Lifetime Earnings and Heterogeneity in Retirement Wealth: the Role of Bequests, Minimum Consumption, and Social Security*

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Abstract

Micro data shows a significant dispersion in wealth at retirement at all levels of lifetime earnings and a weak correlation between lifetime earnings and retirement wealth. Previous research has shown that standard models have trouble generating these important features of the data. This paper studies a quantitative general equilibrium life-cycle model with intergenerational links of voluntary and accidental bequests and ability, government-provided minimum consumption, a history-dependent Social Security system and defined benefit pensions. This model is able to match very well these empirical observations. I analyze the role of each model feature in generating the relationship between lifetime earnings and retirement wealth.

Keywords: Wealth Inequality; Retirement; Earnings Shocks; Bequest; Minimum Consumption; Social Security.

JEL Classification: E21; J14

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1 Introduction

Many papers document that households with similar characteristics, such as lifetime income, age, and family structure, hold very different amounts of wealth at retirement (see, among others, Hurst et al. (1998), and Grafova et al. (2006)). In particular, Hendricks (2007a) documents that the correlation coefficient between lifetime earnings and wealth at retirement (0.61) is much less than unity. Furthermore, substantial wealth difference remains after controlling for lifetime earnings and age: The average of the Gini coefficients in wealth at retirement across lifetime earnings deciles is 0.54, compared with 0.62 in the full sample. Various economists (see, for example, Bernheim et al. (2001), and Hendricks (2007a)) argue that these features of the data are inconsistent with most life-cycle models of consumption-saving behavior, and thus constitute a challenge to such theories and their policy implications.

In this paper I analyze the relationship between lifetime earnings and wealth at retirement in a general equilibrium model with the following features: voluntary and accidental bequests and intergenerational ability transmission, government-provided minimum consumption, defined benefit pensions and a more realistic modeling of Social Security rules. Each of those features has been shown to be important to understanding the saving behavior and wealth distribution in the US.[1] However, little is known about how those features affect the joint distribution of lifetime earnings and wealth at retirement. I find that a model with those features goes a long way toward matching the observed data. The correlation coefficient between lifetime earnings and retirement wealth (0.71) is much lower than unity. Substantial wealth differences remain after controlling for lifetime earnings and age: The average of the Gini coefficients (0.51) is relatively high.

In this model, households are ex-ante identical in wealth.[2] One reason that

[1]See, for example, the discussion of bequest in De Nardi (2004), consumption floor in Hubbard et al. (1995), and history dependent of Social Security in Scholz et al. (2006).

[2]I assume limited sources of heterogeneity, and abstract from ex-ante heterogeneity in wealth holdings by race (see for example Smith (1995), and Altonji and Doraszelski (2005)), by education (see for example Hubbard et al. (1995), and Cagetti (2003)), by preference (see for example Krusell and Smith (1998), Samwick (1998), and Hendricks (2007b)), and by self-

wealth differences at retirement remain, after controlling for lifetime earnings, is because households differ in the timing of earnings over the life cycle. Two households might have the same lifetime earnings, but one might have positive earnings shocks when young and negative earnings shocks when old while the other has negative earnings shocks when young and positive earnings shocks when old. When borrowing constraints prevent households from smoothing consumption intertemporally, those two households will have levels of retirement wealth that differ substantially.

Inheritance adds another source of wealth heterogeneity among households with similar lifetime earnings. Some households might have inherited a large amount of assets. With a voluntary bequest motive, households keep a large amount of these inheritances to leave to their own children, thus holding a substantial amount of wealth at retirement. Some households receive no inheritance and thus own less wealth. I compare the benchmark model with models without bequest motives that differ in distributing inheritances: evenly distributed accidental bequests at age 50; random inheritances at age 50 as in Hendricks (2007a); random inheritances at ages 35 to 55. Those models without bequest motives generate a very tight relationship between lifetime earnings and retirement wealth, although adding random inheritances reduces it: The correlation coefficients are 0.81, 0.77, and 0.76, respectively, and the average of the Gini coefficients are 0.37, 0.45, and 0.46, respectively. This comparison shows that bequest motives are important in explaining the discrepancies between model and data.

Means-tested minimum consumption program increases wealth inequality among households with low lifetime earnings. It provides strong disincentives to save for low-income households with few assets. Due to the persistence of earnings process, those low-income households are more concentrated in low lifetime earnings deciles. Without a consumption floor, there are fewer

control (see for example Ameriks et al. (2007)). I also abstract from ex-post heterogeneity in wealth holdings by marital status (see for example Cubeddu and Rios-Rull (2003), and Guner and Knowles (2007)), by children (see for example Scholz and Seshadri (2007)), by rate of return (see for example Guvenen (2006)), by health expenditure (see for example De Nardi et al. (2010)).

poor households in the lower earnings deciles than in the benchmark model, resulting in lower Gini coefficients at those deciles. As a result, removal of the government-provided minimum consumption level reduces the average of the Gini coefficients considerably to 0.46.

I analyze the role of Social Security and private pensions by removing private pensions and assuming that all retirees receive the same amounts of Social Security. This specification reduces motives to save for retirement among low earnings households and raises saving among high earnings ones, which leads to a higher correlation between lifetime earnings and retirement wealth with a correlation coefficient of 0.74. In addition, it gives unrealistically high (low) pension wealth to households in lower (higher) earnings deciles and thus generates Gini coefficients bigger (smaller) that the data.

I then decompose the effect of earnings heterogeneity and inheritance heterogeneity on wealth heterogeneity in the benchmark model. I find that, differences in the timing of earnings shocks can generate large heterogeneity in wealth at retirement among lower lifetime earnings households, who can rely on government transfers and on higher pension wealth relative to lifetime earnings. Differences in the timing and amount of inheritance help to generate large heterogeneity in wealth at retirement among higher lifetime earnings households, who on average receive more inheritances and are more likely to keep assets due to bequest motives.

