Sources of Lifetime Inequality
AER 2011

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4/14/2017

Fundamental Research Questions

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Huggett, Ventura, and Yaron (henceforth HVY 2011) believe the model they establish can be a new workhorse model "for a wide range of policies considered in macroeconomics, public finance, and labor economics."

Approach

HVY 2011:

- embed a standard model of risky human capital accumulation into a carefully calibrated overlapping generations framework.
- establish key moments of US earnings data which the model is asked to match.
- perform a myriad of robustness checks to confirm the ability of their model to match data moments outside of their calibration targets.
- switch on and off different forms of agent heterogeneity to establish the relative importance of each idiosyncrasy in the determination of earnings inequality.

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  - 61.2% of variation in lifetime earnings, 62.4% of variation in lifetime wealth, and 66% of variation in lifetime utility can be attributed to differences in initial conditions.
- Among initial conditions, variation in human capital is considerably more important than variation in learning ability or financial wealth.
  - The response of expected lifetime wealth to a hypothetical 1 standard deviation increase in financial wealth, learning ability, or initial human capital is 5%, 8%, and 47%, respectively.

Background

Most analysis of lifetime inequality is based on a standard incomplete-markets model in which labor earnings are entirely exogenous. HVY 2011 believe their model improves on the standard approach as typical Bewley models:

1. overstate the importance of idiosyncratic earnings risk as all income dispersion comes from exogenous shocks.
2. overestimate the rise in within cohort consumption dispersion. The HVY 2011 overcomes this issue as earning dispersion is a result of initial conditions, and agents know their initial conditions.
3. are unable to comment on the role played by policy in augmenting lifetime earnings.

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HVY believe their model could bridge the gap between the macro literature on incomplete markets and the human capital literature, offering the field an alternative workhorse model for policy analysis.

The Model

In HVY 2011:

- Agents maximize expected lifetime utility taking initial financial wealth (k_1), initial human capital (h_1), and learning ability (a) as given.
- a Ben-Porath human capital accumulation model is augmented to allow for risky human capital.
- all uncertainty from the agent's perspective comes from their human capital production function.
- there is no aggregate uncertainty, lifetime uncertainty, or intergenerational connection in the model.
- future human capital is an increasing function of an idiosyncratic shock, current human capital, time devoted to human capital production, and learning ability. That is:

$$h_{j+1} = \exp(z_j)H(h_j, s_j, a)$$

The Model: Household Problem

$$\max_{\{c_j, l_j, s_j, h_j, k_j\}_{j=1}^{J}} E\left[\sum_{j=1}^{J} \beta^{j-1} u(c_j)\right] \text{ subject to}$$

(i) $c_j + k_{j+1} = k_j(1 + r_{t+j-1}) + e_j - T_{j,t+j-1}(e_j, k_j), \forall j$ and $k_{J+1} = 0$.

(ii) $e_j = R_{t+j-1} h_j l_j$ if $j < J_R$, and $e_j = 0$ otherwise.

(iii) $h_{j+1} = \exp(z_{j+1}) H(h_j, s_j, a)$ and $l_j + s_j = 1, \forall j$.

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- All idiosyncratic risk comes from z in the h.c. production function.
- Time at each age is devoted to either work (l_j) or schooling (s_j).
- Prior to age J_R, earnings equal the product of the rental rate for human capital, an agent's human capital, and the fraction of time an agent dedicates to market work.
- After age J_R, earnings go to 0 and agents receive a common retirement transfer equal to 40% of mean economy wide earnings.

