The Asset Location Puzzle: Taxes Matter*

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Abstract

Asset location decisions observed in practice deviate substantially from the predictions of theoretical models. This paper develops a life cycle model with a progressive tax system to quantitatively evaluate two explanations of the asset location puzzle. We find that taxes matter significantly for asset location decisions. The key mechanism is the benefits from pre-tax accumulation. We also find that for reasonable parameter values the precautionary motive is not quantitatively important in terms of its effect on asset location.

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1 Introduction

Households with assets in both taxable and tax-deferred accounts need to decide where to hold assets (whether in taxable or in tax-deferred accounts).[1] This is referred to as the "asset location" decision. Asset location decisions observed in practice deviate substantially from the predictions of theoretical models (e.g., Amromin, 2003; Dammon, Spatt, and Zhang, 2004). Survey data show that tax-deferred accounts are the preferred location for stocks, while theoretical models suggest that households should hold taxable bonds in tax-deferred accounts. This discrepancy has been termed the "asset location puzzle."

Two explanations have been proposed as potential resolutions of the "asset location puzzle": (i) pre-tax accumulation of stock returns which we call the "compounding stock returns" explanation (Shoven, 1999); and (ii) precautionary motive (Amromin, 2003). If labor income is risky, households are likely to hold low-risk assets (taxable bonds) in taxable accounts due to the precautionary motive. This is because stocks are risky and there is a penalty on early withdrawal from tax-deferred accounts in the United States. The goal of this paper is to quantitatively evaluate whether the "compounding stock returns" explanation and/or the precautionary motive can account for households' asset location decisions.

Using survey data, recent literature has found that households maintain a higher equity position in tax-deferred accounts than in taxable accounts (e.g., Bodie and Crane, 1997; Amromin, 2003; Bergstresser and Poterba, 2004). According to the 2001 Survey of Consumer Finances (SCF), only 52% of households with assets in both types of accounts hold

[1] Examples of tax-deferred accounts in the United States include Individual Retirement Accounts (IRAs), KEOGH, and employer sponsored defined contribution plans such as 401(k) and 403(b).

stocks in taxable accounts, while 81% hold stocks in tax-deferred accounts. For stock market participants, the mean stock share of financial assets in taxable accounts is 61%, while the mean stock share of financial assets in tax-deferred accounts is 80%.

Theoretical models, however, suggest that tax-deferred accounts should be specialized in higher-taxed assets (taxable bonds). Households are advised not to hold taxable bonds in taxable accounts if an opportunity to move them to tax-deferred accounts exists. Black (1980) and Tepper (1981) make this tax arbitrage argument in a static setting when they analyze optimal investment policy for corporations facing a choice between two accounts with different tax treatments. Auerbach and King (1983) show that this arbitrage extends to individuals making choices between taxable and tax-deferred accounts. Recently, Dammon, Spatt, and Zhang (2004) numerically solve a life cycle model to investigate household asset location decisions and conclude that it is optimal for households to hold taxable bonds in tax-deferred accounts and stocks in taxable accounts. The underlying reasons for their results are: (i) interest income of bonds is taxed at a higher rate than long-term capital gains (capital gains account for most of stock returns), and (ii) only realized capital gains are taxed and households can take advantage of the tax-timing option of stocks to defer capital gains realizations in taxable accounts. One caveat of Dammon, Spatt, and Zhang (2004) is their treatment of taxes. They use a fixed proportional tax system which affects the measure of taxes and the benefits from pre-tax accumulation.[2]

This paper develops a life cycle model to revisit the "asset location puzzle." Households in the model face stochastic labor income, borrowing and short-sale constraints, a progressive tax system, and different tax treatments for taxable and tax-deferred accounts.[3] Given

[2]They also assume that pre-tax nonfinancial (labor) income is a constant fraction of a household's total beginning-of-period wealth prior to age 65 and zero thereafter (there are no social security benefits).

[3]Labor income and interest income are taxed at progressive rates. For stock returns, we consider both

that tax-deferred accounts are mainly for retirement, a life cycle model with a progressive tax system is needed in order to accurately measure taxes on each asset and the benefits from pre-tax accumulation.[4] The model predicts that tax-deferred accounts are the preferred location for stocks for reasonable parameter values. This is because: (i) if stocks are held in tax-deferred accounts, the balance in tax-deferred accounts grows faster to the advantage of households due to higher average stock returns and pre-tax accumulation, and (ii) tax rates are normally lower in retirement periods when households withdraw funds from tax-deferred accounts than in previous periods. This makes pre-tax accumulation more valuable. Thus, taxes matter significantly for asset location decisions.

For a given tax code, our sensitivity analysis shows that how often capital gains are realized is crucial for determining optimal asset location. For a given capital gains realization rate, changes in the tax code may have a large effect on optimal asset location, particularly when there is a change in the tax rate on realized capital gains. Both tax code and capital gains realization rate are important for asset location decisions because they affect the benefits from pre-tax accumulation. We also find that a small probability of a disastrous labor income draw, which is the basis for the precautionary motive explanation, is not quantitatively important in terms of its effect on asset location.

Understanding whether households make optimal asset location decisions is important because: (i) assets held in tax-deferred accounts are a large and growing component of household net wealth in the United States; and (ii) these tax-deferred accounts are widely

dividends and long-term capital gains. Dividends are taxed at the ordinary income tax rate. Long-term capital gains are taxed at different rates, which are lower than ordinary income tax rates. All taxes in taxable accounts are paid on an on-going basis, while tax-deferred accounts defer tax payments until withdrawal.

[4]See examples in Appendix A.

held by households.[5] A number of earlier studies have examined asset location decisions when households have the choice between two accounts with different tax treatments.[6] Shoven (1999) uses deterministic examples to show that holding stocks in tax-deferred accounts is the right asset location strategy for most households and most circumstances. Using actual returns over the 1962 - 1998 period, Poterba, Shoven, and Sialm (2001) confirm that households tend to accumulate higher wealth levels by retirement by locating equity in tax-deferred accounts. Shoven and Sialm (2003) analyze a two-period model and show that corporate bonds and stocks with high distributions have a preferred location in tax-deferred accounts, and that tax-exempt municipal bonds and stocks with low distributions have a preferred location in taxable accounts. Garlappi and Huang (2006) also consider a two-period model. This paper differs from the studies cited above by focusing on the quantitative importance of taxes for households' asset location decisions.

Amromin (2003) uses a three-period model to study the effect of the precautionary motive on asset location decisions. The key message is that stricter accessibility restrictions on tax-deferred accounts and a stronger precautionary motive are associated with lower equity shares in regular taxable accounts, and with higher equity shares in tax-deferred accounts. However, a three-period setting may not be suitable to study the exact effect

[5]In 2003, IRA assets stood at $2.8 trillion, and 401(k) assets were estimated at $1.8 trillion (Vanguard Group, 2004). The U.S. Flow of Funds Accounts show that financial assets held in tax-deferred accounts accounted for 17% of total financial assets at the end of 2001 (Bergstresser and Poterba, 2004). According to the 2001 SCF, 46% of households have assets in both taxable and tax-deferred accounts. Assets held in tax-deferred accounts by these households account for more than 30% of their total financial assets.

[6]For the general effect of taxation on household portfolio choice, see Poterba (2002). For a discussion of whether saving in tax-deferred accounts represents new saving and its effect on capital accumulation, see Imrohoroglu et al. (1998), Bernheim (2002), and Gale and Orszag (2003).

of the precautionary motive. In contrast, the life-cycle model examined in this paper can better study the effect of the precautionary motive, particularly when there is a possible disastrous labor income draw.

