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# On the application of efficient hybrid heuristic algorithms – An insurance industry example

Tzu-Yi Yu[a,*], Yung-Tsung Lee[b], Hong-Chih Huang[c]

[a] National Chi Nan University, Nantou, Taiwan
[b] National Chiayi University, Chiayi, Taiwan
[c] National Chengchi University, Taipei, Taiwan

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ABSTRACT

This paper proposes an optimization approach for generating an investment strategy for multi-period asset-liability management of long-term with-profit life insurance policies. Our approach uses models to simulate the processes insurance companies employ when determining multi-period investment strategies over a given planning horizon. The approach utilizes an enhanced heuristic algorithm to determine optimal multi-period investment strategies. Simulation models take into account asset numbers, objective functions, and asset allocation frequency. Strategy performance is evaluated by applying three single-period investment strategies to the simulation models. Computational results not only verify the efficiency and robustness of the algorithm, but also demonstrate the effectiveness of frequent asset reallocation, and dispute the suitability of traditional top-down investment strategies in maximizing investment returns of with-profit insurance policies.



## 1. Introduction

Over the last few decades, improvements in mortality rates have necessitated a reassessment of the different products offered by the insurance industry. Common products such as pension plans are now facing ever-greater challenges in performing their intended function of protecting retirees from outliving their resources. The recent global financial crisis has drawn this issue into even sharper focus, as overburdened governments and businesses attempt to provide benefits to retirees.

Insurance policy types have many different classifications. The two most common types are referred to as "with-profit" and "unit-linked". A conventional non with-profit and non unit-linked life insurance policy implies that the policyholder earns the assumed (guaranteed) interest rate of the contract, i.e., the interest rate taken into calculations to determine the value of a contract. With conventional policies, the insurance amount is specific, and insurers take on investment risk. This means that policyholders' earnings are guaranteed by that interest rate and are irrelevant to the profit or loss of the insurance company. On the other hand, a with-profit policy (referred to as a "participating policy" in the US) provides an assumed interest rate generally lower than that of a conventional policy, but provides company share dividend payments. This is intended to reduce potential insurer loss when the assumed interest rate is greater than the actual return rate. As the assumed interest rate of a with-profit policy is less than that of a conventional policy, the price of the with-profit policy is greater. This reduces the investment risk faced by insurers and enables them to have the flexibility to pursue a more aggressive investment policy aimed at achieving long-term capital growth. Policyholders are willing to pay a higher premium for the opportunity to share in higher potential profits. Policyholders receive this benefit through dividends, usually an increase in the insurance amount, when the actual return rate is greater than the assumed interest rate. However, the dividend mechanism is not transparent and clear to policyholders, as the dividend amount is determined by the insurer as well as market competition.

"Unit-linked policies" (referred as "variable life policies" in the US, or "segregated funds" in Canada) are a type of insurance that provides both life insurance and investment opportunity. For conventional life insurance policies, including with-profit and unitized with-profit policies, insurers have the authority to manage funds (premiums) collected from policyholders. This type of fund is referred to as a "general fund" when discussing separate funds for

* Corresponding author. Present address: No. 1, University Road, Puli, Nantou Hsien 545, Taiwan. Tel.: +886 49 6003100x4673; fax: +886 49 2915205.
*E-mail addresses:* tyyu@ncnu.edu.tw (T.-Y. Yu), engtsong@mail.ncyu.edu.tw (Y.-T. Lee), jerry2@nccu.edu.tw (H.-C. Huang).

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unit-linked policies. Most of the premiums (minus their deductions to general fund) of a unit-linked policy are located in a separate fund. Any associated deductions are used to buy some low-level life protection and pay expenses. The investment component of unit-linked insurance exists as a separate fund. Policyholders have the authority to allocate his fund, i.e., separate fund, to a basket of mutual funds. However, policyholders take on investment risk and face a high level of uncertainty over the final insurance amount, as these amounts tend to fluctuate in line with stock market movements. On the other hand, policyholders can track the value of their investment as well as the insurance payout and expense charges at any given point in time, and are able to cash in if necessary. While the investment risk for policyholders is higher with unit-linked policies than in conventional policies, unit-linked policies offer policyholders both higher return potential and greater transparency.

Unitized with-profit policies emerged in the UK in the mid-1980s as consumers demanded more transparency into the design of with-profit policies [1]. In reality, unitized with-profit policies are a type of with-profit policy with united feature. The word "unitized" means that the fund is broken into units, just like united-linked policies and general mutual funds. This allows the funds to be an open-ended investment, and investors can pool assets while retaining individual net asset values. This mechanism, combined with a declared rate of interest, helps consumers understand the methods by which with-profit policy returns are determined. Part of the transparency of unitized with-profit policies comes from a specific interest rate declaration process similar to the determination of declared interest rate, $r_p$, discussed in this paper. Policyholders realize the investment return of their premiums based on this declaration. In contrast, policyholders of with-profit policies cannot appreciate the return rate of their premiums when there is an increase of the insurance amount or when the insurer makes a profit.