Equilibrium

$$K_t \equiv \sum_{j=1}^{J} \mu_j \int E[k_{j,t}(\mathbf{x}_1, \mathbf{z}^j)]\, d\psi \text{ and } L_t \equiv \sum_{j=1}^{J} \mu_j \int E[h_{j,t}(\mathbf{x}_1, \mathbf{z}^j) l_{j,t}(\mathbf{x}_1, \mathbf{z}^j)]\, d\psi$$

$$C_t \equiv \sum_{j=1}^{J} \mu_j \int E[c_{j,t}(\mathbf{x}_1, \mathbf{z}^j)]\, d\psi \text{ and } T_t \equiv \sum_{j=1}^{J} \mu_j \int E[T_{j,t}(e_{j,t}, k_{j,t})]\, d\psi$$

DEFINITION: *A balanced-growth equilibrium is a collection of decisions* $\{\{c_{j,t}, l_{j,t}, s_{j,t}, h_{j,t}, k_{j,t}\}_{j=1}^{J}\}_{t=-\infty}^{\infty}$, *factor prices, government spending and taxes* $\{R_t, r_t, G_t, T_t\}_{t=-\infty}^{\infty}$, *and a distribution* ψ *over initial conditions such that*

(1) *Agent decisions are optimal, given factor prices.*

(2) *Competitive Factor Prices:* $R_t = A_t F_2(K_t, L_t A_t)$ *and* $r_t = F_1(K_t, L_t A_t) - \delta$.

(3) *Resource Feasibility:* $C_t + K_{t+1}(1+n) + G_t = F(K_t, L_t A_t) + K_t(1-\delta)$.

(4) *Government Budget:* $G_t = T_t$.

(5) *Balanced Growth: (i)* $\{c_{j,t}, k_{j,t}\}_{j=1}^{J}$ *grow at rate* g *as a function of time, whereas* $\{l_{j,t}, s_{j,t}, h_{j,t}\}_{j=1}^{J}$ *are time invariant. (ii)* (G_t, T_t, R_t) *grow at rate* g*, whereas* r_t *is time invariant.*

Model Specifics

- In the baseline model analyzed in HVY 2011, initial wealth is set to 0 for all agents.
- Thus, the distribution over initial conditions, ψ, is a bivariate distribution over initial h.c. and ability, h_1 and a.
- It is assumed that ψ is a bivariate lognormal distribution, allowing for a skewed distribution of initial human capital.

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The following functional forms are imposed for all future analysis:

$$u(c) = c^{(1-\rho)}/(1-\rho), F(K,LA) = K^{\gamma}(LA)^{1-\gamma} \text{ and } H(h,s,a) = h + a(hs)^{\alpha}$$

$$\mathbf{x} = (h_1, a) \sim \psi = LN(\mu_{\mathbf{x}}, \Sigma) \text{ and } z \sim N(\mu, \sigma^2).$$

Key Model Features

1. No aggregate risk.
2. Two sources of growing earnings dispersion within a cohort:
   - (1) agents have different learning abilities.
   - (2) agents experience different shocks to their h.c.
3. Although there is a single source of shocks in the model, this structure is sufficient to endogenously reproduce many statistical properties of earnings.
4. The model implies that human capital shocks can be inferred from earnings data.

Empirical Analysis

Data is used to address two issues:

1. The evolution of mean earnings, earnings dispersion, and skewness within a cohort is addressed using PSID data.
2. The human capital shock process is estimated using real wage data from the PSID.

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2. The human capital shock process is estimated using real wage data from the PSID.

(1) Establishing Age Profiles:

- Mean earnings and earnings dispersion are estimated for 5 year bins using males 23-60 sampled in the PSID (1969-2004).
- Using age 23-60, there are at least 100 observations per 5 year age bin (after dropping those who do not meet minimum earnings or hours worked requirement).
- Age 60 is used as the upper bound as labor force participation falls around age 65 for reasons that are outside of the HVY 2011 model.

Empirical Analysis: Establishing Age Profiles

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$$ln(e_{j,t}) = \alpha_c + \beta_j + \gamma_t + \epsilon_{j,t}$$

where $\ln(e_{j,t})$ is real mean earnings of individuals in age bin j in year t and is generated by cohort (c), age (j) and time effects (t).