Finally, this paper is also related to the extensive literature on asset allocation decisions (how much of each asset to hold), which focuses on two issues: stock market participation and life-cycle portfolio profiles.[7] However, this literature largely abstracts from the asset location problem, which is the focus of this paper.

The paper is organized as follows. Section 2 discusses the model's assumptions and set-up. The data and benchmark parameterization are presented in section 3. Section 4 shows the simulation results for the benchmark case and performs a number of other experiments. Finally, section 5 concludes. For the construction of variables from SCF data, see Appendix B. For the numerical procedure used to solve the model, see Appendix C.

[7]Empirical studies show that there is significant non-stockownership. See Mankiw and Zeldes (1991), Ameriks and Zeldes (2004), Bertaut and Starr-McCluer (2002), Guiso, Haliassos, and Jappelli (2002), Vissing-Jorgensen (2002), and Campbell (2006). Models of portfolio choice normally predict that, given the equity premium and the assumption of CRRA utility, all households should participate in the stock market as long as saving takes place. There is also a large literature on life-cycle portfolio profiles. Traditional models show that the stock share of financial assets is constant under some conditions. See Merton (1969) and Samuelson (1969). It is common for financial advisors to suggest that households should invest more in stocks when they are young and shift their investments towards safe assets as they age. See Malkiel (1996). The basic economic reason is given by Bodie, Merton, and Samuelson (1992) and Jagannathan and Kocherlakota (1996). Recent studies by Viceira (2001), Cocco, Gomes, and Maenhout (2005), and Gomes and Michaelides (2005) show that the optimal share of financial wealth in equities generally decreases with age.

2 Model

We consider a discrete time life cycle model where households live for J periods and maximize their life-time discounted utility from consumption. There are two financial assets in the economy: bonds and stocks. Both assets can be held in taxable or tax-deferred accounts. Households face idiosyncratic labor income shocks, stock return uncertainty, and a progressive tax system. All households have access to both taxable and tax-deferred accounts. They need to make asset allocation and asset location decisions at the same time.

2.1 Preferences

Households have preferences defined over a consumption stream. The preferences are represented by

$$E_1 \sum_{j=1}^{J} \beta^{j-1} \frac{C_j^{1-\gamma}}{1-\gamma} \tag{1}$$

where $\beta < 1$ is the discount factor, γ is the coefficient of relative risk aversion, and C_j denotes consumption in period j.

2.2 Labor Income Process

Households work in the first $K < J$ periods. After K, households are retired and receive their retirement income. J and K are assumed to be exogenous and deterministic.

In each working period $1 \leq j \leq K$, households receive a stochastic endowment. Following the standard specification in the life-cycle literature, we consider both persistent and transitory income shocks.[8] The income of household i in period j, Y_{ij}, is exogenously given

[8] See Carroll (1992), Carroll and Samwick (1997), Hubbard, Skinner, and Zeldes (1994, 1995), Huggett and Ventura (2000), Gourinchas and Parker (2002), and Gomes and Michaelides (2005).

by:

$$log(Y_{ij}) = \bar{y}_j + z_{ij} + u_{ij} \tag{2}$$

where $\bar{y}_j$ is the mean log income of all period j households; the transitory shocks, u_{ij}, are independent and identically normally distributed $N(-\frac{1}{2}\sigma_u^2, \sigma_u^2)$; and the persistent shocks, z_{ij}, follow an AR(1) process:

$$z_{ij} = \rho z_{ij-1} + \xi_{ij} \tag{3}$$

where ξ_{ij} are independent and identically normally distributed $N(-\frac{1}{2}\sigma_\xi^2, \sigma_\xi^2)$ and are uncorrelated with u_{ij}. We also assume $\bar{y}_j = log(G_j) + \bar{y}_{j-1}$, where G_j governs the age-profile of $\bar{y}_j$.

When $j > K$, the household i is retired. Retirement income is given by:

$$log(Y_{ij}) = log(\lambda_i(z_{iK})) + \bar{y} + z_{iK} \tag{4}$$

where $\bar{y}$ is the mean of $\bar{y}_j$ for all $1 \leq j \leq K$, and the replacement rate (λ_i) depends on household i's persistent income shock in period K (z_{iK}).[9] This specification simplifies the solution of the model since we do not need to track the household's entire income history.

2.3 Financial Assets, Accounts, and Taxation

There are two financial assets in the economy: a riskless asset (called a "bond") and a risky asset (called a "stock"). No transaction costs are incurred for trading these assets, and short sales are not allowed. The riskless asset yields a constant real return r^b. The real return on the stock in period j, r_j^s, is given by

$$r_j^s - r^b = \mu^s + \epsilon_j^s \tag{5}$$

[9]Retirement income is modeled as a fraction (the replacement rate) of lifetime average earnings, where lifetime average earnings depend on a household's persistent income shock in period K.

where μ^s is the average before-tax real equity premium, and ϵ_j^s is assumed to be i.i.d. over time and distributed as $N(0, \sigma_\epsilon^2)$.[10]

Both assets can be accumulated in two accounts: a regular taxable account (TA) and a tax-deferred account (TDA). In the TA, all taxes are paid on an on-going basis. Labor income and interest income are taxed at the ordinary income tax rate, τ^l. The stock returns are taxed at the rate τ^s.

The TDA defers tax payments on contributions and returns. Throughout working life $j \leq K$, each household can contribute to the TDA up to a fraction $\bar{q}$ of before-tax labor income in each period. We assume that borrowing is not allowed in either account. However, assets in the TDA can be accessed prior to some age at the cost of a penalty rate $\phi \in (0, 1)$ in addition to income tax τ^l.[11] During retirement periods, contributions to the TDA are not allowed, and the household must withdraw funds from the TDA. There is minimum required distribution during retirement periods ($j \in [K + 1, J]$).[12] The household pays tax on the withdrawals at the ordinary income tax rate τ^l.

We incorporate a progressive income tax code in the model, which means both τ^l and τ^s depend on the household's income level. As in Ventura (1999), the income tax code is comprised of a number of brackets, defined by different thresholds with corresponding different marginal tax rates. Each household's income subject to ordinary income taxation is defined to be the sum of labor income (net of contributions), interest income in the TA, and withdrawals. Stock returns consist of both dividends and capital gains. Dividends in the TA will be taxed as ordinary income. The tax rate on realized capital gains in the TA

[10]We choose ϵ_j^s in the range from $-2\sigma_\epsilon$ to $2\sigma_\epsilon$.

[11]Distributions before age $59\frac{1}{2}$ are subject to penalties (with exceptions) for many tax-deferred accounts.

[12]According to the current regulations in the United States, individuals must begin to take withdrawals by age $70\frac{1}{2}$.

depends on the marginal ordinary income tax rate the household faces. More details on the tax code are provided in section 3.7.

2.4 Wealth Dynamics and Households' Optimization Problem

In each period households choose their contributions to (withdrawals from) the TDA, consumption, and stock shares in both accounts. For household i, let α_{ij}^T and α_{ij}^D denote the shares of TA and TDA wealth invested in stocks in period j, respectively. Let W_{ij}^T be the after-tax financial wealth in the TA plus current labor income at the beginning of period j (before current contributions and consumption). Similarly, W_{ij}^D is the wealth in the TDA at the beginning of period j (before current contributions). We first consider $j \leq K$ (working periods). The wealth dynamics are given by (we drop i here):

$$W_{j+1}^T = R_{j+1}^T [W_j^T - q_j Y_j - (1 - q_j) Y_j \tau_j^l + X_j (1 - \tau_j^l - \phi) - C_j] + Y_{j+1} \tag{6}$$

$$W_{j+1}^D = R_{j+1}^D (W_j^D + q_j Y_j - X_j) \tag{7}$$

where $R_{j+1}^T = \alpha_j^T [1 + r_{j+1}^s (1 - \tau_{j+1}^s)] + (1 - \alpha_j^T)[1 + r^b (1 - \tau_{j+1}^l)]$ is the gross after-tax return on the portfolio held in the TA from period j to period $j+1$, Y_j is the labor income in period j, $q_j \in [0, \bar{q}]$ is the contribution rate, X_j is the amount of withdrawal from the TDA (if $q_j > 0$, $X_j = 0$), and C_j is consumption.[13] In equation (7), $R_{j+1}^D = \alpha_j^D (1 + r_{j+1}^s) + (1 - \alpha_j^D)(1 + r^b)$ denotes the gross return on the portfolio held in the TDA from period j to period $j + 1$.