This paper is related to the literature that examines the implications of different models on wealth dispersions at retirement age.[3] Engen et al. (1999), Engen et al. (2004), and Scholz et al. (2006) study the adequacy of household retirement saving. Those papers abstract from the intergenerational links of bequests and earnings ability. Gokhale et al. (2001) abstract from voluntary bequest motives. Hendricks (2007a) assumes that households receive bequests at the same age and there is neither a bequest motive nor a government-provided consumption. In my model, households expect and receive different

[3]This paper builds on a large literature that studies the economy-wide wealth inequality (see, among others, Huggett (1996), Quadrini (2000), Casteneda et al. (2003), De Nardi (2004), and Cagetti and De Nardi (2006)).

amounts of inheritances at different times and hold on more wealth due to operative bequest motives, which generates more heterogeneity in retirement wealth among households with similar lifetime earnings. A consumption floor further discourages wealth accumulation for low-income households. Ameriks et al. (2003) offer an interesting and potentially complementary explanation to the heterogeneity in retirement wealth. They use a unique survey data to measure propensity to plan and find a positive relationship between the propensity to plan and the rate of savings.

2 Empirical Findings

This section presents some empirical results from Hendricks (2007a) showing the relationship between wealth at retirement and lifetime earnings. Hendricks (2007a) uses data from the Panel Study of Income Dynamics (PSID) on wealth reported at age 65. Earnings consist of labor income (net of income tax payments and Social Security contributions) received by both the household head and the spouse, which include wages, salaries, bonuses, overtime payments, and the business part of labor income. Lifetime earnings are the present value of earnings between the ages of 18 and 65, discounted to age 65. Wealth at retirement is positively but not perfectly correlated with lifetime earnings: The correlation coefficient between lifetime earnings and wealth at retirement is 0.61. Substantial wealth difference remains after controlling for lifetime earnings and age: Households with similar lifetime earnings hold diverse amounts of wealth at retirement age. Table 1 displays the Gini coefficient of retirement wealth for each lifetime earnings decile. We observe that controlling for age and lifetime earnings reduces wealth inequality: The average of the Gini coefficients in retirement wealth across lifetime earnings deciles is 0.54, compared with 0.62 in the full sample. However, at all levels of lifetime earnings there is large dispersion in wealth at retirement: The Gini coefficients are all above

0.4. The degree of wealth inequality declines with lifetime earnings decile.[4, 5]

Bottom earnings decile										
1	2	3	4	5	6	7	8	9	10	mean
0.66	0.67	0.62	0.55	0.57	0.45	0.43	0.42	0.50	0.55	0.54

Table 1: Gini coefficient of retirement wealth by lifetime earnings decile in PSID (Hendricks (2007a))

The findings that retirement wealth and lifetime earnings are not perfectly correlated and that households with similar lifetime earnings hold diverse amounts of wealth at retirement age constitute a challenge to our theories of saving behavior. In a standard deterministic life-cycle consumption-saving model with permanent difference in earnings and Social Security benefits fully proportional to lifetime earnings, the correlation between lifetime earnings and wealth should be one. If we further assume that the permanent difference in earnings is distributed lognormally with variance σ^2, then retirement wealth is distributed lognormally with variance σ^2. Assuming $\sigma^2 = 0.21$ (Storesletten et al. (2004)), the average Gini coefficient of retirement wealth by lifetime income decile is 0.039, much smaller than the Gini coefficient of retirement wealth (0.254).

3 The Benchmark Model

The economy is a discrete-time overlapping generations world with an infinitely-lived government. There are uninsurable idiosyncratic earnings shocks. The only financial instrument is a one-period bond. Net assets must be non-negative. There is mortality risk but private annuity markets do not exist.

[4]Similar findings arise from Health and Retirement Study (Venti and Wise (2000)). To check the robustness of those findings, Hendricks (2007a) restricts samples to contain only households with similar characteristics. The main findings are not affected by household characteristics such as numbers of children, marital breakups, self-employment, or stock holdings.

[5]Survey of Consumer Finances has a better coverage of high-earner and high-wealth households than PSID and Health and Retirement Study. However, as is shown in Juster, Smith and Stafford (1999), and Cagetti (2003), for lower quartiles, those data sets give similar information.

Members of successive generations are linked by bequests and the children's inheritance of part of their parent's ability. At age 20, each agent enters the model and starts consuming, working, and paying Social Security tax at rate τ_l. After retirement, the agent no longer works but receives interest from accumulated assets and benefits from Social Security provided by the government and from defined benefit plan provided by the firm.[6] The Social Security benefits that individuals receive are linked to their average lifetime earnings. Government taxes capital income at rate τ_a to provide transfers for minimum consumption.

3.1 Technology, Firm, and Defined Benefit Plan

There is one type of goods produced according to the aggregate production function $F(K; L) = K^\alpha L^{1-\alpha}$, where K is the aggregate capital stock and L is the aggregate labor input. The final goods can be either consumed or invested into physical capital. Physical capital depreciates at rate δ. Households rent capital and efficient labor units to the representative firm in each period. The firm maintains a defined benefit plan, which is financed by contributions on each work's behalf at rate τ_{DB}. Retired households receive pensions from defined benefit plan each period until they die. Pension benefit is linked to each individual's average lifetime earnings.[7]

3.2 Demographics, Preferences, and Labor Productivity

During each model period, which is 5 years long, a continuum of people is born. I denote age $t = 1$ as 20 years old, age $t = 2$ as 25 years old, and so on. At the beginning of period 4, the agent's children are born, and four periods later the children are 20 years old and start working. The agents retire at $t = 10$ and die by the end of age $T = 14$. From $t = 10$, each person faces a positive probability of dying, given by $(1 - p_t)$, which is exogenous and independent of

[6] In the model, defined contribution pension wealth is equivalent to wealth accumulated through private saving.

[7] Scholz et al. (2006) propose an alternative model of defined benefit plan, in which pension benefits are linked to individuals' average earnings in the past 5 year before retirement.

other household characteristics. The population grows at rate n.

Individuals derive utility from consumption and from bequests transferred to their children upon death.[8] Preferences are assumed to be time separable, with a constant discount factor β. The momentary utility function from consumption is given by $U(c) = log(c)$. Following De Nardi (2004), the utility from bequests b is denoted by $\phi(b) = \phi_1 log(b + \phi_2)$. The term ϕ_1 reflects the parent's concern about leaving bequests to his/her children, while ϕ_2 measures the extent to which bequests are luxury goods.[9]

The total productivity of worker i at age t is given by $y_t^i = e^{\kappa_t^i + \epsilon_t}$. The process for stochastic productivity shocks κ_t^i is: $\kappa_t^i = \alpha^i + z_t^i + \varepsilon_t^i; z_t^i = \rho_z z_{t-1}^i + \mu_t^i$, $\alpha^i \sim N(0, \sigma_\alpha^2), \mu_t^i \sim N(0, \sigma_\mu^2), \varepsilon_t^i \sim N(0, \sigma_\varepsilon^2)$. To capture the intergenerational correlation of earnings, I assume that this worker's ability α^i is transmitted to children j as follows: $\alpha^j = \rho_\alpha \alpha^i + \nu^j$, $\nu^j \sim N(0, (1 - \rho_\alpha^2)\sigma_\alpha^2)$.