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The statistic of interest is β_j and it cannot be estimated using the above specification (as $c = t - j$). Thus, our authors take two distinct approaches:

1. Cohort Effects View: $\gamma_t = 0$
2. Time Effects View: $\alpha_c = 0$

Age-Earnings Graphs

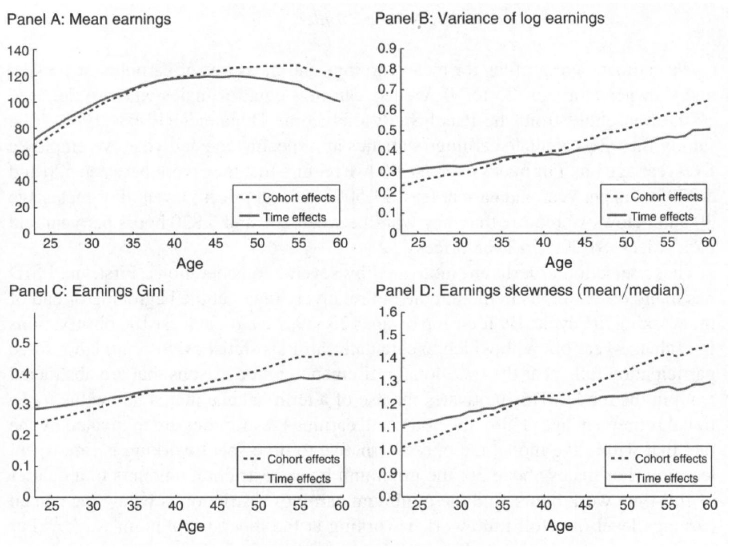

FIGURE 1. MEAN, DISPERSION, AND SKEWNESS OF EARNINGS BY AGE

Calibration of Idiosyncratic Shocks

Late in working life, the model implies that human capital investment is approximately 0.

- If there is no human capital investment, change in an agent's wage rate is entirely determined by rental rates and idiosyncratic shocks.

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- If there is no human capital investment, change in an agent's wage rate is entirely determined by rental rates and idiosyncratic shocks.
- Assuming that in period t through $t+n$ agents make no investment in their human capital:

$$\hat{w}_{t+n} = \ln w_{t+n} = \hat{R}_{t+n} + \sum_{i=1}^{n} z_{t+i} + \hat{h}_t$$

$$y_{t,n} = \hat{w}_{t+n} - \hat{w}_t + \epsilon_{t+n} - \epsilon_t = \hat{R}_{t+n} - \hat{R}_t + \sum_{i=1}^{n} z_{t+i} + \epsilon_{t+n} - \epsilon_t$$

where $y_{t,n}$ is the n-period log wage difference and $\epsilon_{t+n} - \epsilon_t$ is measurement error.

Calibration of Idiosyncratic Shocks

In order to use the log-wage-difference equation to estimate human capital shocks, two *critical* assumptions are needed:

1. measured work time is only work time and not a combination of work and learning time.
2. no time on the job or off the job is spent learning or producing human capital.

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HYV assume z_t and ϵ_t are iid over time and individuals and $z_t \sim N(\mu, \sigma^2)$ and $var(\epsilon_t) = \sigma_\epsilon^2$. With these assumptions in place:

$$\begin{aligned} E[y_{t,n}] &= \hat{R}_{t+n} - \hat{R}_t + n\mu \\ var(y_{t,n}) &= n\sigma^2 + 2\sigma_\epsilon^2 \\ cov(y_{t,n}, y_{t,m}) &= m\sigma^2 + \sigma_\epsilon^2 \quad \text{for } m < n \end{aligned}$$

Individuals are followed for 4 years, and thus 3 log-wage-differentials are calculated per individual.

Estimation Procedure

$$E[y_{t,n}] = \hat{R}_{t+n} - \hat{R}_t + n\mu$$

$$\text{var}(y_{t,n}) = n\sigma^2 + 2\sigma_\epsilon^2$$

$$\text{cov}(y_{t,n}, y_{t,m}) = m\sigma^2 + \sigma_\epsilon^2 \text{ for } m < n.$$

