Stock Market Investment: The Role of Human Capital*

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Abstract

Portfolio choice models counterfactually predict (or advise) almost universal equity market participation and a high share for equity in wealth early in life. Empirically consistent predictions have proved elusive without participation costs, informational frictions, or nonstandard preferences. We demonstrate that once human capital investment is allowed, standard theory predicts portfolio choices much closer to those empirically observed. Two intuitive mechanisms are at work: For participation, human capital returns exceed financial asset returns for most young households and, as households age, this is reversed. For shares, risks to human capital limit the household's desire to hold wealth in risky financial equity.

JEL Codes: E21; G11; J24;

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1 Introduction

Household investment in the stock market is generally limited. Not only is it true that a large fraction of households avoid participation altogether, it is also the case that even for those who do invest in equities, holdings as a share of their financial wealth are frequently modest. These observations, particularly those on stock market participation, have proved extremely challenging to explain within the context of models that avoid the imposition of nonstandard preferences, stock market participation costs, or imperfect information. The contribution of this paper is to show that once human capital investment is allowed for, stock market investment can be well understood within an entirely standard setting.

Our approach is premised on a simple observation: Throughout life, households have human capital as an investment opportunity and, in deciding how to invest over the life cycle, will take this into account. Early in life, households' initial human capital levels are low while the horizon over which they will recoup any payoff from learning is long. This implies a high return to human capital investment relative to stocks and a low opportunity cost in terms of forgone earnings. Early investment in human capital therefore yields a sustained increase in expected future earnings. To ensure that consumption remains smooth in the face of such an increase, all households who invest in human capital early in life will desire, absent risk, to *borrow* and not save in financial assets. However, the returns to both human capital and stocks are risky. This gives households a countervailing incentive to build a buffer stock of riskless savings, leading those households who save to avoid risky stocks. Thus, financial asset positions consistent with early investment in human capital will likely involve low stock market participation when young, savings in both stocks and risk-free assets in middle age as diversification becomes important, and dissaving in retirement.

To investigate this logic, we embed the classic Ben-Porath (1967) model of time allocation between working ("earning") and human-capital accumulation ("learning") into a life-cycle consumption-savings model with uninsurable idiosyncratic labor income risk and financial portfolio choice. To our knowledge, we are the first to study human capital *investment* and financial investment decisions in such a setting.

While intuitively appealing, there is no a priori guarantee that the option to invest in human capital is capable of generating a *quantitatively* plausible account of observed household wealth and portfolio behavior. A principal contribution of our paper is to demonstrate that it is. We will show that when households have access to financial assets yielding empirically accurate returns, a standard human capital investment process, disciplined to be consistent with observed earnings data alone, implies household financial market behavior consistent with the data. Our model is able to account extremely well for limited stock market participation, over the entire life cycle, and improves on existing work in capturing the allocation of assets between stocks and bonds. Importantly, our model's predictions are broadly consistent with the observed path for household wealth levels. This makes clear that the portfolio choices we derive describe empirically relevant magnitudes for the size and division of cash flows that the household receives. It is useful to note that our success in capturing financial investment over the life cycle comes from a model parameterized to match earnings dynamics and dispersion alone, and in which there is no appeal to stock-market participation costs, behavioral assumptions, or informational imperfections. This strongly suggests the importance of human capital investment as an option over the life cycle.

A critical observation is that both total and marginal returns to human capital are individual-specific and depend on the household's current holdings while, from the household's perspective, the marginal return to financial investments is invariant to any household-level characteristics. Heterogeneity in the marginal returns to human capital arises from differences across agents not only in their ability to learn or in their initial human capital, but also from any other source of variation in household productivity. One important source of additional heterogeneity is uninsurable idiosyncratic wage risk. To ensure that the dispersion in the marginal payoffs to human capital is of an empirically reasonable magnitude, we follow a huge body of existing work, and especially that of Huggett, Ventura, and Yaron (2011), and allow for uninsurable idiosyncratic risk to the payoffs from human capital.

The idea that human capital might play a significant role in how households invest their wealth is not new (see, for example, the early work of Brito, 1978). Several papers study, as we do, portfolio choice in a life-cycle setting with uninsurable, idiosyncratic labor income risk. However, in most of these papers, human capital is only implicitly defined as the present value of exogenously imposed labor income processes. Examples include Campbell, Cocco, Gomes, and Maenhout (2001), Gomes and Michaelides (2003), Cocco (2005), Gomes and Michaelides (2005), Davis, Kubler, and Willen (2006), Polkovnichenko (2007), and Chang, Hong, and Karabarbounis (2014).[1] These papers, building on earlier work of Jagannathan and Kocherlakota (1996), argue that it is the risk properties of labor income that are likely to influence households' investment in the stock market.

Despite the richness of the models employed by the work above, little work to date has studied portfolios when households may also invest in their human capital. Indeed, we are only aware of two papers that study financial portfolios in the presence of an option to invest in human capital. In a theoretical contribution, Lindset and Matsen (2011) provide a stylized theory of investment

[1] Chang, Hong, and Karabarbounis (2014) represents an innovation within the class of models with exogenous human capital. They focus on understanding the share of wealth held in risky assets. Their model incorporates front-loaded risk of unemployment into a model where agents must learn about the income-generating process that they are endowed with. They show that data on shares can be interpreted as optimal behavior under a particular specification of parameters, including one regulating the speed of Bayesian learning.

in financial wealth and education as "expansion options" in a complete markets infinite-horizon economy, where the rental price of human capital is perfectly correlated with the risky financial asset return. The paper provides insights into optimal portfolio weights when taking human capital into account. It is, however, abstract and not aimed at confronting empirical regularities. Roussanov (2010) is arguably the closest work to ours, as it studies portfolio choice in the presence of a human capital investment option. Agents can exercise this option only once in their lifetime and cannot work until it matures, which may take several periods. Since borrowing is disallowed in this setting, nonparticipation is driven by agents' need to save in order to to finance consumption and education during the investment period. While Roussanov (2010) does not directly compare model outcomes to data, he finds that allowing human capital investment can generate reasonable implications for the share of equity in portfolios. Interestingly, he also shows that such a model generates plausible average earnings paths even though it is not directly parameterized to do so. In our model, by contrast, households may invest in human capital throughout life and, in particular, after formal schooling is typically completed. They may also borrow. We obtain nonparticipation even while allowing for borrowing because returns to human capital are higher than returns to equity for the majority of young households. Our approach thus emphasizes financial investment in a setting that explicitly captures a variety of empirical dimensions of human capital risk and household heterogeneity over the entire life cycle. This is why, in terms of specifying the mechanism for human capital accumulation, we follow Ben-Porath (1967), Huggett, Ventura, and Yaron (2011) and Kim, Maurer, and Mitchell (2013). Huggett, Ventura, and Yaron (2011), in particular, not only endogenize human capital, but also capture both the life-cycle and cross-sectional distribution of earnings. Kim, Maurer, and Mitchell (2013) examine the dynamics of portfolio adjustment in a model that takes into account the fact that doing so is costly in terms of foregone leisure and human capital. We follow their approach to modeling human capital accumulation, though our focus is on documenting the role of human capital accumulation, absent other costs, in matching life-cycle stock market participation and investment shares.

As noted above, a common assumption in many papers aimed at understanding stock-market behavior is that participation entails a cost, usually in the form of a fixed cost of entry; see, for example, Campbell, Cocco, Gomes, and Maenhout (2001) and Cocco (2005).[2] Some of the preceding papers also make assumptions on preferences, such as allowing for habit formation (Gomes and Michaelides, 2003; Polkovnichenko, 2007) or heterogeneous risk preferences (Gomes

[2]Haliassos and Michaelides (2003) is an example of a paper that introduces a fixed cost in an infinite horizon setting. However, once this entry cost is paid, households hold their entire financial wealth in stocks. In other words, in their setting, the empirically observed coexistence of risky and risk-free asset holdings in household portfolios remains a puzzle. For an assessment of the size of stock market participation costs, though exclusively in models that abstract from human capital, see Khorunzhina (2013) and references therein.

and Michaelides, 2005). Along this dimension, our work is closest to that of Davis, Kubler, and Willen (2006), who do not make additional assumptions on preferences or stock-market participation costs and obtain limited stock-market participation early in life via the presence of a wedge between the borrowing rate and risk-free savings rate. However, they do not allow for human capital investment, and, as we will show, this matters. Nevertheless, it is useful to keep in mind that our model is indeed close to theirs: In the special case of our model where human capital investment is not permitted, we find results very similar to theirs. In essence, therefore, our work can be seen as building most closely on the insights of four papers—Davis, Kubler, and Willen (2006), Roussanov (2010), Huggett, Ventura, and Yaron (2011), and Kim, Maurer, and Mitchell (2013)—to demonstrate that household financial investment behavior can be quantitatively understood with standard tools.

While our model's ability to closely account for participation (the "extensive margin" of stock market investment) represents a contribution to one strand in the literature, our results for the share of wealth invested in stocks (the "intensive margin") connects our work to another strand of the literature, starting with the classic work of Merton (1969) and Samuelson (1969). In general, the studies that have examined the implications of labor income (even when it is endogenous) for life-cycle portfolios concur that, in spite of labor income risk, a young investor should place much of her financial wealth in the risky asset. This result holds in these models because labor income shocks are assumed to be (nearly) independent from stock-market return innovations. Thus, a young investor chooses to diversify away her human capital risk by holding a high fraction of her liquid wealth in a well-diversified portfolio of stocks.[3] However, as we show, once human capital investment is disciplined to match observed earnings dispersion, the typical household's share of financial wealth held in stock-market equity is closer to the data—and far from 100%. Along this dimension, our model shares with recent work the implication that shares should be hump shaped

[3]For example, Cocco, Gomes, and Maenhout (2005) argue that as individuals age, the present value of their labor income decreases because of the decrease in the number of remaining working years. Following the logic of Jagannathan and Kocherlakota (1996), they further argue that labor income usually acts as a substitute for holding a riskless asset and, as such, should encourage households to reduce the share of stocks in their portfolio as they age. In the same spirit, Viceira (2001) shows that the fraction of savings optimally invested in stocks is larger for employed investors than for retired investors when labor income risk is uncorrelated with stock return risk. Within the class of models with exogenous human capital, recent work measures the extent to which earnings are bond-like or stock-like and studies the implications for the share of wealth held in equities (Benzoni, Collin-Dufresne, and Goldstein, 2007; Huggett and Kaplan, 2015). Others examine the role of labor supply. For example, Gomes, Kotlikoff, and Viceira (2008) endogenize the labor supply decision, thus allowing households who fare poorly on the stock market to hedge their losses by working more to increase their labor income. Chai, Horneff, Maurer, and Mitchell (2011) allow for flexibility both in work hours and in the choice of retirement age. Both papers conclude that the optimal share of stocks in the household's portfolio should be age-dependent, with the share being highest at young ages. In important early work, Heaton and Lucas (1997) find that households would want to allocate all of their savings to stocks under a variety of assumptions, including the presence of transactions costs.

over the life cycle (see, e.g. Benzoni, Collin-Dufresne, and Goldstein (2007) and the references therein). The mechanism by which we obtain this result differs, however. While these authors find that shares exhibit a hump shape if labor income and stock market returns are positively correlated at long horizons, we show that positive correlation is not necessary. Moreover, we show that once human capital investments are allowed, optimal behavior implies portfolio shares over the life cycle that are closer to the data than predicted by prior work.

Before laying out the model in detail in Section 3, we describe some facts about household portfolios and earnings in the next section. The calibration is laid out in Section 4 and results are provided in Section 5.

2 Data

2.1 Household Portfolios

We begin by describing salient facts about household financial portfolios from the Survey of Consumer Finances (SCF). The SCF is a survey of a cross section of U.S. families conducted every three years by the Federal Reserve Board. It includes information about families' finances as well as their demographic characteristics. While the SCF provides us with rich detail about household finances, it is not a panel, so it does not enable us to directly observe the evolution of finances over the life cycle. To overcome this, we follow a methodology similar to Poterba and Samwick (1997) to create life-cycle profiles.

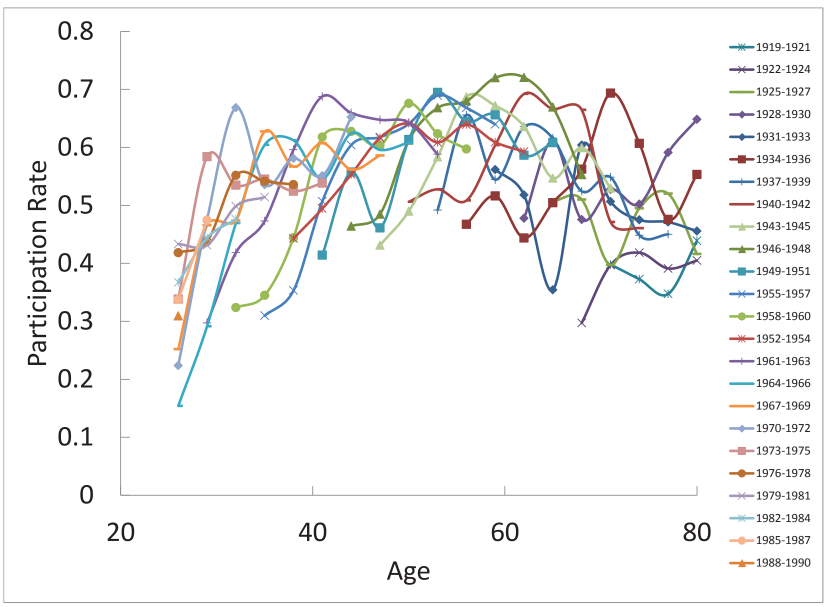
Our goal is to construct life-cycle profiles of participation in the stock market and stockholdings using cohort-level data. As Deaton (1985) describes, each successive cross-sectional survey of the population will include a random sample of a cohort if the number of observations is sufficiently large. Using summary statistics about the cohort from each cross section, a time series that describes behavior *as if* for a panel can be generated. In particular, sample cohort means will be consistent estimates of the cohort population mean.

To implement a procedure in this spirit, we begin by pooling households from all nine waves of the 1989-2013 SCF into a single dataset. We assign a household to a cohort if the head of the household is born within the three-year period that defines the cohort. We have 24 cohorts in all, with the oldest consisting of households whose head was born between 1919 and 1921 and the youngest consisting of households with heads born between 1988 and 1990. We include all observations where the household head is between the ages of 23 and 79, to be consistent with assumptions we make later in our theoretical model. For the same reason, we exclude from our sample those households whose head has less than a high school diploma.

Except for the cohorts that are too young or too old to be represented in all waves of the survey, we have at least a hundred observations of every cohort in each survey year. We use this data to create life-cycle profiles of cohort participation in the stock market. We will define a household as participating in the stock market if they have a positive amount of financial assets invested in equity. The variable in the SCF that measures this includes directly held stocks as well as stocks held in mutual funds, IRAs/Keoghs, thrift-type retirement accounts, and other managed assets.

