The Lost Generation of the Great Recession

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Introduction

- What are the distributional consequences of the Great Recession?
- 2 dimensions that affect generations differently
  - large decline in labor income - hurts young
  - even larger decline in asset prices - hurts old, young can potentially gain from cheaper assets
- Long-term consequences of these channels ⇒ need model to evaluate lifetime welfare consequences of recession

This paper

- Heterogeneous agent life-cycle model with
  - portfolio over risky and risk-free assets
  - household borrowing constraints
  - heterogeneity in income and wealth
- Feed in features of Great Recession
  - decrease in labor income
  - decrease in risky asset price
- Use model allocations to compute lifetime welfare consequences

Model findings

- Welfare changes (one-period consumption equivalents) are diverse
- Households with risky assets before Recession suffered the most
  - Young households (21–29) suffered the most (–37 percent)
  - Old households (84–92) suffered the least (–16 percent)
- Households without risky assets fared better
  - Young households (21–29) suffered the most (–9 percent)
  - Pre-retirement households (57–65) gained the most (15 percent)
- On average, middle-aged households (39–47) suffer the largest welfare loss (–24 percent)

Related Literature

- Asset prices and generations: Kiyotaki et al. (2010), Li and Yao (2007)
- Welfare over the Great Recession: Bell and Blanchflower (2011), Elsby et al. (2010), Glover et al. (2014), Krueger et al. (2016). Menno and Oliviero (2014), Peterman and Sommer (2014)
- Life-cycle heterogenous agent models: Conesa et al. (2008), Del Negro et al. (2010), Heathcote et al. (2010), Huggett (1996)
- with borrowing constraints: Chambers et al. (2009), Favilukis et al. (2013), Fernandez-Villaverde and Krueger (2010), Iacoviello and Pavan (2013), Storesletten et al. (2004)

Model

Preview of the model

- Households become economically active at age 21
- Choose a portfolio over risky and risk-free assets
- Heterogeneity generated by initial wealth differences
  and idiosyncratic shocks to labor endowment and risky asset returns
- Young are net buyers, old are net sellers of risky assets
- Young households typically borrow to finance risky assets
- Low wealth, young households more leveraged than others

Environment

- Continuum of finitely lived households
- Partial Equilibrium
    - exogenous asset prices

Demographics

- Households indexed by i, age denoted by $j \in J \equiv \{1, 2, .., \overline{J}\}$
- ψ_j: survival probability from age j to $j+1$, (let $\Psi_j = \prod_{k=1}^{j-1} \psi_k$)
- Retirement at $j = R$
- Newborns endowed with $\{\omega_i\}$ wealth

Household preferences

- Preferences are given by

$$\mathbf{E}\left[\sum_{j\in J}\beta^{j-1}\Psi_j u_j(c_{ij})\right]$$

  - c: consumption (numeraire)
  - β: time discount factor
- $u_j(c_{ij}) = u\left(\frac{c_{ij}}{e_j}\right)$
  - e_j: number of adult equivalents
  - captures consumption needs of changes in households size

Household labor income

- Each period, working-age households receive idiosyncratic shocks $z \in Z$, which follows a Markov process, with transition matrix Γ
- Household of age j with shock z and past earnings k earns:

$$y_j(z,k) = \begin{cases} e^z \eta_j & \text{if } j < R \\ s(k) & \text{otherwise} \end{cases}$$

  - η_j: age-profile of endowments
  - $s(k)$: retirement income depends on past earnings k
- Let $\Gamma^j = \Gamma$ for $j < R - 1$ and $\Gamma^j = I$ for $j \geq R - 1$

Retirement income

- Retirement income is proportional to previous earnings, summarized by k
- Consistent with the U.S. social security system and following Huggett and Parra (2010), marginal benefit rates are

$$\kappa_1 \text{ for } 0 < k \leq k_1$$

$$\kappa_2 \text{ for } k_1 < k \leq k_2$$

$$\kappa_3 \text{ for } k_2 < k \leq \bar{y}$$

  - $\bar{k}$: maximum earnings that count toward retirement income

Law of motion for past earnings

- Following Kitao (2012) and Peterman and Sommer (2016), previous earnings are summarized by

$$k'(j,z,k) = \begin{cases} \dfrac{\min\{g(e^z\eta_j)), \bar{k}\} + (j-1)k}{j} & \text{if } j \le j^* \\ \max\left\{k, \dfrac{\min\{g(e^z\eta_j), \bar{k}\} + (j-1)k}{j}\right\} & \text{if } j^* < j < R \\ k & \text{if } j \ge R \end{cases} \tag{1}$$