3.3 The Household's Recursive Problem

In a stationary equilibrium, the interest rate is constant at r and the wage rate is at w. I assume that children have full information about their parents' state and children solve their decision problems after observing their parents' decisions. Children infer the size of the bequests they are likely to receive based on this information. The household's state variables are given by $x = (t, a, \alpha, z, \varepsilon, \widetilde{y}, S_p)$, where a denotes the agent's financial assets carried from the previous period, and $\widetilde{y}$ denotes average annual earnings. The last term S_p denotes the agent's parent's state variables and differs in each of the following four cases.

(i) From $t = 1$ to $t = 2$ (from 20 to 25 years of age), the agent survives for sure until next period and does not expect to receive a bequest because his/her parent is younger than 65. In this case, $S_p = (a_p, \alpha_p, z_p, \varepsilon_p, \widetilde{y}_p)$.

$$V(x) = \max_{c,a'} U(c) + \beta E\big[V(x')\big] \tag{1}$$

[8]Note that this form of 'impure' bequest motive implies that an individual cares about the total bequests left to his/her children, but not about consumption of his/her children.

[9]If $\phi_2 > 0$, the marginal utility of small bequests is bounded, while the marginal utility of large bequests declines more slowly than the marginal utility of consumption.

subject to

$$(2) \qquad c + a' = (1-\tau_l)wy + [1 + r(1-\tau_a)]a + Tr,$$

$$(3) \qquad Tr = \max\{0, \underline{c} - (1-\tau_l)wy - [1 + r(1-\tau_a)]a\},$$

$$(4) \qquad a' \geq 0, \; c \geq 0,$$

$$(5) \qquad \widetilde{y}' = \big[(t-1)\widetilde{y} + wy/5\big]/t,$$

$$(6) \qquad \widetilde{y}_p' = \big[(t+6)\widetilde{y}_p + wy_p/5\big]/(t+7),$$

$$(7) \qquad a_p' = a_p'(a_p, \alpha_p, z_p, \varepsilon_p, \widetilde{y}_p).$$

The expected value of the value function is taken with respect to $(z', \varepsilon', z_p', \varepsilon_p')$, conditional on $(z, \varepsilon, z_p, \varepsilon_p)$. At any subperiod, the agent's resources depend on asset holdings, a, labor endowment y, and government transfer Tr. Following Hubbard et al. (1995), I assume government transfers provide a consumption floor $\underline{c}$, as is specified in equation (3). Average earnings for children and parents accumulates according to equations (5) and (6), respectively. The law of motion of assets for the parents, which is their decision rule, is given in equation (7).

(ii) From $t = 3$ to $t = 7$ (from 30 to 50 years of age), the worker survives for sure until the next period. However, the agent's parent is at least 65 years old and faces a positive probability of dying at any period; hence, a bequest might be received at the beginning of the next period. Let $V^I(t, a, \alpha, z, \varepsilon, \widetilde{y})$ and $V(t, a, \alpha, z, \varepsilon, \widetilde{y}, a_p, \widetilde{y}_p)$ denote the value function of a person whose parent is dead and alive, respectively.[10]

$$(8) \qquad V^I(t, a, \alpha, z, \varepsilon, \widetilde{y}) = \max_{c, a'} U(c) + \beta E\big[V^I(t+1, a', \alpha, z', \varepsilon', \widetilde{y}')\big]$$

subject to (2), (3), (4), and (5). In the latter case,

$$V(t, a, \alpha, z, \varepsilon, \widetilde{y}, a_p, \widetilde{y}_p) = \max_{c, a'} U(c) + \beta p_{t+7} EV(t+1, a', \alpha, z', \varepsilon', \widetilde{y}', a_p', \widetilde{y}_p)$$
$$+ \beta(1 - p_{t+7}) EV^I(t+1, a' + a_p'/N, \alpha, z', \varepsilon', \widetilde{y}')$$

subject to (2), (3), (4), (5), and $a_p' = a_p'(a_p, \widetilde{y}_p)$, where N is the average number of kids.

(iii) From $t = 8$ to $t = 9$ (from 55 to 60 years of age), the agent work

[10] In both cases, since parents are retired, α_p, z_p, and ε_p are not in the state space. In the former case, a_p and $\widetilde{y}_p$ are not in the state space any more. In the latter case, $\widetilde{y}_p$ does not change over time.

and does not expect inheritances because the agent's parent is already dead by that time. The agent does not face any survival uncertainty.

$$V(t,a,\alpha,z,\varepsilon,\widetilde{y}) = \max_{c,a'} U(c) + \beta E\big[V(t+1,a',\alpha,z',\varepsilon',\widetilde{y}')\big] \tag{9}$$

subject to (2), (3), (4), and (5).

(iv) From $t = 10$ to $t = 14$ (from 65 to 85 years of age), the agent does not work and does not inherit any more, but faces a positive probability of dying. In case of death, the agent derives utility from bequeathing his/her assets. Households receive Social Security benefits $P(\widetilde{y})$ and pensions from defined benefit plan $DB(\widetilde{y})$.

$$V(t,a,\widetilde{y}) = \max_{c,a'} U(c) + \beta p_t V(t+1,a',\widetilde{y}) + (1-p_t)\phi(a') \tag{10}$$

subject to (4) and

$$\begin{aligned} c + a' &= (1 + r(1-\tau_a))a + P(\widetilde{y}) + DB(\widetilde{y}) + Tr, \\ Tr &= \max\{0, \underline{c} - [1 + r(1-\tau_a)]a - P(\widetilde{y}) - DB(\widetilde{y})\}. \end{aligned}$$

3.4 Definition of the stationary equilibrium

I focus on an equilibrium concept where factor prices and age-wealth distribution are constant over time. Each agent's state is denoted by x. An equilibrium is described as follows.

