Investing over the life cycle with long-run labor income risk

Luca Benzoni and Olena Chyruk

Introduction and summary

Throughout life, people make saving and spending decisions. Moreover, they choose how to allocate their savings among assets that have predictable but low returns, like bonds, and assets that are riskier but could yield higher returns, like stocks. Choices that are made when individuals are relatively young will have large implications for their standard of living in retirement, when much of their income is likely to come from savings. Private pension plans and the Social Security system face similar decisions about how best to invest assets for their clients.

Financial advisors and much of the academic literature often argue that it is optimal for young investors to place most of their savings in stocks, which historically have paid a high risk premium relative to low-risk bonds like Treasuries, and to switch their holdings to less risky securities as they age. For instance, Malkiel (1996) recommends that investors place (100 – age)% of their financial wealth in a well-diversified portfolio of stocks. In contrast, empirical evidence shows that a significant fraction of U.S. households do not hold stocks. Moreover, life-cycle stock holdings are "hump-shaped": Investors typically hold very little in stocks when they are young, progressively increase their holdings as they age, and decrease their exposure to stock market risk when they approach retirement (for example, Ameriks and Zeldes, 2004; and Campbell, 2006). This empirical evidence is commonly referred to as the "limited stock market participation" puzzle.

In this article, which draws on work by Benzoni, Collin-Dufresne, and Goldstein (2007), we discuss how long-run labor income risk helps to explain the limited stock market participation puzzle. We argue that the correlation in labor income flows and stock market returns is a positive function of the investment horizon. At long horizons, labor income and stock market returns are likely to move together, mirroring changes in the broader economy. However, at shorter horizons idiosyncratic events lower the correlation between labor income flows and stock returns. When a worker is young and has her entire career ahead of her, the first effect prevails. Thus, she prefers to buy risk-free bonds rather than risky stocks to compensate for the risk of possible long-run fluctuations in her labor income. This outcome is consistent with empirical observation: As mentioned previously, there is little participation in the stock market among young American households.

To better convey the intuition for this result, it is useful to introduce the notion of "human capital," which is broadly defined as the set of knowledge, skills, health, and values that contribute to making workers productive (for example, Becker, 1964; and Rosen, 2008). A measure of a worker's human capital is the present value of her future labor income flows. When the worker is young, human capital dwarfs financial wealth on hand. Thus, the properties of human capital wealth will have a significant impact on her investment decisions.

At the beginning of her career, a worker is highly exposed to long-run labor income risk. Because of this effect, a significant fraction of her human capital is implicitly tied up in the stock market; that is, the present value of future labor income flows acquires "stock-like" properties. The worker cannot get rid of this forced investment in stocks, since any contract written against future labor services is not strictly enforceable (labor income is a nontraded asset). Thus, the young worker

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finds herself overexposed to stock market risk. To compensate for this effect, she places her financial wealth in a risk-free bond, rather than buying stocks.

When the worker ages, she is less exposed to long-run labor income risk. As a result, the fraction of her human capital implicitly tied up in the stock market declines; that is, the stock-like properties of human capital are attenuated. This effect reduces the worker's overall exposure to stock market risk. Thus, she finds it optimal to place a larger fraction of her financial wealth in stocks, resulting in the upward sloping part of the life-cycle portfolio holding profile.

Finally, as the worker grows older, two counteracting effects are at play. Since the investment horizon is short, long-run labor income risk fades away. As such, the worker's human capital attains "bond-like" properties, in turn increasing the demand for stocks. However, the number of years left to work goes down, and human capital shrinks, which pushes the ratio of human capital to financial wealth to zero. When that happens, labor income no longer affects portfolio choice and the demand for stocks goes down. As the worker approaches retirement, the second effect dominates, resulting in the downward sloping portion of the life-cycle profile.

The rest of the article proceeds as follows. We first present stylized evidence on the relation between stock holdings and age. In the next two sections we outline the Benzoni, Collin-Dufresne, and Goldstein (2007) labor income model and compare it with other specifications previously considered in the literature. The following section gives intuition for the model and its implications for a worker's life-cycle investment decisions. Next, we discuss the role of long-run labor income risk in other applications that are at the center of a heated debate among financial, political, and academic circles: the valuation of pension plan obligations, their funding, and the allocation of pension assets across different investment classes. We conclude the article with some ideas for future work.

The limited stock market participation puzzle

Over the years, participation in the stock market by Americans has increased considerably. Still, a vast number of U.S. households do not hold stocks, either directly (for example, through direct holdings of publicly traded stocks) or indirectly (for example, through investment in mutual funds; individual retirement accounts, or IRAs; or other retirement accounts). Figure 1 illustrates this claim using data from the Federal Reserve Board's *Survey of Consumer Finances* (SCF), while the appendix provides a brief description of the data. The plots show that a very small fraction of young investors have been holding stocks in the past decade. The participation rate is higher for middle-age households and declines for older investors.

Moreover, the share of financial assets placed in stocks is typically low when investors are young, it increases with age, and then it decreases when individuals approach retirement. This pattern is illustrated in figure 2 for the years 1998, 2001, 2004, and 2007. The plots show the median share of stock holdings, computed as a fraction of financial assets, for U.S. households in different age brackets. They are in stark contrast to the recommendations of many financial advisers who suggest investors should place (100 – age)% in stocks (also shown in figure 2).

There may be a legitimate concern that this evidence is biased by the financial decisions of less affluent investors, who own little financial assets and therefore prefer to keep their limited savings in low-risk securities. However, figure 3 shows that the share of financial assets invested in stocks for households participating in the stock market remains low. Moreover, figure 4 (p. 34) depicts stock market participation rates and stock holdings for 2007, broken down by groups of investors holding different amounts of financial assets. The plots show that even the richest households are reluctant to participate in the stock market when they are young (panel A), and their stock holdings are very low (panel B).

