portfolio of stocks. Some interesting results are reported.

The portfolio selection experiments with applications to mutual funds (chapter four) and stocks (chapter five) show that Goal Programming could be used effectively for selecting a portfolio's constituents. Deciding on the constituents' proportions is a subsequent important task. Accordingly, chapter six provides many choices for weighting schemes in order to obtain portfolio constituent proportions. The chapter explores these weighting schemes via experiments on mutual funds and stocks.

Building on the results reported for the experiments in chapters four through six, chapter seven goes beyond return-risk-based portfolio selection and attempts to select portfolios based on extended factors that closely reflect the nature of the portfolio problem in today's world. It therefore considers several factors—such as regional preferences and macroeconomic factors—for the international mutual fund portfolio selection problem. Interesting results are reported and thorough analysis is provided.

The book concludes in chapters eight and nine with a discussion of various further perspectives and thoughts regarding the various topics that have been covered.

I hope the reader will enjoy exploring the suggested investment decision-making framework and will make use of the knowledge thereby gained, whether as a practitioner in the financial markets, an academic in the field or even as a postgraduate student.

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Finally, my thanks go to all the people at Cambridge Scholars Publishing who worked on this book, and to Ben Young of Babel Editing for his careful proofreading. I, of course, retain responsibility for its contents, as well as for any omissions which may unwittingly remain, and will gladly receive comments from readers at rania.a.azmi@gmail.com.

List of Abbreviations and Notations

- APT: Arbitrage Pricing Theory.
- Asset: a financial asset, the term being used throughout this book to indicate either stocks or mutual funds.
- CAPM: Capital Asset Pricing Model.
- GP: Goal Programming.
- LGP: Lexicographic Goal Programming.
- MAD: Mean-Absolute Deviation.
- MF: Mutual Fund.
- PS: Portfolio Selection.
- WGP: Weighted Goal Programming.
- n_i : the i^{th} negative deviational variable.
- α_i : the weighting factor for negative deviational variable i.
- p_i : the i^{th} positive deviational variable.
- β_i : the weighting factor for positive deviational variable i.
- $\mathbf{x}$: the vector of the decision variables.
- $f_i(\mathbf{x})$: the i^{th} objective function.
- b_i : the i^{th} target value.

- σ_{ij} : the covariance between financial assets i and j.
- R_j: Return of the j^{th} asset.
- R_f : Risk-free rate.
- λ : Lambda, represents the maximum deviation.
- S_j : Sharpe Ratio for the j^{th} asset, $j = 1, \ldots, n$.
- SD_j : Standard deviation of the j^{th} asset.
- T_j : Treynor Ratio for the j^{th} asset, $j = 1, \ldots, n$.
- $Beta_j$: Beta Coefficient of the j^{th} asset.
- I_t : Return of relevant index (benchmark) during period t.
- RS_t : Return of Sharpe's portfolio.
- RT_t : Return of Treynor's portfolio.
- RGP_t : Return of GP's portfolio.
- RBM_t : Return of the relevant benchmark (index).
- TE : the Tracking Error.
- RE : the average return in percentage.
- RI : the total risk as measured by the standard deviation.
- AG : the mutual fund age in years.
- GD : the Gross Domestic Product in Purchasing Power Parity as a percentage of world's total.
- CA : the current account balance as a percentage of the GDP.
- IN : the annual inflation rate in percentage change.

- RG : the regional preferences factor.
- h_q : the q^{th} priority level in an LGP model.

CHAPTER ONE

INTRODUCING GOAL PROGRAMMING FOR REAL-WORLD INVESTMENT DECISION MAKING

Finance theory was instrumental in the growth and development of the financial sector. Available data for the period 1980-2007 in the U.S. show that in 1980 the value of financial assets was slightly above that of U.S. GDP (129% of GDP including derivatives). In 1990, the value of the financial assets was more than twice that of GDP (253%). By 2001, the value of the stock of global financial assets was almost six times that of world GDP and by 2007 it represented thirteen times the value of world GDP (Caldentey and Vernengo, 2010).