  - g transforms disposable to gross labor income
  - j^*: k' does not fall below average of first 35 working years

Assets

- Risky asset $x \geq 0$
  - return subject to idiosyncratic shock e^{ξ}, with $\xi \in \Xi$ and probability $\pi(\xi)$
  - pay fixed cost f if $x > 0$
- Risk-free asset b with *marginal* interest rate
  - r_s if $b' \geq 0$
  - r_b if $b' \in [-\lambda p_x x', 0)$
  - $r_h/\psi_j > r_b$ on portion of debt that exceeds $\lambda p_x x'$
  - let $r(b', x', j)$ denote *average* interest rate
- Beginning-of-period wealth: $a' = b'(1 + r(b', x', j)) + p_x x' e^{\xi'}$

Household problem

- Household of age j, wealth a, endowment shock z, and prior earnings k chooses consumption c, risk-free assets b', and risky assets x' to solve:

$$v(j,a,z,k) = \max_{c,b',x'} u_j(c) + \beta\psi_j \sum_{z'\in Z}\sum_{\xi'\in\Xi} \Gamma^j_{z,z'}\pi(\xi')v(j+1,a',z',k') \quad (2)$$

$$\text{s.t. } c + p_x x' + b' \leq y_j(z,k) - \mathbb{1}_{x'>0} f + a$$

$$a' = b'(1 + r(b',x',j)) + p_x x' e^{\xi'}$$

$$k' \text{ follows (1)}$$

$$c \geq 0,\ x' \geq 0$$

- $v_{J+1} = 0$
- Normalize $p_x = 1$

Transition Function

- Define the state space $S \equiv J \times A \times Z \times K$ with Borel σ-algbra $\mathcal{B}$
- For any set $\mathcal{S} \in \mathcal{B}$, $\mu(\mathcal{S})$ is a measure of agents in $\mathcal{S}$
- Define $Q((j,a,z,k), \mathcal{J} \times \mathcal{A} \times \mathcal{Z} \times \mathcal{K})$ as the probability that an agent with state (j,a,z,k) transits to $\mathcal{J} \times \mathcal{A} \times \mathcal{Z} \times \mathcal{K}$ next period
- Formally, $Q : S \times \mathcal{B} \to [0,1]$ and

$$Q((j,a,z,k), \mathcal{J} \times \mathcal{A} \times \mathcal{Z} \times \mathcal{K}) = \qquad (3)$$

$$\psi_j \mathbb{1}_{\{k'(j,z,k) \in \mathcal{K}\}} \mathbb{1}_{\{j+1 \in \mathcal{J}\}} \sum_{z' \in \mathcal{Z}} \sum_{\xi \in \Xi} \mathbb{1}_{\{a'(j,a,z,k;\xi) \in \mathcal{A}\}} \pi(\xi) \Gamma^j_{z,z'}$$

where $\mathbb{1}$ is the indicator function,

$a'(j,a,z,k;\xi) = b'(j,a,z,k)(1 + r(b',x',j)) + x'(j,a,z,k)e^{\xi}$, and

$b'(j,a,z,k)$ and $x'(j,a,z,k)$ are the optimal policy functions

Equilibrium

A *stationary equilibrium* is a value function $v : S \to \mathbb{R}$, policy functions for the households $c : S \to \mathbb{R}_{++}$, $b' : S \to \mathbb{R}$, and $x' : S \to \mathbb{R}_{+}$ and a stationary measure $\mu : S \to \mathbb{R}_{+}$ such that:

1. the policy functions solve the households' problem in (2) and v is the associated value function.
2. for all $(\mathcal{J} \times \mathcal{A} \times \mathcal{Z} \times \mathcal{K}) \in \mathcal{B}$, the invariant measure μ satisfies

$$\mu(\mathcal{J}\times\mathcal{A}\times\mathcal{Z}\times\mathcal{K}) = \int_{J\times A\times Z\times K} Q((j,a,z.k),\mathcal{J}\times\mathcal{A}\times\mathcal{Z}\times\mathcal{K})d\mu(j,a,z,k)$$

   where Q is the transition function defined in (3) and the distribution for newborns is given.