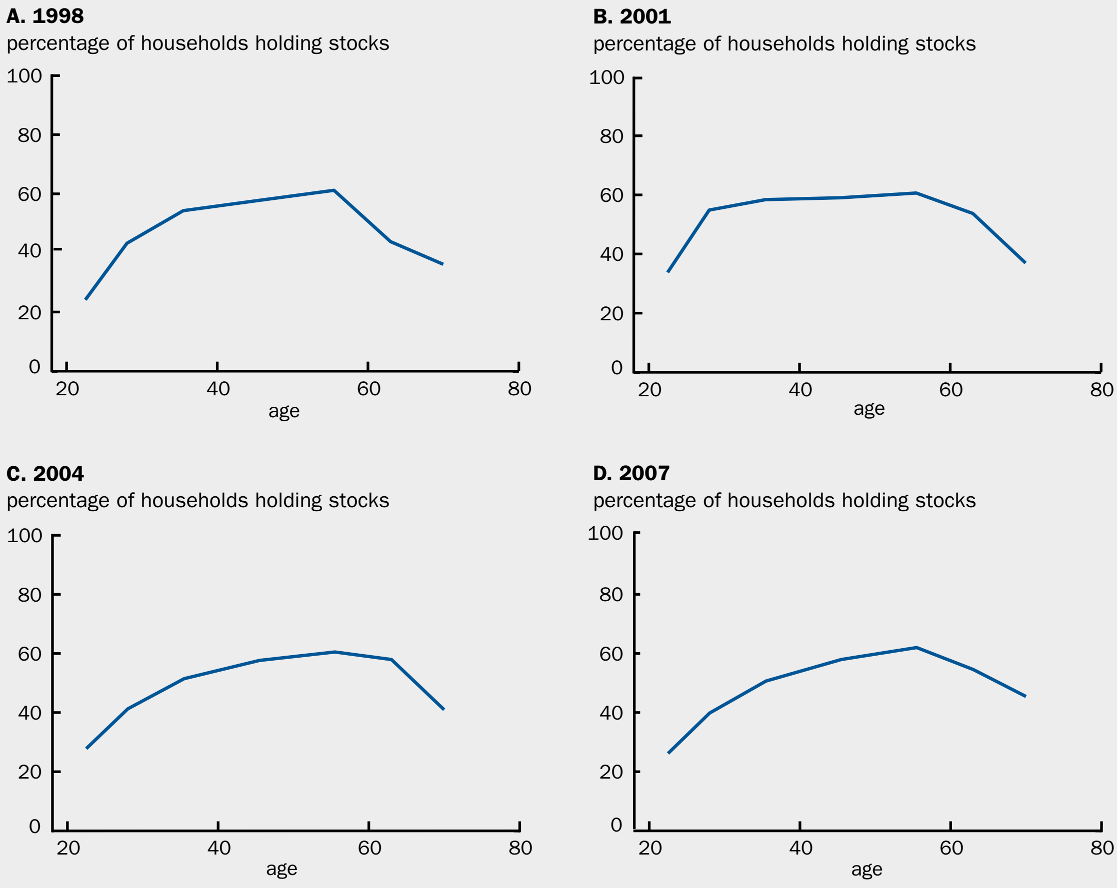
Of course, other factors affect individuals' investment decisions besides age and financial wealth. We do not pursue a more formal analysis here and instead point the interested reader to the vast empirical literature that has studied life-cycle investment decisions (see Ameriks and Zeldes, 2004; Campbell, 2006; Faig and Shum, 2002; Haliassos and Bertaut, 1995; Heaton and Lucas, 2000; Poterba and Samwick, 2001; Wachter and Yogo, 2009; and many others). It is difficult to reconcile the findings of all these studies because of differences in sample period, data sources, and assumptions.[1] The main conclusions of these papers are, however, largely consistent with the stylized evidence presented here. For instance, Campbell (2006) documents a great deal of stock market nonparticipation, even among rich households, and finds hump-shaped life-cycle stock holdings, with a peak when the agent is in her late fifties.

A model of long-run labor income risk

A vast literature has examined the empirical properties of labor income using household-level data—for example, Carroll and Samwick (1997); Cocco, Gomes, and Maenhout (2005); Gomes and

FIGURE 1

U.S. households holding stocks: Empirical evidence



Note: The plots show the percentage of U.S. households holding stocks, either directly or indirectly.
Source: Authors' calculations based on data from the Board of Governors of the Federal Reserve System, 1998, 2001, 2004, and 2007 *Surveys of Consumer Finances.*

Michaelides (2005); Gourinchas and Parker (2002); and Jagannathan and Kocherlakota (1996). These studies generally agree that the flow of labor income has three salient components. First, there is an aggregate stochastic component that captures the effect of economy-wide shocks on total workers' compensation. Second, there is an idiosyncratic stochastic component subject to individual-specific shocks. Third, there is an idiosyncratic deterministic component due to life-cycle predictability in wages.

More specifically, this literature concurs that the (logarithmic) household-level labor income, ℓ, is well approximated by the sum of an aggregate and an idiosyncratic term,

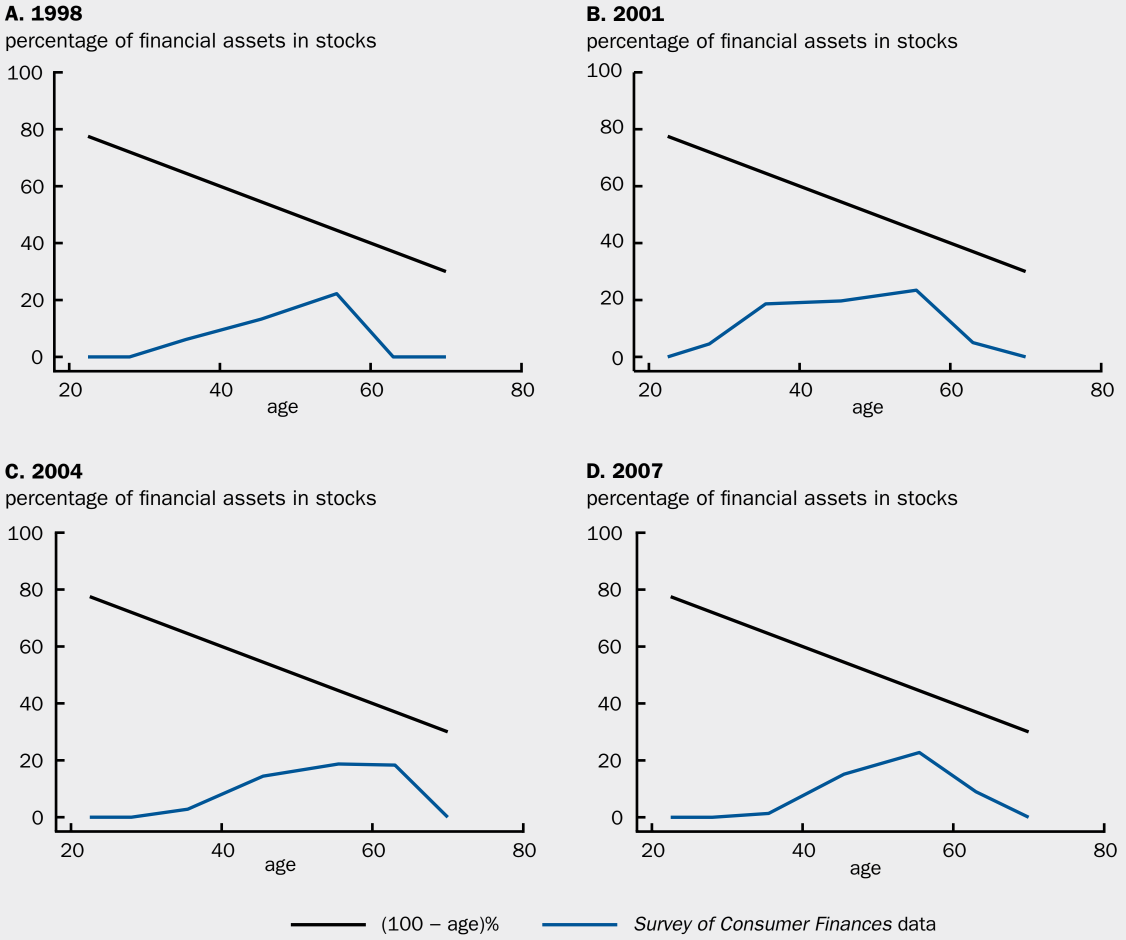
1) $\ell = \ell_1 + \ell_2$.