In Figure 1, we plot the average participation of each of the 24 cohorts over their life cycle (defining the cohort by the mid-point of the age range of the cohort). For example, we observe the cohort born in 1943-45 from the time they are age 44–46 (in the 1989 wave of the SCF) to the time they are age 68–70 (in the 2013 SCF). Figure 1 shows that participation for this cohort increases from roughly 43% to 53%.

Figure 1: Household Stock Market Participation Rate by Cohort (SCF)



The differences in participation rates across cohorts may be the result of three factors: aggregate fluctuations experienced by all cohorts living in a particular year (time effects), lifetime experiences that vary by year of birth (cohort effects), and getting older (age effects). Since we are interested in participation over the life cycle—the changes in a household's portfolio that result from that household getting older—we need to distinguish age effects from cohort and time effects. The three variables are perfectly collinear (age=year of birth–year of observation), which makes separately identifying the three effects empirically challenging. Following Poterba and Samwick (1997), we make the identifying assumption that time effects are zero. We recognize that making different identifying assumptions would generate different life-cycle estimates, particularly for shares (Ameriks and Zeldes, 2004), and we discuss this later in the context of our results.

The decision to invest in stocks can be expressed using a standard probit model

$$S_i^* = \alpha + \sum_{n=2}^{21} \beta_n age_{i,n} + \sum_{m=2}^{24} \gamma_m cohort_{i,m} + \epsilon_i \tag{1}$$

where $S_i = 1$ if $S_i^* > 0$ and 0 otherwise. S_i is the discrete dependent variable that equals 1 if household i invests in stocks and zero otherwise. S_i is determined by the continuous, latent variable S_i^*, the actual amount invested in stocks. S_i^*, and thus S_i, is specified in the above as a function of $age_{i,n}$ and $cohort_{i,m}$. We include 19 dummies for age categories ranging from 23–25 to 77–79, with $age_{i,n}$ being the dummy variable that indicates whether the current age of the household head lies in one of these intervals. We include 24 cohort dummies $cohort_{i,m}$ to represent cohorts born in one of the three-year intervals in the range from 1919–21 to 1988–90.

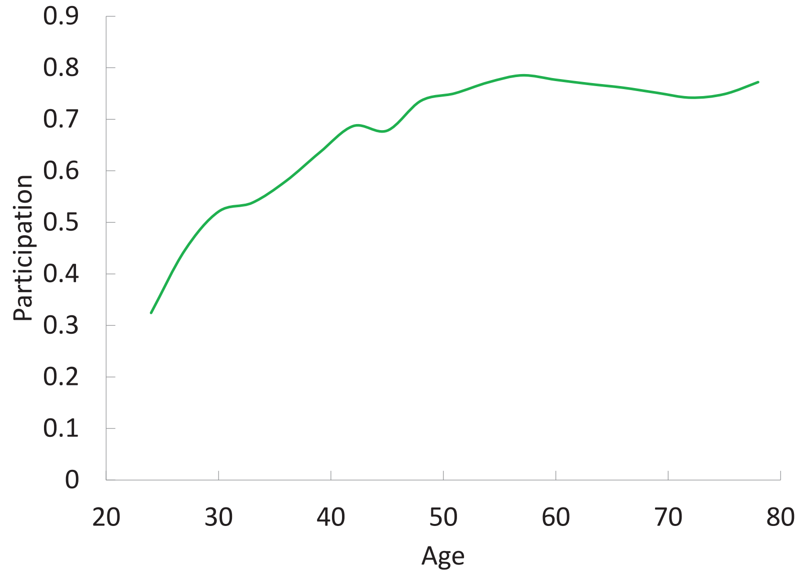
The SCF oversamples wealthy households and therefore needs to be weighted to obtain estimates that are representative of the U.S. population. As in Poterba and Samwick (1997), we estimate Equation (1) using year-specific sample weights normalized such that the sum of the weights (which equals the population represented) remains constant over time. The results of the estimation are reported in Table 2 in the Appendix.[4] We use the coefficients to construct our estimate of the life-cycle profile of stock-market participation. Figure 2 shows the results for the cohort born in 1973–75.[5] By our estimation, participation in the stock market increases till agents reach age 60, after which it levels off.

We are also interested in portfolio allocation over the life cycle conditional on participation. In other words, we want to know how the fraction of assets invested in stocks evolves over the life cycle. As we will describe later, our model will have one risk-free asset b and one risky asset s, so the measure in which we are interested is $\frac{s}{s+b}$. As described earlier, the risky asset is the value of equity that the household holds, which includes directly held stocks and stocks in mutual funds, retirement accounts, and other managed assets. household's household's risk

[4]We use all five implicates from the SCF in our estimation. While this provides accurate coefficients, the statistical significance of the results may be inflated. We only need the values of the coefficients to construct life-cycle profiles; therefore, we do not report the results of the significance tests.

[5]Participation rates would be lower over the life cycle for older cohorts and higher for younger cohorts. We choose to display results for this cohort to be consistent again with the assumptions in our theoretical model. As we will see, debt in our model will be nondefaultable. Those born in 1973–75 would face a nondefaultable student loan regime by the time they go to college.

Figure 2: Estimated Participation Rate over the Life Cycle (SCF, 1973–75 Birth Cohort)



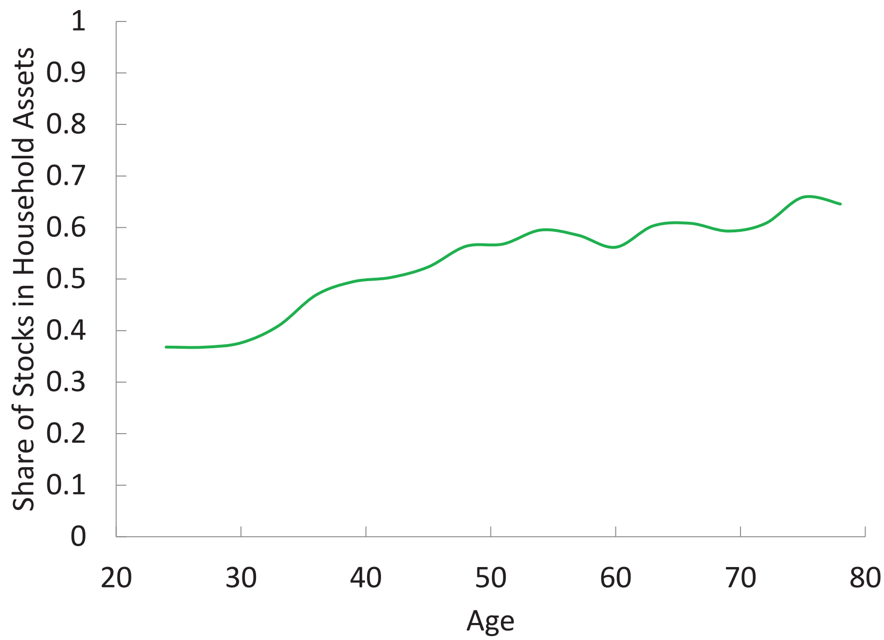
We calculate the fraction $\frac{s}{s+b}$ for those who own equity. This measure lies between 0 and 1 by construction, so we want our life-cycle estimate of it to lie between 0 and 1 as well. To ensure this, we construct a logistic transformation to obtain the variable $Y_i = \ln \frac{\frac{s}{s+b}}{1-\frac{s}{s+b}}$. We run the following Ordinary Least Squares (OLS) regression on this variable.[6]

$$Y_i = \alpha + \sum_{n=2}^{21} \beta_n age_{i,n} + \sum_{m=2}^{24} \gamma_m cohort_{i,m} + \epsilon_i \tag{2}$$

The results are reported in Table 3. As we did for participation, we use the reported coefficients to estimate the life-cycle profile of portfolio allocation for the cohort born in 1973–75. Figure 3 shows the results. The estimated share of risky assets conditional on participation increases steadily after age 25.

[6]Note that, unlike Poterba and Samwick (1997), we do not use Tobit to estimate this equation. By construction, our data is not censored— values below 0 and above 1 are infeasible. Moreover, since our variable of interest is the share of risky assets in the household's portfolio conditional on participation, it will always be strictly positive. It is possible for it to exactly equal 1, but we have very few observations with this value, and in this instance we set it to 0.999999.

Figure 3: Estimated Average Fraction of Stocks in Portfolio over the Life Cycle Conditional on Participation for 1973–75 Birth Cohort (SCF)



2.2 Earnings

Next, we compute statistics of age-earnings profiles from the CPS for 1969-2002 using a synthetic cohort approach, following Ionescu (2009). To be precise, we use the 1969 CPS data to calculate the earnings statistics of 25-year-olds, the 1970 CPS data to compute earnings statistics of 26-year-olds, and so on. We include only those who have at least 12 years of education, to correspond with our modeling assumption that agents start life after high school. To compute the mean, inverse skewness, and Gini of earnings for households of age a in any given year, we average the earnings of household heads between the ages of $a-2$ and $a+2$ to obtain a sufficient number of observations. Life-cycle profiles for all three statistics are shown in Figure 25 in the Appendix.[7]

With these facts in hand, we turn to the description of the model.

[7]We obtain real earnings in 2013 dollars using the Consumer Price Index. We convert earnings to model units such that mean earnings at the end of working life, which equal $70,800, are set to 100.

3 Model

Our model is a standard model of life-cycle consumption and savings in the presence of uninsurable risk (e.g. Gourinchas and Parker, 2002), but it contains two enrichments. First, households choose their level of human capital, and second, households can invest in both risky and riskless assets.

The economy is populated by a continuum of agents who value consumption throughout a finite life. Age is discrete and indexed by $t = 1, ..., T$, where $t = 1$ represents the first year after high school graduation, and $t = J$ represents the age of retirement. Agents enter the model endowed with an initial level of human capital, h_0, which varies across the population.

In each period, households can divide their time between work and the accumulation of human capital, as in the classic model of Ben-Porath (1967). Households consume and decide how to allocate any wealth they have in period t between a risky asset s_{t+1} and a risk-free asset b_{t+1}. Households also have the option to borrow, that is $b_t \geq -\underline{b}$, with $\underline{b} > 0$, may be positive or negative.

To capture risk and heterogeneity, we follow Huggett, Ventura, and Yaron (2011), and allow for four potential sources of heterogeneity across agents — their immutable learning ability, a, human capital stock, h, initial assets, x, and subsequent shocks to the yield on their holdings of human capital, i.e., their earnings. The set of initial characteristics are jointly drawn according to a distribution $F(a, h, x)$ on $A \times H \times X$. Lastly, households are not subject to risks once they retire, i.e., once $t > J$.

3.1 Preferences

All agents have identical preferences, with their within-period utility given by a standard CRRA function with parameter σ, and with a common discount factor β. The general problem of an individual is to choose consumption over the life cycle, $\{c_t\}_{t=1}^{T}$ to maximize the expected present value of utility over the life cycle,

$$\max_{(\{c_t\} \in \Pi(\Psi_0))} E_0 \sum_{t=1}^{T} \beta^{t-1} \frac{c_t^{1-\sigma}}{1-\sigma} \tag{3}$$

$\Pi(\Psi_0)$ denotes the space of all feasible combinations $\{c_t\}_{t=1}^{T}$, given initial state $\Psi_0 \equiv \{a_0, h_0, x_0\}$. Agents do not value leisure.

3.2 Financial Markets

There are two financial assets in which the agent can invest, a risk-free asset, b_t, and a risky asset, s_t, to be interpreted as stock-market equity.

Risk-free assets

An agent can borrow or save by taking negative or positive positions, respectively, in a risk-free asset b_t. Savings ($b_t \geq 0$) will earn the risk-free interest rate, R_f. Borrowing ($b_t < 0$), however, carries an additional (proportional) cost as in Davis, Kubler, and Willen (2006), denoted by ϕ, to represent costs of intermediating credit. The borrowing rate, R_b, therefore, is higher than the savings rate and given by: $R_b = R_f + \phi$. As noted above, borrowing is subject to a limit $\underline{b}$.

Risky assets

For ease of exposition, we will refer to the risky assets as "stocks" and denote the agent's holdings of these claims between period t and $t+1$ by s_{t+1}. Stocks yield their owners a stochastic gross real return in period $t+1$, $R_{s,t+1}$ whereby the excess return on stocks is given by:

$$R_{s,t+1} - R_f = \mu + \eta_{t+1}, \tag{4}$$

The first term μ is the mean excess return to stocks. The second, η_{t+1}, represents the period $t+1$ innovation to excess returns and is assumed to be independently and identically distributed (i.i.d.) over time with distribution $N(0, \sigma_\eta^2)$.

Given asset investments at age t, b_{t+1} and s_{t+1}, financial wealth at age $t+1$ is given by $x_{t+1} = R_i b_{t+1} + R_{s,t+1} s_{t+1}$, with $R_i = R_f$ if $b \geq 0$ and $R_i = R_b$ if $b < 0$.

3.3 Human Capital

The key innovation of our work is to allow for human capital investment in a model of portfolio choice. We do this by employing the workhorse model of Ben-Porath (1967), extended to allow for risks to the payoff from human capital: In each period, agents can apportion some of their time to acquiring human capital, or they may work and earn wages that depend on current human capital and shocks. At any given date, an agent's human capital stock summarizes their ability to turn their time endowment into earnings. In this sense, it reflects *earning* ability and, critically, can be accumulated over the life cycle. By contrast, *learning* ability, which governs the effectiveness of the production function that maps time to human capital investment, is fixed at birth and does not change over time. Both learning ability and initial human capital will be allowed to vary across agents and, as we will demonstrate, heterogeneity in each is implied by earnings heterogeneity in the data among the youngest cohorts and by the subsequent evolution of earnings dispersion.

Human capital investment in a given period occurs according to the human capital production function, $H(a, h_t, l_t)$, which depends on the agent's immutable learning ability, a, human capital, h_t, and the fraction of available time put into human capital production, l_t. Human capital depreciates at a rate δ. The law of motion for human capital is given by

$$h_{t+1} = h_t(1-\delta) + H(a, h_t, l_t) \tag{5}$$

Following Ben-Porath (1967), the human capital production function is given by $H(a, h, l) = a(hl)^{\alpha}$ with $\alpha \in (0, 1)$. As demonstrated by Huggett, Ventura, and Yaron (2006), the Ben-Porath model has the additional advantage of being able to match the dynamics of the U.S. earnings distribution given the appropriate joint distribution of initial ability and human capital.

3.4 Labor Income

Human capital confers a return (i.e., its rental rate, wages) in each period that is subject to stochastic shocks. Specifically, earnings are given by a product of the stochastic component, z_t, the rental rate of human capital, w_t, the agent's human capital, h_t, and the time spent in market work, $(1 - l_t)$.

