

Life-cycle Stock Market Participation in Taxable and Tax-deferred Accounts

Jie Zhou *

Division of Economics, Nanyang Technological University, Singapore

Abstract

The stock market participation patterns differ significantly in taxable (TAs) and tax-deferred accounts (TDAs). This paper develops a quantitative life-cycle model to study the optimal stock market participation choice for households with assets in both TAs and TDAs. We find that differential costs of stock market participation in the two accounts explain the higher participation rate in TDAs early in life relative to TAs and the increasing stock market participation rate in TAs over the life cycle. We also show that the differential tax treatment between TAs and TDAs is responsible for the decline in the participation rate in TDAs late in life, while the basis-reset provision of the tax code is not quantitatively important.

JEL classification: G11; H20

Keywords: Portfolio choice; Stock market participation; Entry costs; Tax-deferred accounts.

*Contact information: Division of Economics, School of Humanities and Social Sciences, Nanyang Technological University, Singapore 637332. Tel: +65 65138162. Fax: +65 67955797. E-mail: zhoujie@ntu.edu.sg.

1 Introduction

A robust empirical finding suggests that a large number of U.S. households do not hold stocks.¹ For example, only 51% of U.S. households hold stocks either directly or indirectly (e.g., through pension funds) according to the 2001 Survey of Consumer Finances (SCF). This empirical fact is puzzling, as standard models, given the equity premium and the assumption of CRRA preferences, predict that all households with positive savings should participate in the stock market. This observation has generated a number of studies exploring potential explanations for the limited stock market participation puzzle.²

However, the literature has largely abstracted from the difference between taxable accounts (TA) and tax-deferred accounts (TDA).³ Figure 1 plots the stock market participation rates in the TA and the TDA for households with assets in both accounts in the 2001 SCF.⁴ It appears that the stock market participation patterns are very different in these two accounts. The participation rate generally increases with age in the TA and decreases with age in the TDA.⁵ Given that households hold a great deal of wealth in both accounts and

¹See Mankiw and Zeldes (1991), Bertaut and Starr-McCluer (2002), Vissing-Jorgensen (2002), Ameriks and Zeldes (2004), and Campbell (2006).

²Heaton and Lucas (2000) offer positive correlation between stock returns and earnings shocks as an explanation. Vissing-Jorgensen (2002), Haliassos and Michaelides (2003), and Gomes and Michaelides (2005) suggest stock market entry costs. Davis et al. (2006) consider a wedge between borrowing costs and the risk-free investment return. Fratantoni (2001), Cocco (2005), Yao and Zhang (2005), and Becker and Shabani (2010) study the effects of housing and mortgage debt on stock holdings.

³A notable exception is Gomes et al. (2009). The authors focus on the effect of tax-deferred accounts on household savings and explicitly consider two types of households. The first type only holds stocks in the TDA, while the second type can hold stocks in both accounts.

⁴Similar patterns can be observed in the 1998 and 2004 SCFs.

⁵We acknowledge the well-known identification problem of time, age and cohort effects.

the stock market participation patterns in these accounts seem different, it is important to simultaneously study the stock market participation choice in both accounts for a potential resolution of the participation puzzle.⁶

[Figure 1 here]

This paper studies the optimal stock market participation choice for households with assets in both taxable and tax-deferred accounts. We develop a quantitative life-cycle model of portfolio choice, which incorporates several key features into the standard life-cycle model: (i) Epstein-Zin preferences; (ii) moderate heterogeneity in risk aversion; (iii) a progressive tax system with a basis-reset provision;⁷ and (iv) households have access to both taxable and tax-deferred accounts and stock market entry costs exist in both accounts.

The intuition of these features is as follows. Epstein-Zin preferences allow us to separate risk aversion from the elasticity of intertemporal substitution (EIS). Households with higher risk aversion and higher EIS accumulate more wealth.⁸ Together with moderate heterogeneity in risk aversion, Epstein-Zin preferences help to generate a wealth distribution in the

⁶Examples 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). According to the 2001 SCF, more than 40% of households have assets in both taxable and tax-deferred accounts. For these households, assets held in tax-deferred accounts accounted for more than 30% of their total financial assets. In 2003, IRA assets stood at \$2.8 trillion, and 401(k) assets were estimated at \$1.8 trillion (Vanguard Group, 2004).

⁷The current tax code in the United States allows the tax basis of an inherited asset to be reset to the prevailing market price upon the death of the original owner/investor. In other words, the capital gains taxes are forgiven for inherited stocks. However, this basis-reset provision only applies to stocks held in taxable accounts.

⁸This result depends on the time-preference-adjusted rate of return on saving. See Campbell and Viceira (1999) for a good discussion.

model that roughly matches the one observed in the data. A realistic tax system is also necessary, as it accurately measures taxes on each asset in an environment where households' income has a life-cycle pattern and households have access to tax-deferred accounts.

Previous studies have considered stock market entry costs, which are a one-time cost paid by investors to participate in the stock market.⁹ The entry costs represent a combination of explicit and implicit hurdles such as information acquisition about investment opportunities, more complicated tax filing, the value of time spent to learn how to trade and rebalance a portfolio, and set-up fees (time and/or money). Alternatively, entry costs may be an economist's description of psychological factors that make equity ownership uncomfortable for some households (Campbell 2006, p.1569).¹⁰ In this paper, households have access to both taxable and tax-deferred accounts. We consider stock market entry costs in both accounts. However, the entry costs in the TDA are set to be much lower than those in the TA. This is because employer sponsored tax-deferred accounts normally provide uniform and simple vehicles for employees to make an investment choice. This makes access to the stock market much easier in the TDA than in the TA.¹¹

The model predictions are broadly consistent with the data. We find that the stock market participation rate in the TA is generally increasing with age in the model. This is because we introduce stock market entry costs. As households age, they accumulate more wealth in the TA, and it becomes worthwhile for them to pay the entry costs. Note that the

⁹See Basak and Cuoco (1998), Halissos and Michaelides (2003), Gomes and Michaelides (2005), and Alan (2006), among others. Moreover, recent empirical work suggests that small entry costs can be consistent with the observed low stock market participation rates (Paiella 2001; Vissing-Jorgensen 2002).

¹⁰The entry costs may also be used to capture investor inertia.

¹¹For example, there are no set-up costs associated with investment in stocks in employer sponsored tax-deferred accounts.

stock market participation rate in the TA for households below age 45 increases much faster in the model than in the data. For reasonable parameter values the model also generates a decline in the stock market participation rate in the TDA for old households. However, the participation rate does not fall sharply in the model as in the data.

Comparing the stock market participation rates in both accounts for young households, the model suggests that the participation rate in the TDA is much higher than in the TA, which is consistent with the data. This is because (i) the entry costs in the TDA are much lower than in the TA and (ii) young households tend to hold stocks because their human capital (future labor income) acts as a substitute for bond holdings if the correlation between the labor income risk and the stock market risk is weak.

For old households, there are two forces in the model that could affect their stock market participation choice in the two accounts. The first mechanism is related to the differential tax treatment between the two accounts and the benefits from pre-tax accumulation. Given that capital gains account for the majority of stock returns and that unrealized capital gains are not taxed in the United States, how often households realize capital gains affects the effective tax rate on stock returns and the benefits from pre-tax accumulation of stock returns if stocks are held in the TDA.¹² As suggested by Shoven and Sialm (2003) and Zhou (2009), when households defer capital gains realizations most of the time, they do not benefit much from holding stocks in the TDA, leading to a low stock market participation rate in the TDA, and vice versa.¹³ The second potential force comes from the basis-reset

¹²According to Ibbotson Associates (2005, Table 2-6), dividends only accounted for 14% (20%) of total stock returns in the last 10 (20) years.