The idiosyncratic term ℓ_2 embeds both stochastic and deterministic components. The idiosyncratic shocks have both transient and persistent features, and the persistent shocks are well characterized by a unit-root process. Moreover, there is compelling evidence that the deterministic life-cycle labor income profile is hump-shaped; that is, on average, labor income is low when a worker is young, increases as she advances in her career, and tends to decrease as she approaches retirement.

In contrast, the properties of the aggregate labor income term ℓ_1 are more controversial. There is an ongoing debate regarding the linkage between the performance of the stock and labor markets. Contemporaneous correlations between aggregate labor income shocks and stock market returns are typically found to be low or zero. Prior studies have examined the implications of this property for life-cycle portfolio

FIGURE 2

Life-cycle stock holdings: Empirical evidence



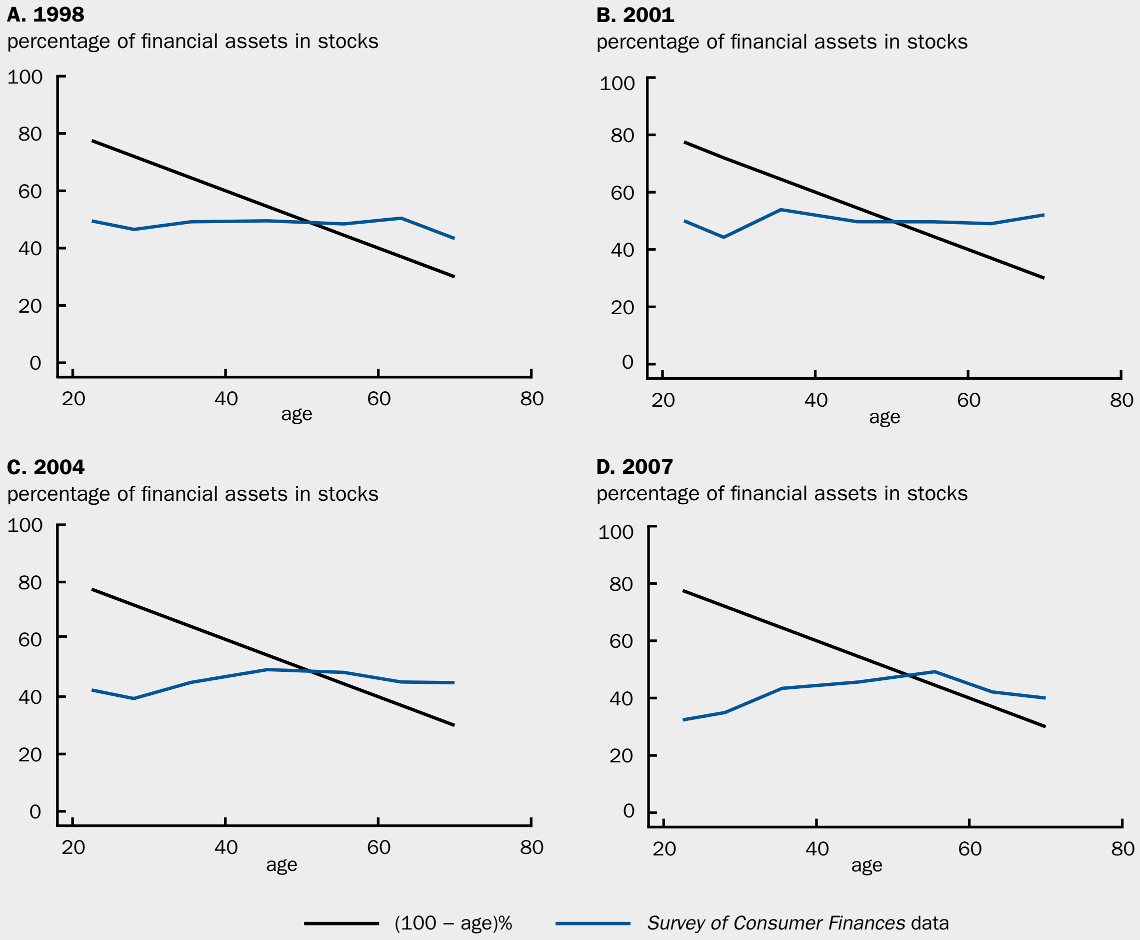
Notes: The blue lines show the median percentage of stock holdings, computed as a share of financial assets, for U.S. households. The black lines show the life-cycle stock holdings for a strategy that invests (100 – age)% of financial assets in stocks.
Source: Authors' calculations based on data from the Board of Governors of the Federal Reserve System, 1998, 2001, 2004, and 2007 *Surveys of Consumer Finances*.

choice—for example, Campbell et al. (2001); Cocco, Gomes, and Maenhout (2005); Davis and Willen (2000); Gomes and Michaelides (2005); Haliassos and Michaelides (2003); and Viceira (2001). This literature concurs that, in spite of labor income risk, a young investor should place much of her financial wealth in the risky asset. This result holds because in these models 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 invested in a well-diversified portfolio of stocks.

These models, however, also restrict long-run correlations between aggregate labor income and stock market shocks to be low or zero. This restriction is controversial. For instance, it is natural to conjecture that a sustained period of high economic growth will result in strong stock and labor market performance over the long run. Along these lines, Baxter and Jermann (1997) argue that aggregate labor income and economic growth, measured as gross domestic product (GDP) growth, are co-integrated, while Benzoni, Collin-Dufresne, and Goldstein (2007) provide evidence that aggregate labor income and dividends on the stock market portfolio are co-integrated.

FIGURE 3

Life-cycle stock holdings for stockholders: Empirical evidence



Notes: The blue lines show the median percentage of stock holdings, computed as a share of financial assets, for U.S. households holding stocks. The black lines show the life-cycle stock holdings for a strategy that invests (100 – age)% of financial assets in stocks.
Source: Authors' calculations based on data from the Board of Governors of the Federal Reserve System, 1998, 2001, 2004, and 2007 *Surveys of Consumer Finances*.