Unitized with-profit policies combine the with-profit policy advantages of participating in insurer profits with the transparency of unit-linked policies. Unitized with-profit policyholders are aware of the value of their investment at any given point in time and are able to cash in if necessary. They also have the chance to achieve an increased return without taking on the risk of investment. In addition, most unitized with-profit policies provide policyholders with the flexibility to change premiums. We have outlined the features of each type of life insurance policy in Table 1.

While the risk associated with unitized with-profit contracts, as with virtually all insurance contracts, includes risk from financial markets, surrenders, and mortality, our study focuses on financial risk. Since the interest rate is declared in advance, it is vital that insurers issuing unitized with-profit contracts take the declared interest rate into account. For example, if the insurer pursues an aggressive investment strategy during the life of a contract and an initial bull market is followed by a bear market, the insurer may suffer serious losses due to excess payments during the bull market period. To reduce financial risk posed by unitized with-profit policies, the approach outlined in this paper utilizes a hybridized evolutionary algorithm to explore optimal asset allocation.

## 2. Models

Typical investment strategies attempt to diversify investment through asset allocation to achieve a high level of return while lowering potential risk. The Markowitz mean-variance (MV) model is widely regarded as the gold standard for asset allocation [2–4]. The MV approach is practical for solving the problem of single-period asset allocation under a restrictive set of assumptions. However, a single-period investment is not suitable for long-term obligations such as insurance liabilities, which extend over a period of five or more years. Applying the MV approach to problems of multi-period asset allocation is also problematic; consequently, mean-variance portfolio optimization is inadequate for insurance liability asset management.

Current popular methods for solving multi-period asset allocation are control theory [5,6] and the Martingale approach [7,8], which are widely applied to financial optimization models. However, the objective of these two approaches is to find a theoretical solution to multi-period asset allocation problems. They fail to deal with realistic objectives owing to their theoretical nature. In order to get a closed-form solution, many real-world issues, such as transaction costs and limitations on the proportion of asset allocation for some specific assets, must be ignored in order to prevent problems from becoming too complex. While these approaches elegantly provide insight into asset allocation problems, they are inapplicable in practice. For example, the proportion of asset allocation for specific assets may be subject to regulatory limits, or there may be a certain probability of insolvency in the objective or constraint function. Neither control theory nor the Martingale approach can obtain a closed-form solution to meet these simple constraints. Linear programming is also incapable of solving complicated asset allocation models, since many are nonlinear [9]. Instead, heuristic algorithms have become the most commonly used techniques for optimization problems, as they provide a general-purpose modeling framework capable of considering a multiplicity of constraints. Practitioners evaluate asset allocation issues through simulations, which enables them to realize potential outcomes over a set of return scenarios with specific asset allocation strategies. Among the heuristic algorithms, the Evolutionary algorithms have been successfully applied to many research fields and became useful simulation tools [9–13].

This paper proposes an optimization approach to generate an optimal investment strategy for multi-period asset liability management of long-term with-profit policies. The objective function considers both investment returns and insolvency risks. The optimal multi-period investment strategy allows insurance companies to achieve the highest investment return while minimizing insolvency risk. Our simulation models replicate the decision processes of insurance companies in determining multi-period investment strategies over a given planning horizon, and a hybrid heuristics algorithm integrated into the simulation models determines optimal multi-period investment strategies. For illustration purposes, a set of equal-probability scenarios of future returns are simulated using Wilkie's investment model [14]. Each scenario represents one potential uncertain return over the planning horizon, and a large scenario set represents highly unlikely market swings. Given a set of plausible scenarios of future returns (e.g., 1000 equal-probability scenarios of returns over 10 years), we developed a simulation model to calculate the terminal profit and insolvency probability for a given multi-period investment strategy. Evolution strategies integrated into the simulation models enable our approach to obtain the optimal investment strategy, and we include different simulation models based on asset numbers, objective functions and asset reallocation frequency. Three single-period investment strategies (conservative, somewhat aggressive and aggressive) were chosen to evaluate the performance of the multi-period investment strategies produced. The information used to generate different scenarios for Wilkie's model is presented in Appendix A. Based on that information, the interested reader may reproduce the approach using the algorithms presented in this study.

Asset liability management for with-profit policies is an important and challenging undertaking for insurance companies, primarily because of the guaranteed returns it provides to policyholders. Since these types of liabilities are long-term in nature, an appropriate investment strategy is required to match them.