When $j > K$ (retirement periods), the wealth dynamics are:

$$W_{j+1}^T = R_{j+1}^T [W_j^T - Y_j \tau_j^l + X_j (1 - \tau_j^l) - C_j] + Y_{j+1} \tag{8}$$

$$W_{j+1}^D = R_{j+1}^D (W_j^D - X_j) \tag{9}$$

[13] τ^l represents a progressive income tax code. We combine interest income, labor income, and minimum required distribution (zero in the working periods) to decide the tax rate on stock returns.

subject to the constraint

$$X_j \geq \frac{1}{J-j+1} W_j^D \tag{10}$$

which imposes a minimum withdrawal rate.

We also impose the following short sale and borrowing constraints for all j:

$$\alpha_j^T \in [0,1], \ \alpha_j^D \in [0,1] \tag{11}$$

$$W_j^T \geq 0, \ W_j^D \geq 0 \tag{12}$$

We assume that all funds are withdrawn from the TDA at the beginning of the last period.

The problem the household faces is to maximize (1) subject to constraints given by (6) to (12), to the labor income process given by (2) to (4), and to the stock returns given by (5), in addition to the non-negativity constraint on consumption. The control variables are: the contribution rate (q_j), withdrawal (X_j), consumption (C_j), the stock share in the TA (α_j^T), and the stock share in the TDA (α_j^D). There are three state variables in each period: the wealth level in the TA (W_j^T), the wealth level in the TDA (W_j^D), and the persistent income shock (z_j). The Bellman equation for this problem is given by:

$$V_j(W_j^T, W_j^D, z_j) = \max_{q_j, X_j, C_j, \alpha_j^T, \alpha_j^D} \frac{C_j^{1-\gamma}}{1-\gamma} + \beta E_j \left[V_{j+1}(W_{j+1}^T, W_{j+1}^D, z_{j+1}) \right] \tag{13}$$

The problem cannot be solved analytically. Given the finite nature of the problem, a solution exists and can be obtained by backward induction. For details see the numerical solution in Appendix C.

3 Data and Benchmark Parameterization

In this section, we provide information on how we construct measures of composition of household portfolio in taxable and tax-deferred accounts using the Survey of Consumer

Finances (SCF) data. We then outline the choice of benchmark parameter values.

3.1 Data Description

The SCF is a triennial survey that provides the most complete data on household balance sheets in the United States. It includes data on assets both inside and outside tax-deferred accounts and also contains extensive demographic information. The data summarized below are from the 2001 SCF.

Since we are interested in household asset location decisions between taxable and tax-deferred accounts, we restrict our attention to financial assets. The numerous accounts where households hold financial assets are grouped into two broad categories: regular taxable accounts (TAs) and tax-deferred accounts (TDAs). The taxable accounts include savings accounts, certificates of deposit, money market accounts, mutual funds, savings bonds and other bonds, directly owned stock, brokerage accounts, trusts and managed investment accounts, and part of miscellaneous assets. We exclude checking accounts from our measure of TAs because holdings of checking accounts are likely driven by liquidity concerns rather than asset allocation or tax issues.[14] For assets held in TAs, SCF respondents separately report the dollar value of direct stock holdings, stocks held in mutual funds, and stocks held in other accounts. Aggregating these reported stock holdings provides a measure of stocks held in TAs.

We define TDAs as retirement accounts in which the owners make pre-tax contributions (with an annual limit) and can choose the allocation of assets. These accounts include IRAs, KEOGH, and most of the defined contribution pension plans (401K/403B/SRA,

[14] When both money market accounts and miscellaneous financial assets are also excluded, the patterns reported below are similar.

Thrift Savings, and TIAA-CREF). Unfortunately, information on allocations to narrowly defined asset classes does not exist for TDAs in the 2001 survey. Thus, the composition of holdings in TDAs has to be inferred from categorical responses. For example, the question on allocation of defined contribution pension plans asks, "How is the money in this account invested? Is it mostly in stocks, mostly in interest earning assets, is it split between these, or what?" Following this question, there is a table of possible answers. We use this information to construct estimates of the asset composition in TDAs. Following Amromin (2003) and Bergstresser and Poterba (2004), I assume that: (i) all of the account value is assigned to the category that is indicated to be the single category in which "mostly or all" holdings are invested, and (ii) the account value is divided equally if a combination of categories is reported. This must of course result in measurement error in retirement account portfolio allocations.[15] More details on the data are provided in Appendix B.

We compute measures of the stock market participation rate and asset allocation in both taxable and tax-deferred accounts. Stock market participation is determined by checking whether the value of stocks in each account is greater than zero. For asset allocation, we look at the stock share of financial assets for stock market participants specifically. All statistics utilize population weights.

This leads to the following key facts. (1) 46% of households in the 2001 SCF have assets in both taxable and tax-deferred accounts. Stock holdings by these households account for 87% of total stock holdings of the entire SCF population.

[15] If we assign 90% (instead of 100%) of the account value to stock in the case of "mostly or all stock" and all else equal (e.g., stock value is still zero in the case of "mostly or all interest earning"), then the mean stock share of financial assets in TDAs will drop about 6 percentage points. The finding that stock share is higher in TDAs still holds.

(2) For households with assets in both taxable and tax-deferred accounts, the stock market participation rate is higher in TDAs than in TAs. The stock market participation rate in TDAs is 81%, while it is only 52% in TAs.

(3) Households maintain much higher equity positions in TDAs than in TAs.[16] For stock market participants, the mean stock share of financial assets in TDAs is 80%, while the mean stock share of financial assets in TAs is 61%.[17] This finding is robust when we sort households by age, income, and net worth.[18]

Next we outline the choice of benchmark parameter values.

3.2 Preference Parameters

A model period is one year. We choose the annual discount factor β equal to 0.96. The coefficient of relative risk aversion γ is calibrated so that the aggregate stock share of total financial assets for households with both taxable and tax-deferred accounts match that in the 2001 SCF given the other parameters in the benchmark. This gives $\gamma = 7$.[19]

[16]This finding is consistent with other studies (see Bodie and Crane, 1997; Amromin, 2003; Bergstresser and Poterba, 2004).

[17]To find the mean stock share of financial assets in each account, we first calculate the stock share of financial assets for each household and then take the average.

[18]One concern is that some 401(k) plans offer company stock as an investment choice for their participants. This could make TDAs biased towards stocks. However, if we only look at IRAs, we still find that the stock market participation rate and the mean stock share of financial assets in IRAs are higher than in TAs.

[19]The aggregate stock share of total financial assets is defined as the ratio of total stock holdings to total financial assets held by households. The share is 66% in the 2001 SCF for households with both taxable and tax-deferred accounts.