Therefore, agent i's earnings in period t are given by

$$log(y_{it}) = G(w_t, h_t, l_t) + z_{it} \tag{6}$$

with $G(w_t, h_t, l_t)$ representing the deterministic component as a function of rental rate w_t, human capital stock at age t, h_t, and labor effort, $1 - l_t$, and z_t representing the stochastic component. The rental rate of human capital evolves over time according to $w_t = (1 + g)^{t-1}$ with the growth rate, g.[8]

The stochastic component, z_{it}, consists of an idiosyncratic temporary (i.i.d) shock $\epsilon_{it} \sim N(0, \sigma_\epsilon^2)$ and a persistent shock u_{it}:

$$z_{it} = u_{it} + \epsilon_{it}$$

where

$$u_{it} = \rho u_{i,t-1} + \nu_{it}$$

[8] The growth rates for wages are estimated from data. See Section 4.1 for details.

follows an AR(1) process as in Gourinchas and Parker (2002) and Hubbard, Skinner, and Zeldes (1995), with $\nu_{it} \sim N(0, \sigma_\nu^2)$ representing an innovation to u_{it}. The variables u_{it} and ϵ_{it} are realized at each period over the life cycle and are not correlated.

3.5 Means-Tested Transfer and Retirement Income

To accurately capture the risk-management problem of the household, it is important to make allowance for additional sources of insurance that may be present. In the United States, there is a vast array of social-insurance programs that, if effective, bound households' purchasing power away from zero. Moreover, it is well known, since at least Hubbard, Skinner, and Zeldes (1995), that such a system may be acting to greatly diminish savings among households who earn relatively little. In our model, this will consist of unlucky households, households with low learning ability, or both. To ensure that we confront households with an empirically-relevant risk environment in which they choose portfolios, we specify a means-tested income transfer system, which, in addition to asset accumulation, can provide another source of insurance against labor income risk (Campbell, Cocco, Gomes, and Maenhout, 2001). Agents receive means-tested transfers from the government, τ_t, which depend on age, t, income, y_t, and net assets, x_t. These transfers capture the fact that in the U.S. social insurance is aimed at providing a floor on consumption. Following Hubbard, Skinner, and Zeldes (1995), we specify these transfers by

$$\tau_t(t, y_t, x_t) = \max\{0, \underline{\tau} - (\max(0, x_t) + y_t)\} \tag{7}$$

Total pre-transfer resources are given by $\max(0, x_t) + y_t$ and the means-testing restriction is represented by the term $\underline{\tau} - \max((0, x_t) + y_t)$. These resources are deducted to provide a minimal income level $\underline{\tau}$. For example, if $x_t + y_t > \underline{\tau}$ and $x_t > 0$, then the agent gets no public transfer. By contrast, if $x_t + y_t < \underline{\tau}$ and $x_t > 0$, then the agent receives the difference, case in which he has $\underline{\tau}$ units of the consumption good at the beginning of the period. Agents do not receive transfers to cover debts, which requires the term $\max(0, x_t)$. Lastly, transfers are required to be nonnegative, which requires the "outer" max.

After period $t = J$ when agents start retirement, they get a constant fraction ψ of their income in the last period as working adults, y_J, which they divide between risky and risk-free investments. this may

3.6 Agent's Problem

The agent's problem is to maximize lifetime utility by choosing asset positions in stocks and bonds (or borrowing), and, in what is novel in our paper, time allocated throughout life to market work and human capital investment

We formulate the problem recursively. Let any period t variable j be denoted by j and its period $t+1$ value by $j^{'}$. The household's feasible set for consumption and savings is determined by its age, t, ability, a, beginning-of-period human capital, h, net worth, $x(b,s)$, current-period realization of the persistent shock to earnings, u, and current-period transitory shock, ϵ.

In the last period of life, agents consume all available resources. The value function in the last period of life is therefore simply their payoff from consumption in that period. Prior to this terminal date, but following working life, agents are retired. Retired agents do not accumulate human capital and do not face human capital risk. Thus, we have $V_T^R(a,x,y_J) = \frac{c^{1-\sigma}}{1-\sigma}$, where $c = x(b,s) + \psi y_J$. Notice that, when retired, human capital is irrelevant as a state, and in what follows, is not part of the household's state. Retired households face a standard consumption-savings problem though, as in working life, they may invest in both risk-free and risky assets. Indeed, in retirement, the only risk agents face comes from the uncertain return on stocks. Their value function for retirees is given by

$$V^R(t,a,b,s,y_J) = \sup_{b^{'},s^{'}}\{\frac{c_t^{1-\sigma}}{1-\sigma} + \beta E_{R_s^{'}} V^R(t+1,a,b^{'},s^{'},y_J)\} \tag{8}$$

where

$$\begin{aligned} c + b^{'} + s^{'} &\leq \psi y_J + R_i b + R_s s \\ b &\geq \underline{b} \end{aligned}$$

In the budget constraint, we remind the reader that $R_i = R_f$ if $b \geq 0$ and $R_i = R_b$ if $b < 0$.

During working life, the agent faces uncertainty from the returns on human capital as well as from any risk assumed in the portfolio they choose. The budget constraint makes clear that current consumption c and total net financial wealth next period $(b' + s')$ must not exceed the sum of current labor earnings $w(1-l)hz$, the value of the portfolio $(R_i b + R_s s)$, and any transfers from the social safety net $\tau(t,y,x)$.

$$V(t,a,h,b,s,u,\epsilon) = \sup_{l,h^{'},b^{'},s^{'}}\{\frac{c_t^{1-\sigma}}{1-\sigma} + \beta E_{u^{'}|u,\, R_s^{'}} V(t+1,a,h^{'},b^{'},s^{'},u^{'},\epsilon^{'})\} \tag{9}$$

where

$$
\begin{aligned}
c + b^{'} + s^{'} &\leq w(1-l)hz + R_i b + R_s s + \tau(t, y, x) \text{ for } t = 1, .., J-1 \\
\text{s.t. } l &\in [0,1],\ h^{'} = h(1-\delta) + a(hl)^{\alpha},\ b \geq \underline{b}
\end{aligned}
$$

The value function $V(t, a, h, b, s, u, \epsilon)$ thus gives the maximum present value of utility at age t from states h, b, and s, when learning ability is a and the realized shocks are u and ϵ. The solution to this problem is given by optimal decision rules $l_j^*(t, a, h, b, s, u, \epsilon)$, $h^*(t, a, h, b, s, u, \epsilon)$, $b^*(t, a, h, b, s, u, \epsilon)$, and $s^*(t, a, h, b, s, u, \epsilon)$, which describe the optimal choice of the fraction of time spent in human capital production, the level of human capital, and risk-free and risky assets carried to the next period as a function of age, t, human capital, h, ability, a, and current assets, b and s when the realized shocks are u and ϵ.

4 Mapping the model to the data

There are four sets of parameters in the model: 1) standard parameters, such as the discount factor and the coefficient of risk aversion; 2) parameters specific to asset markets; 3) parameters specific to human capital and to the earnings process; and 4) parameters for the initial distribution of characteristics. Our approach includes a combination of setting some parameters to values that are standard in the literature, calibrating some parameters directly to data, and jointly estimating those parameters that we do not directly observe in the data by matching moments for several observable implications of the model. We summarize parameter values in Table 1 and describe in detail below how we obtain them.

We follow agents from age 25 onward, as this captures the beginning of the portion of life in which households make nontrivial investments in financial assets and in learning on the job. Agents live $T = 53$ model periods, which corresponds to ages 25 to 78 and retire at age $J = 58$.

4.1 Preference and Financial Market Parameters

The per period utility function is CRRA, $u(c_t) = \frac{{c_t}^{1-\sigma}}{1-\sigma}$, with the coefficient of risk aversion $\sigma = 5$, which is consistent with values chosen in the financial literature. Risk aversion is a key parameter and so we conduct robustness checks on it, in particular we consider higher values up to the upper bound of $\sigma = 10$ considered reasonable by Mehra and Prescott (1985). We also consider lower values, such as $\sigma = 3$. The discount factor ($\beta = 0.96$) chosen is also standard in the literature.

We turn now to the parameters in the model related to financial markets. We fix the mean

Table 1: Parameter Values: Benchmark Model

Parameter	Name	Value
T	Model periods (years)	53
J	Working periods	33
β	Discount factor	0.96
σ	Coeff. of risk aversion	5
R_f	Risk-free rate	1.02
R_b	Borrowing rate	1.11
μ	Mean equity premium	0.06
σ_η	Stdev. of innovations to stock returns	0.157
α	Human capital production function elasticity	0.7
g	Growth rate of rental rate of human capital	0.0013
δ	Human capital depreciation rate	0.0114
ψ	Fraction of income in retirement	0.68
$\underline{\tau}$	Minimal income level	$\$17,936$
$(\rho, \sigma_\nu^2, \sigma_\epsilon^2)$	Earnings shocks	$(0.951, 0.055, 0.017)$
$(\mu_a, \sigma_a, \mu_h, \sigma_h, \varrho_{ah})$	Parameters for joint distribution of ability and initial human capital	$(0.246, 0.418, 87.08, 35.11, 0.57)$

equity premium to $\mu = 0.06$, as is standard (e.g., Mehra and Prescott, 1985). The standard deviation of innovations to the risky asset is set to its historical value, $\sigma_\eta = 0.157$. The risk-free rate is set equal to $R_f = 1.02$, consistent with values in the literature (McGrattan and Prescott, 2000) while the wedge between the borrowing and risk-free rate is $\phi = 0.09$ to match the average borrowing rate of $R_b = 1.11$ (Board of Governors of the Federal Reserve System, 2014). Lastly, we assume that innovations to excess returns are uncorrelated with innovations to the aggregate component of permanent labor income.[9]

4.2 Human Capital and Earnings Parameters

The rental rate on human capital equals $w_t = (1+g)^{t-1}$ where g is set to 0.0013, as in Huggett, Ventura, and Yaron (2006). Given this growth rate, the depreciate rate is set to $\delta = 0.0114$, so

[9]Evidence on this correlation is mixed, ranging from negative to strongly positive. For instance, Lustig and Van Nieuwerburgh (2008) show that innovations in current and future human wealth returns are negatively correlated with innovations in current and future financial asset returns, regardless of the elasticity of intertemporal substitution, while Benzoni, Collin-Dufresne, and Goldstein (2007) argue that the correlation in labor income flows and stock market returns is positive, and large in particular at long horizons. At the same time, prior studies that have examined the relation between labor income and life-cycle financial portfolio choice assume that labor income shocks are (nearly) independent from stock market return innovations (see Cocco, Gomes, and Maenhout, 2005; Davis, Kubler, and Willen, 2006; Davis and Willen, 2013; Gomes and Michaelides, 2005; Haliassos and Michaelides, 2003; Roussanov, 2010 and Viceira, 2001)

that the model produces the rate of decrease of average real earnings at the end of the working life cycle observed in the data. The model implies that at the end of the life cycle negligible time is allocated to producing new human capital and, thus, the gross earnings growth rate approximately equals $(1 + g)(1 - \delta)$. We set the elasticity parameter in the human capital production function, α, to 0.7. Estimates of this parameter are surveyed by Browning, Hansen, and Heckman (1999) and range from 0.5 to 0.9.

In the parametrization of the stochastic component of earnings, $z_{it} = u_{it} + \epsilon_{it}$, we follow Abbott, Gallipoli, Meghir, and Violante (2013) who use the National Longitudinal Survey of Youth (NLSY) data using CPS-type wage measures to estimate the autoregressive coefficients for the transitory and persistent shocks to wages. For the persistent shock, $u_{it} = \rho u_{i,t-1} + \nu_{it}$, with $\nu_{it} \sim N(0, \sigma_\nu^2)$ and for the idiosyncratic temporary shock, $\epsilon_{it} \sim N(0, \sigma_\epsilon^2)$, they report the following values for high school graduates: $\rho = 0.951$, $\sigma_\nu^2 = 0.055$, and $\sigma_\epsilon^2 = 0.017$. We set retirement income to be a constant fraction of labor income earned in the last year in the labor market. Following Cocco (2005) we set this fraction to 0.682, the value for high school graduates. The income floor, $\underline{\tau}$ is expressed in 2013 dollars and is consistent with the levels used in related work (e.g. Athreya, 2008).[10]

Borrowing limits in the model will be allowed to vary across households. We introduce heterogeneity in these limits as follows: We first group agents in the model by quartiles of initial human capital, then compute average earnings over the life cycle for each quartile. We then set the borrowing limit for all agents within a quartile to be a given percentage of the average life-cycle earnings for that quartile. We obtain the relevant percentages from the SCF by dividing the sample into income quartiles and calculating the average credit limit as a percentage of the average income within each quartile. The resulting borrowing limits as a percentage of average earnings by quartiles are: 55%, 48%, 35%, and 27%.[11] Lastly, in our baseline model, we assume that the returns to both risky assets (human capital and financial wealth) are uncorrelated. in

4.3 The Distribution of Assets, Ability, and Human Capital

We turn now to parameters defining the joint distribution of initial heterogeneity in the unobserved characteristics central to human capital accumulation. There are seven parameters, and using only these, we are able to closely match the evolution, over the entire life cycle, of three functions of moments of the earnings distribution: mean earnings, the ratio of mean to median earnings, and

[10]The results turn out to be robust to the choice of this parameter; results are available upon request.

[11]We extrapolate the first percentage from the other three rather than calculating it directly because of the large numbers of zeros in the earnings data for the lowest quartile.

the Gini coefficient of earnings.

To estimate the parameters of this distribution, we proceed as follows. First, for the asset distribution, we use the SCF data described in Section 2 to compute the mean and standard deviation of initial assets to be \$22,568 and \$24,256, respectively, in 2013 dollars. Second, we calibrate the initial distribution of ability and human capital to match the key properties of the life-cycle earnings distribution reported earlier using the CPS for 1969-2002.

Earnings distribution dynamics implied by the model are determined in several steps: i) we compute the optimal decision rules for human capital using the parameters described above for an initial grid of the state variable; ii) we simultaneously compute financial investment decisions and compute the life-cycle earnings for any initial pair of ability and human capital; and iii) we choose the joint initial distribution of ability and human capital to best replicate the properties of U.S. data.