¹³Essentially, households are comparing the benefits from pre-tax accumulation of stock returns and after-tax accumulation of bond returns with the benefits from pre-tax accumulation of bond returns and after-tax accumulation of stock returns.

provision of the current U.S. tax code. Under the basis-reset provision, the capital gains taxes are forgiven for inherited stocks in the TA, while the TDA balance (including capital gains) will be taxed when the beneficiary withdraws funds from the TDA upon the death of an investor. This offers an additional benefit for households holding stocks in the TA and could potentially reduce the incentive to hold stocks in the TDA. As households try to take advantage of the basis-reset provision, the stock market participation rate in the TDA could drop for old households.

Our numerical results show that the capital gains realization rate has a large impact on the stock market participation rate in the TDA for old households. When the capital gains realization rate is low, the model generates a decline in the stock market participation rate in the TDA for old households; when the capital gains realization rate is high, the stock market participation rate in the TDA does not drop for old households. On the other hand, the effect of basis-reset provision turns out to be quantitatively small. This is likely due to two reasons: (i) the potential benefits from the basis-reset provision only occur in the period when an investor dies, while the capital gains realization rate affects the taxes on stock returns and the benefits from pre-tax accumulation for the whole life-time as long as there are capital gains; and (ii) the basis-reset provision is potentially more important for very old households since the mortality risk for them is high. However, the balance in the TA is likely to be small for many households in their old age. Thus, the impact of the basis-reset provision is small.

This paper is related to the large literature on asset allocation decisions (how much of each asset to hold) and asset location decisions (where to hold assets).¹⁴ Its main contri-

¹⁴For asset allocation, see Jagannathan and Kocherlakota (1996), Viceira (2001), Cocco et al. (2005), Gomes and Michaelides (2005), and Campanale (2009). For asset location, see Shoven and Sialm (2003),

bution is to study the optimal stock market participation choice in both taxable and tax-deferred accounts by solving a realistically calibrated life-cycle model. We carefully model institutional features of tax-deferred accounts, capture heterogeneity of access to these accounts, and examine how differential costs of participation and differential tax treatment affect households' stock market participation in these two accounts over the life cycle.

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

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 types of financial assets available to investors: a bond with constant return and a stock (or stock index) with stochastic return. Both assets can be held in a taxable account (TA) and a tax-deferred account (TDA). An investor must pay entry costs before investing in stocks in each account for the first time, while investing in bonds is costless. Households face idiosyncratic labor income shocks, stock return uncertainty, and a progressive tax system. They need to make stock market participation decisions and portfolio choices for each account.

Dammon et al. (2004), Huang (2008), and Zhou (2009).

2.1 Preferences

Households have Epstein-Zin utility functions defined over a consumption stream (Epstein and Zin, 1989). The preferences are given by the following recursion:

$$V_j = \left\{ (1 - \beta)C_j^{1-\frac{1}{\psi}} + \beta \left(E_j \left[p_j V_{j+1}^{1-\gamma} + (1 - p_j)bW_{j+1}^{1-\gamma} \right] \right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \quad (1)$$

where $\beta < 1$ is the discount factor, ψ determines the elasticity of intertemporal substitution, γ is the coefficient of relative risk aversion, C_j is consumption in period j , p_j denotes the probability that an investor is alive in period $j + 1$ conditional on being alive in period j , W_{j+1} is the total amount of after-tax wealth an investor bequeaths to his descendant at death, and b controls the intensity of the bequest motive.¹⁵ Since $p_J = 0$, the terminal condition for the recursive equation is:

$$V_J = \left\{ (1 - \beta)C_J^{1-\frac{1}{\psi}} + \beta \left(E_J \left[bW_{J+1}^{1-\gamma} \right] \right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \quad (2)$$

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 (labor income). Following the standard specification in the life-cycle literature, we consider both

¹⁵ $p_0 = 1$ and $p_J = 0$. Although some special tax rules may apply (at the death of a TDA owner, the designated beneficiary may be able to extend the tax-deferred periods of TDA funds), for simplicity, we assume that all funds in the TDA are withdrawn and are subject to ordinary income tax at the time of death, while there is no tax on capital gains in the TA.

persistent and transitory income shocks.¹⁶ The income of household i in period j , Y_{ij} , is exogenously given by:

$$\log(Y_{ij}) = \bar{y}_j + z_{ij} + u_{ij} \quad (3)$$

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:

$$z_{ij} = \rho z_{ij-1} + \xi_{ij} \quad (4)$$

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:

$$\log(Y_{ij}) = \log(\lambda_i(z_{iK})) + \bar{y} + z_{iK} \quad (5)$$

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}).¹⁷ This specification simplifies the solution of the model since we do not need to track the household's entire income history.

Housing expenditure affects households' disposable income and financial wealth accumulation, which is crucial for the stock market participation decision. Given the importance of housing expenditure in the life cycle, we need to take it into account. We do not model housing directly in the paper. Following Gomes and Michaelides (2005), we subtract the

¹⁶See 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).

¹⁷This implies that 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 .

percentage of household income that is dedicated to housing expenditure (h_j) from the measure of disposable income. More details are given in the calibration of the model.

2.3 Financial Assets, Accounts, and Taxation

There are two types of financial assets in the economy: a riskless asset (“bond”) and a risky asset (“stock”). The riskless asset yields a constant return r^b . The return on the stock in period j , r_j^s , is given by

$$r_j^s - r^b = \mu^s + \epsilon_j^s \quad (6)$$

where μ^s is the equity premium, and ϵ_j^s is assumed to be i.i.d. over time and distributed as $N(0, \sigma_\epsilon^2)$.¹⁸ We consider a constant dividend yield d for the stock return.

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 the 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 ordinary income tax τ^l .¹⁹ During retirement periods, contributions to the TDA are not allowed, and the household must withdraw funds from the TDA after some age.²⁰ The household pays tax on the withdrawals at the ordinary income tax rate τ^l .

¹⁸We choose ϵ_j^s in the range from $-2\sigma_\epsilon$ to $2\sigma_\epsilon$.

¹⁹Distributions before age $59\frac{1}{2}$ are subject to penalties (with exceptions) for many tax-deferred accounts.

²⁰According to the current regulations in the United States, individuals must begin to take withdrawals by age $70\frac{1}{2}$.

We incorporate a progressive income tax code in the model, which means that 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 as 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 depends on the marginal ordinary income tax rate the household faces. The current tax code in the United States allows investors to reset the tax basis to the prevailing market price when their beneficiaries inherit the stocks upon the death of investors. In other words, the capital gains taxes are forgiven for inherited stocks. However, this basis-reset provision only applies to stocks held in taxable accounts. It offers an additional benefit for old investors holding stocks in the TA and would potentially reduce the incentive to hold stocks in the TDA. More details on the tax code are provided in section 3.9.

2.4 Entry Costs

We assume that short sales are not allowed and that no transaction costs are incurred for trading the bond or stock in both accounts. However, an investor must pay entry costs before investing in stocks in either account for the first time, while investing in bonds is costless. Such costs could arise from informational considerations, set-up fees, and investor inertia. It is expressed in the model as a percentage of the persistent component of current labor income, $F^T \times \exp(\bar{y}_j + z_j)$ in the TA and $F^D \times \exp(\bar{y}_j + z_j)$ in the TDA.

