**Term Project**

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**A Stochastic Retirement Planning Tool**

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In this project, your job is to construct a stochastic financial planning tool (FPT) to assist an individual investor who is managing a defined contribution pension plan. Our investor Jennifer Lee must decide the proper level of savings for her retirement plan, the optimal asset allocation before and during retirement, and a plausible date for her retirement to begin. A critical element is to display the tradeoffs in an intuitive manner, among the various policy rules and to offer gentle recommendations, as appropriate. You will build a Monte Carlo simulation system, linked to an optimization component.

Your software tool must be developed in a full programming language (not excel), such as R, Python, Java, AMPL, or Matlab. Students can work alone, or in teams of two or three people. In the latter case, there are extra questions and extensions. The report will be evaluated for completeness, depth of the analysis, and especially readability. Teams will be given a single grade.

Project due date: Monday January 19, 2015 at 5 pm - sharp.

**Scenario Generator**: The first step is to implement a stochastic scenario generator for the performance of the asset categories. In this effort, there are four asset categories – S&P 500 index, long U.S. government bonds, cash, and the FTSE commodity index. The commodity index should be treated as an overlay security (with a maximum of 50% capital). No borrowing is allowed for DC pension plans. **The scenarios should be provided for very long horizons – from the investor’s current age to 100 years old** – **and with annual time steps.** Start with **1000 scenarios**; apply the antithetic-variate approach for variance reduction. Assume that inflation-adjusted expected returns are as follows:

S&P 500 return = 6%, Government bonds = 2.5%, cash = 0.5%, FTSE index = 5%, with temporal independence across the annual time steps.

The covariance matrix is derived from historical return as conduced in homework #6. Assume a multi-normal distribution for generating the scenarios.

*All input parameters should be assigned to a simple input file so that they can be readily adjusted for sensitivity analysis, and for implementation for other investors. The system will be judged by its flexibility and generality. The software should be turned in along the recommendation report.*

**Current Conditions:** Jennifer has a steady job with a large financial company in Philadelphia Pennsylvania – age = 35, salary = $175,000. She anticipates that her salary will increase 2% per year (deterministic, after inflation) going forward.

Her employer Vanguard provides 4% of her salary contribution to a DC pension plan, matched 1-to-1 for any further contribution up to another 4% -- total = 12%. In addition, she can add 6% as a voluntary contribution – total = 18% maximum savings per year in the DC plan. Assume that all savings are given out at the end of each year. For the purposes of this analysis, we assume that Jennifer will remain with Vanguard or a firm with a similar contribution policy.

Jennifer has always been a diligent saver. She has $60k in her current DC plan, and another $60k in savings outside retirement. She plans to set aside 20% of her salary each year, either placed in her retirement plan or in taxable account (also aimed at supporting her during retirement). In the latter case, she must pay taxes (at 30% level) before she can contribute funds in the taxable account. We assume that funds in the taxable account will accumulate and taxes will be paid each year at 10% on any gains (with tax advantages for losses). No taxes are required for any spending in the non-retirement account when taking withdrawals during retirement. We assume that Jennifer will never dip into either account for any non-retirement purpose.

In contrast, ordinary income taxes must be paid when capital is withdrawn from the D.C. plan during retirement (again at 30% rate). A significant issue for Jennifer involves the decision to split savings between retirement and non-retirement.

**Longevity Issues:** For simplicity, we assume that Jennifer will live at least to age 75 for purposes of this analysis, and the attached table will dictate further longevity. The financial planning tool should implement a Markov matrix approach for longevity after age 75 (for the team questions). Jennifer has a modest goal to provide a bequest to her sister upon her passing, as funds are available.

**Goals.** Jennifer has only a vague idea of the best retirement date. Her husband Bill has been advocating an early retirement – such as age 60 (both Jennifer and Bill are the same age), but Jennifer is skeptical that they can manage comfortably thereafter. For her independence, we will only consider Jennifer for the retirement planning evaluation herein.