Here we focus on the Benzoni, Collin-Dufresne, and Goldstein (2007) model. We specify the dividend process $D(t)$ on the stock market portfolio to follow a geometric Brownian motion,

$$2) \quad \frac{dD}{D} = g_D dt + \sigma dz_3.$$

Ito's lemma gives the dynamics for the logarithmic dividend process $\hat{d}(t) \equiv \log[D(t)]$,

$$3) \quad d\hat{d}(t) = \left(g_D - \frac{\sigma^2}{2} \right) dt + \sigma dz_3.$$

Assuming that the pricing kernel has a constant drift equal to the risk-free rate and a constant market price for risk, the return on the investment strategy $S(t)$ that reinvests all proceeds (dividends and capital gains) in the stock market portfolio is:

$$4) \quad ds = \left(\mu - \frac{\sigma^2}{2} \right) dt + \sigma dz_3,$$

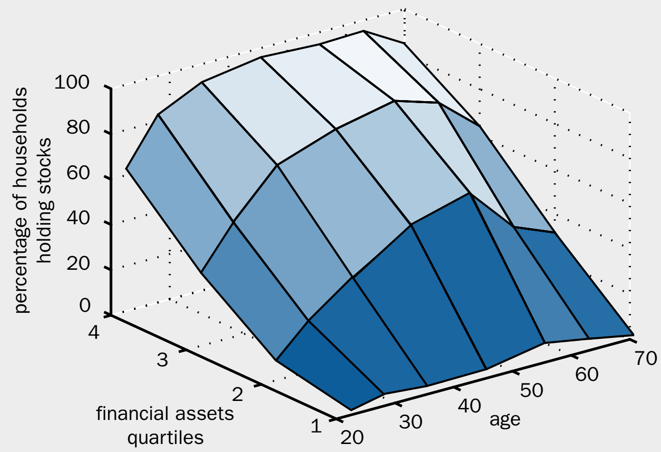
where $s(t) \equiv \log[S(t)]$ and μ is the total expected rate of return of the investment strategy.

In this simple model, the dividend growth rate volatility σ is identical to the stock return volatility. This is counterfactual (stock returns fluctuate more

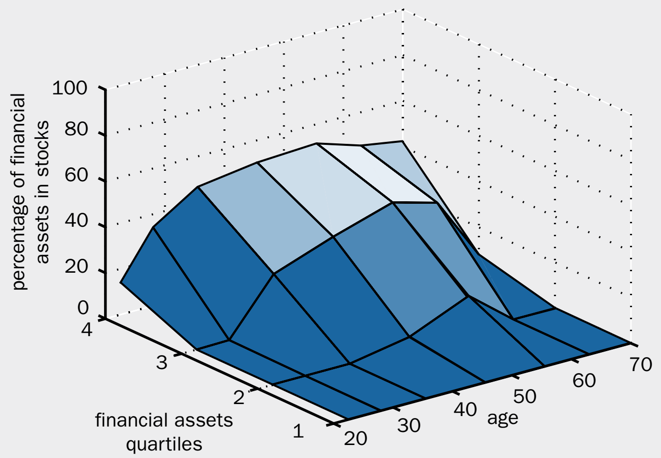
FIGURE 4

Stock holdings and financial assets: Empirical evidence

A. Percentage of U.S. households holding stocks



B. Median percentage of financial assets in stocks for U.S. households



Note: The plots show the percentage of households holding stocks (panel A) and life-cycle stock holdings (panel B) for different groups of U.S. households, categorized by financial assets holdings.

Source: Authors' calculations based on data from the Board of Governors of the Federal Reserve System, 2007 *Survey of Consumer Finances*.

than dividends), but inconsequential for life-cycle portfolio decisions as long as σ is calibrated to match historical stock return volatility.

To capture the notion of long-run dependence between aggregate labor income flow and dividends, Benzoni, Collin-Dufresne, and Goldstein (2007) introduce a variable y that measures the (logarithmic) difference between these two variables,

5) $$y(t) \equiv \ell_1(t) - \hat{d}(t) - \overline{\ell d},$$

where the constant $\overline{\ell d}$ is the long-run logarithmic ratio of aggregate labor income to dividends. They assume that $y(t)$ is a mean-reverting process,

6) $$dy(t) = -\kappa y(t)\,dt + \nu_1\,dz_1(t) - \nu_3\,dz_3(t),$$

where z_1 is a standard Brownian motion independent from z_3. The coefficient κ measures the speed of mean reversion for the process y. Benzoni, Collin-Dufresne, and Goldstein (2007) provide evidence that $\kappa > 0$; that is, y is stationary, so that ℓ_1 and $\hat{d}$ are co-integrated.

Moreover, consistent with the findings of Carroll and Samwick (1997); Cocco, Gomes, and Maenhout (2005); Gomes and Michaelides (2005); and Gourinchas and Parker (2002), Benzoni, Collin-Dufresne, and Goldstein (2007) assume that the idiosyncratic labor income component is subject to permanent shocks:

7) $$d\ell_2(t) = \left(\alpha(t) - \frac{\nu_2^2}{2}\right)dt + \nu_2\,dz_{2,i}(t),$$

where $z_{2,i}$ is a standard Brownian motion independent from both z_1 and z_3. The subscript i emphasizes that this shock pertains to the i-th agent process, in contrast to the aggregate shocks z_1 and z_3. Further, the time-dependent drift term $\alpha(t)$ captures the findings in the literature that the conditional mean of an individual's labor income is a function of her age. Specifically, when

8) $$\alpha(t) = \alpha_0 + \alpha_1 t,$$

the coefficients α_0 and α_1 are calibrated to match the hump shape of earnings over the life cycle (for example, Cocco, Gomes, and Maenhout, 2005).

Taken together, equations 3 and 5–7 yield the following dynamics for the total labor income process $\ell = \ell_1 + \ell_2$:

$$9)\quad d\ell(t) = \left(-\kappa y(t) + g_D - \frac{\sigma^2}{2} + \alpha(t) - \frac{\nu_2^2}{2}\right)dt + \nu_1\, dz_1(t) + \nu_2\, dz_{2,i}(t) + \left(\sigma - \nu_3\right) dz_3(t).$$

Since z_1 and $z_{2,i}$ are orthogonal to the stock return shock z_3, equations 4 and 9 imply that the contemporaneous correlation between stock market and labor income shocks is

$$10)\quad \mathrm{corr}(ds, d\ell) = \frac{(\sigma - \nu_3)}{\sqrt{\nu_1^2 + \nu_2^2 + (\sigma - \nu_3)^2}}.$$

Thus, labor income is contemporaneously uncorrelated with the stock market return when $(\sigma - \nu_3) = 0$, consistent with empirical evidence. Yet, co-integration generates nonzero long-run correlations between labor income and risky asset returns.

A comparison with the extant literature

In previous studies, most authors have specified the labor income process in levels rather than in changes. Furthermore, it is common to write the model in discrete time rather than continuous time. To clarify how the approach in Benzoni, Collin-Dufresne, and Goldstein (2007) relates to the extant literature, here we compare their specifications for the stock price and labor income processes (equations 4 and 9) to those considered in related studies. In particular, we show that in the limit $\kappa \to 0$, these specifications are nearly identical to the standard model.

For example, Campbell et al. (2001) assume that the labor income of an investor i at age t, $Y_{i,t}$, is exogenously given by

$$11)\quad \log(Y_{i,t}) = f(t, Z_{i,t}) + \nu_{i,t} + \varepsilon_{i,t},$$

where $f(t, Z_{i,t})$ is a deterministic function of age and other individual characteristics $Z_{i,t}$, $\varepsilon_{i,t}$ is an idiosyncratic temporary shock uncorrelated across households and distributed as $N(0,\sigma_\varepsilon^2)$, and $\nu_{i,t}$ is given by

$$12)\quad \nu_{i,t} = \nu_{i,t-1} + u_{i,t}.$$

Here, $u_{i,t}$ is distributed as $N(0,\sigma_u^2)$ and is uncorrelated with $\varepsilon_{i,t}$. Moreover, $u_{i,t}$ is decomposed into an aggregate component ξ_t and an idiosyncratic component $\omega_{i,t}$, uncorrelated across households:

$$13)\quad u_{i,t} = \xi_t + \omega_{i,t}.$$

Further, similar to equation 4, Campbell et al. (2001) assume that the excess return on the risky asset is given by

$$14)\quad R_{t+1} - \overline{R}_f = \mu + \eta_{t+1},$$

where the innovations η_t are independent and identically distributed over time and distributed as $N(0,\sigma_\eta^2)$. Campbell et al. (2001) allow for correlation between the aggregate component of labor income shocks, ξ_t, and innovations to stock returns, η_t; they denote the correlation coefficient $\rho_{\eta,\xi}$.