The investment methods used to reach the desired objectives range from quantitative investment, which originated in modern portfolio theory, to more traditional methods of financial analysis. Quantitative investment techniques are now among the most widely used fund management methods. They are generally grouped into two major categories: active investment management and passive investment management. Passive investment covers index investment. The objective of active investment management is to perform better than the market, or better than a benchmark that is chosen as a reference (Grinold and Kahn, 1995).

The basic elements that allow portfolios to be created are assets. These assets, which are traded on financial markets, are numerous and vary greatly in nature. The simplest way to group assets together is to consider asset classes, such as stocks, bonds, etc. Each asset class corresponds to a level of risk (Amenc and Le Sourd, 2003).

For the applications and experiments carried out in this book assets are considered to be either stocks or mutual funds. Stocks represent shares of ownership in a company, while mutual funds are investment companies that create a large pool of money that can be invested in stocks, bonds or other securities. Bonds are the most common lending investment traded on securities markets (Tyson, 2007).

Mutual funds have become a popular structure for investors seeking exposure to financial markets. Gregoriou (2007) claims there are two reasons why rational investors delegate their wealth management to mutual funds: first, economies of scale which reduce wealth management costs; second, private investors might expect that professional mutual fund managers have superior management skills, leading to positive risk-adjusted excess returns.

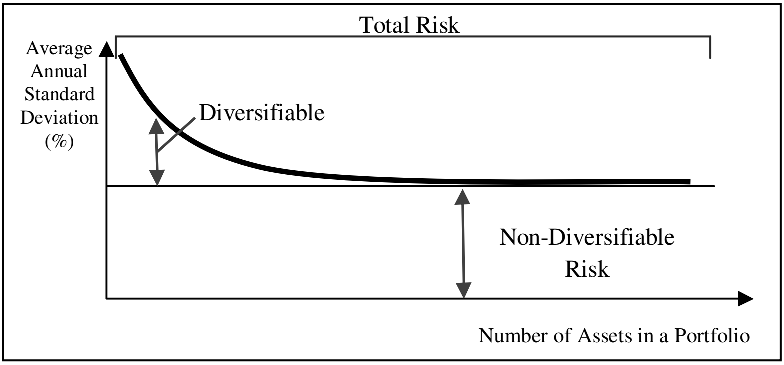
A portfolio is defined as a grouping of assets. An investor can invest in a portfolio of stocks or a portfolio of mutual funds. Portfolio management is about risk and return—although good returns are difficult to achieve and good risk-adjusted returns can be difficult to identify. The concept of return requires no explanation other than to comment that larger returns are preferred to smaller ones. Risk is more challenging, and is inherently a probabilistic or statistical concept. There are various, and sometimes conflicting, notions and measures of risk. As a result, it can be difficult to measure the risk of a portfolio and determine how various investments and asset allocations affect that risk (Pearson, 2002; Travers, 2004).

Risk means different things to different market participants. For theory building, it is important that risk be defined in terms of rational investors, and it is desirable that there is a consensus among all rational investors as to what constitutes risk (Markowitz, 1995). To an investor, the risk of a historical portfolio is the uncertainty or degree of dispersion in the probability distribution of its future market value (Hymans and Mulligan, 1980).

To be able to make decisions, it must be possible to quantify the degree of risk in a particular opportunity. The most common method is to use the standard deviation of the expected returns. This method measures spreads, and it is the possible returns of these spreads that provide the measure of risk. However, there are several different factors that cause risk or lead to variability in returns on an individual investment. Factors that may influence risk in any given investment vehicle include uncertainty of income, interest rates, inflation, exchange rates, the state of the economy, liquidity risk, etc. The goal is to hold a group of investments within a portfolio potentially to reduce the risk level suffered without reducing the level of return (Pearson, 2002).

An important insight of modern financial theory is that some investment risks yield an expected reward, while other risks do not. Risks that can be eliminated by diversification (called unsystematic risks) do not yield an expected reward, while risks that cannot be eliminated by diversification (called systematic or market risks) do yield an expected reward. Diversification reduces risk, but only up to a point (Corrado and Jordan, 2005) as illustrated in figure 1.1.

Figure 1.1: Diversifiable and Non-Diversifiable Risks



In portfolio management it is common to think about risk in terms of a portfolio's return relative to the return on a benchmark portfolio. Market indices are quoted on stock exchanges and are therefore simple to use as benchmarks. In particular, if the FTSE 100 index is the benchmark, an investor might be concerned about the difference between the return on his/her portfolio and the return on the FTSE 100, rather than on the return on the portfolio only.