We calculate real wages in PSID data as total male labor earnings divided by total hours for male head of household, using the Consumer Price Index to convert nominal wages to real wages. We follow males for four years and thus calculate three log wage differences (i.e., $y_{t,n}$ for $n = 1,2,3$). In utilizing the wage data we impose the same selection restriction as in the construction of the age-earnings profiles but also exclude observations for which earnings growth is above (below) 20 (1/20) to trim potential extreme measurement errors. In estimation we use all cross-sectional variances and all cross-sectional covariances aggregated across panel years.[15] For each year we generate the sample analog to the moments: $\mu_{t,n} \equiv \frac{1}{N_t}\sum_{i=1}^{N_t} y_{t,n}^i$ and $\frac{1}{N_t}\sum_{i=1}^{N_t}(y_{t,n}^i - \mu_{t,n})^2$ and $\frac{1}{N_t}\sum_{i=1}^{N_t}(y_{t,n}^i - \mu_{t,n})(y_{t,m}^i - \mu_{t,m})$. We stack the moments across the panel years and use a two-step General Method of Moments estimation with an identity matrix as the initial weighting matrix.

Calibration of Idiosyncratic Shocks

TABLE 1—ESTIMATION OF HUMAN CAPITAL SHOCKS

Age range	Period	e_{min}	e_{max}	N	σ	SE(σ)	σ_ϵ	SE(σ_ϵ)
55–65	1969–2004	2,000	1.8 M	103	0.111	0.007	0.137	0.005
50–60	1969–2004	2,000	1.8 M	199	0.117	0.006	0.142	0.004
55–65	1969–2004	3,000	1.8 M	98	0.104	0.006	0.130	0.004
55–65	1969–2004	2,000	1.8 M	103	0.111	0.007	0.137	0.005
55–65	1969–2004	1,500	1.8 M	106	0.119	0.007	0.137	0.004
55–65	1969–2004	1,000	1.8 M	110	0.132	0.007	0.134	0.005
55–65	1969–1981	2,000	1.8 M	104	0.108	0.008	0.130	0.006
50–60	1969–1981	2,000	1.8 M	210	0.107	0.007	0.137	0.005
55–65	1982–2004	2,000	1.8 M	102	0.107	0.011	0.159	0.009
50–60	1982–2004	2,000	1.8 M	193	0.142	0.009	0.146	0.006

Note: Robustness checks include comparing younger workers (50-60) who may violate assumptions (1) and (2) but may also display less selection out of the work force in response to shocks than older workers (55-65).

Model Calibration

TABLE 2—PARAMETER VALUES: BENCHMARK MODEL

Category	Symbol	Parameter value
Demographics	(J, J_R, n)	$(J, J_R, n) = (53, 39, 0.012)$
Preferences	$\beta, u(c) = c^{(1-\rho)}/(1-\rho)$	$(\beta, \rho) = (0.981, 2)$
Technology	(γ, δ, g)	$(\gamma, \delta, g) = (0.322, 0.067, 0.0019)$
Tax system	$T_j = T_j^{ss} + T_j^{inc}$	$T_j^{ss}(e_j) = 0.106 e_j$ for $j < J_R$ $T_j^{ss}(e_j) = -0.4\overline{e}$ otherwise T_j^{inc}—see text
Human capital shocks	$z \sim N(\mu, \sigma^2)$	$(\mu, \sigma) = (-0.029, 0.111)$
Human capital technology	$h' = \exp(z')H(h,s,a)$ $H(h,s,a) = h + a(hs)^{\alpha}$	$\alpha = 0.70$
Initial conditions	$\psi = LN(\mu_{\mathbf{x}}, \Sigma)$	$\mu_{\mathbf{x}} = (\mu_h, \mu_a) = (4.66, -1.12)$ $(\sigma_h^2, \sigma_a^2, \sigma_{ha}) = (0.213, 0.012, 0.041)$

Demographics, Preferences, Technology, and Taxes are all set outside of the model. μ is set so that the model matches the average rate of decline of mean earnings for older workers.