2.5 Wealth Dynamics and Households' Optimization Problem

In each period, households choose their contributions to (withdrawals from) the TDA, consumption, and the equity proportions 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 define dummy variables I^T and I^D that are equal to one when the household chooses to pay the one-time entry costs (the entry costs are incurred for the first time in each account) and are zero otherwise. We first consider $j \leq K$ (working periods). The wealth dynamics are given by (we drop i here):

$$W_{j+1}^T = R_{j+1}^T [W_j^T - q_j Y_j - (1 - q_j) Y_j \tau_j^l - h_j (1 - q_j) Y_j (1 - \tau_j^l) + X_j (1 - \tau_j^l - \phi) - C_j - I^T F^T \exp(\bar{y}_j + z_j)] + Y_{j+1} \quad (7)$$

$$W_{j+1}^D = R_{j+1}^D (W_j^D + q_j Y_j - X_j - I^D F^D \exp(\bar{y}_j + z_j)) \quad (8)$$

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 , $q_j \in [0, \bar{q}]$ denotes the contribution rate, h_j represents the fraction of labor income dedicated to housing-related expenditure, X_j is the amount of withdrawal from the TDA (if $q_j > 0$, $X_j = 0$), and C_j is consumption.²¹ In equation (8), $R_{j+1}^D = \alpha_j^D (1 + r_{j+1}^s) + (1 - \alpha_j^D) (1 + r^b)$ denotes the gross return on the portfolio held in the TDA from period j to period $j + 1$.

²¹ τ^l represents a progressive income tax code. We combine interest income, labor income (net of contributions), and minimum required distribution (zero in the working periods) to decide the marginal ordinary income tax rate. τ^s is a function of stock return and the marginal ordinary income tax rate. For more details on τ^s , please see the last paragraph of section 3.9 and footnote 34.

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

$$W_{j+1}^T = R_{j+1}^T [W_j^T - Y_j \tau_j^l - h_j Y_j (1 - \tau_j^l) + X_j (1 - \tau_j^l) - C_j - I^T F^T Y_j] + Y_{j+1} \quad (9)$$

$$W_{j+1}^D = R_{j+1}^D (W_j^D - X_j - I^D F^D Y_j) \quad (10)$$

We impose a minimum withdrawal rate equal to the inverse of life expectancy for households 70 years of age or older.

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

$$\alpha_j^T \in [0, 1], \alpha_j^D \in [0, 1] \quad (11)$$

$$W_j^T \geq 0, W_j^D \geq 0 \quad (12)$$

At the time of death, the asset holdings in the TA are liquidated without incurring a capital gains tax. This is consistent with the basis-reset provision of the current U.S. tax code. We also assume that all funds in the TDA are withdrawn at the time of death and that the proceeds are taxed as ordinary income, as heirs are required to pay income taxes on the withdrawal when they inherit a tax-deferred account. We omit the estate tax because the estate of model households is likely to be lower than the exemption level.

The problem a household faces is to maximize (1) subject to constraints given by (7) to (12), to the labor income process given by (3) to (5), and to the stock returns given by (6), in addition to the non-negativity constraint on consumption. There are six state variables: period j , the wealth level in the TA (W_j^T), the wealth level in the TDA (W_j^D), the persistent income shock (z_j), and participation status in each account (whether the entry cost has been paid or not). The control variables are: the contribution rate (q_j), withdrawal (X_j), consumption (C_j), the decision to pay the entry cost or not in each account, the equity proportion in the TA (α_j^T), and the equity proportion in the TDA (α_j^D). 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 B.

3 Parameterization

In this section, we outline the choice of benchmark parameter values.

3.1 Preference Parameters

A model period is one year. The annual discount factor β is set at 0.96. We allow for preference heterogeneity and use Epstein-Zin preferences.²² Following Gomes and Michaelides (2005), we consider a 50% split between households with low risk aversion and low elasticity of intertemporal substitution ($\gamma = 1.2$ and $\psi = 0.2$) and households with moderate risk aversion and moderate elasticity of intertemporal substitution ($\gamma = 5.0$ and $\psi = 0.4$). We use the 2000 life table of the National Center for Health Statistics to parameterize the conditional survival probabilities. Given all the other parameters, the importance of the bequest motive (b) is set at 0.2 in the benchmark. This will allow us to match the wealth accumulation documented in section 4.1. We will present sensitivity analysis respect to the bequest motive.

3.2 Labor Income Process

Households are born at the age of 22 (model period 1) and live up to the age of 85 (model period 64). They begin to receive retirement benefits at age 65 (model period 44). Thus, we set $J = 64$ and $K = 43$.

²²As shown in Gomes and Michaelides (2005) and Gomes et al. (2009), these features are important to match wealth accumulation over the life cycle.

For the labor income process, we first 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 $\bar{Y}_1 = \exp(\bar{y}_1)$.²³ Thus, \bar{Y}_1 is the median income of all period 1 households in the model and is set to \$25,000.²⁴

G_j governs the age-earnings profile $(\bar{y}_1, \dots, \bar{y}_K$ or $\bar{Y}_1, \dots, \bar{Y}_K)$. It is a common practice to estimate different labor income profiles for different education groups (college graduates, high-school graduates, and households without a high-school degree). For households with assets in both taxable and tax-deferred accounts in the 2001 SCF, 50.5% have grades of 15 years or more; 43.0% have grades of 12-14 years; and 6.5% have grades of less than 12 years. For simplicity, we split households in the model between college and high school.²⁵ The corresponding parameter values for the age-earnings profiles of these two groups are taken from Cocco et al. (2005).

The remaining parameters of the labor income process in working periods are ρ , σ_ξ^2 , and σ_u^2 . We set $\rho = 0.95$, the persistent shocks $\sigma_\xi^2 = 0.02$, and the transitory shocks $\sigma_u^2 = 0.04$. These parameters are taken from Hubbard et al. (1994). We discretize the idiosyncratic income shocks using the Tauchen method outlined in Adda and Cooper (2003). The AR(1) process is approximated by a Markov process characterized by a transition matrix.

²³If income is log normally distributed, the mean log income and the median income are related as follows: median income = exp (mean log income).

²⁴This number is slightly higher than the median non-financial income of households at age 21 to 23 in the 2001 SCF, but lower than that of households with both taxable and tax-deferred accounts at the same age. We choose this number because (i) households that have access to TDAs tend to have higher income compared to households without TDAs, and (ii) there is income growth over time.

²⁵Therefore, we have four subgroups in the model: college with low risk aversion and EIS, college with high risk aversion and EIS, high school with low risk and EIS, and high school with high risk aversion and EIS.

3.3 Housing Expenditure

To account for housing expense, we subtract exogenous housing expenditure from the measure of labor income. Gomes and Michaelides (2005, Table 1) estimate the percentage of households' labor income that is dedicated to housing expenditure using data from the Panel Study of Income Dynamics (PSID). Given their parameter estimates, we use

$$h_j = \max\{A + B_1 * age + B_2 * age^2 + B_3 * age^3, 0\} \quad (13)$$

and truncate h_j at zero for $age \geq 80$.

3.4 Entry Costs

As mentioned above, the entry costs represent a combination of explicit and implicit hurdles to participating in the stock market. In this paper, we consider the costs in both taxable and tax-deferred accounts. In the TA, we follow Gomes et al. (2009) and set F^T at 5% of the current persistent income.²⁶ In the TDA, we set $F^D = 0.5\%$, which is one tenth of that in the TA. This is because access to the stock market is much easier in the TDA, as employer sponsored tax-deferred accounts normally provide uniform and simple vehicles in which employees make investments for their retirement.

3.5 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

²⁶In an infinite-horizon model of household portfolio choice, Halissos and Michaelides (2003) suggest entry costs ranging between 3 and 24% of mean annual labor income for different preference parameters.

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).²⁷

3.6 Distribution of Years since First Access to TDA

The historical access to tax-deferred accounts has not been uniform across the age cohorts. Therefore, to replicate the average wealth accumulation of households in both accounts, we cannot assume that all of them have had access to a TDA since the beginning of their working life. We compute the distribution of the number of years that a household has had access to a TDA in the 2001 SCF and use it as an input for the model.