Using equation 11 at date t and date $(t + \Delta t)$ and then using equation 12, we can write the change in labor income as

$$\begin{aligned}15)\quad & \log(Y_{i,t+\Delta t}) - \log(Y_{i,t}) \\ &= \left[f(t,Z_{i,t+\Delta t}) - f(t,Z_{i,t})\right] + \left[\nu_{i,t+\Delta t} - \nu_{i,t}\right] + \left[\varepsilon_{i,t+\Delta t} - \varepsilon_{i,t}\right] \\ &= \left[f(t,Z_{i,t+\Delta t}) - f(t,Z_{i,t})\right] + u_{i,t+\Delta t} + \left[\varepsilon_{i,t+\Delta t} - \varepsilon_{i,t}\right] \\ &= \left[f(t,Z_{i,t+\Delta t}) - f(t,Z_{i,t})\right] + \omega_{i,t+\Delta t} + \xi_{t+\Delta t} + \left[\varepsilon_{i,t+\Delta t} - \varepsilon_{i,t}\right].\end{aligned}$$

After some relabeling and minor changes, this labor income specification closely matches the specification of Benzoni, Collin-Dufresne, and Goldstein (2007) reproduced in equation 9. Let us ignore for now the temporary shock term $[\varepsilon_{i,t+\Delta t} - \varepsilon_{i,t}]$. We do this for two reasons. First, it is not feasible to capture this temporary shock in continuous time in the way that Campbell et al. (2001) do without introducing another state variable, which would significantly increase the difficulty of solving the model numerically. Instead, Benzoni, Collin-Dufresne, and Goldstein (2007) capture the notion of temporary shocks by placing them into the wealth dynamics rather than the labor income dynamics. Second, and more importantly, both Campbell et al. (2001) and Benzoni, Collin-Dufresne, and Goldstein (2007) find this term to have a negligible effect on optimal portfolio decisions. We then relabel $\Delta\ell(t) \equiv \log(Y_{i,t+\Delta t}) - \log(Y_{i,t})$, $\omega_{i,t+\Delta t} \equiv \nu_2\, \Delta z_{2,i}(t)$ and

$\left[f(t,Z_{i,t+\Delta t})-f(t,Z_{i,t})\right]\equiv\left(g_D-\frac{\sigma^2}{2}+\alpha^{(\kappa=0)}(t)-\frac{\nu_2^2}{2}\right)$. Finally, since Campbell et al. (2001) allow aggregate labor income shocks ξ to correlate with innovations in market returns η, we decompose ξ into two terms $\xi_\perp\equiv\nu_1\Delta z_1$ and $\xi_\parallel\equiv(\sigma-\nu_3)\,\Delta z_3$, which are "orthogonal" and "parallel" to stock market shocks η_t, respectively. Thus, we write $\xi_t\equiv\xi_\perp+\xi_\parallel=\nu_1\,\Delta z_1+(\sigma-\nu_3)\,\Delta z_3$. With this relabeling and the dropping of the temporary component term, the labor income dynamics in the Campbell et al. (2001) and Benzoni, Collin-Dufresne, and Goldstein (2007) models can be written as

16) $$\Delta\ell^{CCGM}=\left(g_D-\frac{\sigma^2}{2}+\alpha^{(\kappa=0)}(t)-\frac{\nu_2^2}{2}\right)\Delta t+\nu_1\,\Delta z_1+\nu_2\,\Delta z_{2,i}+\left(\sigma-\nu_3\right)\Delta z_3,$$

17) $$\Delta\ell^{BCDG}=\left(-\kappa y+g_D-\frac{\sigma^2}{2}+\alpha^{\kappa}(t)-\frac{\nu_2^2}{2}\right)\Delta t+\nu_1\,\Delta z_1+\nu_2\,\Delta z_{2,i}+\left(\sigma-\nu_3\right)\Delta z_3.$$

Here, the superscript in $\alpha^\kappa(t)$ emphasizes that $\alpha(t)$ is calibrated for a *given* κ to match the labor income profile of Cocco, Gomes, and Maenhout (2005). Clearly, the two models differ only in the conditional drift, and are identical in the limit where the mean reversion parameter $\kappa\to0$. Even though these two models are extremely difficult to distinguish econometrically for "small" values of κ, Benzoni, Collin-Dufresne, and Goldstein (2007) show that they have substantially different predictions for the optimal portfolio choice of young agents.

This analysis is also useful to clarify the link with the labor income models considered in recent work by Lynch and Tan (2008) and Storesletten, Telmer, and Yaron (2004, 2007). Storesletten, Telmer, and Yaron (2004) estimate that idiosyncratic risk is strongly countercyclical, with a conditional standard deviation that increases by 75 percent (from 0.12 to 0.21) as the macroeconomy moves from peak to trough. In the context of our framework, fluctuations in the ν_2 coefficients over the business cycle would capture this feature. Storesletten, Telmer, and Yaron (2007) show that when idiosyncratic shocks become more volatile during economic contractions, human capital acquires stock-like features. In a realistic calibration of their model they also obtain a hump-shaped life-cycle investment profile.

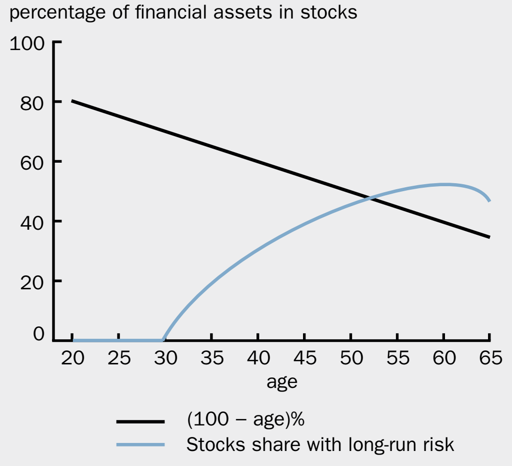
Lynch and Tan (2008) extend the work by Storesletten, Telmer, and Yaron (2004, 2007) by showing that the conditional mean of the labor income flow also fluctuates at business cycle frequencies. They use the dividend yield to predict aggregate labor income growth and find that mean labor income growth is procyclical. They refer to this feature as the state-dependent mean channel. Combined with the state-dependent volatility channel of Storesletten, Telmer, and Yaron (2004, 2007), this effect generates realistic portfolio holdings over the life cycle. The Lynch and Tan (2008) state-dependent mean channel is cast within our framework by replacing the state variable that drives the conditional mean of labor income flow in equation 17. In Benzoni, Collin-Dufresne, and Goldstein (2007), the predictive variable is y, the logarithmic difference between aggregate labor income and dividends, which underlies the co-integration relation. In Lynch and Tan (2008), the predictive variable is the dividend yield. While the condition explored by Lynch and Tan (2008) is weaker than the co-integration relation, it is still sufficiently powerful to have a first-order effect on the agent's investment decision. Specifically, Lynch and Tan (2008) find the correlation between the growth rate in labor income and the lagged dividend yield to be approximately 3 percent. As they note in their paper, the magnitude may seem small, but the effect on portfolio allocations could be large, much in the same way that return predictability regressions with a low R^2 coefficient can still induce large hedging demands for stock.