3.3 Labor Income Process

Households are born at the age of 25 (model period 1) and live up to the age of 85 (model period 61). They begin to receive retirement benefits at age 65 (model period 41). Thus, we set $J = 61$ and $K = 40$.

For the labor income process, first we need to specify the median income of households in period 1 and the age-earnings profile. Recall that $\bar{y}_1$ is the mean log income of all period 1 households. Let $\bar{Y}_1 = exp(\bar{y}_1)$.[20] Thus, $\bar{Y}_1$ is the median income of all period 1 households in the model and is set to \$38000.[21] G_j reflects the age-earnings profile ($\bar{y}_1, \cdots, \bar{y}_K$ or $\bar{Y}_1, \cdots, \bar{Y}_K$). We set $G_j = 1.03$ for $2 \leq j \leq 30$ and $G_j = 1.00$ for $31 \leq j \leq 40$, which implies that the median income increases at a rate of 3% from period 2 to period 30 and is constant from period 31 to period 40. The 2001 SCF shows that the annual growth rate of median household income is 1.23% from age 25 to 55 for households with both the TA and the TDA.[22] However, we also need to consider income growth over time. Thus, we set a higher income growth rate before age 55 and zero income growth between age 55 and 64.[23]

[20]If income is log normally distributed, the mean log income and the median income are related as follows: median income = exp (mean log income).

[21]This number is higher than the median income of all households at age 24 to 26 in the 2001 SCF, but lower than that of households with both TAs and TDAs at the same age. Our choice is based on the following considerations. First, households that have access to TDAs tend to have higher income compared to households without TDAs. Second, there is income growth over time. For example, the Economic Report of the President (2002, Table B-33) shows that the annual growth rate of median real family income between 1982 and 2000 is 1.31%. Thus, we choose a median income lower than the median income of current young households with both accounts.

[22]We calculate the median non-financial income for those households at age 24 to 26 and households at age 54 to 56. The non-financial income equals total income minus income from interests, dividends, capital gains, and other investment. It is not surprising that households' non-financial income drops after age 55.

[23]We also try a hump-shaped age earnings profile. We let the median income increase at a rate of 3% for

The remaining parameters of the labor income process in working periods are ρ, σ_ξ^2, and σ_u^2. Hubbard et al. (1994) estimate ρ to be about 0.95, σ_ξ^2 and σ_u^2 range from 0.016 and 0.014, respectively, for households with a college education to 0.033 and 0.040, respectively, for households with less than high school education. We set $\rho = 0.95$, the persistent shocks $\sigma_\xi^2 = 0.02$, and the transitory shocks $\sigma_u^2 = 0.04$. We discretize the idiosyncratic income shocks using Tauchen method outlined in Adda and Cooper (2003). The persistent shocks are discretized as a five-state Markov process.

3.4 Social Security Benefits

During retirement periods, households receive social security benefits. Households with different working-life average earnings have different replacement rates in the U.S. social security system. For computational tractability, we let the working-life average earnings depend on households' persistent income levels in the last working period prior to retirement. We set the replacement rates according to the U.S. social security benefit formula (with lower income households having a higher replacement rate).[24]

3.5 TDA Contributions and Withdrawal

According to Joulfaian and Richardson (2001), approximately 85% of households that participate in defined contribution pension plans contribute less than 10% of income. The average employee contribution rate is 5.9%. We set the contribution limit, $\bar{q}$, to 10% before

$2 \leq j \leq 10$, 2.5% for $11 \leq j \leq 20$, 2% for $21 \leq j \leq 30$, and decrease at a rate of 1% for $31 \leq j \leq 40$. This change does not affect the asset location decisions much. The reason may be due to the fact that a small income drop after age 55 does not change the tax brackets for most households.

[24]For the U.S. social security benefit formula, see Figure 1 in Huggett and Parra (2006).

retirement.[25] Contributions are not allowed during retirement periods. The early withdrawal penalty (before age 60), ϕ, is set at 10%. This penalty is a common feature of many tax-deferred retirement accounts in the United States.[26] During retirement we assume that households are forced to begin withdrawing funds from TDAs at age 65. We follow Dammon, Spatt, and Zhang (2004) and set the withdrawal rate to $\frac{1}{remaining\ years}$.

3.6 Asset Return Process

The constant bond return r^b is set at 3%, which is the annual real return on long-term corporate bonds reported by Ibbotson Associates (2005).[27] For the stock return we consider a mean equity premium (μ^s) equal to 4% and a standard deviation (σ_ϵ) of 16%.[28] An equity premium of 4% is a fairly common choice in the literature (e.g., Cocco, Gomes and

[25] In practice the government sets the limit allowable. In 2000, employees and their employers were allowed to jointly contribute the lesser of 25% of an employee's earnings or $30,000 to a defined contribution plan. There is a separate limit on the contribution made by employees. For example, the Internal Revenue Service (IRS) 401(k) contribution limit for employees was $10,500. The employers also impose their own limits on employee contributions in order to make it easier to pass non-discrimination tests.

[26] We do not model penalty free early withdrawals from TDAs, for example medical expenses, purchase of a principal residence, and payment of tuition for postsecondary education. The magnitude of these hardship withdrawals is small. Investment Company Institute (Spring 2000) reports that only 4 percent of 401(k) participants whose current plan allowed hardship withdrawals had taken such a withdrawal since joining the plan. The medium amount of most recent 401(k) plan hardship withdrawals was $5,100.

[27] The geometric (arithmetic) mean of the annual real return on long-term corporate bonds is 2.9% (3.1%) from 1926 to 2004. These long-term corporate bonds are nearly all AAA and AA rated bonds. The geometric (arithmetic) mean of the annual real return on long-term government bonds is 2.4% (2.7%).

[28] The mean equity premium is lower than the historical value reported in Mehra and Prescott (1985). McGrattan and Prescott (2003) reexamine the equity premium puzzle, taking into account taxes and diversification costs and focusing on long-term rather than short-term saving instruments. They find that there is no equity premium puzzle.

Maenhout, 2005; Gomes and Michaelides, 2005). 4% is also close to the expected equity risk premium reported in Fama and French (2002).

Table 1 reports the benchmark parameter values.

[Table 1 here]

3.7 Tax Code

For the income tax, our strategy is to mimic the federal income tax code in the United States prevailing in 1993 - 2000. There are 5 tax brackets, with marginal tax rates of 15%, 28%, 31%, 36%, and 39.6%. We set the taxable income thresholds at $40000, $100000, $150000, and $260000, respectively, which were roughly the thresholds during 1993-2000. In order to find the corresponding tax brackets in terms of total income, we need to approximate the complex exemptions and deductions present in the actual tax code first. We take the case of a household comprised of a couple filing jointly. The standard deduction is between $6200 and $7350 and the personal exemption is between $2350 and $2800 in 1993 - 2000. We set the sum of the standard deduction and personal exemptions to $11500, which is about 30% of $\bar{Y}_1$. We normalize $\bar{Y}_1$ as 1. Table 2 describes the marginal tax rates we use:

[Table 2 here]

Stock returns consist of two parts: dividends and capital gains. For computational reason, we do not model dividends and capital gains directly in order to reduce the dimensionality of the problem (we do not need to track unrealized capital gains). However, given the different tax treatments for dividends and capital gains in the U.S. tax code, we need to take a stand on them. We assume a constant dividend yield, 2%.[29] For capital gains,

[29] A dividend yield of 2% is also used in Dammon et al. (2004).

we only consider long-term capital gains.[30] The reason is that most gains are realized on stocks that have been held for a long time.[31] In order to abstract from questions of timing of capital gains, we assume that a fraction of capital gains are realized automatically in each period. We set this fraction to $\frac{2}{3}$ in the benchmark.[32] We will examine the effect of how often capital gains are realized by changing the capital gains realization rate in section 4.2.2.