Table 1 reports the distribution of years of participation in employer-provided tax-deferred retirement plans by age group from the 2001 SCF and the corresponding coverage distribution assumed in the model. For example, for households with both accounts and heads aged 23-24 in the 2001 SCF, 57% have access to a TDA for at least two years and 43% no more than one year. In the model, we assume that half households have access to a TDA for two years and another half for one year in the same age group. According to the distribution of TDA coverage, we randomly distribute the access to a TDA across households of a given cohort in the model. Once a household has access to a TDA, we assume that it will keep its TDA coverage. In the model, we also assume that the distribution of years of TDA coverage for households over age 64 is the same as that of households at age 60-64.

[Table 1 here]

²⁷For the U.S. social security benefit formula, see Figure 1 in Huggett and Parra (2010).

3.7 TDA Contributions and Withdrawal

According to Joulfaian and Richardson (2001), 95% of households that participate in employer-sponsored retirement plans contributed less than 15% of their income. The average contribution rate is 5.9%. As a result, we set the contribution limit, \bar{q} , to 15% before retirement. 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.²⁸ During retirement, we assume that households have to withdraw funds from the TDA at age 70. We set the minimum withdrawal rate to $\frac{1}{\text{life expectancy}}$, starting at age 70.

3.8 Asset Return Process

The constant bond return r^b is set at 3%. For the stock returns, we consider a mean equity premium (μ^s) equal to 4% and a standard deviation (σ_ϵ) of 16%.²⁹ An equity premium of 4% is a fairly common choice in the literature (e.g., Cocco et al., 2005; Gomes and Michaelides, 2005). The value of 4% is also close to the expected equity risk premium reported in Fama and French (2002). For stock returns, we also assume a constant dividend yield, $d = 2\%$.³⁰

Stock returns consist of two parts: dividends and capital gains.³¹ For computational

²⁸We 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 according to Investment Company Institute (Spring 2000).

²⁹The 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.

³⁰A dividend yield of 2% is also used in Dammon et al. (2004) and Zhou (2009).

³¹We consider long-term capital gains in the paper.

reasons, we do not model capital gains directly, to reduce the dimensionality of the problem (we do not need to track unrealized capital gains). 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 $\frac{1}{3}$, which is close to the capital gains realization rate of stock mutual funds in Barclay, Pearson, and Weisbach (1998).³² We will examine the effect of how often capital gains are realized by changing the capital gains realization rate in section 4.3.1.

Stock returns and shocks to the persistent component of labor income could be correlated. However, the empirical evidence for such a correlation is rather weak, as documented in Heaton and Lucas (2000) and Cocco et al. (2005).³³ As a result, we choose to set the correlation to zero.

Table 2 reports the benchmark parameter values.

[Table 2 here]

3.9 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 five tax brackets, with marginal tax rates of 15%, 28%, 31%, 36%, and 39.6%. We set the taxable income thresholds at \$40,000, \$100,000, \$150,000, and \$260,000, respectively, which were roughly the thresholds during 1993-2000. To find the corresponding tax brackets in terms of the total taxable income, we

³²They find that stock mutual funds realized an average of 38.60% of total capital gains annually in 1976 - 1992.

³³Davis and Willen (2000) find a moderate correlation. They show that the correlation tends to rise with educational attainment.

first need to approximate the complex exemptions and deductions present in the actual tax code. We take the case of a household comprised of a couple filing jointly and set the sum of the standard deduction and personal exemptions to \$11,500, which is 46% of \bar{Y}_1 . We normalize \bar{Y}_1 as 1. Table 3 describes the marginal tax rates we use:

[Table 3 here]

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 gains is 10%. For higher-bracket taxpayers, the tax rate is 20%. These are the tax rates used in the model.³⁴

4 Simulation Results

In this section, we present our simulation results. We start with the wealth accumulation. We then discuss the benchmark case and conduct sensitivity analysis.

³⁴Stock returns can be positive or negative. If stock returns are positive in a period, we check whether they are higher than the dividend yield 2%. If yes, the first 2% are taxed as dividends and the other part goes to capital gains. The tax on capital gains depends on the capital gains realization rate. On the other hand, if stock returns are negative, then there is no tax on stock returns in that period. 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. This tends to overestimate the effective tax rate on stock returns. However, households in reality also realize short-term capital gains and short-term capital gains are taxed at a higher rate than long-term capital gains. We do not consider short term capital gains. This will underestimate the tax rate on stock returns in the model.

4.1 Financial Wealth Accumulation

Because we introduce stock market entry costs in the model and households' financial wealth level could affect their willingness to pay the costs, it is important to match the financial wealth accumulation over the life cycle. Given the skewness of the financial wealth distribution in the data, we therefore choose to match the median financial wealth-to-earnings ratio for certain ages over the life cycle.

Table 4 shows the median financial wealth-to-earnings ratios in both taxable and tax-deferred accounts in the 2001 SCF and the model for different age groups. The results are obtained by taking the medians across households and across age groups. Young households face a high expected future labor income, against which they cannot borrow. As a result, they consume most of their income and only save for precautionary reasons. Saving increases as households age. The jump in the financial wealth-earnings ratio at age 69-71 is mainly driven by lower income, as households are retired by that age. Although the model overshoots for the later part of the life cycle, overall, the financial wealth accumulation across age groups in the model is comparable to its empirical counterparts.

[Table 4 here]

4.2 Benchmark

Figure 2 shows the stock market participation rates in both taxable and tax-deferred accounts for households with both accounts in the benchmark. The stock market participation rate is generally increasing with age in the TA (except for very old households). This result is not surprising, as households need to pay entry costs to participate in the stock market in the TA. Young households would like to hold stocks in the TA but are liquidity constrained.

As a result, the participation rate in the TA is low for young households. As age increases, households accumulate more financial wealth, and it becomes worthwhile for them to pay the entry costs. Consequently, the stock market participation rate increases. Note that the stock market participation rate in the TA increases fast for households below age 45. The participation rate is about 32% for households below age 35, while it stands at 70% for households at age 35-44.

[Figure 2 here]

The stock market participation rate in the TDA is higher than that in the TA for households below age 55. This is likely because the entry costs in the TDA are much smaller than those in the TA. We find that the participation rate in the TDA initially increases with age and then drops after age 55.

There are two potential forces in the model that may lower the stock market participation rate in the TDA as households age. First, how often capital gains are realized affects the effective tax rate on stocks returns and the benefits from pre-tax accumulation of stock returns. As a result, the capital gains realization rate affects stock market participation decision in each account. The decline in the stock market participation rate in the TDA may imply that with a low capital gains realization rate (and a lower effective tax rate on stock returns) in the benchmark, it is optimal for many households to hold stocks in the TA and bonds in the TDA when households age and the equity proportion of total financial assets drops. The reason is that the benefits from pre-tax accumulation of stock returns and after-tax accumulation of bond returns are lower compared to the benefits from pre-tax accumulation of bond returns and after-tax accumulation of stock returns.

Second, the capital gains taxes are forgiven for inherited stocks in the TA under the basis-reset provision, while capital gains will be taxed when the beneficiary withdraws funds from the TDA upon the death of an investor. As a result, the basis-reset provision provides an incentive for old households to quit stock market in the TDA and thus lowers the stock market participation rate in the TDA.

Given these two potential forces, it is interesting to distinguish the effect of the basis-reset provision from that of the capital gains realization rate. We run an experiment where we shut down the basis-reset provision; that is, the capital gains in the TA will be taxed when an investor dies. We find that the effect is quantitatively small. The participation rates in the TA and the TDA do not change much over the life cycle. It only increases by 2 percentage points in the TDA for households above 75.