To set values for these parameters, we search over the vector of parameters that characterize the initial state distribution to minimize a distance criterion between the model and the data. We restrict the initial distribution to lie on a two-dimensional grid spelling out human capital and learning ability, and we assume that the underlying distribution is jointly log-normal. This class of distributions is characterized by five parameters.[12] We find the vector of parameters $\gamma = (\mu_a, \sigma_a, \mu_h, \sigma_h, \varrho_{ah})$ characterizing the initial distribution by solving the minimization problems $\min_\gamma \left(\sum_{j=5}^{J} |log(m_j/m_j(\gamma))|^2 + |log(d_j/d_j(\gamma))|^2 + |log(s_j/s_j(\gamma))|^2 \right)$, where $m_j, d_j,$ and s_j are mean, dispersion, and inverse skewness statistics constructed from the CPS data on earnings, and $m_j(\gamma)$, $d_j(\gamma)$, and $s_j(\gamma)$ are the corresponding model statistics. Overall, we match 102 moments.[13] Figure 4 illustrates the earnings profiles for individuals in the model versus CPS data when the initial distribution is chosen to best fit the three statistics considered. We obtain

$$\gamma = (0.246, 0.418, 87.08, 35.11, 0.57)$$

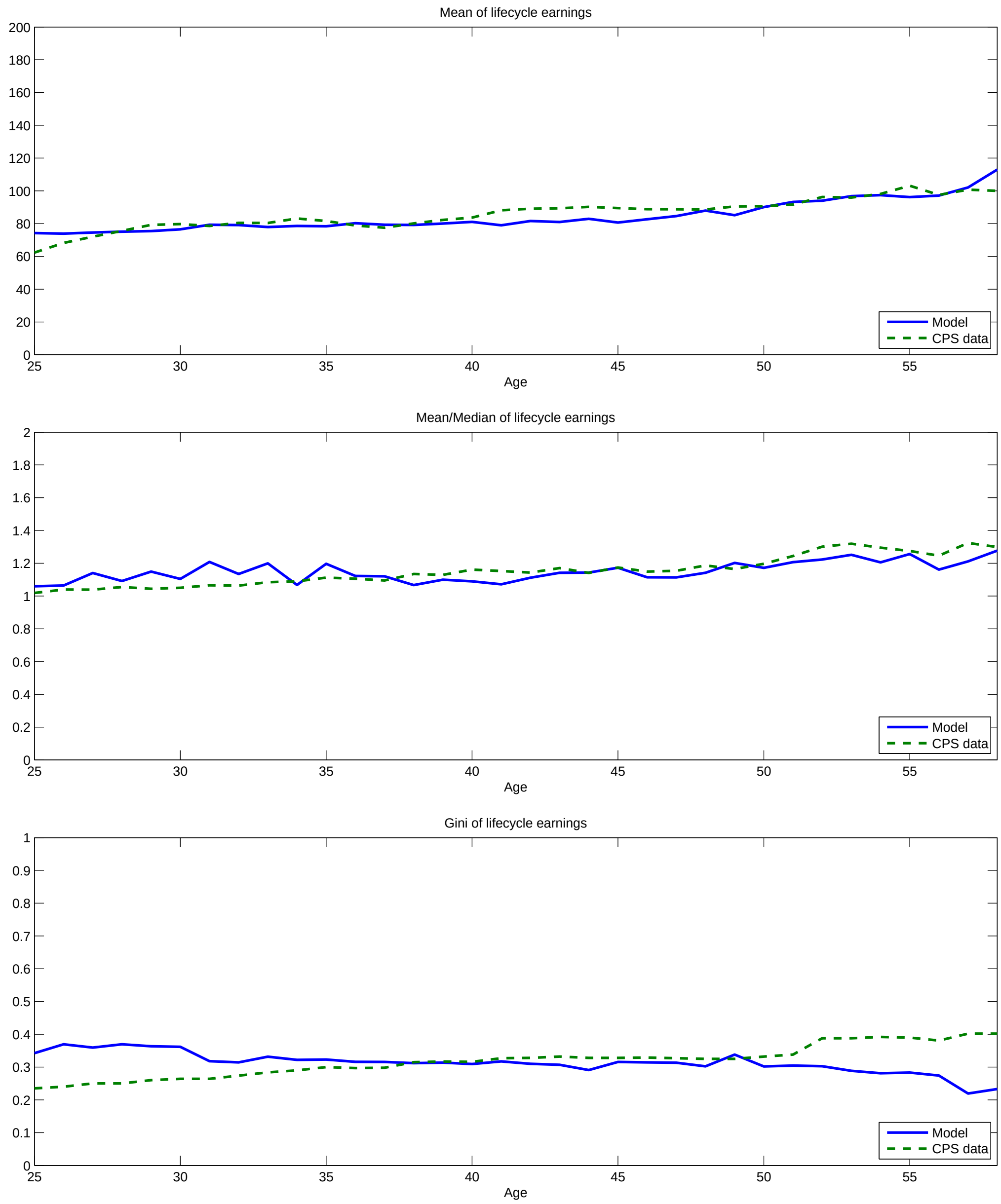
The model performs well given riskiness of assets and stochastic earnings in the current paper.[14]

[12] In practice, the grid is defined by 20 points in human capital and ability.

[13] For details on the calibration algorithm see Huggett, Ventura, and Yaron (2006) and Ionescu (2009).

[14] We obtain a fit of 9.4% (0% would be a perfect fit). As a matter of perspective, we note that a close relative of this part of our model, Huggett, Ventura, and Yaron (2006), obtain a fit of 7% (for the same value of the elasticity parameter $\alpha = 0.7$). Theirs is a Ben-Porath model where the main choice is investment in human capital to maximize lifetime earnings in a framework without investments in financial assets, debt, and without earnings uncertainty. As a measure of goodness of fit, we use $\frac{1}{3J} \sum_{j=5}^{J} |log(m_j/m_j(\gamma))| + |log(d_j/d_j(\gamma))| + |log(s_j/s_j(\gamma))|$. This represents the average (percentage) deviation, in absolute terms, between the model-implied statistics and the data.

Figure 4: Life-cycle earnings



5 Results

Our paper aims to provide a quantitative explanation for the behavior of two observables over the life cycle: stock-market participation and the share of financial wealth held in stocks. We will therefore focus exclusively on these two objects and provide evidence from the model that helps explain our findings. Before proceeding, we recall the basic mechanism at work. Early in life, forgone wages are low while marginal returns to human capital investment are high. Moreover, the horizon over which to reap the benefits of such high marginal rewards is long. This resolves the competition between human and financial investment, especially that in risky equity, in favor of the former. Later in life, this process reverses itself, making equity investment relatively more attractive. The fact that acquiring human capital necessarily takes time away from working means that, unlike financial investments, it alters the time path of earnings. This implies that prior to making human capital investments, the household will consider how best to use financial assets to ensure that consumption is smooth, given that earnings will not be. To illustrate this intuition more explicitly, it is useful to consider a simplified, two-period version of our model.

5.1 A Simple Two-Period Model

Consider a setting in which there is only one financial asset, which is risk-free and can be used for saving or borrowing. In the initial period, 0, agents choose how much to save or borrow using this asset as well as how much of their time endowment to invest in human capital. There is no uncertainty and we assume agents have standard CRRA preferences, with $\sigma = 1$ (log utility). The remainder of the notation is as above, with h_0 denoting initial human capital, R_b denoting the interest rate on risk-free assets, δ the depreciation rate of human capital, α the elasticity of investment in human capital, and a the ability to learn. w_1 denotes first-period wages and $\underline{b}$ denotes the exogenous limit on risk-free borrowing. Initial-period and first-period consumption are given by c_0 and c_1, respectively. Given this, the agent's problem simplifies to:

$$\max_{l_0, b_1} \ln(c_0) + \beta \ln(c_1)$$

subject to

$$\begin{aligned} c_0 + b_1 &\leq w_0(1 - l_0)h_0 \\ c_1 &\leq w_1 h_1 + R_b b_1 \\ h_1 &= h_0(1 - \delta) + a(h_0 l_0)^{\alpha} \\ b_1 &\geq \underline{b} \end{aligned}$$

With $w_1 = w_0(1 + g)$, the optimal solution is:

$$l_0^* = \frac{1}{h_0} \left[\frac{(1 + g)a\alpha}{R_b} \right]^{\frac{1}{(1-\alpha)}}$$

and

$$b_1^*(l_0^*) = \frac{\beta R_b w_0(1-l_0^*)h_0 - w_0(1+g)\left[h_0(1-\delta) + a(h_0 l_0)^\alpha\right]}{R_b(1+\beta)}$$

A first result is that the time invested in human capital increases in the growth rate of the rental rate of human capital ($\frac{dl_0^*}{dg} > 0$) and in the elasticity of investment in human capital ($\frac{dl_0^*}{d\alpha} > 0$). Intuitively, as the returns to human capital grow, or as human capital accumulation becomes more productive, individuals have a higher incentive to invest in human capital and respond accordingly.

Second, we see that to compensate for a low initial endowment of human capital, agents will invest more time in its accumulation. That is, we have that ($\frac{dl_0^*}{dh_0} < 0$). Investment in human capital also increases as the rental rate of *human* capital decreases ($\frac{dl_0^*}{dw_0} < 0$). Intuitively, a low h_0 or w_0 means a lower opportunity of investing in human capital because of a low market value of human capital ($w_0 h_0$) in the first period. In a life-cycle setting, this explains why agents will front-load educational investments, with investment later in life being too costly—precisely because of the additional human capital having been accumulated earlier.

Lastly, and most central for our investigation, is the question of how the relative rates of return on human and financial assets matter for investment choices. We see that optimally, $\frac{dl_0^*}{dR_b} < 0$. This shows that individuals will invest less in human capital when financial investments are more rewarding. More to the point, the simple model tells us that individuals who invest in human capital early in life will lower their exposure to, or investment in, financial assets: We see that $\frac{db_1^*}{dl_0^*} < 0$.

When it comes to the implications of the ease with which households to accumulate human capital for financial investment, the intuition is straightforward: As human capital depreciates faster, or its rewards grow at a slower pace over the life cycle, individuals would rather invest in financial assets. This intuition holds in the simple model: Optimal behavior implies that b_1^* increases in δ. That is, as the depreciation rate of human capital grows, financial assets become more attractive, all else equal. Similarly, decreases in g, the growth rate of the wages (i.e., the rental rate of human capital), increase the appeal of, and investment in, financial assets. With these findings in mind, we now turn to the results from the full quantitative model.

5.2 Stock Market Investment

We begin by studying our model's predictions for the stock-market participation rate. Figure 5 compares our results with their empirical counterparts from the SCF data. It captures one of our paper's two key results—stock-market participation in our model is completely consistent, not just qualitatively, but quantitatively, with the data, over the *entire* life-cycle. Importantly, we see that nonparticipation is not a pathology, but rather it is a direct implication of a standard model. As the two-period model suggests, and as we will show shortly, this result is driven primarily by the presence of human capital investment in our model. As a first step, we turn to Figure 6, which shows the trajectory of time invested in human capital over the life cycle. As is clear, time spent on human capital accumulation is at its highest early in life. For instance, at age 25, households spend about a third of their time endowment on human capital accumulation. During the early part of life, we see also that only around 30% of all households participate in the stock market. Diminishing returns, and a shorter horizon to recoup the investment, imply that human capital accumulation falls with age. As this occurs, we see that stock-market participation steadily increases, reaching around 80% at retirement age. As retirement approaches, we see that the fraction of time allocated to human capital falls sharply, reaching below 0.05 by retirement age.

Figure 5: Life-Cycle Stock Market Participation

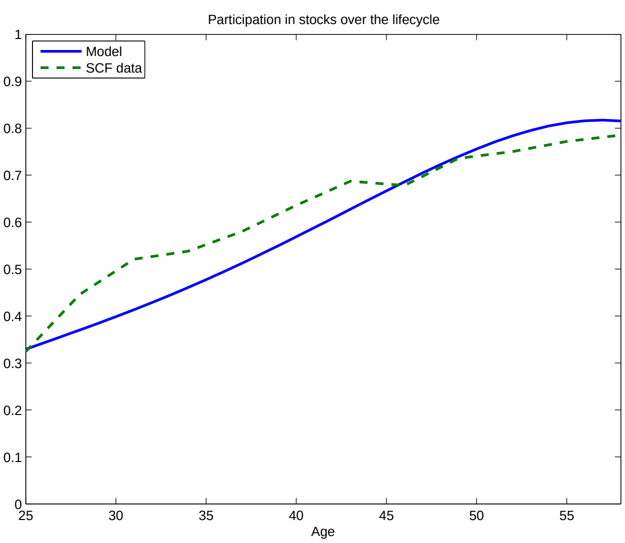
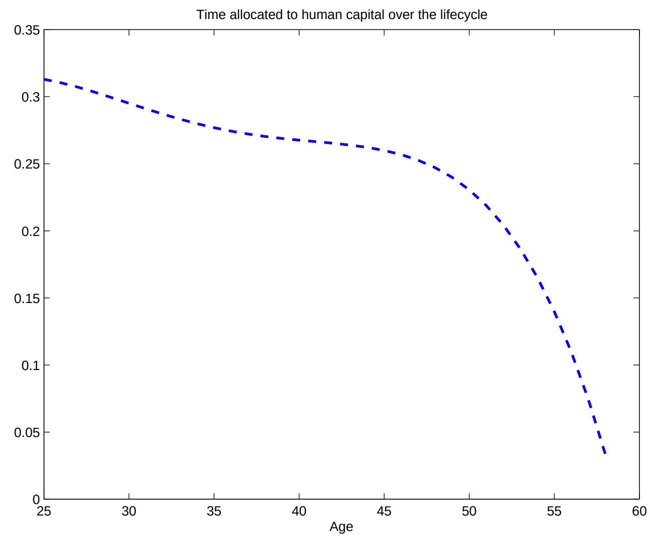
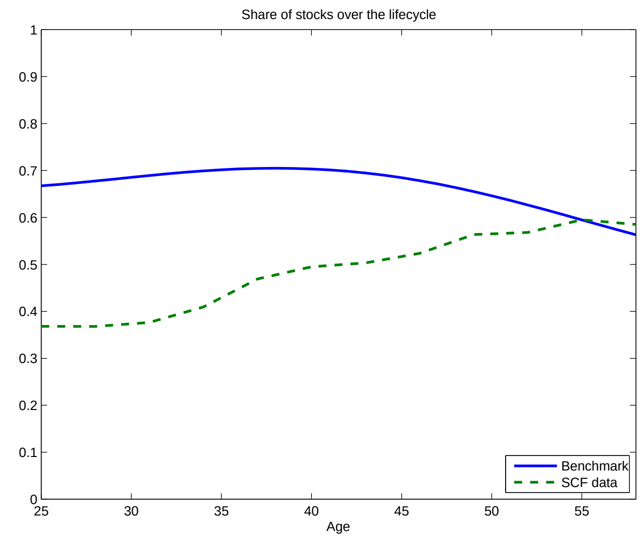