Portfolio Selection issues have been the subject of extensive research ever since Markowitz's pioneer article on the topic (1952). In an autobiography written at the time of his Nobel Prize in 1990, Markowitz mentioned that the focus in much research has been on the application of mathematical or computer techniques to practical problems, in which existing techniques were applied or new techniques were developed (Frangsmyr, 1991).

Markowitz (1991) was the first to quantify the link that exists between portfolio risk and portfolio return. By this, he founded modern portfolio theory. The Markowitz model was the starting point for numerous developments in finance. It contains, in particular, the fundamental elements of the Capital Asset Pricing Model which is the source of the first risk-adjusted performance measures (Sharpe, 1963; 1964; Treynor, 1965).

The Markowitz theory (1952) does not speak of efficient markets, but of efficient portfolios. The market is efficient if the prices of assets at any moment reflect all available information (Amenc and Le Sourd, 2003). An efficient portfolio is defined as a portfolio with minimal risk for a given return, or, equivalently, as the portfolio with the highest return for a given level of risk.

To construct a portfolio, investors need to define first the categories of assets that they wish to include in the portfolio, depending on their objectives and constraints. The asset allocation methods may depend on the nature of the assets, but, in all cases, asset allocation is carried out in two stages:

- Investors define the long-term allocation, based on the risk and return estimations for each asset class. This is strategic allocation.
- Investors may carry out adjustments based on short-term anticipations. This is tactical allocation.

The last stage in the construction of a portfolio is the stock picking, or more generally, assets picking. This takes into account the microeconomic market trends and concerns stocks in particular. In addition to the methods drawn from modern portfolio theory, some methods allow stock picking to be carried out on a quantitative basis. Once the portfolio has been constructed, the final stage of the investment management process consists of evaluating its performance (Amenc and Le Sourd, 2003).

Managing the portfolio is an integral part of portfolio construction, wherein an investor seeks to regularly readjust the proportions of the different asset classes in the portfolio, to take into account short-term forecasts of market movements and the evolution of the economic environment, while respecting the risk constraints. Therefore, a portfolio cannot be analysed as a closed system without some consideration of the responsiveness of assets to external factors and asset-specific performance (Lee, 1972).

While emphasising the importance of selecting suitable factors for portfolio analysis, Markowitz (1995) designs his model based on only two objectives, as they are the common ones to all investors.

Elton and Gruber (1995) discuss the two categories for breakthroughs in implementation of portfolio theory in the following terms:

- Simplifications of the amount and type of input data needed to perform portfolio analysis.
- Simplification of the computational procedure needed to calculate optimal portfolios.

A great deal of research by academics and financial practitioners has been devoted to performance measurement for portfolios (allowing past results to be quantified) and performance analysis (allowing the results to be explained).

As has often been noted (Lee, 1972; Lai and Hwang, 1994), a major concern in making decisions is that almost all decision problems have multiple and usually conflicting criteria. The soundness of decision making is thus measured by the degree to which the relevant goals are achieved. To that end, an application of the scientific approach is necessary, and this calls for systematic analysis of the decision system. Systematic investigation enables the decision maker to consider all pertinent factors related to the decision so that the best ultimate course of action can be identified from among a set of alternatives.

The book strives to provide both practitioners and academics with a scientific approach to portfolio selection using goal programming, an approach which is capable as far as is possible of achieving a required set of preferences.

Goal Programming (GP) is perhaps the most widely used approach in the field of multiple criteria decision making that enables the decision maker to incorporate numerous variations of constraints and goals. The original portfolio selection problem, with risk and return optimisation, can be viewed as a case of Goal Programming with two objectives. Additional objectives representing other factors can be introduced for a more realistic approach to portfolio selection problems.

Although any Goal Programming problem of meaningful size would be solved on the computers, the notion of programming in GP is associated with the development of solutions, or programs, for a specific problem. Hence, GP has nothing intrinsically to do with computer programming and the name GP is used to indicate seeking the (optimal) program for a mathematical model that is composed solely of goals (Ignizio, 1985).