This experiment clearly shows that the drop in the participation rate in the TDA is mainly due to the low capital gains realization rate. A relatively low capital gains realization rate ($\frac{1}{3}$ in the benchmark) leads to lower benefits from pre-tax accumulation of stock returns relative to bond returns. Therefore, it is optimal for many old households to hold stocks in the TA and bonds in the TDA. The effect of the basis-reset provision is small. This is likely due to two reasons: (i) the potential benefits from the basis-reset provision only occur in the period when an investor dies, while the capital gains realization rate affects the taxes on stock returns and the benefits from pre-tax accumulation for the whole life-time as long as there are capital gains, and (ii) the mortality risk is high for very old households and the basis-reset provision is potentially more important for these households. However, the balance in the TA is likely to be small for many households in their old age; as a result, the benefits from the basis-reset provision are small.

4.3 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 the capital gains realization rate, the bequest motive, the contribution limit, a possible disastrous labor income draw, and per-period stock market participation costs.

4.3.1 Capital Gains Realization Rate

Given that unrealized capital gains are not taxed in the United States, the capital gains realization rate affects stock market participation decisions in both accounts, as it affects the benefits from pre-tax accumulation. Intuitively, if households never realize capital gains, they are likely to hold stocks in the TA and bonds in the TDA, as the benefits from pre-tax accumulation of bond returns (and the after-tax accumulation of stock returns) will be relatively high. Therefore, the stock market participation rate will be high in the TA and low in the TDA. Here, we examine the effects of a higher capital gains realization rate on stock market participation by setting the rate equal to $\frac{2}{3}$.³⁵

Figure 3 summarizes the results. When the capital gains realization rate increases to $\frac{2}{3}$, the stock market participation rate in the TA is still generally increasing with age (except for very old households). Compared to the benchmark, the participation rate is slightly lower in each age group. For example, it drops from 70% to 68% at age 35-44.

[Figure 3 here]

Similar to the benchmark, the stock market participation rate in the TDA increases for

³⁵Barber and Odean (2004) find that the stock turnover rate in retail and discount brokerage accounts is high.

young households. A notable change is that with a higher capital gains realization rate, the participation rate in the TDA does not drop for old households in the model. This result has to do with the benefits from pre-tax accumulation of stock returns. The higher average stock returns combined with a relatively high capital gains realization rate (and a higher effective tax rate on stock returns) lead to higher benefits from pre-tax accumulation of stock returns relative to bond returns. The balance in the TDA grows more quickly to the advantage of households if they hold stocks in the TDA. A related benefit is that households normally face a lower marginal tax rate when they withdraw funds from the TDA during retirement periods. This makes the pre-tax accumulation of stock returns more valuable. Consequently, participating in the stock market in the TDA is desirable for most households in their life-time when the capital gains realization rate is high. To summarize, the capital gains realization rate has a large impact on the stock market participation choice.

4.3.2 Stronger Bequest Motive

Here, we consider a stronger bequest motive, $b = 0.5$. We expect that it will affect wealth accumulation over the life cycle and thus households' willingness to pay the entry costs. Figure 4 plots the stock market participation rate in each account when the bequest motive is increased to 0.5.

With a stronger bequest motive, the stock market participation rate increases slightly in both accounts. The increase is more apparent for old households. For example, the stock market participation rates increased by more than four percentage points in both accounts for households above 75 when $b = 0.5$ compared to those in the benchmark ($b = 0.2$). The reason is that the bequest motive has a large impact on dissaving for the retirees, as suggested by De Nardi (2004). A stronger bequest motive leads to higher wealth for old

households and thus a higher stock market participation rate.

[Figure 4 here]

4.3.3 Higher Contribution Limit

The contribution limit is set at 15% in the benchmark. Here, we consider a higher contribution limit, 20%, and examine its effect. An increase in the contribution limit is likely to raise wealth in the TDA and lower wealth in the TA for some households. Compared to the benchmark, we find that the impact of this change on the stock market participation rate is quantitatively small. On average, the participation rate in the TDA increased by about one percentage point, while the participation rate dropped by one percentage point in the TA. The small impact is not surprising. First, most households have chosen to pay the entry costs (in either account) under the initial contribution limit; Second, for households that contribute less than the initial limit, an increase in the contribution limit is irrelevant for them, as it will not affect their wealth accumulation in both accounts.

4.3.4 Disastrous Labor Income Shock

Previous work has studied the effects of a disastrous labor income draw on household saving and portfolio choice; see Carroll (1992) and Cocco et al. (2005). To understand its effect on stock market participation, we add a transitory income shock, a small probability of a disastrous labor income draw, to the benchmark. We consider the following situation: households face a 5% labor income realization with a probability of 0.5% in each period. It turns out that households accumulate more wealth and accumulate wealth much earlier in the TA when facing such a disastrous income shock. More than 90% of households have already paid the entry cost in the TA after five years of working life. However, the partici-

participation rate in the TDA is lower for young households compared to that in the benchmark. This is because households contribute less to the TDA.

4.3.5 Matching Aggregate Stock Market Participation Rates

Pooling households with assets in both accounts in the population together, we can compute the aggregate stock market participation rate in the TA, in the TDA, and in either account or both accounts for these households. The aggregate participation rates implied by the benchmark parameterization are counterfactually high. In this section, we explore the model's ability to produce more realistic results for the aggregate participation rates and then check what the implications are for the life-cycle participation pattern in each account.

As we introduce stock market entry costs in the model, an increase in the entry costs in each account is expected to lower the participation rate in the account. We also know that households with both low risk aversion and low EIS accumulate less wealth in the model. These households have a weaker incentive to pay the entry costs and therefore are less likely to participate in the stock market, especially in the TA. Thus, the composition of household types also affects the aggregate participation rates. Next we consider a few cases by incorporating these two forces and compare the aggregate participation rates in the TA, in the TDA, and in either account or both accounts implied by the model with the data.

Table 5 reports the model results and the empirical evidence from the 2001 SCF for households with assets in both accounts. Case 1 is the benchmark, in which we consider a 50% split between households with both low risk aversion and low EIS ($\gamma = 1.2$ and $\psi = 0.2$), and households with moderate risk aversion and EIS ($\gamma = 5.0$ and $\psi = 0.4$). Entry costs are 5% of the persistent income in the TA and 0.5% in the TDA. Compared to the data, the benchmark generates higher aggregate participation rate in each account

and a high rate for those households that participate in stock market in either account or in both accounts.

[Table 5 here]

Case 2 also assumes two groups of households, with 50% weight each, but entry costs are doubled in each account, with 10% in the TA and 1% in the TDA. As expected, the aggregate participation rate in each account drops. However, the participation rates implied by the model are still higher than in the data. In Case 3 the weight of the first group ($\gamma = 1.2$ and $\psi = 0.2$) increases from 50% to 66.67%, while the weight for the second group drops to 33.33%. The entry costs are kept at 10% in the TA and 1% in the TDA as in Case 2. We find that the aggregate participation rates in Case 3 are close to those in the data. However, an important drawback of Case 3 is that the median financial wealth-to-earnings ratio is significantly reduced at every stage of the life cycle, especially in the TA. This is because the majority of households in the model are those with low risk aversion and low EIS. For example, the median financial wealth-to-earnings ratio in the TA at age 39-41 is only 0.07, while the ratio is 0.19 in the data.

Given these results, we further consider a small per-period participation cost in Case 4. This feature is motivated by Vissing-Jorgensen (2002) and Campanale (2009). For example, Vissing-Jorgensen (2002) argues that a per-period stock market participation cost of just \$50 is sufficient to explain the choice of half of stock market nonparticipants. Thus, in Case 4 we add a per-period participation cost, \$25, in each account. The weights for the two groups are again 50% and 50%. Stock market entry costs are set at 8% in the TA and 0.8% in the TDA. Table 5 suggests that the participation rates implied by Case 4 broadly match with the empirical evidence, although the participation rate in the TA is still higher

than in the data. This can be reduced by a small increase in entry costs or per-period cost in the TA. The key message from Case 4 is that introducing a per-period cost helps to get the aggregate participation rates closer to the data without resort to a very high entry cost or very high proportion of households with both low risk aversion and low EIS in the population.