Model Calibration

The parameters governing the distribution of initial conditions ($\psi = LN(\mu_x, \Sigma)$), the elasticity of h.c production (α), and the discount factor (β) are set by:

- Establishing a trial guess of (μ_x, Σ, α).
- Set β so that the equilibrium interest rate equals its pre-specified target ($r = 0.042$).
- Estimate model moments for mean, variance, and skewness and then minimize the squared distance of log model moments from log data moments via the selection of a new triplet (μ_x, Σ, α).
- $(\mu_h, \mu_a, \sigma_h^2, \sigma_a^2, \sigma_{ha}) = (4.66, -1.12, 0.213, 0.012, 0.041)$
- α has been predicted in the human capital literature to be between 0.5-0.9. The minimization routine described above selects an $\alpha = 0.7$.

Properties of the Benchmark Model

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(a) **Matching earnings dynamics (established in the Data portion of the paper).**

(b) **Establishing Properties of the initial distribution of human capital, ability, and the variation in each variable.**

(c) **Analyzing model implication for consumption dispersion in relation to both the applied and theoretical literature on consumption dispersion.**

Matching the Earnings Distribution

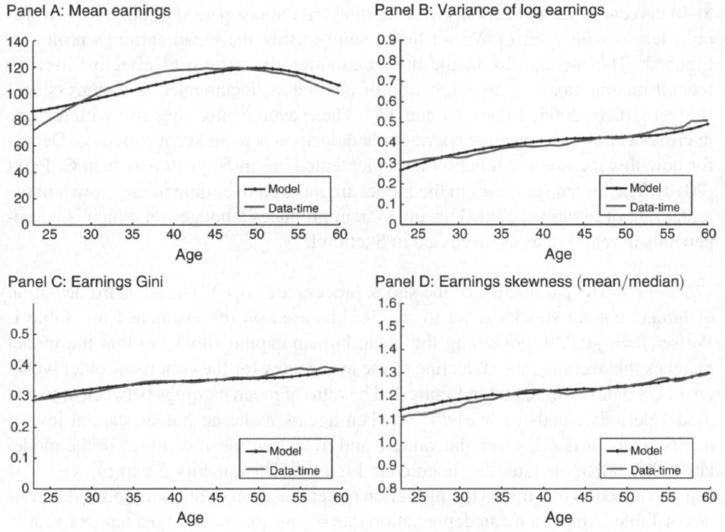

Figure 2. Mean, Dispersion, and Skewness of Earnings by Age: Time Effects

Human Capital Investment and Stock

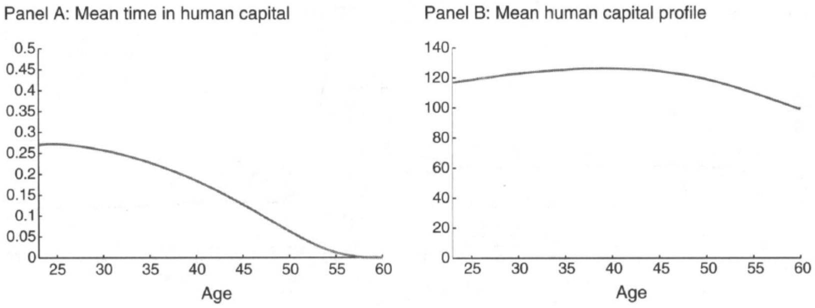

Figure 3. Properties of Human Capital by Age

"A relatively flat mean human capital profile and a declining time allocation profile to human capital production is how the model accounts for a hump-shaped earnings profile." Thus, hump-shaped earnings appear to result from a time allocation story.

Human Capital and Earnings

- Mean human capital is much flatter than the earnings profile.
- This means average human capital at age 23 is quite high.
- This is why HVY find that human capital differences are the most important source of individual differences at age 23 (compared to ability and wealth differences).

Initial Distribution of ψ

TABLE 3—PROPERTIES OF THE INITIAL DISTRIBUTION

Statistic	Benchmark model	Benchmark model with initial wealth differences
Mean learning ability (a)	0.329	0.328
Coefficient of variation (a)	0.112	0.124
Mean initial human capital (h_1)	116.9	117.5
Coefficient of variation (h_1)	0.487	0.476
Correlation (a, h_1)	0.746	0.655

Note: Entries show properties of the distribution of initial conditions for the parameters that best match the profiles of mean earnings, earnings dispersion, and skewness.