Figure 6: Time Allocated to Human Capital over the Life Cycle



Having shown that stock-market participation can be very well accounted for by the accommodation of human capital, we turn now to the "intensive" margin of stock market investment. As seen in Figure 7, three things are salient. First, the model implies a higher share for wealth held in equity than in our SCF data early in life, but this gap closes later in life. This is important because the bulk of financial wealth is accumulated in this model, as in the data and in "standard" theory, late in life. Households are buffer-stock savers for the early- to middle-age portions of the life cycle, and only begin accumulating substantial wealth (as we will show further below) later in life. As a result, our model accounts well for the proportion of wealth allocated to equity when most relevant. Second, we see that the share implied by optimal behavior in the presence of human capital remains far away from 100%. Importantly, this occurs despite the fact that households in our model retain the ability to work to undo poor returns from the stock market. Third, the hump-shaped profile for shares generated by our model is empirically more plausible than the decreasing profile derived by much of the existing work. Recall that our data estimates for shares are generated under the identifying assumption that time effects are zero and that cohort effects matter. In fact, if we assumed the reverse, we know from Ameriks and Zeldes (2004) that the life-cycle profile of shares would be estimated to be flat or mildly hump shaped. If we abstracted from time and cohort effects altogether and compared our estimates to life-cycle averages as in Gomes and Michaelides (2005), our model's predictions for shares would be very close to the data. Our model implies that the conventional "100 minus age" rule of thumb often prescribed in financial planning circles is not ideal in settings where human capital accumulation is an available decision. has lesson is that

Figure 7: Fraction of Stocks in Household Portfolio

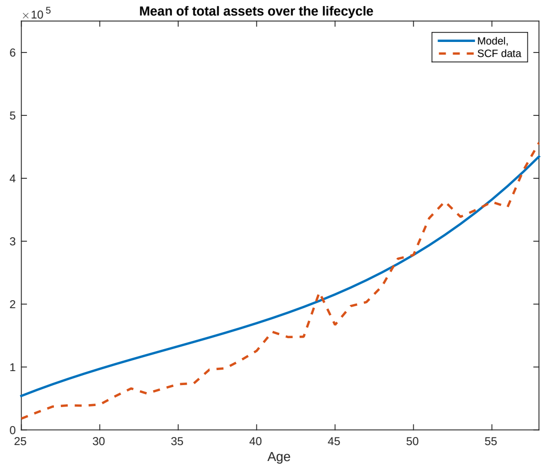


5.3 Implications for Wealth

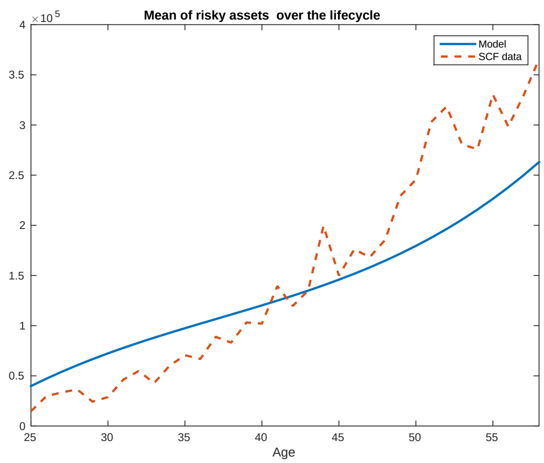
While we have focused so far on stock market investment, our model also produces empirically consistent estimates of life-cycle wealth and its allocation between risky and risk-free assets. Figure 8 shows our model's predictions for wealth accumulation over the life cycle. The trend in wealth accumulation predicted by our model—as well as the trend of each of its components (risky and risk-free assets)—is consistent with the data, despite not being targeted.[15] Thus, our findings for stock market investment arise from a model that captures the magnitude of household savings and consumption throughout the life cycle.

[15] For the data reported in this set of figures, we pool the 1989–2013 waves of the SCF and calculate age-specific weighted means, following a process similar to Cagetti (2003).

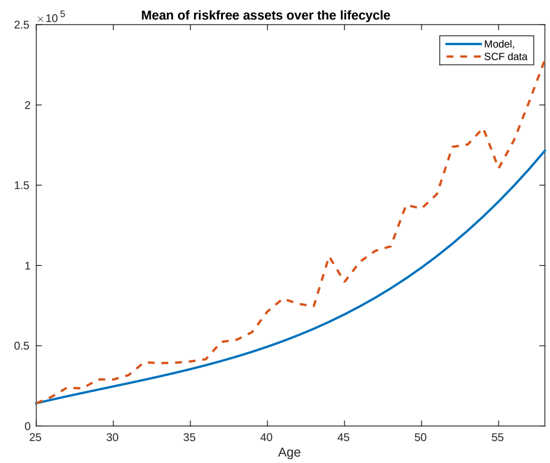
Figure 8: Life-Cycle Wealth Accumulation



(a) Total Assets



(b) Risky Assets



(c) Risk-free Assets

5.4 The Role of Endogenous Human Capital

The most direct route to seeing that that our results are driven primarily by the presence of endogenous human capital investment is to consider outcomes in which this channel is shut down. To do this, we now study a setting in which agents exogenously obtain the labor income stream generated by our *benchmark* model, but do not spend any time on human capital accumulation. To study a case while retaining comparability to the benchmark model requires an additional step, however. Specifically, we "assign" earnings to agents based on their initial endowment of human capital.[16] We retain all the other features of our model, including the shocks to earnings

[16]Note that we still allow agents to differ in their initial endowments but assume that initial human capital and ability are uncorrelated.

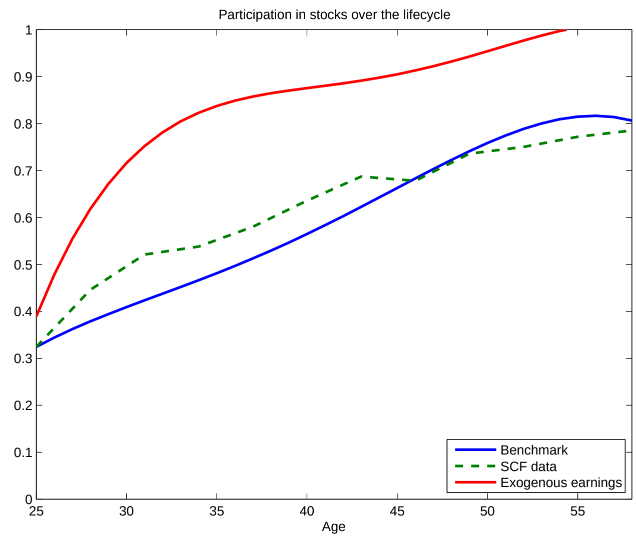
as well as the wedge between the interest rate on borrowing and savings. As such, this setting is very close to that of Davis, Kubler, and Willen (2006). The result is a model in which the distribution of earnings unfolds as in the benchmark model, but does so without requiring human capital investment.

5.4.1 Exogenous Human Capital Investment and Stock-Market Investment

We first report results for participation in Figure 9. Observe now that the participation rate is much higher than in the case with endogenous human capital accumulation. Indeed, we see that it reaches 100% around age 55—a result similar to what Davis, Kubler, and Willen (2006) obtain. This is an important observation because with exogenous human capital, our setting, including its quantitative implications, becomes very similar to theirs, as well as papers cited earlier (e.g., Gomes and Michaelides, 2005).[17] Indeed, we are able to recover the result in these papers that participation increases rapidly to a 100%, with the only deterrent being, just as in Davis, Kubler, and Willen (2006), the presence of the borrowing wedge. By making borrowing expensive—especially for those young households who would like to borrow—this wedge is helpful in keeping households away from stock market participation early in life. However, this result clarifies that the mechanism of high borrowing costs alone is not sufficient to explain limited stock participation later in life, when households are less likely to borrow. The relative improvement provided by our benchmark model drives home the relevance of households' ability to augment their human capital for their financial portfolio choices.

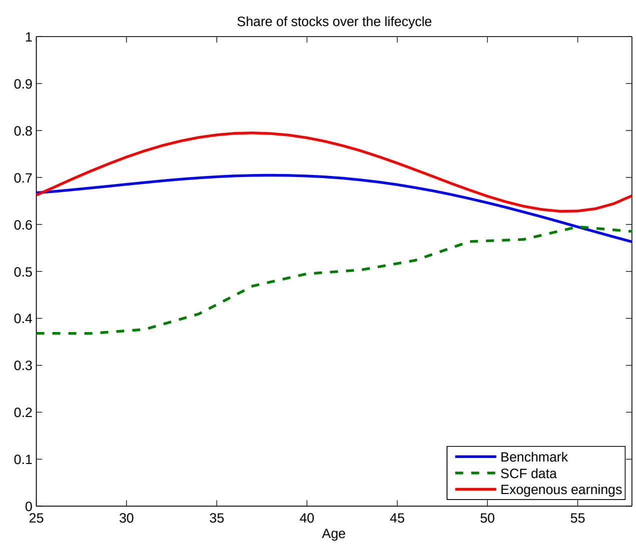
[17]Note, however, that there are still quantitatively meaningful differences in our parameters and theirs, including in risk-aversion, the interest rate on borrowing, and the share of income taken into retirement.

Figure 9: Life-Cycle Stock-Market Participation Under Exogenous Earnings



Turning next to shares, we see from Figure 10 that the exogeneity of earnings—as long as it implicitly reflects the human capital accumulation undertaken in the benchmark economy—does not strongly alter either the quantitative or qualitative properties of the model. As before, the share of wealth held in stocks at any given age is strongly affected by households' need for diversification. In this particular case, the implicit path for human capital, as a quantitative matter, exposes households to slightly less risk than in the benchmark, whereupon they increase their exposure to equity markets.

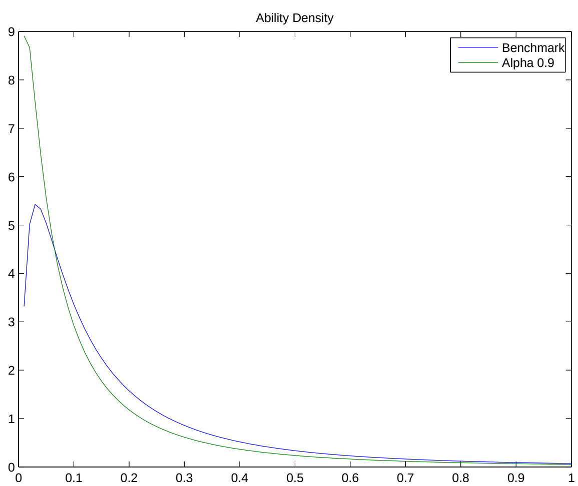
Figure 10: Life-Cycle Stock-Market Shares Under Exogenous Earnings



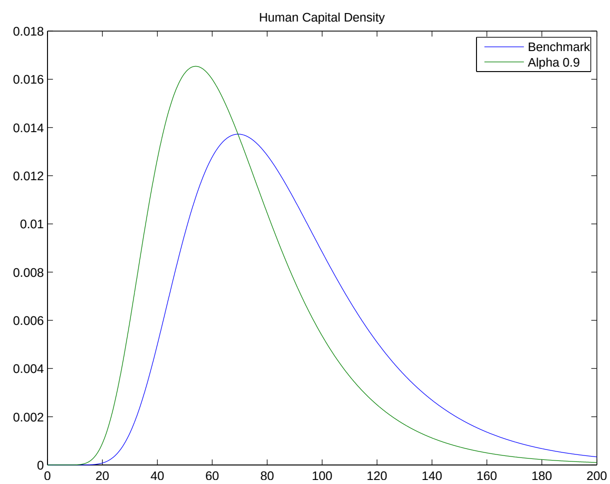
5.5 Human Capital Accumulation Technology

An implication of our model is that the better the technology for learning, the less attractive stock market investment will be. In other words, if the earnings that we observe in the data were generated by a more productive human capital technology than in the benchmark, then we should expect to see lower participation in the stock market than in the benchmark. To illustrate this, consider a case in which the human capital technology is extremely productive: $\alpha = 0.9$.[18] To preserve comparability, we recalibrate all the parameters needed to match earnings facts as in the benchmark. The marginal densities for ability and initial human capital obtained from the recalibration are to the left of those in the benchmark (Figure 11).

Figure 11: Comparison of Marginal Densities in Model with $\alpha = 0.7$ and $\alpha = 0.9$



(a) Ability

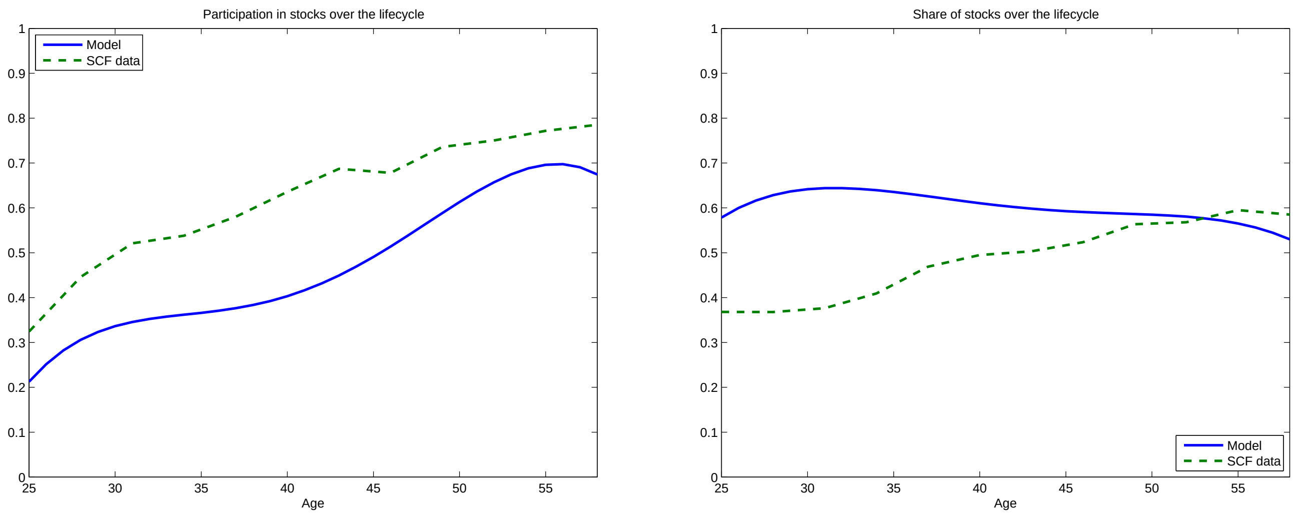


(b) Initial Human Capital

The main results are reported in Figure 12. Participation in the stock market is indeed much lower than in the benchmark, particularly in the middle of the life cycle. This is consistent with the idea that human capital competes with financial assets as an investment option. With a high α, it competes favorably for longer because households encounter marginal returns to human capital investment that diminish more slowly than in the benchmark model. As a result, more households choose to forgo participation in the stock market in favor of human capital accumulation. Conditional on investing in the stock market, households' wealth allocation decisions are driven primarily by other considerations such as their risk preferences. Shares, therefore, are not markedly different in this experiment from those observed in the benchmark model.