Next, we need to set the tax rate on dividends and realized capital gains. During the 1990s, dividends were taxed as ordinary income. According to the Taxpayer Relief Act of 1997, the tax rate on realized long-term capital gains depends on the marginal income tax rate of the household. For taxpayers in the 15% bracket, the tax rate on long-term capital

[30] Given that households also realize short-term capital gains and short-term capital gains are taxed at a higher rate than long-term capital gains, this will underestimate the tax rate on stock returns in the model. There could be capital loss in the model. In reality, realized (net) capital loss in the TA can be deducted from taxable income. The limit of allowable capital loss deductions is $3,000 ($1,500 in the case of a married individual filing a separate return). We do not model capital loss deductions directly. To offset the effect of capital loss deductions, we do not tax dividends when there is capital loss.

[31] For example, Wilson (2003) shows that in the United States, long-term net capital gains realized in 1999 by selling corporate stocks were 7.3 times the short-term net capital gains.

[32] It is challenging to pin down the realization rate of capital gains. Because households can hold stocks directly or through mutual funds, we need to find the stock turnover in both cases. Barber and Odean (2004) report that the individual stock sell turnover in taxable accounts is 78.10%. We use this number as the turnover of individual stocks. Barclay, Pearson, and Weisbach (1998) claim that stock mutual funds realized an average of 38.60% of total capital gains annually in 1976 - 1992. Shoven and Sialm (2003) show that the five largest mutual funds in their sample distributed about 47% of long-term capital gains in 1962 - 1998. We choose 40% as the mutual funds capital gains realization rate. According to the 2001 SCF, individual stocks are 2.4 times the stocks held in mutual funds. Thus, the realization rate of capital gains is: 0.781*(2.4/3.4)+0.40*(1/3.4)=0.6689. This is about 2/3.

gains is 10%. For higher bracket taxpayers the tax rate is 20%. These are the tax rates used in the model.

4 Simulation Results

In this section we present and discuss our simulation results. We start with the benchmark case. Then we conduct sensitivity analysis and other experiments.

4.1 Benchmark

Table 3 reports the results for the benchmark parameter values. The benchmark predicts that the TDA is the preferred location for stocks in terms of both stock market participation rate and the average stock share of assets. The stock market participation rate is much higher in the TDA than in the TA. For households with assets in both accounts, all households in the model hold stocks in the TDA, while only 68% hold stocks in the TA.[33] For stock market participants, the mean stock share of financial assets in the TDA is 85%, which is higher than the mean stock share of financial assets in the TA (75%).[34]

The benchmark does not do well in terms of asset allocation decisions. Compared to the data, the stock market participation rate and the mean stock share of financial assets in both accounts are higher in the model.[35] This is a common problem in the literature

[33]High stock market participation rate is a common feature in the literature (e.g., Heaton and Lucas, 1997, 2000; Cocco, Gomes and Maenhout, 2005).

[34]Comparing the mean stock share of financial assets for different persistent income groups, we find that the high-income households maintain a higher equity position in the TDA than the medium-income or low-income households.

[35]Although the benchmark predicts that the TDA is the preferred location for stocks, it has the same problem as related literatures in quantitatively matching the age profile of equity proportion. Our model

given the equity premium and the assumption of CRRA preferences. We will address this problem in section 4.2.3.

[Table 3 here]

Why does this model qualitatively account for households' asset location decisions? In order to maximize their after-tax wealth, households make asset location decisions to take advantage of the feature of pre-tax accumulation in TDAs. Although the tax rate on stock returns is lower than that on bond returns, average stock returns are higher than bond returns. It is unclear by holding which type of asset in TDAs households can benefit more from pre-tax accumulation. If households never realize capital gains, they should hold stocks in TAs and bonds in TDAs because the effective tax rate on stock returns is very low and households do not benefit much from pre-tax accumulation of stock returns. However, if capital gains are realized more frequently, the effective tax rate on stock returns increases. Holding stocks in TAs may not be optimal in this case, as the benefits from pre-tax accumulation of stock returns and after-tax accumulation of bond returns could exceed the benefits from pre-tax accumulation of bond returns and after-tax accumulation of stock returns.

The benchmark results imply that households prefer to hold stocks in TDAs. This is because higher average stock returns combined with a relatively high capital gains realization rate ($\frac{2}{3}$ in the benchmark) lead to higher benefits from pre-tax accumulation of stock returns relative to bond returns. The balance in TDAs grows faster to the advantage of households by holding stocks in TDAs. A related benefit is that households normally face a lower marginal tax rate when they withdraw funds from TDAs during retirement periods.

predicts almost 100% stock holdings for young households as in Cocco, Gomes and Maenhout (2005).

This makes pre-tax accumulation more valuable. Thus, households maintain a higher equity position in TDAs than in TAs. We note that it is important to incorporate a progressive tax system and accurately measure taxes on each asset since they affect the benefits from pre-tax accumulation and hence asset location decisions.

4.2 Sensitivity Analysis

Here we perform a number of experiments by changing the parameter values within the context of the benchmark specification. Specifically, we examine the effects of a possible disastrous labor income draw, the capital gains realization rate, and the risk aversion coefficient.

4.2.1 Disastrous Labor Income Shocks

A precautionary motive may also play a role when households make asset location decisions. In the United States there is a penalty on early withdrawal from TDAs. As pointed out by Amromin (2003), if labor income is risky, households are likely to hold more bonds in TAs because stocks are risky and households try to avoid making early withdrawal. However, a three-period setting in Amromin (2003) may not be suitable to study the exact effect of the precautionary motive.

In order to better understand the effect of the precautionary motive on asset location decisions, we add another transitory income shock, a small probability of a disastrous labor income draw, and examine its effect. Caroll (1992) and Cocco, Gomes, and Maenhout (2005) consider a zero-income realization with probability 0.5%. Amromin (2003) uses a 1% income realization with probability 0.5%. However, Zhang (2003) argues that these shocks are too extreme. Here, we consider a 5% labor income realization with probability

0.5%.

Compared to the benchmark, when there is a 5% income draw with probability 0.5%, the mean stock share of financial assets in the TA drops slightly from 75% in the benchmark to 72%, reflecting the concern of liquidity needs in the TA. The mean stock share of financial assets in the TDA and the stock market participation rates in both accounts do not change.

This experiment shows that the effect of a possible disastrous labor income draw on asset location is small. The reason is the following. A small probability of a disastrous labor income draw only has a large effect on very young households that have accumulated very little financial assets. With a higher labor income risk, these young households choose to hold fewer stocks. As households age and accumulate more financial assets, a transitory income shock does not affect their decisions that much. Moreover, a small probability of a disastrous labor income draw has little impact on stock market participation. All households participate in the stock market in the model due to the equity premium and the assumption of CRRA preferences.

4.2.2 Capital Gains Realization Rate

Capital gains account for the majority of stock returns. Households can defer capital gains realizations to avoid immediate tax payment in TAs (unrealized capital gains are not taxed in the United States). Thus, how often capital gains are realized affects the effective tax rate on stocks and the benefits from pre-tax accumulation of stock returns. We expect that it also affects asset location decisions. Intuitively, if households never realize capital gains, they will prefer to hold stocks in TAs and bonds in TDAs. This is because the benefits from pre-tax accumulation of stock returns will be relatively low because the effective tax rate on stock returns is very low, while the benefits from pre-tax accumulation of bond returns will be relatively high. However, if households realize capital gains frequently, the benefits from pre-tax accumulation of stock returns increase and households' asset location decisions may change. Here we examine the effects of the long-term capital gains realization rate on asset location by setting the rate equal to $\frac{1}{3}$ and 100%, respectively.[36]

Table 4 summarizes the results. Compared to the benchmark, when the capital gains realization rate is 100%, stock returns will be taxed more heavily. We find that the stock market participation rate in the TA drops from 68% to 58%. The stock market participation rate in the TDA (100%) does not change. For stock market participants, the mean stock share of financial assets in the TA decreases, while the mean stock share of financial assets in the TDA increases slightly. A higher capital gains realization rate strengthens the prediction that the TDA is the preferred location for stocks. This is due to the higher benefits households receive from pre-tax accumulation of stock returns.