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- **Key Finding:** human capital and learning ability are positively correlated at age 23.
- **Note:** The correlation of human capital and learning ability is a result of equilibrium calibration of ψ.
- The model with initial wealth differences generates a very similar initial distribution of a and h_1, which foreshadows the implication that wealth is not an important factor for lifetime inequality.

Initial Distribution Continued

To develop intuition behind the correlation between a and h_1, consider 2 agents (a_{high} and a_{low}) with different a but identical h_1:

- a_{high} will invest more time in producing human capital when young.
- Thus, the earnings profile for a_{high} will be rotated counterclockwise compared to that of a_{low}.
- This results from a_{high} earning less when young (lower l) and more when old (higher h) than a_{low}.
- If a and h_1 had zero correlation, then the model would predict a U-shaped earnings dispersion profile as higher ability agents would overtake lower ability agents in earnings late in life.
- As the data do not support a U-shaped earnings dispersion profile (Fig 1), the model accounts for this by making learning ability and initial human capital correlated.

Model Consumption

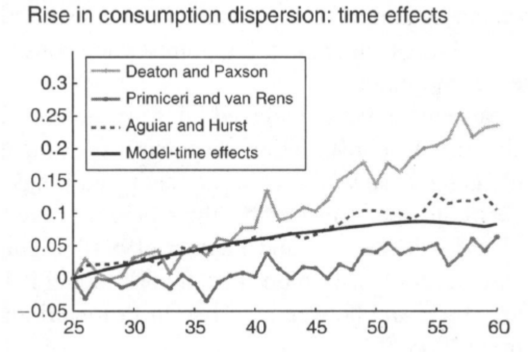

FIGURE 5. RISE IN CONSUMPTION DISPERSION: MODEL AND DATA

- Where D&P use CEX data and provide an upper bound for consumption dispersion, PvR use CEX data over a longer time horizon, and A&H look at nondurable expenditures only.

Consumption Dispersion

HVY claim their benchmark model produces lower consumption dispersion than most exogenous earnings models because:

- earnings dispersion in the HVY model is a result of initial conditions.
- Thus, agents foresee differences in lifetime earnings and make consumption smoothing decisions when young.
- Heckman et al (2005), Geuvenen (2007), and Guvenen and Smith (2008) find individuals know much early in life about future earnings prospects.

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This model assumes agents do not face borrowing constraints, so individuals in the model have the ability to smooth consumption that agents in the real world may not, assuming borrowing limits truly exist.

Results and Discussion

Now that we have confirmed that the baseline model matches reality, we are ready to address the initial research questions:

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2. Which initial conditions are the most important in generating lifetime outcomes?

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1. What is the relative contribution of initial conditions vs shocks to lifetime inequality?
2. Which initial conditions are the most important in generating lifetime outcomes?

- Lifetime outcomes are established for utility, earnings, and wealth for a given shock history z^j and initial conditions $x_1 = (h_1, k_1, a)$.
- HVY exploit the fact that we can decompose total variance into variance from initial conditions vs variance due to shocks.

Sources of Inequality

TABLE 5—SOURCES OF LIFETIME INEQUALITY

Statistic	Benchmark model	Benchmark model with initial wealth differences
Fraction of variance in lifetime utility due to initial conditions	0.640	0.661
Fraction of variance in lifetime earnings due to initial conditions	0.615	0.613
Fraction of variance in lifetime wealth due to initial conditions	0.615	0.626

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Fraction of variance in lifetime wealth due to initial conditions	0.615	0.626

- The model with wealth differences is a partial equilibrium analysis where every variable except for those governing the initial distribution ψ is set to its value in the benchmark model.
- It is assumed that no agent holds negative wealth at age 23 ($k_1 \geq 0 \ \forall$ agents).
- If σ_z is increased from 0.111 to 0.118, the fraction of variance in lifetime utility due to initial conditions falls to 0.57 in the benchmark model.

Relative Importance of Initial Conditions

Q: How much compensation is equivalent to starting at age 23 with a 1 standard deviation change in any initial condition (all else equal).

