Part I
Introduction

Asset and Liability Management Systems for Long-Term Investors: Discussion of the Issues

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1 Introduction

This book surveys optimal investment policies for long term investors – especially those who wish to achieve goals and meet future obligations. This domain is called asset and liability management (ALM). Allocating assets lies at the heart of a strategic risk management system. In addition, liability streams and their uncertainty, institutional constraints and policies, taxes, transaction costs and the like are important features in real financial planning. Application areas described here include pension plans, insurance companies, investment conglomerates, banks, university endowments, and wealthy and ordinary individuals. These investors possess future liabilities and goals. They must make investment decisions while considering the use of their funds, that is, investing for a purpose. Risks must be measured in the context of the entire organization's or individual's financial situation.

Many investors do not manage their strategic asset mix despite much evidence that asset allocation decisions are critical for investors with diversified portfolios. Why do these investors ignore strategic planning? First, there are few computer systems for evaluating asset allocation decisions while taking into account an investor's particular temporal circumstances, liabilities and goals. The analysis is made more difficult since each investor has a unique set of qualifying factors. The adage 'one size fits all' is clearly wrong when it comes to long-term financial planning. The difficult actuarial task of evaluating the soundness of a pension plan illustrates the problem. Each U.S. company with a defined-benefit pension plan must conduct a comprehensive analysis of its plan in the context of its long-term liabilities.

As a second barrier, evaluating long-term investment strategies requires several components that are not now commonly available. There must be a way to generate scenarios that is logically consistent and based on sound economic principles. Parameters of the scenario generator must fit past data and trends. Yet the stochastic model must take into account changing economic conditions, for example, the deregulation of interest rates and currencies. The behavior of the investor must also be accounted for. We must include risk aversion in the context of the temporal nature of the decision problems. The optimization module must integrate asset decisions, liability decisions, and goal payments over time. Combining these elements into an easily computable stochastic optimization system is technically challenging.

For large investors, asset allocation typically consists of two steps. First, there is the setting of target values for the major asset categories (large cap stock, cash, bonds, international stocks, etc.) Once these targets are set, the investor (or an investment committee) hires managers who attempt to beat the associated risk adjusted indices. Alternatively they might purchase index funds to match the target proportions. Typically about one quarter of active managers beat their benchmarks, and sometimes like 1996 to 1998, much less for the widely followed S&P500 index. Reasons for this and sample data appear in the financial press and in investment research papers and books; see e.g. Ziemba & Schwartz (1991). Active managers must meet or beat their index, or face being fired for lack of acceptable performance. A portfolio manager is generally given several years to sort out the performance issue, in order to reduce the chances that luck enters into the manager choice decision. Periodically, the strategic issue is revisited. Typically, the allocation decision is evaluated at least annually, for example, at the company's board of directors meeting.

This is not to minimize the strong results from passive management strategies. Hensel, Ezra and Ilkiw's paper in this volume studies this. They considered seven representative US clients of the Frank Russell Company who were using professional money managers whose goal was to 'beat their benchmarks with lower risk' for sixteen quarters from January 1985 to December 1988. The specified fix mix was 50% US equity, 5% nonUS equity, 30% fixed income, 5% real estate and 10% cash equivalents, which was rebalanced quarterly. The results detailed in Table 1 indicate that most of the volatility is explained by the naive fixed-mix policy allocation. T-bills and the naive portfolio allocation explain most of the return and market timing security selection, etc. provided little benefit.

The papers by Chopra and Ziemba, Hensel and Turner, and Grinold and King deal with static portfolio problems in a mean variance context. Chopra and Ziemba show that errors in mean estimation are crucial to obtaining accurate portfolio weights. Errors in variances are about twice as damaging as errors in co-variances with the means being about ten times more important than the variances. Hensel and Turner explore this further, focusing on ways to massage the inputs and constrain the outputs to obtain superior investment decisions. Grinold and Kelly develop a model that allows one to track over time the impact of various sources to the performance of the portfolio. Specifically they decompose the expected returns used to select the optimal portfolio into those from an ex-ante efficient portfolio, those from the manager's special

Table 1. Average Return and Return Variation Explained (Quarterly) by Seven Clients of the Frank Russell Company

Decision Level	Average Contribution	Additional Variation Explained by this Level (Volatility)
Minimum Risk Portfolio (T-Bills)	1.62%	2.66%
Naive Policy Allocation (what other pension funds are doing; fixed-mix)	2.13	94.35
Specific Policy Allocation	0.49	0.50
Market Timing	(0.10)	0.14
Security Selection	(0.23)	0.40
Interaction and Activity	(0.005)	1.95
Total	3.86%	100.00%

insights and those due to legal, policy, diversification and other constraints.