When the capital gains realization rate drops to $\frac{1}{3}$, the effective tax rate on stock returns drops considerably and the benefits from pre-tax accumulation of stock returns are much lower compared to the benchmark. Thus, it is not surprising to find that the stock market participation rate increases in the TA and decreases in the TDA. A notable change is that the mean stock share of financial assets in the TA (90%) is now higher than that in the TDA (77%). This implies that with a lower tax rate on stock returns, it is optimal for many households to hold more stocks in the TA and more bonds in the TDA. To summarize, how often capital gains are realized is crucial for determining asset location because it affects the benefits from pre-tax accumulation of stock returns.

[Table 4 here]

[36] Ideally, we would like to endogenize the capital gains realization. However, this will make solving the model computationally more difficult since we need to track stock prices for households.

4.2.3 Risk Aversion

The benchmark predicts that the TDA is the preferred location for stocks. However, the stock market participation rate and the mean stock share of financial assets implied by the benchmark parameters are higher than in the data. Here we examine the effect of different risk aversion coefficients on household asset location and allocation decisions. Because stocks are risky assets, we expect that the mean stock share will drop if we increase the risk aversion coefficient.

The effect of risk aversion is presented in Table 5. We report results for a lower risk aversion coefficient ($\gamma = 5$) and a higher one ($\gamma = 10$). The asset location decisions do not change in either case. The stock market participation rate and the mean stock share of financial assets in the TDA are higher than in the TA, as in the benchmark. The TDA is still the preferred location for stocks. Changes in the risk aversion coefficient do have a large impact on household asset allocation decisions. Compared to the benchmark ($\gamma = 7$), lowering the risk aversion coefficient increases the mean stock shares of financial assets in both accounts. It increases from 75% to 86% in the TA and from 85% to 92% in the TDA. Similar to the benchmark, all households hold stocks in the TDA. The stock market participation rate in the TA is also higher. With a higher risk aversion coefficient ($\gamma = 10$), the mean stock shares of financial assets in both the TA and the TDA decrease as expected. The stock market participation rate in the TA is much lower now. It drops from 68% in the benchmark to 58%. We notice that, when $\gamma = 10$, the results are closer to the data except that the model still predicts a much higher stock market participation rate in the TDA. To deal with the problem of high stock market participation rate, some studies introduce frictions such as entry costs to lower the participation rate (e.g., Vissing-Jorgensen, 2002;

Gomes and Michaelides, 2005).

[Table 5 here]

4.2.4 Other Experiment

The benchmark incorporates a progressive tax system. Here we change the progressive tax code to a proportional one and examine its effects on households'asset location decisions.[37] We assume that labor income and interest income (bond returns) are taxed at a constant rate of 25%. For stock returns, we consider two different rates: 8% and 12.5%.

Table 6 reports the results. The tax rate on stock returns is 8% in case I and 12.5% in case II. When the tax rate on stock returns is low (8%), the model predicts that the TA is the preferred location for stocks (see column "Prop. Tax I"). Both the stock market participation rate and the mean stock share of financial assets in the TA are higher than in the TDA. However, in case II when the tax rate on stock returns is high (12.5%), the TDA is the preferred location for stocks. Both the stock market participation rate and the mean stock share of financial assets in the TDA are now higher than in the TA. Note that the tax rate on stock returns is lower than that on bond returns in both cases.

[Table 6 here]

This experiment shows that the benefits from pre-tax accumulation is the key for determining optimal asset location. In the experiment, the tax rate on bond returns is fixed.

[37]We run an experiment where we consider state income tax and find that our benchmark results are robust to the introduction of state income tax. We also run an experiment where we consider President Bush's tax cut. Our numerical results show that the tax cut would have a great impact on households' asset location decisions if the tax cut were permanent.

When the tax rate on stock returns is high enough (as in case II), the benefits from pre-tax accumulation of stock returns are high and households prefer to hold stocks in the TDA. When the tax rate on stock returns is relatively low (as in case I), households prefer to hold bonds in the TDA. We also conduct another experiment by keeping the tax rate on stock returns fixed and changing the proportional tax rate on bond returns. We find that the mean stock share in the TA is higher when the tax rate on bond returns is high enough, while the mean stock share in the TDA is higher when the tax rate on bond returns is low enough.

4.3 Discussion

This paper does not address some related issues. For example, we do not model Roth IRA and Roth 401(k).[38] We abstract from the eligibility of (employer sponsored) tax-deferred accounts. The paper only focuses on households with assets in both TAs and TDAs since we are interested in their asset location decisions. Defined benefit (DB) pension plans may affect households' asset allocation decisions. However, we do not think DB plans are central to households' asset location decisions and do not model them in the paper. In the model setting, we let the correlation between labor income shocks and stock returns be zero, consistent with the empirical (lack of) correlation between labor income shocks and stock market returns, as documented in Heaton and Lucas (2000) and Cocco, Gomes, and Maenhout (2005).[39] It seems that the correlation between labor income shocks and stock returns may have a large effect on asset allocation decisions but not much effect on asset

[38]In contrast to tax-deferred accounts modelled in this paper, a Roth plan requires post-tax contributions. Withdrawals from a Roth plan are generally tax free, provided that some conditions are satisfied.

[39]Davis and Willen (2000) find a moderate correlation. They show that the correlation tends to rise with educational attainment.

location decisions. Housing may also play an important role when households make portfolio choices and it is not included in the model. Given the liquidity need (down-payment or mortgage payment) takes place in TAs and there is a penalty on early withdrawal from TDAs, if households choose to hold more low-risk assets in the presence of housing, it is likely that households will hold low-risk assets in TAs. This will strengthen the result of this paper. Another simplification in this paper is the absence of any bequest motive.[40] Finally we have a certain lifespan as opposed to a stochastic one. However, we believe that our main results would not change in any drastic manner in spite of these limitations.

Given that the frequency of realizing capital gains affects the effective tax rate on stock returns and asset location decisions, why do households realize capital gains when they have the opportunities to defer the realizations and reduce their tax payments? A number of studies suggest that non-tax considerations may outweigh tax factors in households' trading decisions (see Shefrin and Statman, 1985; Odean, 1998; Barber and Odean, 2004). These considerations include: (i) the "disposition effect": a stock's purchase price "frames" subsequent trading decisions and households are reluctant to dispose of assets at a loss; (ii) portfolio rebalancing: households may sell winners to rebalance their portfolios; and (iii) households' belief in mean-reverting stock prices. In reality we do observe that households realize a substantial amount of capital gains.[41]

[40] We run an experiment where we add a bequest motive in the benchmark and assume that the utility function applied to the bequest is identical to the one applied to the investor's own consumption when alive. The capital gains taxes are forgiven for inherited stocks in the taxable account. We find that introducing a bequest motive does not change benchmark results much. The basis reset provision only affects very old investors, especially in the next to last period.

[41] For example, Wilson (2003) shows that taxpayers reported net capital gains of $225 billion in 1999 by selling corporate stocks.