- The compensation (called equivalent variation) is displayed in terms of the percentage change in consumption *in all periods* an agent would require to be indifferent between a one standard deviation change in the relevant initial condition and the increased consumption.
- Baseline initial conditions are set so that an agent receives the median value of h_1, a, k_1.
- A second measure analyzes the the percent by which an agent's expected lifetime wealth changes in response to a 1 stdev. change in an initial condition.
- A shock to h_1 shifts an agent's earning profile up, a shock to a rotates an agent's earnings profile counterclockwise, a shock to k_1 impacts both initial wealth and time allocation decisions (thus, lifetime earnings).

Relative Importance of Initial Conditions

TABLE 6—CHANGES IN INITIAL CONDITIONS

Variable	Change in variable	Equivalent variation (%)	Change in lifetime wealth (%)
Human capital	+1 st. deviation	39.3	47.5
	−1 st. deviation	−28.3	−31.7
Learning ability	+1 st. deviation	5.7	8.1
	−1 st. deviation	−2.6	−3.9
Initial wealth	+1 st. deviation	7.1	5.0
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Relative Importance of Initial Conditions

TABLE 6—CHANGES IN INITIAL CONDITIONS

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- A 1 stdev shock to h_1 amounts to an increase in initial human capital of roughly 57%. Thus, the change lifetime wealth is slightly less than the change in h_1.
- HVY 2006 prove that, absent risk, the effect on the present value of wealth is equal to the percentage increase in h_1.

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- The model's mean earnings profile is primarily driven by time allocation, and it is very unclear to what extent off the job training is a driving force behind human capital accumulation relative to on the job experience/training.
- The model's predictions regarding the role of initial conditions vs shocks is dependent on the shock process (estimated for exclusively older agents) being the correct process for all agents of all ages in the economy.

Brief Recap of My Research

JMP:

- I imbed present biased agents into an overlapping generations model in which agents receive idiosyncratic income shocks, face a borrowing constraint, and live for a finite number of periods.
- I intend to analyze the role of preference heterogeneity and inheritance in generating realistic wealth dispersion in general equilibrium.
- Thus far, I have found that a present biased society is characterized by a higher interest rate, higher wealth inequality, a higher percentage of wealth being held by the top 1% of the wealth distribution and a poorer bottom 40% of the wealth distribution than a baseline model with exponential discounters implies.

Brief Recap of My Research

Field Paper:

- I examine a 3 period OLG model in which agents split time between acquiring education and low skill labor when young.
- Agents then receive education augmented and deterministic earnings when middle-aged and retire when old.
- I find that present biased agents dedicate less time to acquiring education than exponential discounters, leading to lower lifetime consumption, education, and utility.
- Further, shifting social security taxes to fund education incentive programs increases the college attainment and welfare in a present biased society.

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For my third chapter, I intend to imbed the decision making problem analyzed in my field paper into a carefully calibrated overlapping generations framework to analyze the impact of present bias on formal human capital investment (i.e. college education) and lifetime earnings/ wealth accumulation.

Alternative Formation of the Problem

- Back the problem addressed by HVY up 5 years so that agents begin life at age 18.
- Have agents (who differ in ability and initial wealth) make choices regarding human capital investment via a traditional college education channel.
- Allow agents to decide between attending school and receiving unskilled labor compensation.
- Once an agent stops attending school, their human capital is set and they receive an exogenous, stochastic earning profile (as in a typical Bewley model) that is specific to their education choice (calibrated using earnings data).

Uses of Alternate Model

- The model could be calibrated to match relevant proportions of skilled and unskilled laborers in the United States.
- By realistically calibrating access to wealth (to pay for college) at age 18, we could attempt to match wealth of young households resulting from their personal investment decision in education.
- Further, interacting this model with behavioral biases (as in my field paper and JMP) could aid in the recreation of dropout rates (and timing) that may be difficult to accomplish with a model populated by exponential discounters.
- I could then explore the impact on welfare of different policies (like free education, vs unemployment insurance vs social security) for PB and exponential societies.
- Interested in how initial wealth and ability map into lifetime outcomes when human capital investment requires both an opportunity cost **and** a financial cost.