Multiperiod stochastic asset allocation improves upon static strategies. Instead of passive management between meetings of the investment committee who are responsible for setting asset allocation strategy, a dynamic asset allocation adjusts the mix as conditions change. The Cariño–Turner paper demonstrates how the strategy changes as time and uncertainty unfold themselves with a simple three period five year example. This and other papers in the volume show the superiority of stochastic dynamic models over, for example, simple fixed-mix or buy-and-hold strategies. Dynamic strategies pinpoint the relationship between asset risks, liability risks, and goal achievement which ultimately maximizes the investor's wealth net of liabilities and penalty costs and goals.

Liabilities and goals alter the investment process. First, we differentiate *intrinsic* from *contextual* risks. Intrinsic risk refers to uncertainty surrounding a single security, e.g. Microsoft stock. The price of the stock may increase or decrease in tandem with the market – this risk cannot be easily eliminated through diversification strategies by asset-only investors. In contrast, risks which are unrelated to market movements, namely non-systematic risks, can be mitigated through diversification. For investors with long-term liabilities, market risks can be reduced since the financial well being for long-term investors is a function not only of assets, but also among other elements liabilities, interest rates (through discounting), goals, and possibly inflation. A standard formula for determining financial well being is: Wealth = assets − PV (liabilities). For example, see Sharpe & Tint (1990) and Peskin (1997). We define an alternative measure for financial soundness as: 'surplus wealth', indicating the investor's financial position relative to both liabilities and goals: Surplus wealth = assets − PV(liabilities) − PV (goals). A positive surplus indicates that the investor will be likely to meet future financial obligations along with his goals. A deficit portends the opposite – the investor should then re-evaluate his situation.

To calculate surplus wealth, we must expand the traditional asset and liability framework. Goals must be modeled. The aim is to move up the risk ladder (Figure 1) so that the asset and liability management system includes greater details, and thus is more representative of the investor's financial condition. At the top of the risk ladder, we estimate surplus wealth through the concepts of 'Total integrated risk management' TIRM (Mulvey, Armstrong & Rothberg 1995).

Rung 5:	Total integrated risk management
Rung 4:	Dynamic asset and liability management
Rung 3:	Dynamic asset-only
Rung 2:	Static asset-only portfolios
Rung 1:	Pricing single securities

Figure 1. The Risk Ladder

At every level on the ladder, there are numerous applications of dynamic investment strategies. Most relevant for our purposes are investors who possess long-term liabilities and/or goals and are keen to build a system for evaluating the long-term consequences of today's actions. An integrated approach assists in setting and evaluating financial expectations. It helps investors plan ahead in a consistent fashion. It also helps measure past performance. Noteworthy applications include the following areas:

A. Pension plans

Actuaries evaluate the long-term viability of pension plans with respect to future contributions, anticipated pay-outs to beneficiaries, and other future uncertainties. Uncertainty has been addressed traditionally via a smoothing approach. Legislation and changes in regulation, however, have pushed the analysis towards measuring economic viability and including risks in their studies. ALM examples include implemented models such as: Frank Russell's Mitsubishi Trust Model, see Cariño *et al.* (1995), and Swiss Bank Corporation models, the Towers Perrin CAP:Link System (Mulvey 1996b), and ORTEC's system in the Netherlands (Boender 1995). Elements of these systems are described in this volume: Cariño *et al.* 1994 provides the framework used for the Mitsubishi and Swiss Bank models, Mulvey & Thorlacius describes CAP-Link and Boender, van Aalst & Heemskerk describe ORTEC's model.

B. Insurance companies

Similar to pension plans, insurance companies are highly regulated and therefore their approach for analyzing a company's economic soundness is dictated by past regulations (some of which can be dated). The market is another evaluator of performance. Examples of ALM in insurance are the Russell–Yasuda Kasai Model (Cariño *et al.* 1994, Cariño & Ziemba 1998, Cariño, Myers & Ziemba 1998), Falcon Asset Management (Mulvey, Correnti & Lummis 1997), Renaissance Re-insurance (Lowe & Stanard 1996) and the CALM system described in this volume by Consigli & Dempster.

C. Banks

Banks have been slow to implement integrated risk management systems at the strategic level, despite the severe problems that grew out of the US Savings and Loan crisis in the 1980s and the Japanese banking crisis in the 1990s. The latter was caused by the severe decline in the land and stock markets because of high valuations and high interest rates. The former was caused by regulatory aspects associated with fixed versus variable interest rates. See Pyle (1995), Shaw, Thorp & Ziemba (1995) and Stone & Ziemba (1993) for analyses of these crisis situations, respectively. Funds are often allocated based on a short-term notion of risk – called value at risk (VAR). Recently, however, a thrust has begun to employ tactical risk management systems that tend to be one or two period models such as Algorithmics's risk-watch; see Dembo (1995). For discussions, see e.g. Davidson (1996), Jorion (1996a,b) and Linsmeier & Pearson (1996). Banks rarely employ traditional asset allocation strategies since their portfolios consist of fixed income, real estate and other illiquid asset categories. J.P. Morgan and others are active in this area. Zenios's paper discusses stochastic programming models for fixed-income securities using interest rate contingencies. Portfolios of mortgage backed securities provide the setting for the empirical analyses.