5 Conclusion

Asset location decisions observed in practice deviate from the predictions of theoretical models, which is labelled the "asset location puzzle." This paper reexamines the puzzle. We develop a quantitative model to solve numerically for the portfolio choices of finitely-lived households that face labor income uncertainty, borrowing and short-sale constraints, a progressive tax code, and different tax treatments for taxable and tax-deferred accounts. These households need to make asset location decisions and asset allocation decisions simultaneously. We find that taxes matter significantly for asset location decisions. For a given tax code, how often capital gains are realized is crucial for determining the optimal location of assets because it affects the effective tax rate on stock returns and the benefits from pre-tax accumulation of stock returns. Changes in the tax code may have a large effect on optimal asset location, particularly when there is a change in tax rate on realized capital gains. We also show that the precautionary motive is not quantitatively important in terms of its effect on asset location.

Our model predicts a high stock market participation rate. This is a common feature for similar models used in the literature. It would be very interesting to jointly match the life-cycle profiles of stock holdings and stock market participation in both taxable and tax-deferred accounts. Due to the rapid development of self-managed tax-deferred accounts, understanding the shift from defined benefit plans to defined contribution plans, as well as participation and contributions in tax-deferred accounts, are also important subjects for future research.

Appendix A: Examples

The tax arbitrage argument works as follows in a one-period scenario where investors face borrowing and short-sale constraints.[42] Suppose that an investor gives preference to holding stocks in the tax-deferred account (TDA) and is sufficiently risk-averse to hold some bonds in the taxable account (TA). Let R_B and τ_B be bond returns and tax rate on bond returns. Let R_S and τ_S be stock returns and tax rate on stock returns. This investor can generate a risk-free profit by rebalancing the portfolio.

For example, suppose the investor rebalances the TDA and switches \$1 from stocks into bonds. The \$1 in bonds will accumulate to $\$(1 + R_B)$ at the time of retirement or to $\$(1 - \tau_B)(1 + R_B)$ taking into account that withdrawals at retirement are taxed at the ordinary income tax rate. On the other hand, the \$1 in stocks would have accumulated to $\$(1 - \tau_B)(1 + R_S)$ after subtracting the income tax at retirement. Thus, the proposed portfolio rebalancing will change the value of the withdrawals during retirement by $\$(1 - \tau_B)(R_B - R_S)$.

The investor needs to also adjust the asset holdings in the TA to maintain a similar risk level. Suppose that the investor sells $\$\frac{1-\tau_B}{1-\tau_S}$ of bonds in the TA and purchases $\$\frac{1-\tau_B}{1-\tau_S}$ of stocks. We can show that the proposed rebalancing will change the value of the taxable account during retirement by $\$(1 - \tau_B)(R_S - \frac{1-\tau_B}{1-\tau_S} R_B)$.

The portfolio rebalancing in both accounts will change the after tax wealth at retirement by $\$(1-\tau_B)(R_B - R_S) + \$(1-\tau_B)(R_S - \frac{1-\tau_B}{1-\tau_S} R_B) = \$\frac{1-\tau_B}{1-\tau_S}(\tau_B - \tau_S)R_B$. Note that the total gain from the portfolio rebalancing is risk-free and is strictly positive as long as $\tau_B > \tau_S$

[42] Huang (2008) argues that the arbitrage argument can be generalized to cover multiple periods under a series of assumptions.

and $R_B > 0$. Thus, the optimal asset location does not depend on the expected return of stocks; it just depends on the marginal tax rates.[43]

Suppose $R_B = 0.03$, $\tau_B = 0.28$, $R_S = 0.10$, and $\tau_S = 0.20$. The net gain of the above portfolio rebalancing would be \$0.00216. The main reason is that withdrawals at retirement are taxed at the ordinary income tax rate. If stocks are held in the TDA, stock returns are taxed at τ_B, not τ_S. Thus, it is not optimal to hold stocks in the TDA.

Note that this type of arbitrage argument underestimates the power of pre-tax accumulation and the benefits from lower ordinary income tax rate during retirement. It may not work in a life cycle setting with a progressive tax system where future tax rates are decided by asset returns and future income. Next, we consider a three-period scenario and show that the investor could prefer to hold stocks in the TDA when $\tau_B > \tau_S$.

Suppose $\tau_B = 0.28$ and $\tau_S = 0.20$ in the first two periods, while $\tau_B = 0.15$ and $\tau_S = 0.10$ in the third period. R_B and R_S are the same as in the one-period scenario. We consider three asset location strategies in the beginning of period one.

Strategy A: \$1 stocks in the TDA and \$1 bonds in the TA

Strategy B: \$1 bonds in the TDA, $\$\frac{1-\tau_B}{1-\tau_S} = \$0.9$ stocks in the TA, and \$0.1 bonds in the TA

Strategy C (higher risk level): \$1 bonds in the TDA and \$1 stocks in the TA

For each strategy, we assume that asset returns in the TA are realized and taxed in each period. After-tax returns are used to buy the same type of asset. We also assume that the investor faces restrictions on borrowing or selling short. The following tables calculate the after-tax wealth for each strategy.[44]

[43] The expected return of stocks would affect the asset allocation.

[44] All values are after-tax values except values in the TDA in the first two periods.

	beginning of period 1	end of period 1	end of period 2	end of period 3
TDA	\$1.0 stocks	\$1.10000	\$1.21000	\$1.13135
TA	\$1.0 bonds	\$1.02160	\$1.04367	\$1.07028
Tax payments		\$0.00840	\$0.00858	\$0.20435

Table A.1: Strategy A

	beginning of period 1	end of period 1	end of period 2	end of period 3
TDA	\$1.0 bonds	\$1.03000	\$1.06090	\$0.92882
TA	\$0.9 stocks	\$0.97200	\$1.04976	\$1.14424
	\$0.1 bonds	\$0.10216	\$0.10437	\$0.10703
Tax payments		\$0.01884	\$0.02030	\$0.17488

Table A.2: Strategy B

	beginning of period 1	end of period 1	end of period 2	end of period 3
TDA	\$1.0 bonds	\$1.03000	\$1.06090	\$0.92882
TA	\$1.0 stocks	\$1.08000	\$1.16640	\$1.27138
Tax payments		\$0.02000	\$0.02160	\$0.17557

Table A.3: Strategy C

According to Table A.1, the total after-tax wealth at the end of period 3 is \$2.20163 (\$1.13135 in the TDA and \$1.07028 in the TA) for strategy A. It is greater than that for strategy B (\$2.18009). This implies that strategy A dominates strategy B given the tax structure and asset returns in the example. The reason is that the investor benefits more from pre-tax accumulation by holding stocks in the TDA. We do not consider stock return uncertainty here. The example is used to show that the TDA could be the preferred location for stocks in a multiple-period setting when $\tau_B > \tau_S$. Comparing Table A.1 with Table A.3, we note that strategy A also dominates strategy C (\$2.20020), although strategy C has a higher risk level.

Appendix B: The Survey of Consumer Finances Data

The Survey of Consumer Finances (SCF) is probably the most comprehensive source of data on U.S. household assets. We use the 2001 survey to construct household portfolio composition in both taxable (TAs) and tax-deferred accounts (TDAs). The specific variables in the codebook used are given below.