Definition 1 *A stationary equilibrium is given by government policies $(\tau_l, \tau_a, P(\widetilde{y}))$; an interest rate r and a wage rate w; defined benefit policies $(\tau_{DB},\ DB(\widetilde{y}))$; value functions $V(x)$, allocations $c(x)$, $Tr(x)$, $a'(x)$; and a constant distribution of people $m^*(x)$, such that the following conditions hold:*

(i) Given government policies and defined benefit policies, the interest rate and the wage rate, the functions V, c, Tr, and a' solve the maximization problem described above.

(ii) m^* is the invariant distribution of households over the state variables for this economy.

(iii) All markets clear.

$$C = \int cm^*(dx),\ K = \int am^*(dx),\ L = \int ym^*(dx),\ C + (n+\delta)K = F(K;L).$$

(iv) The price of each factor is equal to its marginal product.

$$r = F_1(K,L) - \delta,\ w = F_2(K,L)/(1+\tau_{DB}).$$

(vi) The defined benefit pension budget and the government budget are balanced at each period.

$$\int I_{t>9} DB(\widetilde{y}) m^*(dx) = \tau_{DB} wL,\quad \int I_{t>9} P(\widetilde{y}) m^*(dx) = \tau_l wL,\quad \int Tr m^*(dx) = \tau_a rK.$$

3.5 Calibration

	Parameters		Value
Demographics	n	annual population growth	1.2%
	p_t	survival probability	see text
Labor productivity	ϵ_t	age-efficiency profile	see text
	ρ_α	AR(1) coef. of ability inher. process	0.67
	σ^2_α	variance of ability shock	0.2105
	ρ_z	AR(1) coef. of the persistent process	0.9989
	σ^2_μ	variance of the persistent process	0.0166
	σ^2_ε	variance of the transitory process	0.0630
Government policy	$P(\widetilde{y})$	Social Security benefit	see text
	$\underline{c}$	minimum consumption	0.21
Technology	α	capital share in National Income	0.36
	δ	annual depreciation rate of capital	6%
	$DB(\widetilde{y})$	pension from defined benefit plan	see text

Table 2: Parameters used in the benchmark model (at annual frequency)

Table 2 lists the parameters picked from other studies, at annual frequency. I set the rate of population growth, n, to the average value of population growth from 1950 to 1997 from the Council of Economic Advisors (1998). The p_t's are the vectors of conditional survival probabilities for people older than 65 and is set to the mortality probabilities for people born in 1965 (Bell et al. (1992)). The deterministic age-profile of labor productivity ϵ_t is taken from Huggett and Ventura (2000). I take persistence ρ_α of the ability inheritance process from Zimmerman (1992). The remaining four parameters regarding earnings are from Storesletten et al. (2004).[11]

[11] I first simulate a panel data of annual earnings using parameters reported in Table 2. I then estimate from this data the five-year earnings process following the procedure in

The minimum consumption floor $\underline{c}$ is 0.21 of average household income.[12] The Social Security benefit is calculated to mimic the Old Age and Survivor Insurance component of Social Security system:

$P(\widetilde{y}) = 0.9min(\widetilde{y}, 0.2) + 0.32max(0, min(\widetilde{y}, 1.24) - 0.2) + 0.15max(0, \widetilde{y} - 1.24)$. The bend points, expressed as average earnings, and marginal rates are from Huggett and Ventura (2000). I take α, the share of income that goes to capital, to be 0.36 (Prescott (1986), and Cooley and Prescott (1995)). I take depreciation to be 6% (Stokey and Rebelo (1995)). The defined benefit is equal to

$$
\begin{aligned}
DB(\widetilde{y}) = {} & 0.50max[0, min(\widetilde{y}, 0.67) - 0.54] + 0.34max[0, min(\widetilde{y}, 0.83) - 0.67] \\
& +0.27max[0, min(\widetilde{y}, 1.02) - 0.83] + 0.21max[0, min(\widetilde{y}, 1.24) - 1.02] \\
& +0.16max[0, min(\widetilde{y}, 1.54) - 1.24] + 0.28max[0, min(\widetilde{y}, 2.05) - 1.54] \\
& +0.03max[0, min(\widetilde{y}, 3.16) - 2.05].
\end{aligned}
$$

The bend points, expressed as average earnings, and marginal rates are chosen to mimic the holding of defined benefit wealth relative to Social Security wealth by lifetime earnings from Health and Retirement Study reported in Scholz et al. (2006).

I choose β, ϕ_1, ϕ_2, τ_l, τ_a, and τ_{DB} to match the capital-output ratio, bequest-capital ratio (Gale and Scholz (1994)), the amount of bequest left at the lowest 90th percentile (Hurd and Smith (2002)), and to balance Social Security, government transfer, and private pension budgets.[13]

Storesletten et al. (2004). The result is $\rho_z = 0.9951$, $\sigma_\varepsilon^2 = 0.0118$, and $\sigma_\mu^2 = 0.0825$. I discretize the persistent process and the ability inheritance process according to Tauchen (1986). The persistent shocks take 7 equally spaced values, and range from $-3\sigma_{z_t}$ to $3\sigma_{z_t}$. The transitory shocks take two values $\{\pm\sigma_\varepsilon\}$. The ability takes two values $\{\pm\sigma_\alpha\}$.

[12] In 1992, the consumption floor was $8,159 (Scholz et al. (2005)) and the average income was $38,840 (Census Bureau). Hubbard et al. (1995) use a slightly higher value.

[13] Discount factor affects saving and average capital in the economy. The term ϕ_1 reflects the parent's concern about leaving bequests to his/her children, thus I choose the aggregate bequest as a moment. The term ϕ_2 measures the extent to which bequests are luxury goods, affecting the bequest distribution, especially the high end of it. Since the model abstracts from government spending, the value of τ_a is small compared with the effective capital tax in the US.

Moment		Data	Model
Capital-output ratio		2.80	2.80
Bequest-capital ratio		0.0088	0.0089
Bequest left at the lowest 90th percentile to income		4.53[a]	4.63
Social Security budget surplus		0.0	0.0
Government budget surplus		0.0	0.0
Private pension budget surplus		0.0	0.0
Parameters		Value	
β	discount factor	0.95	
ϕ_1	weight of bequest in utility function	3.70	
ϕ_2	shifter of bequest in utility function	35.1	
τ_{DB}	contribution rate to defined benefit plan	4.3%	
τ_l	tax on labor income	10.4%	
τ_a	tax on capital income	2.8%	

[a]I use distribution for single decedents instead of the one for all decedents. Typically a surviving spouse inherits a large share of the estate, consumes part of it, and only leaves the remaining to the couple's children.