D. Portfolio and mutual fund managers

Many fund managers aim to beat a specified index such as the S&P 500 or the Russell 2000 (small cap stocks), and they are evaluated based on their risk-adjusted performance compared to the benchmark index. An interesting example is Keynes' management of the trading assets of King's College, Cambridge from 1928–45, see Chua & Woodward (1983). In this context, the index equates to the liabilities – the investment goal is to compute risks relative to return on the index. Portfolio managers place constraints on the investments. Asset categories can vary widely, such as broad categories, or sub-indices such as industry sectors, or even individual securities. The number of decision variables increases as investment details are included.

E. Individuals

Individuals can benefit by implementing dynamic asset and management strategies. They can evaluate the level of savings and investment strategies appropriate for meeting future financial goals, such as college education and retirement. Berger and Mulvey's paper describes a multi-stage asset and liability system for individuals that optimizes over decision rules. Fan, Murray & Turner (1997) describe an implemented system for individual customers of the large Italian bank, Banca Fideuram in Rome, using multiperiod stochastic programming.

F. University Endowments

By their nature, universities must consider the long-run when managing their endowment assets. Nevertheless, goals and future liabilities influence their investment risks. This is discussed in Merton's paper in this volume. The basic idea is to locate investment opportunities that are closely correlated with liabilities and goals. All else being equal, risks are reduced by finding asset categories which display co-movements with the present value of liabilities and goals. An example is to invest in real estate for faculty housing in the neighborhood surrounding the university. This investment serves two aims: (1) it maintains the integrity of the area – a worthy goal; and (2) it assists in faculty compensation – an important liability – by supplementing salaries by means of subsidizing housing expenses. This also reduces contextual risks to surplus wealth. The Rudolf & Ziemba (1997) paper is an extension of the Merton (1969, 1990) continuous time model to include liabilities via mutual fund representations.

Another application domain involves insurance for industrial and other large corporations possessing catastrophic property loss exposure. In this case, asset categories are the company's major operating components. Liabilities refer to borrowing decisions. Goals can be dividends, purchases of other companies, etc. The result is an enterprise wide risk management system, built around the scenario generator and the multi-period optimization model. Through integrated risk management, critical insurance decisions are made at the highest corporate level as they affect the overall probability

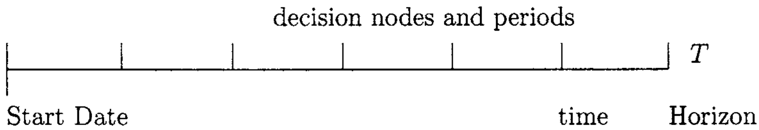

Figure 2. The Planning Period ($t = 1, 2, 3, \ldots, T$)

distribution of shareholders' surplus, rather than at lower levels of the enterprise. Insurance modifies the surplus distribution in a predictable fashion – an example of financial engineering, see Correnti *et al.* (1996). The next section highlights the primary components of long-term asset and liability management systems.

2 Model Structure

The investment process consists of $t = \{1, 2, 3, \ldots, T\}$ time stages. The first stage represents the current date. The end of the planning period, T, is called the planning horizon. Typically, it depicts a point at which the investor has some critical planning purpose, such as the repayment date of a substantial liability. In some models a separate *end effects* period represents periods $T+1, \ldots$; – see Grinold (1980, 1983) for general technique and Cariño, Myers & Ziemba (1998) for application to the Russell–Yasuda Kasai model discussed in the Cariño *et al.* paper in this volume. This technique, which assumes that the dual prices in the periods $T+1, \ldots,$ past the horizon increase in relation to the rate of interest, yields one more steady state period in the model with accompanying variables for that period.

At the beginning of each period, the investor makes decisions regarding the asset mix, the liabilities, and the financial goals. There are uncertainties between time periods. For example, the stock market and bond returns are correlated. The analysis can utilize a system of stochastic differential equations for modeling the stochastic parameters over time of asset pricing models. These relate a set of key economic factors to remaining components, such as asset and liability returns. See, for an example, the Towers–Perrin CAP:Link system discussed by Mulvey (1996b) and in Mulvey & Thorlacius' paper in this volume. Alternative modeling approaches address the integration of the stochastic and the optimization models in a different manner.