Other previous studies have also considered specifications consistent with the notion that labor income flow and stock returns correlate highly over the long run. For example, Campbell (1996) assumes that labor income follows an autoregressive AR(1) process with low contemporaneous correlation with stock dividends. He finds a highly time-varying discount factor for security prices, and assumes that this same discount factor is appropriate for discounting labor income. This assumption generates a high correlation for stock returns and returns to human capital. Moreover, Santos and Veronesi (2006) consider a model in which labor income and dividends are co-integrated. They show that, consistent with the model's predictions, the lagged ratio of labor income to consumption predicts stock returns.

Yet not all the literature concurs that the long-run correlation of shocks to labor income and stock returns is positive and high. For instance, Lustig and Van Nieuwerburgh (2008) attribute the component of consumption growth innovations that cannot be explained by their model to news about expected future returns on human wealth. They back out the implied human wealth and market return process and conclude that innovations in human wealth and financial asset returns are negatively correlated. This conclusion, however, would

FIGURE 5

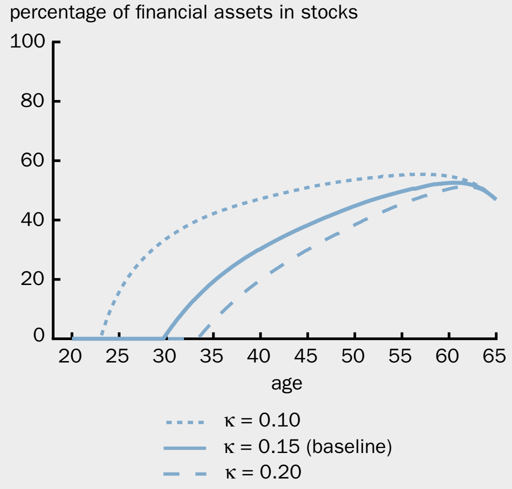
Life-cycle stock holdings: Model predictions



Notes: The blue line shows the life-cycle stock holdings for a worker subject to long-run labor income risk. The black line shows the life-cycle stock holdings for a strategy that invests (100 – age)% of financial assets in stocks.
Source: Benzoni, Collin-Dufresne, and Goldstein (2007), figure 3, panel B, p. 2149.

FIGURE 6

Life-cycle stock holdings: Exposure to long-run risk



Note: The plots show life-cycle stock holdings for workers subject to different degrees of exposure to long-run labor income risk (measured by the model coefficient κ).
Source: Benzoni, Collin-Dufresne, and Goldstein (2007), figure 6, p. 2154.

deepen the limited stock market participation puzzle: Under this condition the young agent would want to invest even more in risky assets, since human capital would become a hedge to stock market holdings.

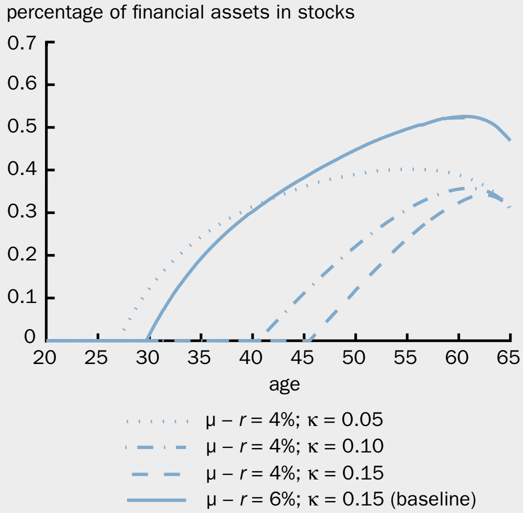
Nontradable labor income and life-cycle asset allocation

Benzoni, Collin-Dufresne, and Goldstein (2007) solve the life-cycle portfolio choice problem of an agent who maximizes time-separable constant relative risk aversion (CRRA) utility when the stock return and labor income dynamics are those in equations 4 and 9. They use a 1929–2004 sample of data on total after-tax U.S. employee compensation and dividends on a well-diversified portfolio of U.S. stocks to estimate the coefficients of the co-integration relation in equation 6. Moreover, they calibrate the idiosyncratic labor income dynamics in equation 7 to match the evidence in prior papers that have studied the properties of labor income using household-level data. In their baseline case, they assume an equity premium of 6 percent and a CRRA coefficient of 5. Further, they impose short-selling constraints on the stock and the bond. They do not impose any entry cost to participate in the stock market. Figure 5 illustrates the life-cycle portfolio holdings predicted by this model calibration, and contrasts it to the recommendation of many financial advisers to invest (100 – age)% of financial assets in stocks. Consistent with empirical evidence, the optimal portfolio share is hump-shaped.

The intuition for this finding is as follows. When the investor is young, there is sufficient time for the co-integration effect to act. Thus, the young agent's human capital displays a high level of co-movement with the stock market due to long-run labor income risk; that is, human capital has stock-like features. Since much of a young investor's wealth is tied up in her human capital (financial wealth is relatively small when she is young), she finds herself overexposed to stock market risk and therefore chooses to invest her financial wealth in the risk-free asset. As the investor grows older, co-integration has less time to act so that idiosyncratic shocks become the prevalent source of human capital risk. Since these latter shocks are orthogonal to stock market fluctuations, the investor has an incentive to diversify them away via a larger position in stocks. This effect generates the increasing part of the portfolio holding profile. When the agent approaches retirement, human capital has mainly bond-like features. However, the present value of future labor income flows shrinks to zero, since there are few remaining years of employment. Thus, the agent reduces her position in the stock market to buy more of the risk-free asset.

FIGURE 7

Life-cycle stock holdings: Equity risk premium

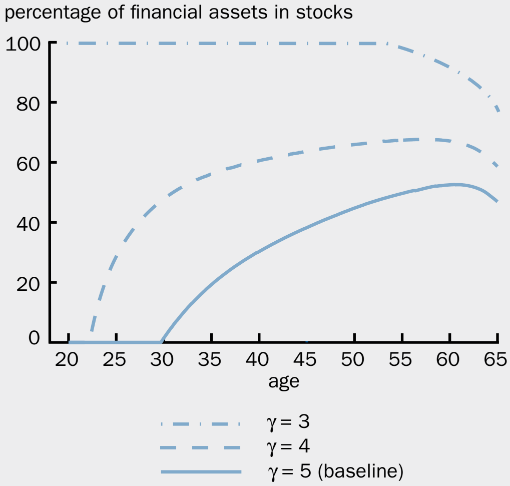


Note: The plots show life-cycle stock holdings for different values of the equity risk premium (measured by the expected stock return minus the risk-free rate, $\mu - r$) and different degrees of exposure to long-run labor income risk (measured by the model coefficient κ).