Ignizio and Romero (2003) highlight that real-world decision problems are usually changeable, complex and resist treatment with conventional approaches. Therefore, the optimisation of a single objective subject to a set of rigid constraints is in most cases unrealistic, and that is why Goal Programming was introduced, in an attempt to eliminate or at least mitigate this shortcoming.

The two philosophical concepts that serve to best distinguish Goal Programming from conventional methods of optimisation (with a single objective) are the incorporation of flexibility in constraint functions and the adherence to the philosophy of Satisficing as opposed to Optimisation.

Satisficing is an old Scots word that refers to the desire to find a practical and real-world solution to a problem, rather than an idealistic or optimal solution to a highly simplified model of that problem. In Goal Programming, the decision maker usually seeks a useful, practical, implementable and attainable solution rather than one satisfying the mathematician's desire.

CHAPTER TWO

SELECTED LITERATURE ON GOAL PROGRAMMING FOR INVESTMENT DECISION MAKING AND MODELLING

2.1 Introduction to Goal Programming for Portfolio Selection

Finance theory has produced a variety of models that attempt to provide some insight into the environment in which financial decisions are made. By definition, every model is a simplification of reality. Hence, even if the data fail to reject the model, the decision maker may not necessarily want to place too much weight on it. At the same time, the notion that the models implied by finance theory could be entirely worthless seems rather extreme. Hence, even if the data reject the model, the decision maker may still want to use the model at least to some degree (Pastor, 2000).

Some researchers involved in the mean-variance analysis of Markowitz (1952) for portfolio selection have only focused on PS as risk-adjusted return with little or no effort being directed to the inclusion of other essential factors. Therefore, the usual portfolio analysis assumes that investors are interested only in returns attached to specific levels of risk when selecting their portfolios. In a wide variety of applications, neither part of this restriction is desirable or important. Consequently, a portfolio analysis model that includes more factors in the analysis of portfolio problems is a more realistic approach. Some of these factors include asset region, micro economics, macro economics, liquidity and market dynamics.

The purpose of the analysis of portfolio is to find portfolios which best meet the objectives of the investor. A portfolio analysis must be based on criteria which serve as a guide to the important and unimportant, the relevant and irrelevant (Markowitz, 1995).

As mentioned in the previous chapter, the original portfolio selection problems, which are concerned with risk and return optimisation, can be viewed as a case of Goal Programming with two objectives. Additional objectives representing other factors can be introduced for a more realistic approach to PS problems.

Charnes, Cooper and Ferguson developed Goal Programming in 1955. GP is a multi-objective programming technique. The ethos of GP lies in the Simonian concept of satisficing of objectives (Tamiz, Jones and Romero, 1998). Herbert Simon introduced the concept of satisficing in 1956, a word that originated in Northumbria, in the Scottish border regions, where it meant "to satisfy." Satisficing is a strategy for making decisions in cases wherein one has to choose among various alternatives which are encountered sequentially, and which are not known ahead of time (Ignizio and Romero, 2003; Reina, 2005).

GP is an important technique for decision-making problems where the decision maker aims to minimise the deviation between the achievement of goals and their aspiration levels. It can be said that GP has been, and still is, the most widely used multi-objective technique in management science because of its inherent flexibility in handling decision-making problems with several conflicting objectives and incomplete or imprecise information (Romero, 1991, 2004; Chang, 2007).

Ignizio and Romero (2003) label Goal Programming as the workhorse of multiple objective optimisation, as over many years GP has seen successful solutions for important real-world problems, such as the following:

- The analysis of executive compensation for General Electric.
- The design and deployment of the antenna for the Saturn II launch vehicle as employed in the Apollo manned moon-landing program.
- The determination of a siting scheme for the Patriot Air Defence System.
- The design of acoustic arrays for U.S. Navy torpedoes.
- The audit transactions within the financial sector and a host of problems in the area of finance, resource allocation, etc.

2.2 The Use of Multi-Criteria Decision Analysis in Portfolio Selection and the Importance of Goal Programming

Optimisation is a process by which the most favourable trade-off between competing interests is determined subject to the constraints faced in any decision-making process. Within the context of portfolio management, the competing interests are, among others, risk reduction and return enhancement (Kritzman, 2003).