What are the implications for the life-cycle participation patterns in Case 4? Figure 5 plots the stock market participation rate in each account for households with both accounts in Case 4. Compared to the benchmark, the participation rate is lower in each account for every age group. This is mainly due to the per-period cost. However, the life-cycle participation patterns are similar to those in the benchmark. The participation rate is higher in the TDA than in the TA for young households. There is a decline in participation rate in the TDA for old households. It is important to mention that the magnitude of the decline is still smaller than observed in the data.³⁶

[Figure 5 here]

5 Conclusions

In this paper, we develop a quantitative life-cycle model to study the optimal stock market participation choice for households with assets in both taxable and tax-deferred accounts. We find that the stock market participation rate in the TA is generally increasing with age due to the entry costs. In the TDA, the participation rate is relatively high for young households. For old households, the model generates a decline in the participation rate in

³⁶One may argue that the per-period cost is not high enough in the TDA. The problem of increasing the per-period cost in the TDA is that it will lower the aggregate participation rate in the TDA.

the TDA for reasonable parameter values. We also show that the basis-reset provision of the tax code is not quantitatively important for stock market participation choice. Finally, our model predicts a very high equity proportion of financial wealth (almost 100%) for young households that have already paid the entry costs. This is a common problem for similar models used in the literature on asset allocation.³⁷ Given the model set-up, we are not able to solve the problem in this paper.³⁸ It is an interesting topic for future research.

³⁷See Cocco et al. (2005) and Gomes and Michaelides (2005).

³⁸For studies that deal with the problem of high equity proportion for young households, see Polkovnichenko (2006) and Campanale (2009).

Acknowledgments

I thank Jim MacGee, Igor Livshits, seminar participants at NTU, and conference participants at the 2010 meeting of the Society for the Advancement of Economic Theory (SAET) for helpful comments. I am particularly thankful to the Editor and two anonymous referees for their insightful comments that helped to improve the paper. This work was made possible by the computing facilities of SHARCNET. The financial support provided by the School of Humanities and Social Sciences at NTU is gratefully acknowledged.

Appendix A: The Survey of Consumer Finances Data

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

Financial assets in the TA (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), annuities, trusts and managed investment accounts (x6820, x6835). Checking accounts, cash value of life insurance, and miscellaneous assets are excluded from the TA. Financial assets in the TDA (W^D) include IRA/KEOGH accounts (x3610, x3620, x3630) and pensions from current main job (values of 401k/403b/SRA, Thrift or savings, and TIAA-CREF).

We construct measures of stocks held in both accounts. Stocks held in the TA consist

of directly held stocks (x3915), stocks held in mutual funds (x3822 plus $\frac{1}{2}$ *x3830), and stocks held in annuities, trust and managed investment accounts. Stocks held in the TDA 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). Stock market participation is determined by checking whether the value of stocks in each account is greater than zero.

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 B: Numerical Solution

We use numerical dynamic programming techniques to approximate the decision rules as well as the value function. The dynamic program has six state variables: period (j), the wealth level in the TA (W_j^T), the wealth level in the TDA (W_j^D), the persistent income shock (z_j), and stock market participation status in each account. In each period we need to solve for the following control variables: the contribution rate (q_j), the withdrawal amount from the TDA (X_j), consumption (C_j), the decision to pay the entry costs or not in each

account, the equity proportion in the TA, and the equity proportion in the TDA.³⁹ 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.⁴⁰ In the last period ($j = J$) the policy functions are determined by the bequest motive, regardless of whether the entry cost has been paid or not. Using these decision rules, we obtain this period's value function. We follow Tauchen (1986) method outlined in Adda and Cooper (2003) to approximate the distributions of the innovations to the labor income process and the stock returns.

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. Given the stock market entry costs, the optimizing agent has to decide whether to enter into stock market or not in an account before he decides how to allocate his wealth in that account at each point of the state space. The participation decision is computed by comparing the value function conditional on having paid the entry costs (adjusting for the payment of the costs) with the value function conditional on non payment. 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 $j = 1$.

³⁹If the entry costs have not been paid, the equity proportion in this account will be zero in that period.

⁴⁰The grids are unequally spaced. They are finer for lower values of wealth.

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 64 groups of households. Each group consists of 12,000 households.⁴¹ 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 64 corresponds to the period 64 households (the oldest) in the model. The income history of group 64 includes 64 periods. These households are subject to the whole series of stock returns. Finally, we compute the stock market participation rate for households with assets in both accounts. 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.⁴²

⁴¹This means that we have 3,000 households for each subgroup. See footnote 25.

⁴²SHARCNET is a multi-institutional High Performance Computing network that spans 17 leading academic institutions in Ontario, Canada.

References

- Adda, J., Cooper, R., 2003. *Dynamic Economics: Quantitative Methods and Applications*. The MIT Press, Cambridge.
- Alan, S., 2006. Entry costs and stock market participation over the life cycle. *Review of Economic Dynamics* 9(4), 588-611.
- Ameriks, J., Zeldes, S., 2004. How do household portfolio shares vary with age? Working Paper, Columbia Business School.
- Barber, B.M., Odean, T., 2004. Are individual investors tax savvy? Evidence from retail and discount brokerage accounts. *Journal of Public Economics* 88(1-2), 419-442.
- Barclay, M.J., Pearson, N.D., Weisbach, M.S., 1998. Open-end mutual funds and capital-gains taxes. *Journal of Financial Economics* 49(1), 3-43.
- Basak, S., Cuoco, D., 1998. An equilibrium model with restricted stock market participation. *Review of Financial Studies* 11(2), 309-341.
- Becker, T., Shabani, R., 2010. Outstanding debt and the household portfolio. *Review of Financial Studies* 23(7), 2900-2934.
- Bertaut, C., Starr-McCluer, M., 2002. Household portfolios in the United States, in: Guiso, L., Haliassos, M., Jappelli, T. (Eds.), *Household Portfolios*. The MIT Press, Cambridge, MA.
- Campanale, C., 2009. Life-cycle portfolio choice: the role of heterogenous under-diversification. *Journal of Economic Dynamics and Control* 33(9), 1682-1698.

- Campbell, J., 2006. Household finance. *Journal of Finance* 61(4), 1553-1604.
- Campbell, J., Viceira, L., 1999. Consumption and portfolio decisions when expected returns are time varying. *Quarterly Journal of Economics* 114(2), 433-495.
- Carroll, C., 1992. The buffer stock theory of saving: some macroeconomic evidence. *Brookings Papers on Economic Activity* 2, 61-135.
- Carroll, C., Samwick, A., 1997. The nature of precautionary wealth. *Journal of Monetary Economics* 40, 41-71.
- Cocco, J., 2005. Portfolio choice in the presence of housing. *Review of Financial Studies* 18(2), 535-567.
- Cocco, J., Gomes, F., Maenhout, P., 2005. Consumption and portfolio choice over the life-cycle. *Review of Financial Studies* 18(2), 491-533.
- Dammon, R., Spatt, C., Zhang, H., 2004. Optimal asset location and allocation with taxable and tax-deferred investing. *Journal of Finance* 59(3), 999-1037.
- Davies, S., Kubler, F., Willen, P., 2006. Borrowing costs and the demand for equity over the life cycle. *Review of Economics and Statistics* 88(2), 348-362.
- Davis, S., Willen, P., 2000. Using financial assets to hedge labor income risks: estimating the benefits. Working Paper, University of Chicago.
- De Nardi, M., 2004. Wealth inequality and intergenerational links. *Review of Economic Studies* 71(248), 743-768.
- Epstein, L., Zin, S., 1989. Substitution, risk aversion, and the temporal behavior of con-