Jennifer would like to retire when her total savings generates adequate cash to support her retirement expenses. For this analysis, she is aiming to spend[[1]](#footnote-1) during retirement: 70% of her average salary over the three years prior to retirement (if she retires at age 68 or younger; otherwise she will be satisfied with her average salary from ages 66 to 68 if she retires after age 68). She expects to receive social security income = $30k at age 68 – and these funds will help support her during the years thereafter, either to increase savings, or for spending if she has retired before or at age 68.

For the first step, she is aiming to spend 4% of her total savings each year during retirement – if all funds are taken from her DC plan. Otherwise, any capital taken from the non-retirement savings has a 30% bonus as compared with retirement funds (since taxes are assumed to have been paid as capital gains over the years).

**Policy Rules:** As we know, the discovery of sound and robust policy rules is an eternal quest and depends upon a variety of well-developed rules of thumb. For example, the age dependent rule has received enormous press. As an example, the Bogle variant states that the percentage in stock should be 100 minus the investor’s-age. In comparison, the fixed mix rule can be quite good over long time periods.

**Stay tuned: We will propose a few policy rules in updates over the next few days.**

Possible policy rules:

1. There might be an advantage to reducing risks when Jennifer is close to attaining her goals. For example, you might compute her funding ratio (with future inflows counted and discounting at the government bond rate = 2.5%). If this ratio is equal to or greater than one, Jennifer could switch to an all-bond portfolio and retire at age 68 with certainty. However, she would give up the opportunity to retire early if she immunizes herself.
2. It is generally thought that stocks provide greater upside potential over long time periods and that individuals should switch to a greater portion of bonds, as they get closer to retirement. Another line of reasoning suggests that the proportion of equity should remain relatively high throughout one’s working years. The latter is based on projections that lifespans will increase greatly over the next decades with breakthroughs in medicine and health care technology. A policy rule might allow for a change in the asset allocation at fixed time junctures – such as every ten years – as a way to span these concepts.

**Integrated Planning System:** The planning system will consider alternative policy rules such as the split between retirement savings and non-retirement savings and various asset allocation proposals.

Jennifer’s current goal is to retire at age 68. But she is somewhat flexible if her savings are inadequate to support her lifestyle at that time. Show the range of capital values and possible retirement dates that she might expect via the alternative policy rules.

Write a carefully constructed report with clear recommendations and an explanation of your analysis and process for arriving at your recommendations. What questions would you ask Jennifer to assist with the next steps? What should she be looking out for? Assume that she is willing to meet you annually for a financial health checkup.

**Questions:**

**For everyone:** Show the distribution of her savings in both the retirement and the non-retirement account at select ages – 60, 65, 68, 70, and 75, and the probability of meeting her retirement goal, for various asset allocation mixes. Also, show the range of dates for which she might achieve her retirement goals if she waits longer for retiring. Assume that the level of spending increases by .30% of capital each year after age 68, thus she can spend 4.6% of capital at age 70. You should provide one and two standard deviation ranges.

Should Jennifer max-out the retirement side of her savings? What are the pros and cons of selected splits between savings for retirement and non-retirement accounts? Herein, we assume, as above, that Jennifer saves 20% of her salary each year no matter what.

What is the distribution of ages that Jennifer achieves her retirement goal, again for various asset allocation mixes? Show the accompanying retirement diamonds.

**For teams of two and three students:** Develop and test alternative policy rules for Jennifer during retirement. Assume that she can reduce her retirement needs by 15% per year if stock markets take a large hit – similar to Princeton’s “worst-case” rule. Address the issue: should Jennifer take money from the D.C. retirement account or her taxable retirement account during the early years of retirement?

**For teams of three students:** Assume that Jennifer can borrow funds before retirement at 3% per year (after taxes) up to 50% of her non-retirement capital or 40% of her annual salary – whichever is larger. Analyze this contingency for viability. What are the pros and cons?

Team reports should be thorough and more comprehensive than those completed by single-person projects.

1. Ordinary income taxes will be taken out of the spending. [↑](#footnote-ref-1)