Financial assets in TAs (W^T) include savings accounts (x3804, x3807, x3810, x3813, x3816, x3818), certificates of deposit (x3721), money market accounts (x3706, x3711, x3716, x3718), mutual funds (x3822, x3824, x3826, x3828, x3830), bonds (x3902, x3906, x3908, x3910, x7633, x7634), directly held publicly traded stocks (x3915), brokerage accounts (x3930), trusts and managed investment accounts (x6835), and part of miscellaneous assets (x4018, x4022 if $61 \leq$ x4020 ≤ 74, x4026 if $61 \leq$ x4024 ≤ 74, x4030 if $61 \leq$ x4028 ≤ 74). Checking accounts are excluded from TAs. Financial assets in TDAs (W^D) include IRA/KEOGH accounts (x3610, x3620, x3630) and pension from current main job (values of 401k/403b/SRA, Thrift or savings, and TIAA-CREF).

Next we construct measures of stocks held in both TAs and TDAs. Stocks held in TAs consist of directly held stocks (x3915), stocks held in mutual funds (x3822 plus $\frac{1}{2}*$x3830), and stocks held in trust and managed investment accounts (x6835 if x6841=1, or $\frac{1}{2}*$x6835 if x6841=5, or $\frac{1}{3}*$x6835 if x6841=6). Stocks held in TDAs consist of stocks held in

IRA/KEOGH accounts (total account value if x3631=2, or half of account value if x3631=5 or 6, or a third of account value if x3631=4) and stocks held in the current job pension plan (if the answer to the question of how the money in this account is invested is "mostly or all stock", all of the account value is assigned to stocks; if the answer is "split; between stock and interest earning assets", half of the account value goes to stocks; otherwise the stock value is zero.).

We only distinguish two types of assets in each account: a risky asset (stock) and a riskless asset (bond). Once we have the measure of stock holdings in each account, we subtract it from the total financial wealth and obtain the bond holdings in the account.

For non-financial income we adopt a broad definition. It is defined as the sum of total reported labor income, unemployment or worker's compensation, social security, child support and other welfare and transfers. In practice, we use the following measure: x5729-x5706-x5708-x5710-x5712-x5714.

Appendix C: Numerical Solution

We use numerical dynamic programming techniques to approximate the decision rules as well as the value function. The dynamic program has three state variables in addition to period j: W_j^T, W_j^D, and z_j. We need to solve for five control variables in each period: the contribution rate, the withdrawal amount from the TDA, consumption, the stock share in the TA, and the stock share in the TDA. We exploit the scale-independence of the maximization problem and rewrite the level variables as ratios to $\bar{Y}_1$ (where $\bar{Y}_1 = exp(\bar{y}_1)$). We use lowercase letters to denote them: $w_j^T = \frac{W_j^T}{\bar{Y}_1}$, $w_j^D = \frac{W_j^D}{\bar{Y}_1}$, $x_j = \frac{X_j}{\bar{Y}_1}$, $c_j = \frac{C_j}{\bar{Y}_1}$.

We discretize the state-space along the two continuous state variables, W_j^T and W_j^D.

The model is solved using backward induction. We optimize using grid search.[45] In the last period ($j = J$) the policy functions are trivial.[46] In periods prior to J, we calculate optimal decision rules for each possible combination of nodes, using stored information about the subsequent period's decision rules and value function. We follow Tauchen (1986) to approximate the distributions of the innovations to the labor income process and the stock returns. For points which do not lie on the state-space grids, we evaluate the value function using a bi-cubic spline interpolation along the two wealth dimensions. After computing the values of all the alternatives, we pick the maximum, thus obtaining the decision rules for the current period. This process is iterated until $j = 1$.

Once we determine the optimal decision rules for all possible nodes in each period, we conduct simulations. For each simulation, we first generate a series of stock returns. Then we simulate the income history of 61 groups of households. Each group consists of 10,000 households. Group 1 corresponds to the period 1 households (the youngest) in the model. The income history of group 1 only includes one period. These households have labor income but do not hold financial assets before the realization of labor income. Thus, stock returns are irrelevant for them. Group 2 corresponds to the period 2 households in the model. Their income history includes two periods. These households are subject to the latest realization of stock returns. The same approach is applied to other groups. Group 61 corresponds to the period 61 households (the oldest) in the model. The income history of group 61 includes 61 periods. These households are subject to the whole series of stock returns. Finally, for households with assets in both the TA and the TDA, we compute the

[45] The grids are unequally spaced. They are finer for lower values of wealth.

[46] Households withdraw all funds from the TDA at the beginning of the last period. They consume all available after-tax wealth when there is no bequest.

stock market participation rate and the mean stock share of financial assets in each account for stock market participants by applying the optimal decision rules. We then compare the average of 100 simulations to the real data. Because a large amount of computation time is required to solve the model, all programs are parallelized and run on SHARCNET.[47]

[47]SHARCNET is a multi-institutional High Performance Computing network that spans 17 leading academic institutions in Ontario, Canada.

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Parameter	Parameter Value	Source/Target
Lifespan (J)	61	Target: real age 25-85
Working Periods (K)	40	Target: retired at age 65
Discount Factor (β)	0.96	Macroeconomics literature
Risk Aversion (γ)	7	Target: aggregate stock share
Age-Earnings Profile (G_j)	1.03 or 1.00	See text
AR(1) Term (ρ)	0.95	Hubbard et al. (1994)
Variance of Transitory Shocks (σ_u^2)	0.04	Hubbard et al. (1994)
Variance of Persistent Shocks (σ_ξ^2)	0.02	Hubbard et al. (1994)
Contribution Limit ($\bar{q}$)	10%	See text
Early Withdrawal Penalty (ϕ)	10%	Regulations on TDAs in U.S.
Min Required Distribution	$\frac{1}{remaining\ years}$	Dammon et al. (2004)
Bond Return (r^b)	3%	Ibbotson Associates (2005)
Equity Premium (μ^s)	4%	Cocco et al. (2005)
Std. Dev. of Stock Return (σ_ϵ)	16%	Cocco et al. (2005)

Table 1: Benchmark parameter values

Income	Normalized Income	Marginal Tax Rate
($0, $11500]	(0, 0.3000]	0%
($11500, $51500]	(0.3000, 1.3553]	15%
($51500, $111500]	(1.3553, 2.9342]	28%
($111500, $161500]	(2.9342, 4.2500]	31%
($161500, $271500]	(4.2500, 7.1447]	36%
$271500 +	7.1447 +	39.60%

Table 2: Tax code used in the model

	Data	Benchmark
Stock Market Participation Rate in TA	52%	68%
Stock Market Participation Rate in TDA	81%	100%
Mean Stock Share in TA for Participants	61%	75%
Mean Stock Share in TDA for Participants	80%	85%

Table 3: Benchmark results

	Data	Realize 1/3	Benchmark (realize 2/3)	Realize 100%
Stock Market Participation Rate in TA	52%	82%	68%	58%
Stock Market Participation Rate in TDA	81%	96%	100%	100%
Mean Stock Share in TA for Participants	61%	90%	75%	69%
Mean Stock Share in TDA for Participants	80%	77%	85%	86%

Table 4: Effects of capital gains realization rate

	Data	$\gamma = 5$	Benchmark ($\gamma = 7$)	$\gamma = 10$
Stock Market Participation Rate in TA	52%	76%	68%	58%
Stock Market Participation Rate in TDA	81%	100%	100%	100%
Mean Stock Share in TA for Participants	61%	86%	75%	66%
Mean Stock Share in TDA for Participants	80%	92%	85%	76%

Table 5: Effects of risk aversion coefficient

	Data	Benchmark	Prop. Tax I	Prop. Tax II
Stock Market Participation Rate in TA	52%	68%	99%	68%
Stock Market Participation Rate in TDA	81%	100%	87%	100%
Mean Stock Share in TA for Participants	61%	75%	95%	70%
Mean Stock Share in TDA for Participants	80%	85%	68%	85%

Table 6: Effects of proportional tax