Table 3: Parameters calibrated from the model

4 Numerical Results

I will study the benchmark model and the quantitative role of bequests, consumption floor, and Social Security.[14] I first compare models that differ in bequest motives and in distributing inheritances. First, to see how much wealth inequality can be generated by the life-cycle structure when only earnings uncertainty is activated, I turn off bequest motives and assume accidental bequests are equally redistributed among 50-year-old people. The second experiment adds random inheritances uncorrelated with earnings at age 50 to the first one. The probabilities of inheritance are (0.50, 0.30, 0.10, 0.08, 0.02) and the corresponding amounts are (0.0, 1.43, 3.83, 14.2, 51.7) of average after-tax earnings.[15] Third, I make the time of inheritances random. The probabilities of receiving inheritances at ages 35 to 55 coincide with parents' death probabilities. The amounts of inheritances at each age are adjusted by discounting. Forth, I add intergenerational links and bequest motives. As in De Nardi (2004), children only observe their parent's ability. Fifth, I remove

[14]Details about computing the benchmark model are provided in the Appendix.
[15]Those are taken from Hendricks (2007a), discounted to age 50.

government-provided minimum consumption and τ_a. Finally, I show how Social Security and private pensions affect saving by assuming that all retirees receive only equal amounts of Social Security. In each experiment, I solve for the equilibrium.[16] I then simulate 100,000 households starting from age 20 drawn from the initial distribution. I define retirement wealth to be the wealth at age 65, and lifetime earnings to be the total earnings from ages 20 to 60, discounted to age 65.

4.1 Distribution of Earnings

Table 4 compares values for the lifetime earnings distribution in all models with those in the PSID. The earnings process used in those models generates a skewed distribution of lifetime earnings comparable with the data.

		Top percentile (%)							
	Gini	1	1-5	5-10	10-20	20-40	40-60	60-80	80-100
PSID[a]	0.32	4.4	9.5	9.1	15.5	24.5	18.0	12.3	6.6
All models	0.36	4.2	11.1	10.3	16.5	23.7	16.3	11.0	6.8

[a]From Hendricks (2007a)

Table 4: Lorenz curve of lifetime earnings

Mean lifetime earnings at each decile, in the data and in the models, normalized by average lifetime earnings, is shown in Table 5. The earnings process used in those models produces lifetime earnings at each decile similar as those reported in the PSID.

	Top earnings decile									
	1	2	3	4	5	6	7	8	9	10
PSID[a]	2.31	1.56	1.33	1.14	0.97	0.83	0.68	0.56	0.43	0.24
All models	2.57	1.65	1.29	1.08	0.89	0.74	0.61	0.49	0.40	0.28

[a]From Hendricks (2007a)

Table 5: Mean of lifetime earnings for each lifetime earnings decile

[16]I recalibrate parameters in Table 3, except for the last case in which I calibrate P. The marginal distribution of earnings in the first period is the same in all cases.

4.2 Wealth Distribution

Table 6, row one, shows values for the wealth distribution at retirement. In the PSID, wealth at age 65 is highly unevenly distributed. The benchmark model with intergenerational links and bequest motives generates a skewed retirement wealth distribution that is comparable with the data, except for the top 1% of the wealth holding. The three models without intergenerational links and bequest motives fail to replicate a skewed retirement wealth distribution. Compared with the benchmark, assuming children have limited information slightly increases the wealth inequality, removing minimum consumption reduces wealth inequality by encouraging low-income individuals to save, while assuming equal Social Security increases wealth holdings for the rich and decreases those for the poor and thus generates a bigger Gini coefficient.

			Top percentile (%)					
		Gini	1	1-5	5-10	10-20	20-40	40-60
Age 65	PSID (Hendricks (2007a))	0.62	15.7	18.3	13.8	17.0	18.8	10.2
	Benchmark model	0.63	11.5	20.4	14.8	19.1	18.8	10.3
	Change bequest motives and inheritance							
	Equal inher. at age 50	0.55	9.1	18.4	13.2	18.2	20.6	11.6
	Random inher. at age 50	0.57	8.9	17.8	13.9	19.3	20.9	12.0
	Random inher. at ages 35-55	0.58	8.8	18.3	14.1	18.9	21.2	11.8
	Bequest motives, limited infor.	0.64	12.0	20.9	14.7	18.7	18.5	10.2
	No consumption floor	0.61	11.0	19.9	14.8	18.7	18.7	10.4
	Equal Social Security	0.65	11.2	20.0	15.1	19.8	21.1	9.6
All	PSID (Hendricks (2007a))	0.76	22.8	22.5	14.4	16.8	16.3	6.4
	Benchmark model	0.81	20.6	27.8	17.8	17.8	14.1	2.0
	Change bequest motives and inheritance							
	Equal inher. at age 50	0.76	15.0	24.9	17.7	20.2	18.0	4.2
	Random inher. at age 50	0.77	14.8	26.9	18.2	20.1	16.6	3.4
	Random inher. at ages 35-55	0.77	15.3	26.8	18.0	19.9	16.5	3.5
	Bequest motives, limited infor.	0.81	21.4	27.6	17.5	17.5	14.0	2.0
	No consumption floor	0.79	19.6	27.2	17.6	17.8	14.4	3.3
	Equal Social Security	0.82	21.1	28.7	18.0	18.4	12.8	1.1

Table 6: Lorenz curve of wealth

Table 6, row two, reports values for the wealth distribution for the whole economy. Wealth for the whole economy is more unevenly distributed than wealth at retirement both in the data and in all models. This shows that a large amount of wealth dispersion in the economy is due to differences in age. Those three models without intergenerational links and bequest motives fail to generate a skewed wealth distribution. Models with intergenerational links and bequest motives generate a skewed wealth distribution that is comparable with the data.