[18] The literature provides a range of estimates for this parameter (Browning, Hansen, and Heckman, 1999). While this example reinforces one of the main mechanisms underlying our results, it is important to note that a value of $\alpha = 0.9$ is at the very high end of estimates in the literature and hence has less empirical plausibility.

Figure 12: Results with $\alpha = 0.9$ in Recalibrated Model



(a) Participation (b) Shares

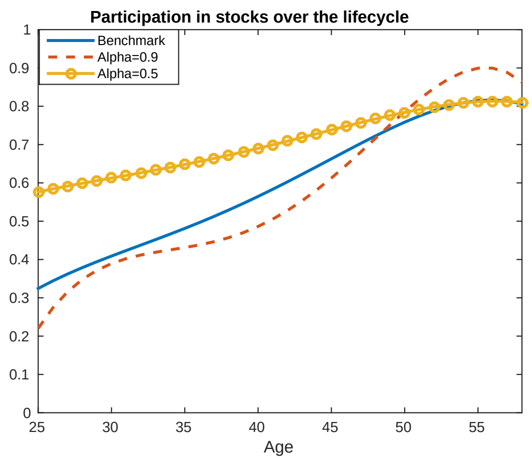
Our model can also shed light on the effects of exogenous or policy-induced changes in the learning technology. How would households in our model respond if they were to be confronted with a change in the productivity of the learning technology? We address this case by considering the effect of decreasing the value of α to 0.5 and increasing it to 0.9. To understand the implications in this case, it is important to keep all other parameters as in the benchmark. The results are reported in Figure 13.

First consider the case where the human capital technology is less productive (α=0.5). Two opposing forces are at work here. On the one hand, because human capital is less productive, agents have less incentive to invest time in it. On the other, to the extent that agents do want to accumulate human capital, they need to invest more time to accumulate the same level of human capital as in the benchmark. It turns out that the first effect dominates; agents invest less time in human capital than in the benchmark, as the bottom left panel shows, with the effect that their human capital levels are lower throughout working life than in the benchmark (bottom right panel). This has two effects on participation. Less time invested in human capital leads to higher participation early in life, while the slower growth rate of human capital over the life cycle (which translates into a flatter path for earnings) leads to a flatter profile of participation over the life cycle.

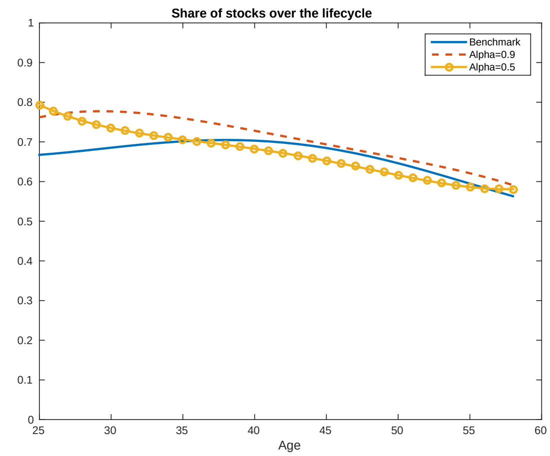
In the case where the human capital technology is more productive (α=0.9), the two opposing forces described earlier also lead agents to invest less time in human capital accumulation. Despite this, their human capital levels are higher and increasing much more steeply than in the benchmark.

The participation rate in the stock market is lower early in life but rises steeply to move past the rate observed in the benchmark by age 50.

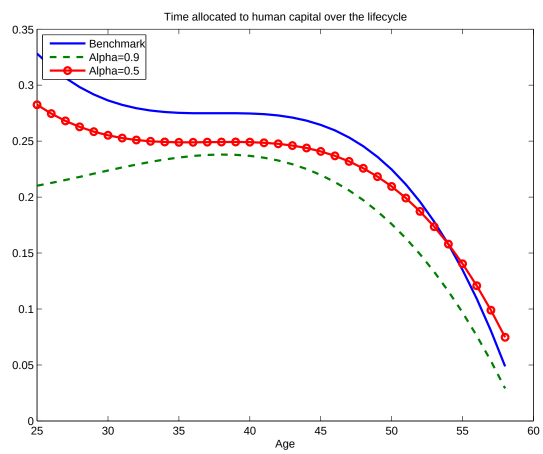
Figure 13: The Effect of the Elasticity of Human Capital Production on Investments



(a) Participation



(b) Shares



(c) Time Invested in Human Capital

This experiment reveals a more general mechanism that is at work in our model. Agents have two ways to move resources through time—using financial assets or human capital. The more human capital pays off in the future, the steeper the earnings profile and the higher the incentive to invest in human capital now. If agents can use financial assets to bring some of those future earnings into the present to smooth consumption, they will, with the result that they do not invest in stocks early in life and instead borrow to the extent possible. On the other hand, if earnings are going to be flat, or if agents don't expect high returns to human capital in the future, they will enter financial markets early. The findings are similar if we change the growth rate of the rental rate of human capital, g (results available upon request).

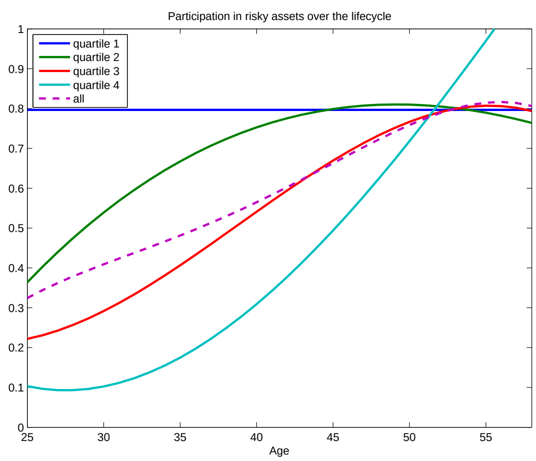
5.6 The Role of Initial Characteristics

In our setting, initial ability and initial human capital both influence the life-cycle earnings profile. Specifically, initial human capital determines the initial level of earnings, while initial ability affects the rapidity with which earnings grow from that level. We have already seen some of the effects of the earnings profile on stock-market investment in the previous experiment; here we trace these effects back to initial conditions. In our benchmark model, initial ability and human capital are positively correlated. In order to describe their effects separately, the figures below are derived from an experiment in which the conditional distributions of ability given human capital do not vary with the level of human capital, and vice versa.

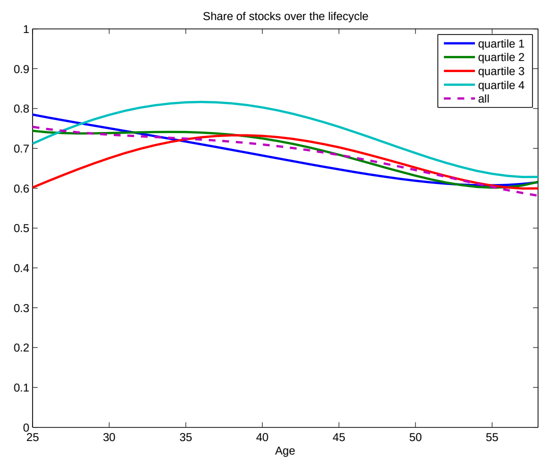
Figure 14 shows participation and human capital investment behavior by quartiles of ability levels, with quartile 1 being the lowest. Agents with high ability accumulate human capital more rapidly than agents with low ability. This is driven by the fact that investing time in human capital is more productive for these agents, which increases their incentive to do so. Of course, these agents do not have to invest as much time to accumulate the same amount of human capital as those with lower ability, and as a result, will be able to enter retirement with a given wealth level with less effort by virtue of their greater earnings capacity. These two forces work in opposite directions, with the result that we observe that agents in the middle two quartiles invest the most time in human capital investment, especially early in life (Figure 14c). Agents in the lowest quartile of ability invest the least time in human capital accumulation, and their time investment remains relatively flat over the life cycle.

When it comes to one of the main questions of interest to us, namely, stock-market participation, we turn to Figure 14a. Recall that in the baseline model, a lower time investment in human capital is associated with a higher stock-market participation rate. This is seen in stark terms here: The lowest quartile participates at extremely high rates (80%). The intuition is simply that for low-ability households, the effective rate of return from human capital is much lower than from equity investment. Further, their earnings profile is relatively flat, which means that their participation rate also remains flat over the life cycle. In contrast, the high initial investment in human capital, particularly for quartiles 2 and 3, and the steeper earnings profile, particularly for quartile 4, is associated with these groups exhibiting a steeply increasing stock market participation rate over the life cycle. For these households, learning, especially when young, is a better investment than earning and investing in equities. This analysis makes clear that once human capital investment is allowed, the model suggests that learning ability, *all else equal*, should be inversely related to equity investment. Of course, this fact and the fact that the model captures observed participation suggests there are other forces at work. In terms of shares, we see (Figure 14b) that quite unlike for participation, those who have chosen to invest in the stock market diversify in fairly consistent manner: Shares are quite similar across ability quartiles, especially as households age. We will see later that initial human capital as well as the risk properties of stock market returns and individual risk aversion are the main drivers of shares and none of these are in play in this experiment.

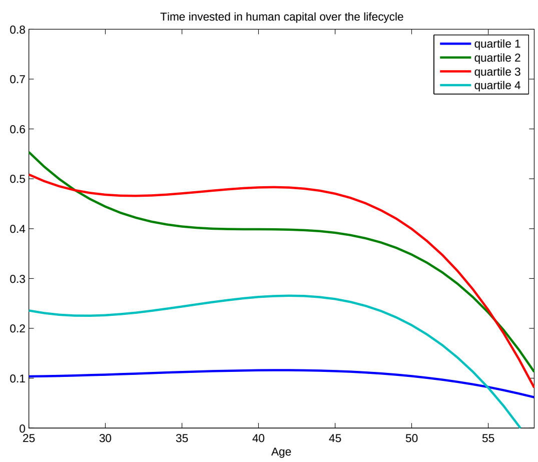
Figure 14: Investment by Quartiles of Ability



(a) Participation



(b) Shares



(c) Time invested in human capital

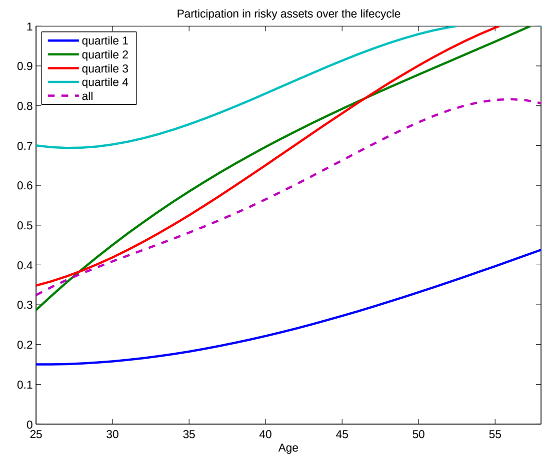
Another dimension of initial heterogeneity is in the level of human capital with which households enter the model. Figure 15 reports stock market investment (both participation and shares) as well as the time allocated to human capital investment by quartiles of initial human capital. As seen in panel 15c, time allocation as a function of initial human capital is inversely proportional to its initial level: Those in quartile 1 (the lowest level of initial human capital) invest the most time, while those in the highest quartile invest the least. The intuition is natural. Those with high initial human capital face not only a high opportunity cost of additional accumulation, but also stand to reap only low marginal returns. The reverse holds for those with low initial human capital. For brevity we do not report the evolution of human capital levels but note that initial differences in human capital levels persist over time, although with some "catch-up" due to those with low initial human capital allocating higher amounts of time towards its accumulation.

What does this imply for the accompanying investment that households make in the stock market? Those with the highest levels of initial human capital (quartile 4) participate in the stock market at the highest rates, while those with the lowest levels participate at by far the lowest rates. Specifically, participation within the top quartile is about 70% at age 25 and reaches 100% participation by age 50 (Figure 15a). Quartiles 2 and 3 participate at around a 30% rate early in life, and reach 100% participation after age 55. For the lowest quartile, participation starts at around 15% and remains below 50% throughout working life. When we look at the shares of financial wealth held by quartiles of initial human capital, as displayed in Figure 15b, we find that all but the lowest quartile invest a fairly similar fraction of their wealth in stocks over the life cycle.

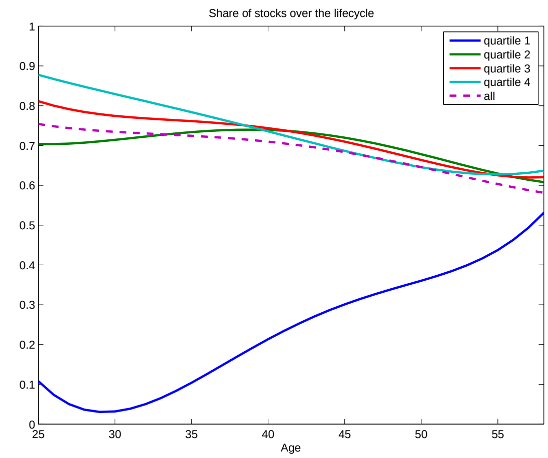
Stock market behavior in this case is influenced by two forces. First, households with high initial human capital not only have relatively high earnings, but also do not expect earnings to rise as rapidly over the life cycle as those with low initial human capital do. As a result, their motivation to borrow early in life is limited, and the same force that leads to low time allocation towards human capital investment encourages stock market participation. In other words, the optimal overall portfolio for those with high initial human capital reflects the relative value of savings, even early in life, and this leads to a relatively high rate of equity market participation. By contrast, those with low human capital find it to be a far better investment and, moreover, expect future earnings to be higher than present levels. Higher expected future earnings make savings less attractive, as that would hinder the intertemporal smoothing of consumption. Indeed some of these households would value borrowing (or, at the very least, not accumulating wealth). Thus, saving via any financial asset, especially risky stocks, is less attractive. The individuals in the lowest quartile also earn the least of all groups, and hence face significant uninsurable risk, especially early in life. The riskiness of equity makes such investment unattractive. For households in the middle quartiles of initial human capital, optimal investment behavior falls between these two extremes.

While this case is instructive, it is important to note that it holds the correlation between initial human capital and learning ability at zero. Overall participation will depend, in general, on the joint distribution of ability and initial human capital. Indeed, in the baseline model, these characteristics are positively correlated. Thus, those who face high costs of learning—and hence wish to invest primarily in stocks—are frequently also those with low initial human capital—who wish to invest in human capital instead. The net result is that participation rates in the baseline model fall in between the levels implied by Figures 14 and 15.