- sumption and asset returns: a theoretical framework. *Econometrica* 57(4), 937-969.
- Fama, E., French, K., 2002. The equity premium. *Journal of Finance* 57(2), 637-659.
- Fratantoni, M., 2001. Home Ownership, Committed Expenditure Risk, and the Stockholding Puzzle. *Oxford Economic Papers* 53(2): 241-259.
- Gomes, F., Michaelides, A., 2005. Optimal life cycle asset allocation: understanding the empirical evidence. *Journal of Finance* 60(2), 869-904.
- Gomes, F., Michaelides, A., Polkovnichenko, V., 2009. Optimal savings with taxable and tax-deferred accounts. *Review of Economic Dynamics* 12(4), 718-735.
- Gourinchas, P., Parker, J., 2002. Consumption over the life cycle. *Econometrica* 70(1), 47-89.
- Haliassos, M., Michaelides, A., 2003. Portfolio choice and liquidity constraints. *International Economic Review* 44(1), 143-177.
- Heaton, J., Lucas, D., 2000. Portfolio choice in the presence of background risk. *Economic Journal* 110(460), 1-26.
- Huang, J., 2008. Taxable and tax-deferred investing: a tax-arbitrage approach. *Review of Financial Studies* 21(5), 2173-2207.
- Hubbard, G., Skinner, J., Zeldes, S., 1994. The importance of precautionary motives in explaining individual and aggregate saving. *Carnegie-Rochester Conference Series on Public Policy* 40, 59-125.
- Hubbard, G., Skinner, J., Zeldes, S., 1995. Precautionary saving and social insurance.

Journal of Political Economy 103(2), 360-399.

Huggett, M., Parra, J., 2010. How well does the US social insurance system provide social insurance? Journal of Political Economy 118(1), 76-112.

Huggett, M., Ventura, G., 2000. Understanding why high income households save more than low income households. Journal of Monetary Economics 45(2), 361-397.

Ibbotson Associates, 2005. Stocks, Bonds, Bills and Inflation 2005 Yearbook: Market Results for 1926 - 2004. Ibbotson Associates, Chicago.

Investment Company Institute, Spring 2000. 401(k) plan participants: characteristics, contributions, and account activity. ICI Research Series. Washington, DC: Investment Company Institute.

Jagannathan, R., Kocherlakota, N., 1996. Why should older people invest less in stocks than younger people? Federal Reserve Bank of Minneapolis Quarterly Review 20(3), 11-23.

Joulfaian, D., Richardson, D., 2001. Who takes advantage of tax-deferred saving programs? Evidence from federal income tax data. National Tax Journal 54(3), 669-688.

Mankiw, G., Zeldes, S., 1991. The consumption of stockholders and non-stockholders. Journal of Financial Economics 29(1), 97-112.

McGrattan, E., Prescott, E., 2003. Average debt and equity returns: puzzling? American Economic Review 93(2), 392-397.

Mehra, R., Prescott, E., 1985. The equity premium: a puzzle. Journal of Monetary Economics 15(2), 145-161.

Paiella, M., 2001. Limited financial market participation: a transaction cost-based explanation. Institute for Fiscal Studies working paper No. W01/06.

Polkovnichenko, V., 2006. Life cycle portfolio choice with additive habit formation preferences and uninsurable labor income risk. *Review of Financial Studies* 20(1), 83-124.

Shoven, J., Sialm, C., 2003. Asset location in tax-deferred and conventional savings accounts. *Journal of Public Economics* 88(1-2), 23-38.

Tauchen, G., 1986. Finite state Markov chain approximations to univariate and vector autoregressions. *Economics letters* 20(2), 177-181.

The Vanguard Group, 2004. How America saves, 2004: a report on Vanguard defined contribution plans. www.vanguardretirementresearch.com.

Ventura, G., 1999. Flat tax reform: a quantitative exploration. *Journal of Economic Dynamics and Control* 23(9-10), 1425-1458.

Viceira, L., 2001. Optimal portfolio choice for long-horizon investors with nontradable labor income. *Journal of Finance* 56(2), 433-470.

Vissing-Jorgensen, A., 2002. Towards an explanation of household portfolio choice heterogeneity: nonfinancial income and participation cost structures. NBER Working Paper No. 8884.

Yao, R., Zhang, H., 2005. Optimal consumption and portfolio choices with risky housing and borrowing constraints. *Review of Financial Studies* 18(1), 197-239.

Zhou, J., 2009. The asset location puzzle: taxes matter. *Journal of Economic Dynamics and Control* 33(4), 955-969.