The primary decision variables designate asset proportions, liability related decisions, and goal payments, namely:

$x^s_{j,t}$ investment in asset j
$y^s_{k,t}$ liability decision k
$u^s_{l,t}$ goal payment l,
for time t and scenario s.

In each time period t, the model maximizes its objective function, $f(x)$, by moving resources between asset categories, adjusting liabilities, and achieving goals. There are several candidates for the objective function; see subsection 2.1. In addition, we impose constraints on the process such as limiting borrowing to certain ratios, addressing transactions costs whenever assets are bought or sold, or taking advantage of investment opportunities. There are several modeling approaches for including constraints. These constraints tend to provide preference relations in addition to the objective function. For example, there is utility by satisfying a constraint on a liability. These constraints also provide more curvature of the objective function which, in many cases such as the Frank Russell models, is simply the maximization of expected terminal wealth net of penalty costs on cash flows, goals, etc. Our goal is to find a feasible point, which maximizes a temporal objective function. Since we are dealing with uncertainty in a temporal setting, the optimal solution, like all points, will encompass a set of paths – trajectories – for the investor's wealth (or other measures such as surplus wealth). Ranking these paths is discussed in the next subsection.

There are two basic equations for the flow of funds:

For the jth asset category:

$$x^s_{j,t+1} = (x^s_{j,t} + r^s_{j,s}) - p^s_{j,t}(1+t_j) + q^s_{j,t}(1-t^+_j) \quad \text{for asset } j\text{, time } t\text{, scenario } s,$$

where

$r^s_{j,s}$ = return for asset j,
$p^s_{j,t}$ = sales of asset j,
$q^s_{j,t}$ = purchase of asset j
t_j = transaction costs for asset j for time t and scenario s.

For the cash flows:

$$x^s_{l,t+1} = (x^s_{l,t} + r^s_{l,s}) - \sum_j q^s_{j,t} + \sum_j p^s_{j,t}(1 - t^-_j) + w^s_t - \sum_k y^s_{k,t} - \sum_l u^s_{l,t}$$

where w^s_t = cash inflows at time t, scenario s, cash is asset category l.

The multi-stage investment model avoids looking into the future in an inappropriate fashion. The model cannot optimize over scenarios that do not represent a range of plausible outcomes for the future. To prevent this occurrence, non-anticipatory constraints are added to the model which have the form:

$$x^{s_1}_{j,t} = x^{s_2}_{j,t}$$

for all scenarios s_1 and s_2 inheriting a common past up to time t, that is these prior decisions must be the same; see Rockafellar & Wets (1991).

The financial planning system addresses these non-anticipatory conditions, either explicitly or implicitly, and special purpose algorithms are available for solving the stochastic optimization model.

2.1 Objective Functions

A major element of asset and liability management involves trading off risks and rewards. The standard assets-only theory based on capital asset or arbitrage pricing theory, see e.g. the papers in this volume by Beckers, Connor & Curds, and Chaumeton, Connor & Curds. Connor & Korajczk (1995), survey asset pricing models. Chaumeton *et al.* argue that six fundamental risk factors – four for stocks and two for bonds – explain most of the common volatility of individual international stocks and bonds. The cross-national component of the risk factors is stronger within the European Union than it is elsewhere. Their model is useful for worldwide asset selection and allocation decisions. Ferson (1995) and articles in the companion volume Keim & Ziemba (1998) assume that investments possessing more volatility generate greater expected returns over time than assets with lower levels of volatility. For a factor model that argues the opposite for several countries, see Haugen & Baker (1996). Early multiple fundamental anomaly factor models appear in Jacobs & Levy (1988) for the US and Ziemba & Schwartz (1991) for Japan. The latter is discussed by Ziemba & Schwartz in Keim & Ziemba. The articles by Beckers *et al.* and Chaumeton *et al.* have an international setting in the factor model tradition of their firm BARRA. The temporal issue complicates the decision since longer term horizons dictate a longer time span to recoup losses, thus the more volatile assets may be, in fact, safer in terms of contextual risks. An example is the stock/cash comparison: stocks provide higher expected returns but are more volatile than cash. Indeed, the longer the horizon, the safer are the high return high variance assets. We must consider the time horizon in measuring contextual risks. The paper by Brennan and Schwartz in this volume analyzes this issue among other questions using a Merton-type continuous time instantaneous model where the asset returns depend upon fundamental factors such as interest rates, dividend yields, price–earnings ratios and the like. They show the effect of the time horizon and demonstrate that higher return riskier assets do seem to be safer the longer the horizon.

There are numerous ways to evaluate financial risks, just as there are alternative measures of profitability. We might consider the chance of a loss over the next year to be 15%. Or, we might set a profitability target and evaluate the probability of missing the target. In both cases, risk increases as a function of probability. An improved alternative for evaluating risks is to