Source: Benzoni, Collin-Dufresne, and Goldstein (2007), figure 7, p. 2155.

FIGURE 8

Life-cycle stock holdings: Risk aversion



Notes: The plots show life-cycle stock holdings for workers with different levels of risk tolerance. For most workers, the risk aversion measure γ is positive. Values of γ below 10 are considered to be common.

Source: Benzoni, Collin-Dufresne, and Goldstein (2007), figure 10, p. 2158.

The hump-shaped life-cycle profile is robust to a wide range of model calibrations. The most important model coefficient is κ, which measures the time scale of the co-integration relation in equation 6. Larger values of κ determine faster reversion of the variable y toward its long-run mean, which tends to increase the long-run correlation between labor income and stock returns. As a result, the worker invests more conservatively; that is, she reduces her stock holdings throughout the life cycle (figure 6, p. 37). In contrast, when κ is smaller the worker invests more aggressively in stocks. When κ is zero the effect of long-run labor income risk vanishes (as shown in the previous section). In this case the effect of idiosyncratic shocks prevails, and the worker invests most of her financial assets in stocks. But even for an estimate of κ as low as 0.05, which implies a time scale of $\frac{1}{0.05} = 20$ years, and a risk premium of 4 percent (the same risk premium assumed by, for example, Campbell et al., 2001; Cocco, Gomes, and Maenhout, 2005; and Gomes and Michaelides, 2005), it is optimal for the young agent not to invest in the risky market portfolio (figure 7). This is important, since such a low value of κ makes co-integration hardly detectable in the data. Yet, the effect on her risky asset holding is significant.

Increasing the variance of the permanent idiosyncratic shocks increases the diversification motive, inducing an investor to buy more stocks. This effect, however, does not fully offset the long-run aggregate risk component when the investor is young. Consistent with the findings of the prior literature, transient labor income shocks do not have a significant impact on portfolio holdings. Finally, the hump shape of the portfolio profile holds even when we account for stock return predictability. This last result is important, since several recent studies have documented that the expected future stock returns are high when current returns are low. Thus, when returns are predictable an investment in the stock market creates its own hedge, which makes stock ownership even more appealing than when returns are uncorrelated.

In Benzoni, Collin-Dufresne, and Goldstein (2007), the results are quite sensitive to the agent's attitude toward risk. In their baseline case, they fix the CRRA coefficient at 5, a value well below the upper bound CRRA=10, which most economists find to be reasonable. Of course, higher values of risk aversion reinforce the long-run labor income risk effect and make the agent hold even less of her portfolio in stocks. However, as the agent becomes more risk tolerant, for example, CRRA=3, the diversification motive due to idiosyncratic shocks prevails, and a young investor places most of her financial wealth in stocks (figure 8). This is a nice feature of the model. The literature has documented a great deal of heterogeneity in stock market participation, and this property is useful to explain the equity premium puzzle (for example, Basak and Cuoco, 1998; and Mankiw and Zeldes, 1991). Heterogeneity in risk aversion (possibly combined with different degrees of exposure to economy-wide and idiosyncratic shocks across agents) is a possible explanation for this evidence.

The valuation of pension plan obligations, their funding, and the optimal allocation of pension assets

The ideas set forth in the literature that studies life-cycle asset allocation find direct application in other fundamental problems. For instance, long-run labor income risk strongly affects the valuation of pension plan obligations, their funding, and the allocation of pension assets across different investment classes. In this section, we discuss recent research that has addressed these issues, focusing in particular on the work by Lucas and Zeldes (2006) on defined benefit (DB) pension plans and Geanakoplos and Zeldes (2007) on Social Security.

Lucas and Zeldes (2006) study the valuation and hedging of DB plans. A DB plan awards the employee deferred compensation in the form of future payments (typically a retirement annuity) linked to the length of her tenure with the firm and the salary received during the final year(s) of employment. In spite of much recent growth in defined contribution (DC) plans, a number of firms still offer DB plans as an important part of the retirement package for their employees.

Uncertainty about future wages, the date of the worker's separation from the firm, and the size and composition of the pool of existing and future employees complicates the analysis of DB plans. These factors affect the measure of the firm's liability (for example, Lucas and Zeldes, 2006). On one extreme, the firm can focus on a narrow measure of the DB plan's liabilities that accounts only for accrued benefit obligations (ABOs) toward former and current workers, computed based on current years of employment and wages. On the opposite extreme is a broad measure of the firm's obligations that also accounts for liabilities toward all employees (former, current, and expected future workers), computed based on past and projected future years of employment and wages. Lucas and Zeldes refer to this latter measure as an "all-inclusive" projected benefit obligation (PBO).

This distinction is important in the analysis of the problem. First, different measures of DB pension liabilities are relevant in various contexts because of institutional restrictions. For instance, the ABO is a legal obligation that the firm can avoid only through bankruptcy. Related, the ABO measure serves as a basis to compute minimum funding requirements by which firms are legally required to abide. Moreover, insurance by the Pension Benefit Guaranty Corporation (PBGC) makes the ABO an essentially safe asset, up to a certain cap. In addition, the valuation and hedging of various measures of DB pension liabilities differ depending on the uncertainty associated with such obligations. For instance, since ABOs are a firm's obligations of a known amount, they should be discounted accordingly when one computes their present value. Moreover, to fund these obligations the firm should invest the assets in its pension plan entirely in bonds that match the cash flows of the current ABOs (for example, Bodie, 1990, 2006). However, the valuation and funding of PBOs should reflect the risk associated with these uncertain future payments.

The choice of how to optimally fund such obligations is complicated by multiple factors, including taxes, the effect of PBGC guarantees, accounting and tax regulations, corporate liquidity needs (funds tied up in the pension plan may not be easily redirected to other corporate needs), and other labor contracting considerations. Abstracting from some of these issues, Lucas and Zeldes (2006) focus on the problem of hedging PBOs. They argue that, while the hedging of ABOs is best accomplished with a portfolio of bonds, the hedge portfolio for PBOs should contain a mix of stocks and bonds, with a share of stocks versus bonds that depends on firm and worker characteristics—for example, the probability of bankruptcy, worker separation, and mortality. This result is robust to taking into account the possible reduction of future wages by the value of current pension accruals (for example, Bulow, 1982). Moreover, the rate at which to discount uncertain PBOs is a function of similar macroeconomic, firm, and worker characteristics.

The intuition for these results is as follows. If wage growth correlates positively with stock returns over the long run, then future pension liabilities will also correlate positively with the performance of the stock market. Thus, stocks should be part of the hedge portfolio, and firms with a higher percentage of active workers should invest more heavily in stocks. Moreover, firms should discount their projected PBOs at a rate that increases with the share of active workers relative to separated and retired employees. Similar to Benzoni, Collin-Dufresne, and Goldstein (2007), these results are driven by long-run labor income risk: Because of the long-run correlation between labor income flows and stock returns, human capital has a stock-like component, and this component is higher for younger workers. Thus, the PBO of a firm with a higher fraction of active (that is, younger) workers also has stock-like properties. This feature determines a higher hedge position in stocks, increases the rate at which to discount the PBO, and reduces the PBO's present value.