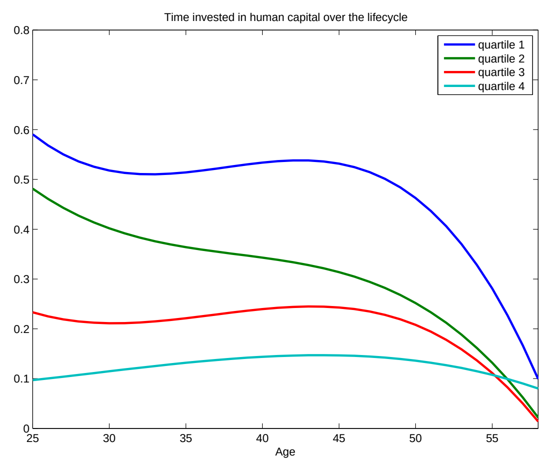
Figure 15: Investment by Quartiles of Initial Human Capital



(a) Participation



(b) Shares



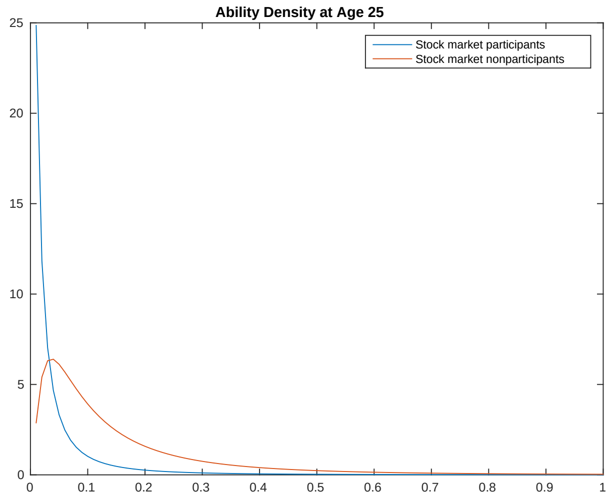
(c) Time invested in human capital

A common theme that emerges from the experiments described above is that higher human capital accumulation, if achieved through a higher initial endowment of human capital and ability or an improvement in its production technology, leads to an increase in earnings and stock market participation. In these instances, the agent accumulates more human capital without necessarily allocating additional time to it. On the other hand, any increase in human capital that comes from households allocating more time to human capital investment leads to lower stock-market participation.

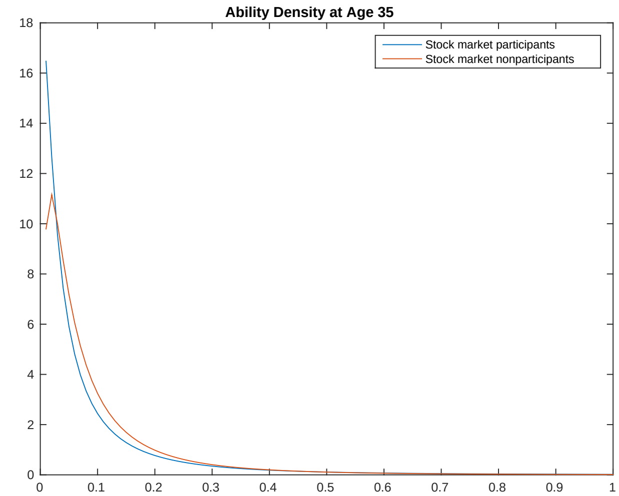
5.7 Comparing Participants and Non-Participants

What does our model say about who participates in the stock market? In Figures 23, we compare the distribution of ability, a, across participants and non-participants at various ages. Consistent with our message that the presence of a high-return alternative deters stock-market participation, we see that in the first two panels of Figure 23, when households are young, non-participants have substantially higher ability levels than stock-market participants. It is only in middle age and beyond, as seen in Figure 23c that ability is similarly distributed across stock-market participants and non-participants. As seen in the earlier figures documenting time allocated to human capital, we see that by middle age, as households have accumulated levels of human capital consistent with their innate ability, marginal returns to human capital are no longer substantially higher than the returns on stocks for even those with high innate ability.

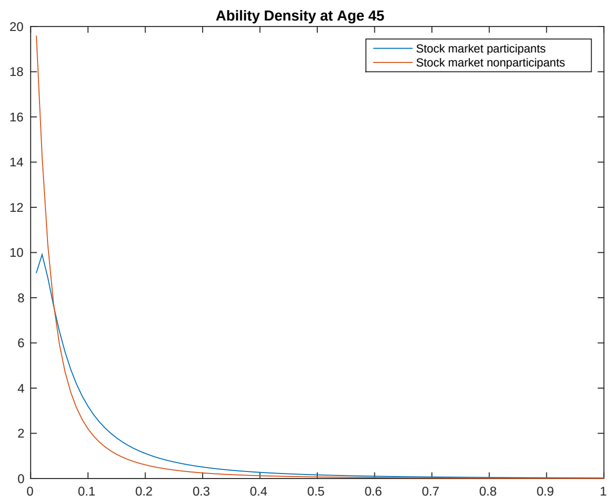
Figure 16: Ability Distribution of Participants and Non-Participants



(a) Age 25



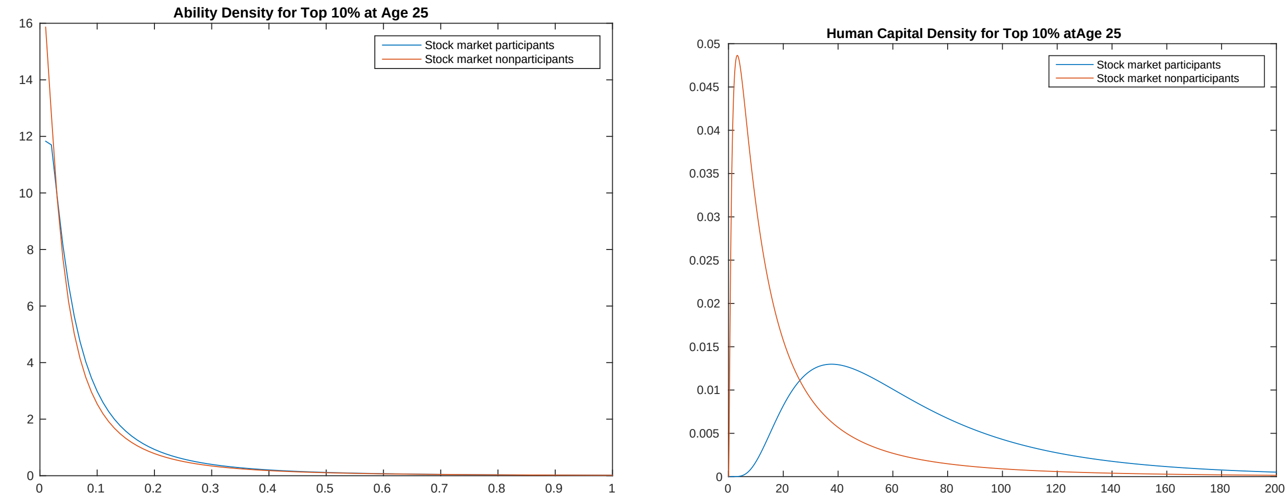
(b) Age 35



(c) Age 45

We now look at households with high initial wealth, defined here as being in the top 10 percent of the wealth distribution at age 25. Figure 24 shows clearly the central mechanism that we have emphasized: within the group of households with similar ability, it is precisely those with low initial human capital who elect not to participate in the stock market (Figure 24b).

Figure 17: Distribution of Ability and Human Capital across Participants and Non-Participants (Wealthy Households at Age 25)



(a) Ability (b) Human Capital

5.8 The Role of Borrowing

5.8.1 The Role of the Wedge Between the Interest Rate on Savings and Borrowing

As described earlier, Davis, Kubler, and Willen (2006), show that—in a standard household portfolio choice model without the option to invest in human capital—borrowing costs are a decisive barrier to stock market participation. In this experiment, we study the effect of borrowing costs on stock market investments when the option to invest in human capital is present. We consider a case in which borrowing is inexpensive, that is, there is no wedge between the interest rate on savings and borrowing.[19]

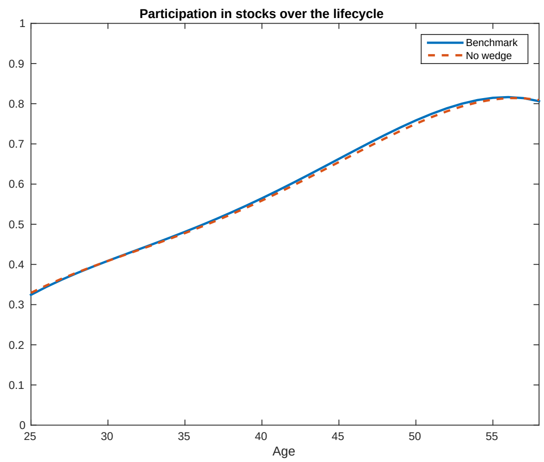
While cheap credit could induce borrowers to invest more in both human capital accumulation and stocks, we find that households only do the former in our benchmark model. Figures 16a and 18a show that households do not significantly change their stock market investment behavior despite having access to cheaper credit. Instead, households who borrow allocate more time to human capital investment (Figure 17b) and use credit to smooth consumption in the face of lower current (and potentially higher future) earnings.

Note that we do recover the flavor of the result in Davis, Kubler, and Willen (2006) when we remove the borrowing wedge in the setting where earnings are exogenous (the setting that we describe in Section 5.4). Specifically we see that stock market participation reaches nearly

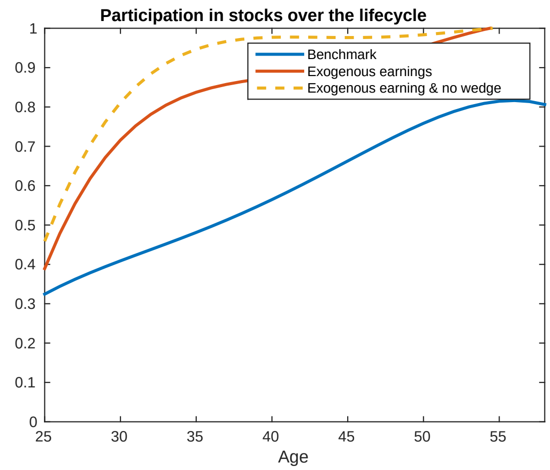
[19] We also conduct an experiment in which the credit limit is more generous. We find that it has little effect on human capital and stock market investment in our model. The results are available upon request.

100% early in the life-cycle (Figure 18b). In this sense, our model suggests that the transactions costs used in models that abstract from human capital may be instead capturing the effect of the presence of a better alternative investment.