Present-day theory of portfolio analysis prescribes a way of thinking about opportunities for investment. Instead of extensive evaluation of a single asset in isolation, the theory prescribes that investment policy be formulated in a manner in which a purchase of an asset is done if and only if it will cause a rise in the overall personal satisfactions. A rise may come about via one of three schemes as follows (Renwick, 1969):

- The new asset can cause a net increase in total present expected return on the portfolio.
- The new asset can cause a net decline in total risk exposure on the entire portfolio.
- There can be some subjectively acceptable trade off between change in total risk and change in total expected return on the portfolio.

The first two are the traditional and direct schemes for selecting portfolios, while the third is open to many possibilities and consequently has stimulated many studies in search of better portfolio selection strategies for investors.

Besides portfolio selection issues, there is the issue of performance measurement for portfolios. Treynor (1965), Sharpe (1966) and Jensen (1968) develop the standard indices to measure portfolios' performances, i.e., risk-adjusted returns for portfolios.

Numerous studies have tested the performance of portfolios (mutual funds) compared to a certain benchmark, usually a market index, based on Sharpe, Treynor and Jensen's performance measures (Artikis, 2002; Cresson, Cudd and Lipscomb, 2002; Daniel et al., 1997; Lehmann and Modest, 1987; Matallin and Nieto, 2002; Otten and Schweitzer, 2002; Raj, Forsyth and Tomini, 2003; Zheng, 1999).

Bottom-line performance measurement concentrates on the question of how a portfolio fared, both absolutely and relative to a benchmark.

Markowitz (1952) suggests that investors should consider risk and return together and determine the allocation of funds among investment alternatives on the basis of the trade-off between them. Later, the recognition that many investors evaluate performance relative to a benchmark led to the idea of PS based on return and relative risk (Cremers, Kritzman and Page, 2005). For many investors, both approaches fail to yield satisfactory results. Chow (1995) emphasises that portfolio optimisation techniques can assist in the search for the portfolio that best suits each investor's particular objectives.

An alternative to the Markowitz model is the Mean-Absolute Deviation (MAD) model, proposed by Konno and Yamazaki (1991). While the

Markowitz model assumes the normality of stock returns, the MAD model does not make this assumption. The MAD model also minimises a measure of risk, where the measure is the mean absolute deviation (Kim, Kim and Shin, 2005; Konno and Koshizuka, 2005). Konno and Yamazaki (1991) further develop the MAD model into an equivalent GP model.

Konno and Kobayashi (1997) propose a new model for constructing an integrated stock-bond portfolio, which serves as an alternative to the popular asset allocation strategy. The fund is first allocated to indexes corresponding to diverse asset classes and then allocated to individual assets using appropriate models for each asset class.

Their model (Konno and Kobayashi, 1997) determines the allocation of the fund to individual assets in one stage by solving a large scale mean-variance or mean-absolute deviation model using newly developed technologies in large-scale quadratic programming and linear programming analysis, respectively. Computational experiments show that the new approach can serve as a more reliable and less expensive method to allocate the fund to diverse classes of assets.

Konno (2003) shows that there is a possibility of applying standard portfolio optimisation methods to the management of small- and medium-scale funds. Konno (2003) shows that the use of the mean-absolute deviation model can handle concave transaction costs and minimal transaction unit constraints in an efficient manner using a branch and bound algorithm. But the transaction cost is still not negligible for the majority of standard investors.

Parra, Terol and Uria (2001), amongst other authors, claim that there has been a growing interest in incorporating additional criteria beyond risk and return into the PS process. Multiple criteria PS problems normally stem from multiple-argument investor utility functions. For investors with additional concerns, steps can be taken to integrate them into the portfolio optimisation process more in accordance with their criteria status.

Chow (1995) mentions that investment practitioners have implicitly sent a message that optimisation models have limited relevance in real-world investment decisions. One of the best arguments for this assertion is that few investors allocate their assets in the proportions indicated by an optimisation model.

Furthermore, Christiansen and Vames (2008) present a framework for understanding how portfolio decision making is shaped through appropriate decision making. They find that the identity of the decision maker is shaped and influenced by four factors: the formal system and rules, observations of others, the organisational context, and organisational learning. In practice, the decision maker must deal with multiple factors