4.3 Wealth Inequality and Lifetime Earnings

I now show, in Table 7, some statistics summarizing the relationship between retirement wealth and lifetime earnings in the PSID and those in each model. Both earnings and wealth in the data may subject to measurement error. To address this issue, I add random noise into the sample simulated from each model. I assume that the log of observed earnings for household i at age t, $\hat{e_t^i} = e_t^i + v_t^i$, and $v_t^i = \rho_v e_t^i + \iota_t^i$, $\iota_t^i \sim N(0, \sigma_\iota^2)$. The observed log wealth at age 65, $\hat{W}^i = W^i + \eta^i$, and $\eta^i \sim N(0, \sigma_\eta^2)$. η^i and ι_t^i are uncorrelated with each other. I use $\rho_v = -0.104$, and $\sigma_\iota^2 = 0.136$ (Bound et al. (1989)).[17] The measurement error of wealth may be substantial as well. I choose a small variance $\sigma_\eta^2 = 0.01$ as a lower bound.

The benchmark model generates a relationship between lifetime earnings and retirement wealth close to the data. The correlation coefficient between retirement wealth and lifetime earnings of 0.71, although a bit higher than that in the data (0.61), is quite low. Substantial wealth difference remains after controlling for lifetime earnings and age: The average of the Gini coefficients (0.51) is considerably high, compared with the data counterpart of 0.54. I then show the quantitative role of bequests, minimum consumption, and Social Security in generating the results in the benchmark model.

The Role of Bequests In the model in which accidental bequests are equally redistributed, the only source of heterogeneity is the timing of earnings shocks. Table 7 shows that this model implies a very tight relationship between lifetime earnings and retirement wealth. The correlation coefficient of 0.81

[17] Using 1982 PSID earnings, Bound et al. (1989) reported that $\sigma_v^2/(\sigma_v^2 + \sigma_e^2) = 0.15$, and $\rho_v = -0.104$. In the model σ_e^2 is 0.819, which gives $\sigma_v^2 = 0.145$ and $\sigma_\iota^2 = 0.136$.

is much stronger and the mean Gini of 0.37 is much lower than the data counterparts. The comparison indicates that the timing of earnings shocks and the existence of borrowing constraints in the bonds market along are not enough to generate the observed relationship between lifetime earnings and retirement wealth.

	Corr(W, E)[a]	Mean Gini[b]
PSID (Hendricks (2007a))	0.61	0.54
Benchmark	0.71 (0.10)	0.51 (-0.03)
Change bequest motives and inheritances		
Equal inher. at age 50	0.81 (0.20)	0.37 (-0.17)
Random inher. at age 50	0.77 (0.16)	0.45 (-0.09)
Random inher. at ages 35-55	0.76 (0.15)	0.46 (-0.08)
Bequest motives, limited infor.	0.69 (0.08)	0.52 (-0.02)
No consumption floor	0.71 (0.10)	0.46 (-0.08)
Equal Social Security	0.74 (0.14)	0.54 (-0.00)

[a]The correlation coefficient between lifetime earnings and retirement wealth
[b]The average of the Gini coefficients of retirement wealth within lifetime earnings deciles

Table 7: Relationship between retirement wealth and lifetime earnings (The numbers in the parentheses are deviations from the data)

I then look at the random inheritance models without bequest motives. Adding random bequests uncorrelated with earnings at age 50 in an otherwise standard life-cycle model weakens the relationship between lifetime earnings and retirement wealth. However, the correlation coefficient (0.77) is still higher than that in the data and the mean Gini coefficient (0.45) is still lower than that in the data. Making the time of receiving inheritance random at ages 35 to 55 further weakens the relationship between lifetime earnings and retirement wealth: A household who is borrowing constrained and receives an inheritance earlier consumes more of it and holds on less wealth at retirement than an otherwise identical household who receives an inheritance later. However, the quantitative effect is small. This comparison shows that random bequests are not sufficient to generate the observed relationship between lifetime earnings and retirement wealth. The reason is, without an operative bequest motive, those who have received large inheritances will consume a large part of them before retirement. In the benchmark model households hold on more wealth due to operative bequest motives, which generates more heterogeneity in retirement wealth for given lifetime earnings.

Next I add intergenerational links and bequest motives. As in De Nardi (2004), children only observe their parent's ability. Without perfect information, children of poor parents will save less whereas children of richer parents will save more, compared with the benchmark model. This enhances the effect of inheritance heterogeneity on generating heterogeneity in retirement wealth for given lifetime earnings. However, the quantitative effect is small, indicating that children can infer other relevant information of their parents, thus the amounts of future inheritances, very well based on their parents' ability. For example, the average expected inheritance at age 50, when parents die for sure next period, is only 0.09 when parents have low ability, while the value is 2.23 when parents have high ability.

The Role of Government-provided Minimum Consumption Shutting down government-provided minimum consumption reduces the mean Gini by 0.05 to 0.46. Figure 1 illustrates the Gini coefficients of retirement wealth for each lifetime earnings decile. We notice two important features. First, after controlling for age and lifetime earnings, there is still large wealth inequality in the benchmark model: All the Gini coefficients are above 0.36. Second, the degree of wealth inequality declines as lifetime earnings increases, as is observed in the data. As in Hubbard et al. (1995) and Scholz et al. (2006), means-tested minimum consumption provides strong incentives for low-income individuals not to save. Due to the persistence of earnings process, those low-income households are more concentrated in low lifetime earnings deciles. Without a consumption floor, the Gini coefficients decrease a lot at the lowest 4 earnings deciles, since there are fewer poor households in those deciles. Gini coefficients at the higher deciles barely change, since households in those deciles receive high pension and social security income and are not qualified for a transfer.

The Role of Social Security and Pensions Finally, I deactivate defined benefit pensions and history-dependent Social Security by assuming only

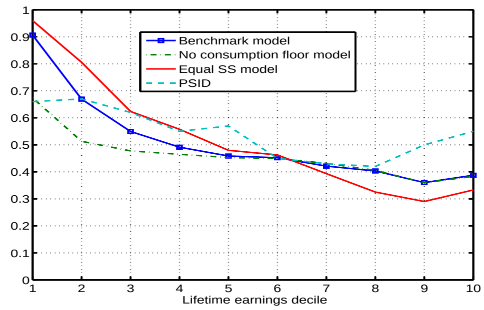


Figure 1: Gini coefficients of retirement wealth for each lifetime earnings decile