Rest of talk

- Calibrate model to 2007
    - Important moments: household leverage and risky asset participation
- Show that the model matches data along important dimensions
- Shock the model with recession and present welfare analysis

Functional forms

- Preferences

$$u_j(c) = \frac{\left(\frac{c}{e_j}\right)^{1-\sigma} - 1}{1-\sigma}, \quad \sigma = 3$$

▸ Sensitivity

- Period in model: 3 years

Estimation of endowment process

- Compute residual disposable labor earnings
  - PSID 1970–1997 core sample (ages 21–65)
  - disposable labor earnings using TAXSIM
  - obtain residuals from model with age and year fixed effects
- Model specification

$$\log(y_t) = z_t + \nu_t, \;\; \nu_t \sim N(0, \sigma_\nu^2),$$

$$z_t = \rho z_{t-1} + \varepsilon_t, \;\; \varepsilon_t \sim N(0, \sigma_\varepsilon^2)$$

  where y_t is residual disposable earnings

- GMM estimation: $\rho = 0.938$, $\sigma_\varepsilon = 0.215$, $\sigma_\nu = 0.171$

Endowment process

- Treat transitory shock as measurement error: $\widehat{\sigma}_\nu = 0$
- Convert to 3-year persistence: $\widehat{\rho} = \rho^3 = 0.825$
- Convert variance so that cross-sectional variance is consistent:

$$\widehat{\sigma}_\varepsilon = \sigma_\varepsilon \sqrt{\frac{1-\widehat{\rho}^2}{1-\rho^2}} = 0.351$$

- Discretize using Rouwenhorst method described in Kopecky and Suen (2010) with 11 grid points

Endowment in retirement

- Normalize average working age disposable-earnings to 1
- Retirement endowments depend on previous earnings k
- Marginal replacement rates are:

$$\begin{cases} 0.90 & \text{if } k \in (0, 0.27] \\ 0.32 & \text{if } k \in (0.27, 1.65] \\ 0.15 & \text{if } k \in (1.65, 3.10] \end{cases}$$

- Consistent with social security replacement rates (Huggett and Parra 2010), adjusting for units

Main parameters

- 5 parameters jointly calibrated to match 5 data targets

Variables	Value	Targets
Discount factor $\beta^{\frac{1}{3}}$	0.990	average leverage*: 0.23
Risky asset variance σ_{ξ}^2	0.082	90/50 wealth ratio: 7.43
Participation cost f	0.060	risky asset participation: 0.81
Risky return $E(\xi)^{\frac{1}{3}} - 1$	7.9%	risky assets/21–65 disp. lab. inc.: 8.78
Interest rate $(1 + r_s)^{\frac{1}{3}} - 1$	2.5%	safe assets/21–65 disp. lab. inc.: 0.40

- Risky assets: stocks (direct and indirect), real estate, and non-corporate business assets
- Safe assets: all other assets
- $*$: Leverage $= \left[\dfrac{-\text{safe}}{\max\{\epsilon, \text{risky}\}}\right]_0^1$

Other parameters

Variable	Value	Target/Source
Number of cohorts J	25	ages 21–95 (3-year intervals)
Retirement R	16	ages 66–68
Wealth endowments $\{\omega_i\}$	graph	wealth, ages 18–23 (SCF 2007)
adult equivalents $\{e_j\}$	graph	SCF 2007
Endowment profile $\{\eta_j\}$	graph	disposable labor income (SCF 2007)
Survival prob. $\{\psi_j\}$	graph	2007 US Life Tables
Borrowing spread $r_b - r_s$	1.3%	15-year mortgage rate* (2001–2007)
High spread $r_h - r_s$	8.7%	credit card rate* (2001–2007)
Collateral constraint λ	0.8	discussion below sensitivity

* : less 10-year treasury rate

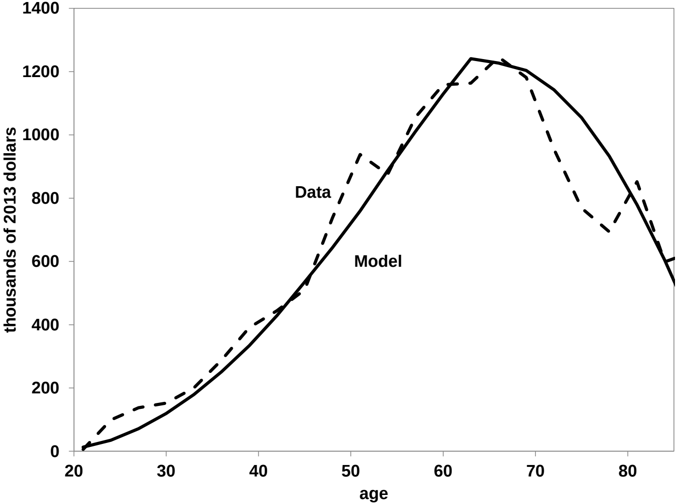
- Residential mortgages: rates and fees higher if loan-to-value higher than 80%
- Commercial loans: typically require 65–80 percent collateral
- Stock based lines of credit loans: typically require 50–65 percent collateral