Figure 1: Stock market participation for households with both accounts: 2001

SCF

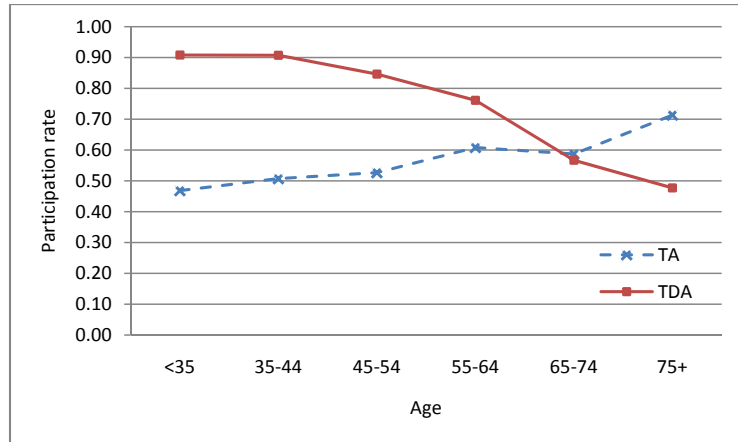


Figure 2: Stock market participation: benchmark results

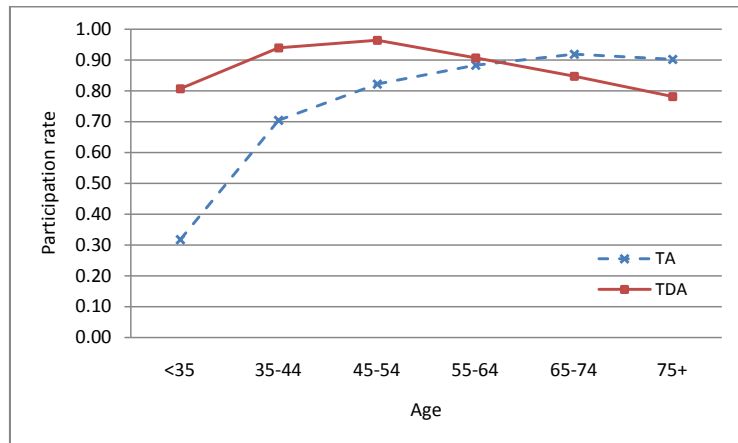


Figure 3: Stock market participation: higher realization rate

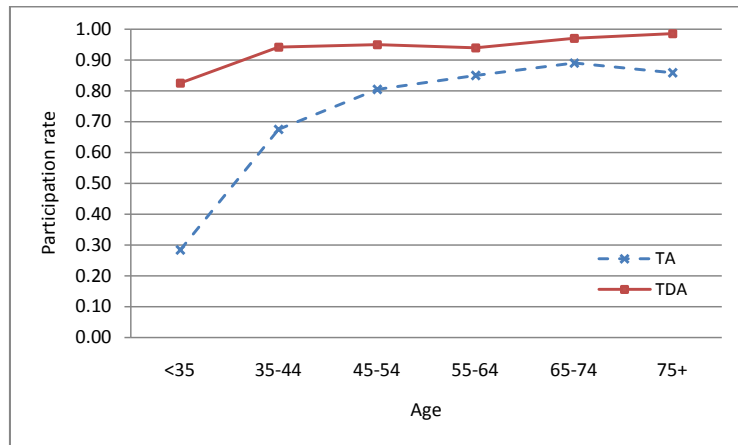


Figure 4: Stock market participation: stronger bequest motive

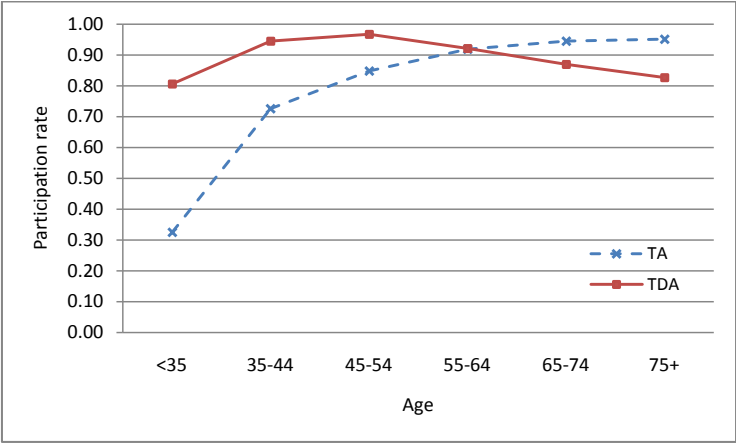


Figure 5: Stock market participation: Case 4

Case 4 assumes two groups of households, ($\gamma = 1.2$ and $\psi = 0.2$) and ($\gamma = 5.0$ and $\psi = 0.4$), with 50% weight each. Stock market entry costs are set at 8% and 0.8% in the TA and TDA, respectively. In addition, there is a per-period participation cost, \$25, in each account.

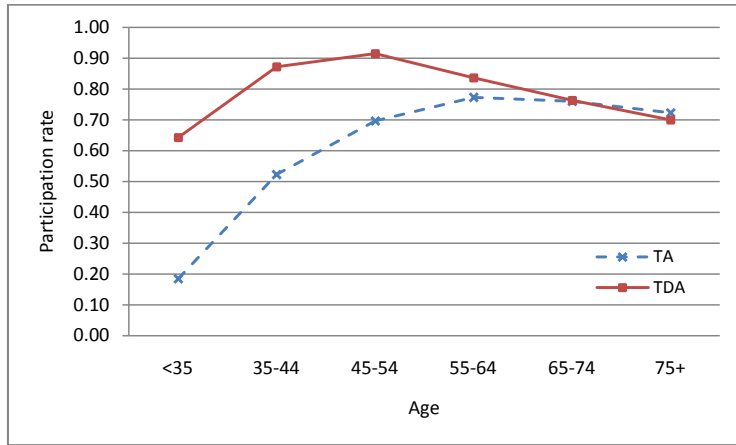


Table 1: Distribution of years of participation in TDA

This table reports the distribution of years of participation in employer-provided tax-deferred retirement plans by age group from the 2001 SCF and the corresponding coverage distribution assumed in the model. The tax-deferred plans include 401K/403B/SRA, Thrift Savings, and TIAA-CREF from the current main job.

Age of head	Years of coverage in the SCF	% in the SCF	Years of coverage in the model	% in the model
22	any	100	1	100
23 - 24	≤ 1	43	1	50
	≥ 2	57	2	50
25 - 29	≤ 1	38	1	33.3
	2 - 3	35	2	33.3
	≥ 4	26	4	33.3
30 - 34	≤ 1	28	1	25
	2 - 3	22	2	25
	4 - 6	30	5	25
	≥ 7	20	8	25
35 - 39	≤ 2	25	1	25
	3 - 5	33	4	25
	6 - 8	20	7	25
	≥ 9	22	10	25
40 - 44	≤ 3	29	2	25
	4 - 8	26	6	25
	9 - 13	25	11	25
	≥ 14	21	15	25
45 - 49	≤ 3	24	2	25
	4 - 8	28	6	25
	9 - 13	23	11	25
	≥ 14	25	15	25
50 - 54	≤ 3	23	2	25
	4 - 8	32	6	25
	9 - 13	21	11	25
	≥ 14	24	15	25
55 - 59	≤ 3	26	2	25
	4 - 8	21	6	25
	9 - 15	25	12	25
	≥ 16	28	17	25
60 - 64	≤ 3	24	2	25
	4 - 8	27	6	25
	9 - 13	23	11	25
	≥ 14	26	15	25

Table 2: Benchmark parameter values

Parameter	Parameter Value	Source/Target
Lifespan (J)	64	Target: real age 22-85
Working Periods (K)	43	Target: retired at age 65
Discount Factor (β)	0.96	Macroeconomics literature
Risk Aversion (γ) and EIS (ψ)	(1.2, 0.2); (5.0, 0.4)	Gomes and Michaelides (2005)
Bequest Motive (b)	0.2	Target: wealth accumulation
Age-Earnings Profile (G_j)		Cocco et al. (2005)
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})	15%	See text
Early Withdrawal Penalty (ϕ)	10%	Regulations on TDAs in U.S.
Min Required Distribution	$\frac{1}{\text{life expectancy}}$	See text
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)
Capital Gains Realization Rate	$\frac{1}{3}$	Barclay et al. (1998)

Table 3: Tax code used in the model

Income	Normalized Income	Marginal Tax Rate
(\$0, \$11500]	(0, 0.46]	0%
(\$11500, \$51500]	(0.46, 2.06]	15%
(\$51500, \$111500]	(2.06, 4.46]	28%
(\$111500, \$161500]	(4.46, 6.46]	31%
(\$161500, \$271500]	(6.46, 10.86]	36%
\$271500 +	10.86 +	39.60%

Table 4: Financial wealth-to-earnings ratios over life cycle

This table reports the median financial wealth-to-earnings ratios in each account for different age groups over the life cycle for households with assets in both accounts in the 2001 SCF and the model.

Age	Data: 2001 SCF		Model	
	TA	TDA	TA	TDA
29-31	0.13	0.19	0.18	0.17
39-41	0.24	0.40	0.19	0.51
49-51	0.29	0.53	0.50	0.81
59-61	1.06	0.87	1.52	0.92
69-71	3.34	1.28	5.05	2.19

Table 5: Aggregate participation rates

For households with assets in both accounts, this Table shows the aggregate participation rates in the TA, in the TDA, and in either account or both accounts. The first row reports data from the 2001 Survey of Consumer Finances, while the other four panels report the results from different versions of the model. Case 1 assumes two groups of households, ($\gamma = 1.2$ and $\psi = 0.2$) and ($\gamma = 5.0$ and $\psi = 0.4$), with 50% weight each. Entry costs are 5% of the persistent income in the TA and 0.5% in the TDA. Case 2 also assumes two groups of households, with 50% weight each, but entry costs are doubled in each account, with 10% in the TA and 1% in the TDA. Case 3 changes the weights of these two groups of households, with weight of 66.67% for the first group ($\gamma = 1.2$ and $\psi = 0.2$) and weight of 33.33% for the second group. The entry costs are kept at 10% in the TA and 1% in the TDA as in Case 2. In Case 4, the weights for the two groups are again 50% and 50%. Stock market entry costs are set at 8% in the TA and 0.8% in the TDA. We also add a per-period participation cost, \$25, in each account.

	Participation in TA (%)	Participation in TDA (%)	Participation in either account or both (%)
Data: households with both accounts	54	81	89
Model (Case 1)	75	87	96
Model (Case 2)	65	82	93
Model (Case 3)	59	83	92
Model (Case 4)	60	79	91