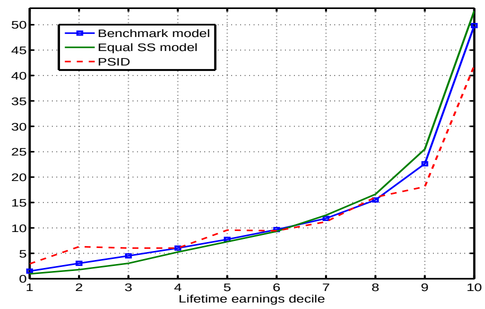


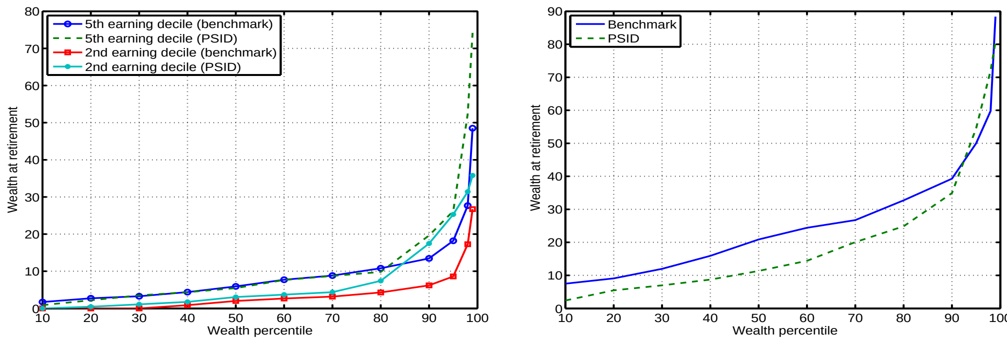
Figure 2: Mean of retirement wealth for each lifetime earnings decile

the same amounts of Social Security for all retirees. This modification brings the correlation coefficient further away from the data. The average Gini becomes closer to the data. However, as is shown in Figure 1, it generates bigger (smaller) Gini coefficients for low (high) earnings deciles than the data and the benchmark model. This is because, in this model, there are more (less) poor households in the low (high) earnings deciles due to unrealistically high (low) pension wealth.

To understand the correlation coefficient, I show, in Figure 2, the mean retirement wealth at each lifetime earnings decile, normalized by average household after-tax earnings. In the PSID, the earnings-rich households on average hold more wealth than the earnings-poor households. The benchmark model matches very well the mean retirement wealth observed in the data for each earnings decile. In this model, households with higher lifetime earnings will save more than households with lower lifetime earnings because a bequest is a luxury good, government transfers are means-tested, and benefits from Social Security and from defined benefit plans follow a concave function of lifetime earnings.[18] The model with only equal Social Security generates lower mean wealth for households in the low earnings deciles and higher wealth in the high earnings deciles than the data and the benchmark model. This is because, in this model households in the low (high) earnings deciles anticipate more (less) pension wealth and carry fewer (more) assets into retirement than

[18]Removal of minimum consumption only raises slightly mean wealth at the lowest 3 deciles.

in the benchmark model. This discrepancy explains why this modification brings the correlation coefficient further away from the data.



(a) 2nd and 5th lifetime earnings deciles (b) 9th lifetime earnings decile

Figure 3: Distribution of wealth (normalized by average household after-tax earnings)

To better gauge the amount of wealth dispersion at retirement generated by the benchmark model, I show in Figure 3 the retirement wealth distributions for the 2nd, 5th, and 9th deciles, respectively. The model successfully replicates the fact that households with similar lifetime earnings hold diverse amounts of wealth. At each lifetime earnings decile, households in the lower wealth deciles hold very little wealth while households in the higher wealth deciles hold much more wealth. Compared with the data, the model generates less high wealth at the 2nd and 5th deciles but more low wealth at the 9th decile.

4.4 Investigating the Model's Mechanisms

In the benchmark model, retirement wealth inequality arises, among household with similar lifetime earnings, because households differ in the timing of earnings over the life cycle and in the amount and timing of inheritances received. Let us now try to understand the role of each force on the heterogeneity in retirement wealth.

The Effect of Earnings Heterogeneity Suppose two households have the same lifetime earnings, but one has positive earnings shocks when young and negative earnings shocks when old, the other has the reverse. The household with positive earnings shocks when young would save more in the earlier ages to buffer against negative earnings shocks later. Then he/she suffers negative earnings shocks later, he/she uses assets to finance consumption, resulting in low level of retirement wealth. The household with negative earnings shocks when young anticipates high earnings in the future and would like to borrow to finance consumption but cannot. When he/she gets positive earnings shocks later, he/she saves most of them for retirement, and ends up holding a relatively large amount of wealth at retirement.

			Age									
			20	25	30	35	40	45	50	55	60	65
2nd decile	1	Earnings	49	49	77	133	78	271	540	950	562	
		Assets	0	0	0	0	0	0	33	137	280	280
	2	Earnings	86	194	187	226	142	140	128	94	109	
		Assets	0	0	0	2	11	16	23	23	0	2.6
6th decile	3	Earnings	123	123	192	333	195	678	1351	2378	1407	
		Assets	0	0	0	3	23	33	137	400	816	1166
	4	Earnings	216	485	468	565	356	350	321	236	274	
		Assets	0	0	0	16	47	67	96	137	137	137

Table 8: Simulation of earnings and assets (in \$1000)

Table 8, rows 1 and 2, show the simulated 5-year earnings and assets holding for two households in the 2nd earnings decile with the same discounted lifetime earnings of $\$552,800$. Their parents are identical so their expectations of bequests are the same. Neither of them receives any bequests. But because of the different timing of earnings, the 1st household has retirement assets of $\$280,000$, 109 times as big as the 2nd household has ($\$2,600$). Table 8, rows 3 and 4, show the simulated paths for two households in the 6th earnings decile with the same discounted lifetime earnings of $\$1,381,000$. The 3rd household has retirement assets 9 times as big as the 4th household has.

In summary, households with negative earnings shocks when young and positive earnings shocks later, hold a relatively large amount of wealth at retirement, than households with earnings in the reversed sequence. This holds for all earnings deciles. But the relative difference in wealth holdings is higher among lower earnings households (row 1 vs row 2) than higher earnings households (row 3 vs row 4).