Figure 18: The Role of the Borrowing Wedge in Stock Market Participation

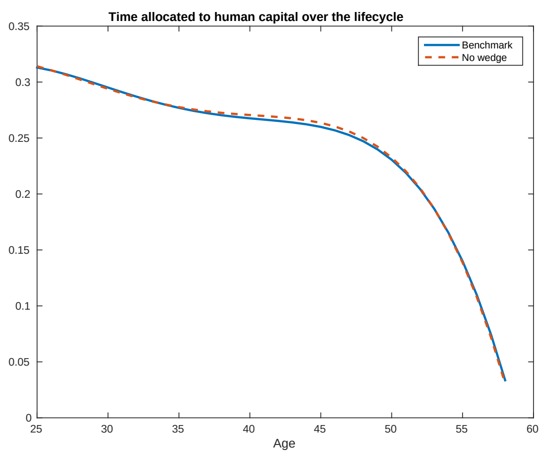


(a) Benchmark: Wedge vs. No Wedge

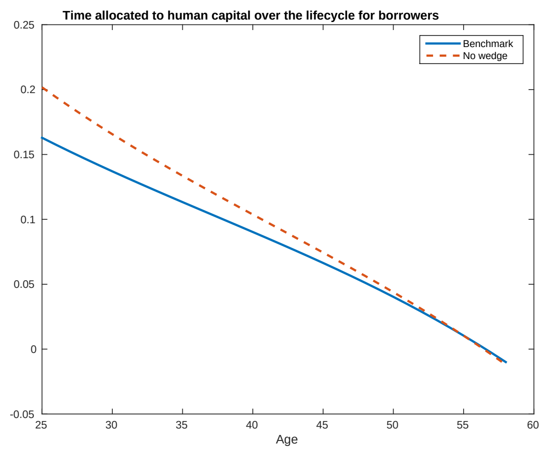


(b) Exogenous Earnings: Wedge vs. No Wedge

Figure 19: The Effect of No Borrowing Wedge on Time Allocated to Human Capital

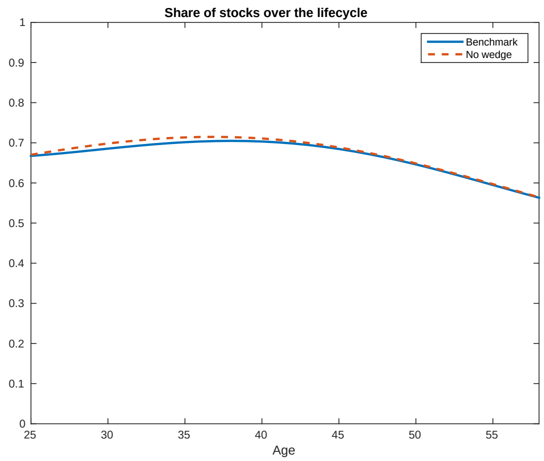


(a) All Households

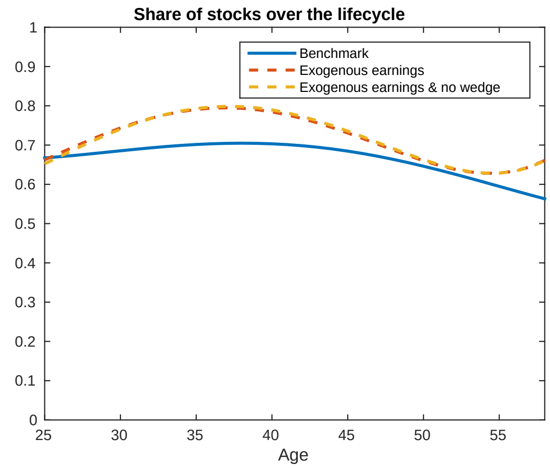


(b) Borrowers

Figure 20: The Role of the Borrowing Wedge in Stock-Market Shares



(a) Benchmark: Wedge vs. No Wedge

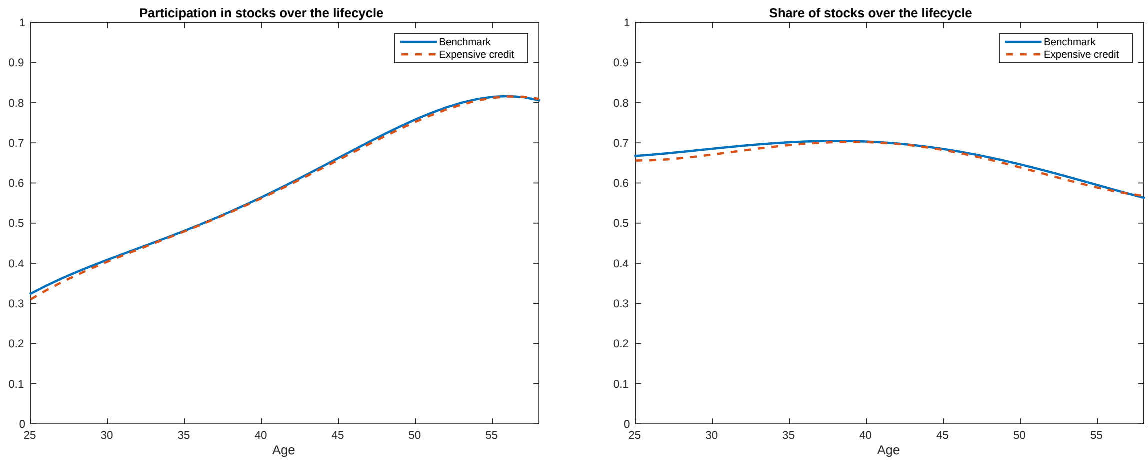


(b) Exogenous Earnings: Wedge vs. No Wedge

5.8.2 The Role of Expensive Credit

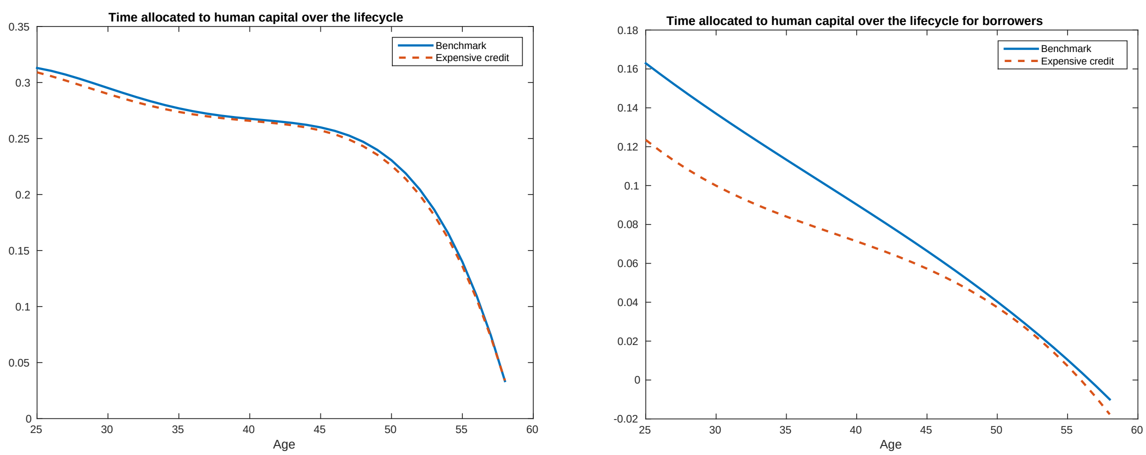
In our model, credit potentially serves two functions. First, it makes it possible for agents to borrow to invest in stocks. Second, it enables agents to smooth consumption while they invest time in human capital and forego current earnings. However, the benefits to using credit diminish with borrowing costs. To provide a quantitative sense of the importance of borrowing costs, we next consider a case in which the interest rate on borrowing is 22%—double the rate in the benchmark. Figures 19 and 20 show that higher borrowing costs have virtually no impact on participation and shares. This again is consistent with people borrowing primarily to smooth consumption while they invest in human capital rather than to invest in stocks. While time allocated to human capital does not change much in the aggregate, (Figure 20a), there is a marked difference if we look only at households who borrow. Figure 20b shows that, when credit is expensive, borrowers spend much less time investing in human capital than households who borrow under in the interest rate in the benchmark, particularly early in life. An increase in the price of credit hinders households' efforts to smooth consumption intertemporally. This in turn diminishes the benefits to human capital accumulation as households' living standards can only rise once human capital payoffs are realized. The reason that the reduction in time invested in human capital by borrowers has little effect in the aggregate (Figures 20a) is simply because the set of borrowers is small in the benchmark itself and only shrinks as borrowing costs rise.

Figure 21: The Role of Expensive Credit in Stock Market Investment



(a) Participation (b) Shares

Figure 22: The Effect of Expensive Credit on Time Allocated to Human Capital

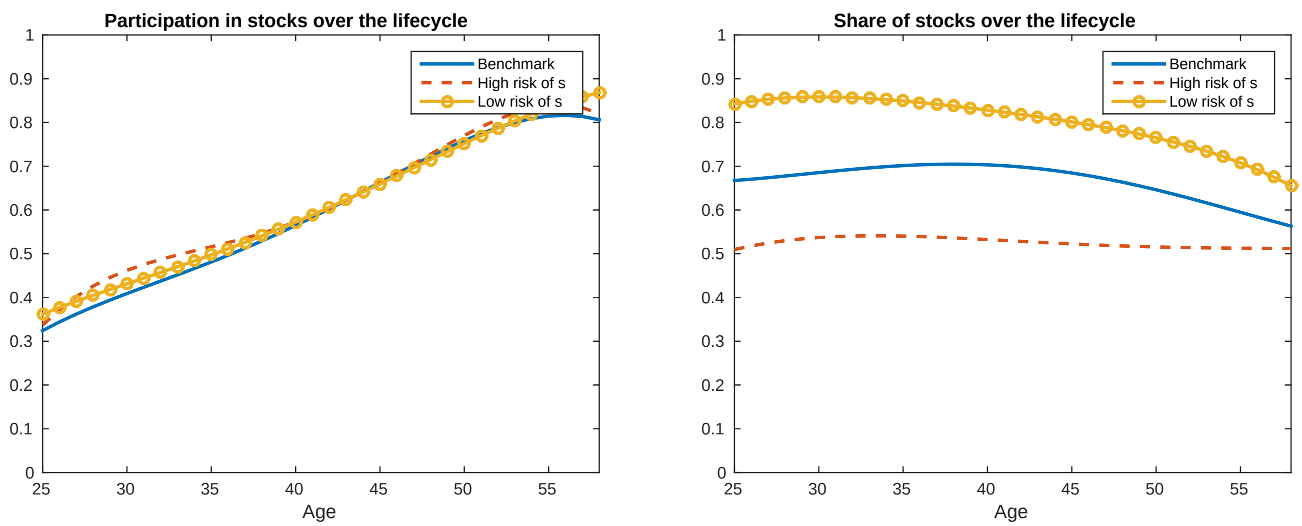


(a) All Households (b) Borrowers

5.9 The Role of Stock-Market Risk

The stock market, while it clearly offers a far higher average rate of return than risk-free savings, may still not attract overwhelming participation due to the exposure that it creates for households. To study the effect of the risk properties of stock returns on participation and shares, we examine two cases in which equity market risk is different than in the baseline model. In Figure 21, we report results under the assumptions that the standard deviation of stock market returns is low (50% less) or high (50% more) compared to our benchmark (0.078 and 0.236, respectively). Interestingly, these large differences in the risk properties of stocks have almost no effect on participation compared to the benchmark. Rather, all the adjustment is on the intensive margin, and it is sizable. In the case of higher-than-baseline riskiness of stock return, we find that household diversification pays a significant role and leads to much lower proportions of wealth held in stocks than in the baseline. Conversely, we observe that when stock market risk is cut, wealth shares balloon to nearly 80% when averaged over the life cycle. Thus, an interesting implication of our analysis is that while initial human capital levels and ability govern the decision to invest at all in the stock market, the risk of stocks is what matters for the share of wealth held in equity.

Figure 23: Stock Market Investment with Low and High Risk of Stocks



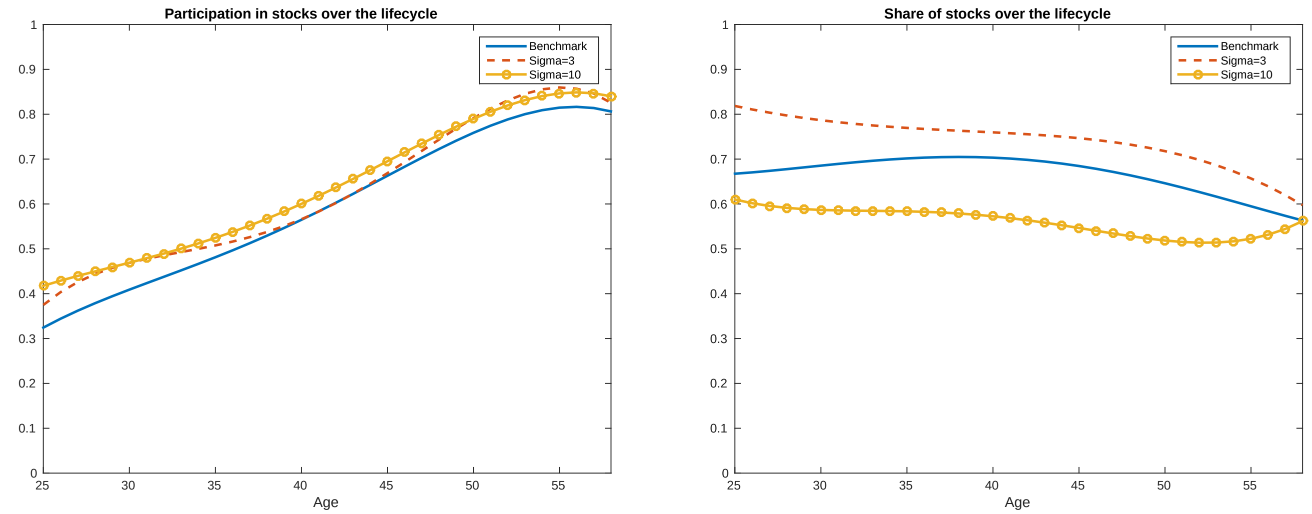
(a) Participation

(b) Shares

5.10 Agents' Risk Aversion

We study the effect of changing agents' risk aversion in our setting. We consider two cases, $\sigma = 3$ and $\sigma = 10$. The results are shown in Figure 22.

Figure 24: Effect of Changing Risk Aversion on Household Portfolios



(a) Participation

(b) Shares

As seen clearly in the figures, the effect of changing risk aversion is qualitatively similar to changing the riskiness of stock returns, in the sense that it does not have much effect on stock market participation in the economy. Rather, households adjust the amount of their wealth that they allocate to stocks in a completely natural manner, allocating a larger share to stocks when they are less risk averse and a smaller share when they are more risk averse. One useful implication of these results is that while we have employed a risk-aversion value that is standard in the portfolio-choice literature, it is higher than the value typically assumed in macroeconomics, which ranges from 1 to 3 for example. Therefore, it is worth noting that neither stock-market participation nor shares change substantially under lower risk aversion. This is only suggestive, however, as we do not recalibrate the entire model when we change risk aversion.

6 Conclusion

Research on household portfolios frequently predicts that households will almost universally participate in equity markets and allocate a high share of financial wealth to equity, especially early in life. These predictions are counterfactual and empirically consistent predictions have proved hard to obtain without stock-market participation costs, informational frictions, or departures from standard preferences. The central contribution of this paper is to demonstrate that once human capital investment is allowed for, a standard model predicts stock-market participation and equity-investment shares that are much closer to those empirically observed throughout the life cycle.

Our approach is both novel and straightforward: We embed the classic human capital model of Ben-Porath (1967) into a standard life-cycle model of portfolio choice where households face uninsurable idiosyncratic shocks to productivity (e.g., Cocco, Gomes, and Maenhout, 2005)). Importantly, as in Huggett, Ventura, and Yaron (2006), households in our model are heterogeneous with respect to characteristics governing initial human capital and their ability to acquire it.

Our findings flow from two simple and intuitive mechanisms: First, the returns to human capital investment are highest early in life and exceed the constant returns on financial assets for most households. As households age, this relationship reverses. Thus, stock-market participation starts low and grows over the life-cycle, just as in the data. As for shares, the risks to human capital limit the household's desire to hold wealth in risky financial equity. Our results suggest that the option to invest in human capital is important for understanding observed household portfolio choices over the life cycle.

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A Regression Tables

Table 2: Probit for Stock Market Participation (SCF), N=34,008

Age	Coefficient	Cohort	Coefficient
23-25	(omitted)	1919-1921	(omitted)
26-28	0.3195	1922-1924	-0.0338
29-31	0.5079	1925-1927	0.2211
32-34	0.5510	1928-1930	0.3671
35-37	0.6580	1931-1933	0.2360
38-40	0.8026	1934-1936	0.3158
41-43	0.9430	1937-1939	0.3858
44-46	0.9177	1940-1942	0.4348
47-49	1.0862	1943-1945	0.4710
50-52	1.1310	1946-1948	0.6053
53-55	1.2002	1949-1951	0.5457
56-58	1.2459	1952-1954	0.6078
59-61	1.2166	1955-1957	0.6222
62-64	1.1894	1958-1960	0.6679
65-67	1.1660	1961-1963	0.8107
68-70	1.1346	1964-1966	0.7916
71-73	1.1051	1967-1969	0.8857
74-76	1.1265	1970-1972	0.9654
77-79	1.2015	1973-1975	0.9716
		1976-1978	1.0055
		1979-1981	0.9860
		1982-1984	0.9626
		1985-1987	1.0282
Constant	-1.4273	1988-1990	0.9297

Table 3: OLS for Share of Risky Assets in Household Portfolio (SCF), N=21,778

Age	Coefficient	Cohort	Coefficient
23-25	(omitted)	1919-1921	(omitted)
26-28	-0.0010	1922-1924	0.4470
29-31	0.0353	1925-1927	0.5412
32-34	0.1739	1928-1930	0.6711
35-37	0.4163	1931-1933	0.5723
38-40	0.5209	1934-1936	0.7014
41-43	0.5531	1937-1939	0.8419
44-46	0.6351	1940-1942	0.7739
47-49	0.7963	1943-1945	0.9438
50-52	0.8147	1946-1948	0.8771
53-55	0.9260	1949-1951	1.0174
56-58	0.8842	1952-1954	1.1772
59-61	0.7891	1955-1957	1.0696
62-64	0.9596	1958-1960	1.3184
65-67	0.9803	1961-1963	1.3533
68-70	0.9177	1964-1966	1.5286
71-73	0.9793	1967-1969	1.4329
74-76	1.1988	1970-1972	1.6140
77-79	1.1405	1973-1975	1.4651
		1976-1978	1.5958
		1979-1981	1.4606
		1982-1984	1.4250
		1985-1987	1.1774
Constant	-2.0059	1988-1990	1.0460

B Figures

Figure 25: Earnings Statistics (CPS)