Lucas and Zeldes (2006) provide evidence consistent, at least in part, with the predictions of their model. Companies with relatively few retirees and separated workers hold more stocks in their pension plans. However, the hedging demand for long-run labor income risk cannot explain why some firms that have a high proportion of retirees and separated workers still invest much of their pension fund assets in stocks.

Similar issues arise when we study the valuation of Social Security obligations. A key input to this problem is the rate at which to discount future liabilities. The traditional actuarial approach uses a risk-free rate to discount future expected cash flows. Geanakoplos and Zeldes (2007) argue that this approach underestimates the riskiness of such obligations. Social Security benefits depend on the realization of the future economy-wide wage level. If future wages and stock market performance correlate positively over the long run, then the appropriate discount rate for Social Security obligations toward active workers should exceed the risk-free rate. This risk adjustment reduces the present value of the obligation, which is relevant to assessing the projected burden of Social Security on the taxpayer. Moreover, there is much debate on the costs and benefits associated with investing a fraction of the Social Security fund in stocks (for example, Abel, 2001). This problem resembles optimal allocation of the assets that fund private DB pension plans. Thus, the results derived in Lucas and Zeldes (2006) apply to this setting, too. Specifically, the portfolio that hedges projected Social Security obligations contains a share of stocks that depends on macroeconomic conditions and worker characteristics.

Finally, there is a heated debate in the U.S. about the opportunity to replace part of the existing DB Social Security system with a system of DC personal accounts. If such a reform were to occur, it is possible that the private sector would take over some of the obligations that are currently guaranteed by Social Security. For instance, Geanakoplos and Zeldes (2008) advocate a system of *progressive personal accounts* with two main features. First, accruals in the personal accounts would be in a new kind of derivative security that pays its holder one inflation-adjusted dollar during every year of life after her statutory retirement date, multiplied by the economy-wide average wage at retirement date. They call this derivative a personal annuitized average wage security (PAAW). Second, households would buy their new PAAWs each year with their Social Security contributions, augmented or reduced by a government match. Some of these securities, which effectively define benefits for the future retiree, could be pooled together and sold to financial markets.[2] In this event, how would investors price them? Geanakoplos and Zeldes (2007) show that accounting for long-run labor income risk is a key ingredient in a model to value these claims.

Conclusion

The recent literature has offered various alternative explanations for the limited stock market participation puzzle. The discussion here, focused on the work of Benzoni, Collin-Dufresne, and Goldstein (2007), shows that long-run labor income risk has a first-order effect on optimal life-cycle asset allocation. We make no attempt to discuss the other numerous important contributions, which are reviewed in the excellent articles by, for example, Campbell (2006) and Curcuru et al. (2004). We do not view the explanation discussed here as a substitute for these previous theories, but rather as a complement.

The importance of long-run labor income risk is further underscored in the recent work by, for example, Lucas and Zeldes (2006) and Geanakoplos and Zeldes (2007, 2008). In particular, these studies show that long-run labor income risk is an important conduit through which macroeconomic uncertainty affects the valuation of DB pension plans, their funding, and the allocation of pension assets across different investment classes.

The ideas developed in Benzoni, Collin-Dufresne, and Goldstein (2007) are also potentially useful to shed light on other important topics. For instance, heterogeneity in risk aversion combined with different degrees of exposure to long-run labor income risk can generate limited stock market participation. Thus, an extended version of the model with two different agent groups that endogenously choose whether to buy stocks may provide a general equilibrium foundation for the setting considered by, for example, Basak and Cuoco (1998) and Mankiw and Zeldes (1991), who show that limited stock market participation helps explain the equity premium puzzle.

Finally, it is natural to conjecture that, similar to labor income, real estate ownership is an important conduit for macroeconomic uncertainty. For instance, Quan and Titman (1997) argue that the housing and stock markets are co-integrated. Since real estate has a significant share in the portfolio of most households, a model that accounts for the long-run correlation between real estate and stock market returns would prescribe that an investor should be even more cautious about bearing stock market risk.

NOTES

[1]For instance, it is impossible to separately identify three effects on life-cycle asset allocation: the investor's age, the investor's birth cohort, and the time of observation (Ameriks and Zeldes, 2004). This is because the investor's age is given by the difference between the date at the time of observation and her birth date. As a result, researchers typically focus on two of the three effects and set the third one (typically the cohort effect) to zero.

[2]Geanakoplos and Zeldes (2008) advocate a system of regulations to ensure that firms purchasing these securities fully collateralize their obligations. While Social Security obligations are guaranteed by the federal government, a privatized system would not have such a guarantee.

APPENDIX: THE *SURVEY OF CONSUMER FINANCES*

We use data from the 1998, 2001, 2004, and 2007 *Surveys of Consumer Finances* to construct the plots in figures 1–4 (pp. 31–34). The SCF is an interview survey of U.S. households sponsored by the Board of Governors of the Federal Reserve System. The survey contains information on household balance sheets, income, labor force participation, and demographic characteristics. It has been conducted every three years since 1983; the most recent available data were collected in 2007, when 4,422 households were interviewed.

We downloaded the SCF data from the SCF website at www.federalreserve.gov/pubs/oss/oss2/scfindex.html, and we produce core variables using the SCF macro posted at www.federalreserve.gov/pubs/oss/oss2/bulletin.macro.txt. In our analysis, we mainly focus on four variables produced by the macro: the age of the head of the household (denoted by *AGE* in the macro), financial assets (*FIN*), financial assets invested in stocks (*EQUITY*), and sample weights (*WGT*).

We use the *AGE* variable to create a new categorical variable that splits the population into seven age groups: 18–25, 26–30, 31–40, 41–50, 51–60, 61–65, and 66 and above. In figures 1–4, the horizontal axis values of the points that make up the plots are the midpoints of these age intervals. Financial assets (*FIN*) include checking, savings, money market, and call accounts; certificates of deposit; mutual funds; stocks; bonds; IRAs; cash value of life insurance; business assets; and other managed assets. Financial assets invested in stocks (*EQUITY*) include directly held stocks, stock mutual funds, IRAs/Keoghs invested in stock, other managed assets with equity interest (annuities, trusts, and managed investment accounts), and thrift type retirement accounts invested in stock. The SCF's sample design consists of two parts: a standard geographically based random sample and a special oversample of relatively wealthy families. Thus, we use the weights (*WGT*) provided in the survey to combine information from the two samples and make estimates for the full population.

To create the subsample of stockholders we use the variable *HEQUITY*, which equals one if *EQUITY* is greater than zero. The percentage of households holding stocks is given by the mean of the *HEQUITY* variable. Our measure of the share of stocks in the portfolio of financial assets is the ratio of the variables *EQUITY* and *FIN* when *FIN* is strictly positive, and is zero when *FIN* is zero.

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