This comparison indicates that, earnings heterogeneity caused by the different timing of earnings plays a more important role in generating heterogeneity on retirement wealth among households in the lower earnings deciles. The main reasons are that the government-provided minimum consumption is means-tested and that benefits from Social Security and defined benefit pensions follow a concave function of lifetime earnings. Households in all earnings deciles use assets to finance consumption when suffer negative earnings shocks later in life. Households in the lower earnings deciles, who will anticipate government transfers and higher pension wealth relative to current assets, use more assets to finance consumption and carry fewer assets into retirement than households in the higher earnings deciles.

The Effect of Inheritance Heterogeneity The general equilibrium model with intergenerational links of bequests and ability endogenously generates differences in the timing and amount of inheritances. To see how large the variation in inheritance is, Table 9 reports values for the inheritance distribution. Inheritances are deflated and discounted to the year where the head is 50 years old. In the PSID, inheritances are highly unevenly distributed with a Gini coefficient of 0.89. The top 1% of the households receive 35% of all the inheritances. 50% of the households receive very little or no inheritances. The model generates a skewed inheritance distribution that is comparable with the data. Treating bequests as luxury goods and modeling the transmission of earnings ability across generations are essential to match the observed skewness in the inheritance distribution. First, the marginal utility from bequeathing is finite at zero bequests, which helps to generate a large fraction of households without any inheritances. Secondly, some large inheritances are transmitted across generations because of the voluntary bequests. Because the marginal utility of bequests declines more slowly than the marginal utility of consumption, the richest households have strong bequest motives to save some assets for their children even when very old. When there is a positive correlation between parents and children in earnings, their offspring are more likely to be earnings-rich and tend to leave more wealth to their offspring, thus generating a skewed inheritance distribution.

		Top percentile (%)						
	Gini	1	1-5	5-10	10-20	20-30	30-50	50-100
PSID (Hendricks (2007a)	0.89	35.3	30.9	14.1	12.5	4.9	2.3	0.0
Benchmark model	0.90	31.1	37.5	15.9	11.6	3.5	0.4	0.0

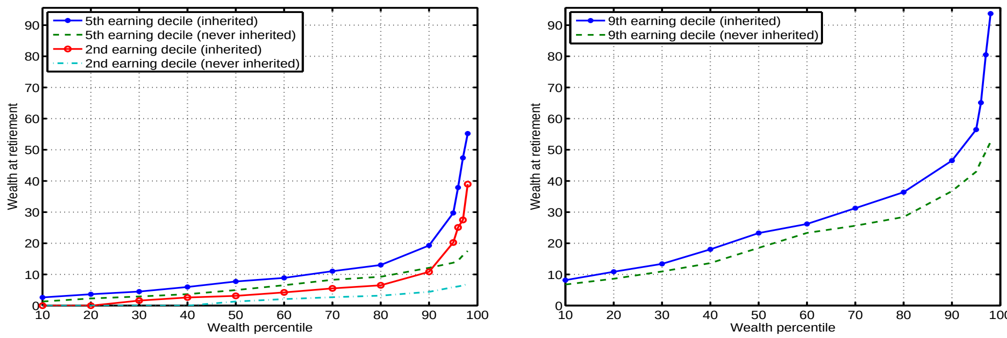
Table 9: Lorenz curve of inheritance distribution

Table 10 shows the fraction of lifetime inheritances received by households in each lifetime earnings decile. In the PSID, there is a positive correlation between lifetime inheritances and lifetime earnings. The model generates an increasing relation between inheritances and lifetime earnings. This is because those who have high lifetime earnings are more likely to have high ability parents: In the lowest decile, only 18% have high ability parents; the corresponding number is 80% in the highest decile. Modeling the transmission of earnings ability across generations and a highly correlated lifetime earnings process is key in generating this pattern.

	Top earnings decile				
	1-2	3-4	5-6	7-8	9-10
PSID (Hendricks (2001))	41.3	16.6	22.2	6.0	13.9
Benchmark model	28.0	25.8	20.5	14.4	11.4

Table 10: Fraction of inheritances received by lifetime earnings decile (%)

Now I show the effect of inheritance heterogeneity on retirement wealth. Figure 4 compares wealth distributions, in the 2nd, 5th and 9th lifetime earnings deciles, among those who did and did not inherit. At each decile, those who never inherited hold less wealth than those who have inherited, and the difference increases as wealth percentile increases. The reason is, with operative bequest motives, those who have inherited hold a large part of the inheritances at retirement. We also notice that the difference between two distributions of retirement wealth increases by lifetime earnings decile. For example, those two distributions of retirement wealth for the 2nd earnings decile differ after the 30th percentile, while those two distributions for the 9th earnings decile differ since the 10th percentile. One reason is that, since a bequest is modeled as a luxury good, households in the high lifetime earnings deciles, holding relatively more wealth, tend to leave more wealth to their offspring by carrying relatively more wealth towards retirement. The other reason is that, as is shown in Table 10, those who have high lifetime earnings are more likely to inherit large estates.



(a) 2nd and 5th lifetime earnings deciles

(b) 9th lifetime earnings decile

Figure 4: Distribution of wealth at retirement (benchmark model)

5 Conclusions

Empirical studies using micro data find that there is large heterogeneity in retirement wealth among households with similar lifetime earnings, and raise doubts about the ability of a standard life-cycle model of saving behavior to reproduce the observed facts.

I use an incomplete-market life-cycle general equilibrium model with intergenerational links of bequests and ability, government-provided minimum consumption, a history-dependent Social Security system, and a defined benefit pension. I show that this model with earnings heterogeneity and inheritance heterogeneity generates a substantial amount of heterogeneity in retirement wealth for given lifetime earnings. This suggests that a properly specified life-cycle model with bequest motives, consumption floor, and Social Security pensions captures the fundamental determinants of households saving and wealth accumulation.

6 Appendix: Computation of the Benchmark Model

For a given set of parameters, I solve for the steady state equilibrium as follows:

1. Guess an initial value of τ_l, τ_a and τ_{DB}, and interest rate r, use the equilibrium conditions in the factor markets to obtain the wage rate w.

2. Solve the approximated optimal consumption and saving plans recursively.

3. Guess an initial joint distribution of parents and children at the beginning of the life cycle, compute the associated stationary distribution of households.

4. Compute the implied joint distribution of parents and children at the beginning of the life cycle. If the distributions converge, go to step 5; otherwise go to step 3.

5. Given the stationary distribution and prices, check whether all markets clear and whether the government transfer and Social Security budgets and defined benefit pension budget are balanced. If so, an equilibrium is found. If not, go to step 1.

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