Steady state

- Model generates
    - wealth profile over age
    - risky asset profile over age
    - risky asset participation over age
    - wealth distribution
    - household leverage

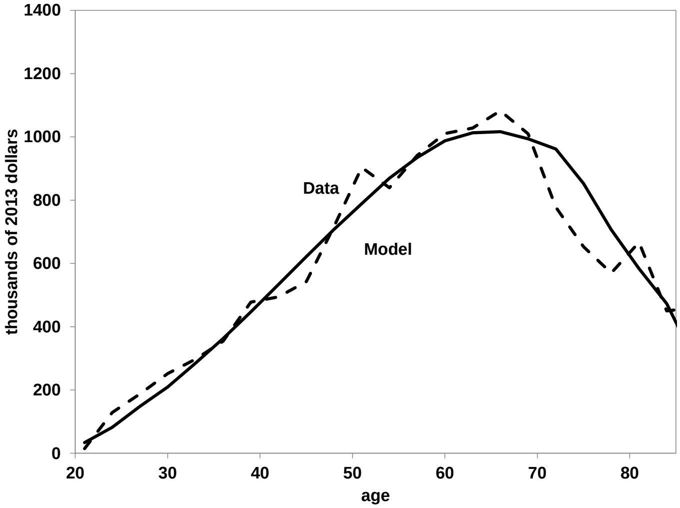
  consistent with US 2007 household data

Household net wealth



data source: SCF 2007

Household risky assets



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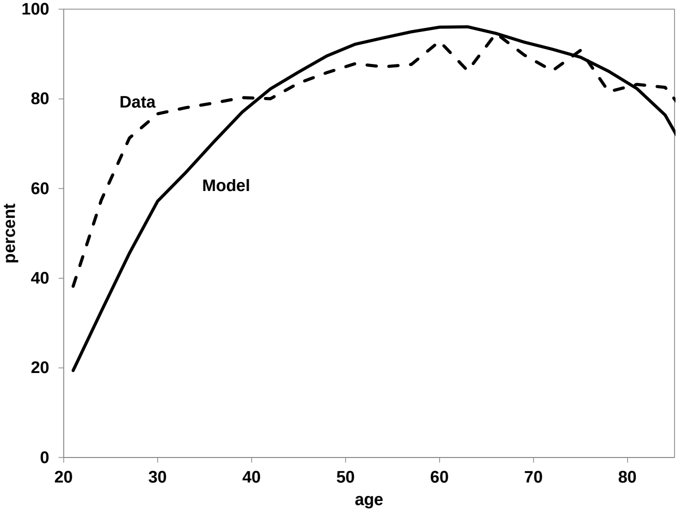
Risky asset participation



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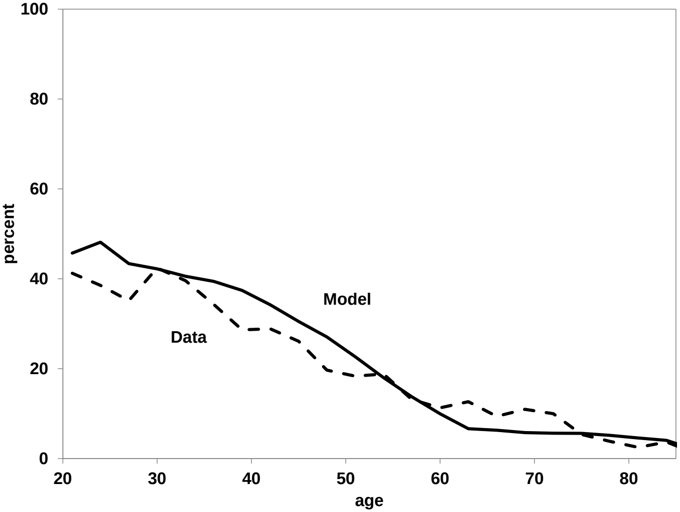
Leverage



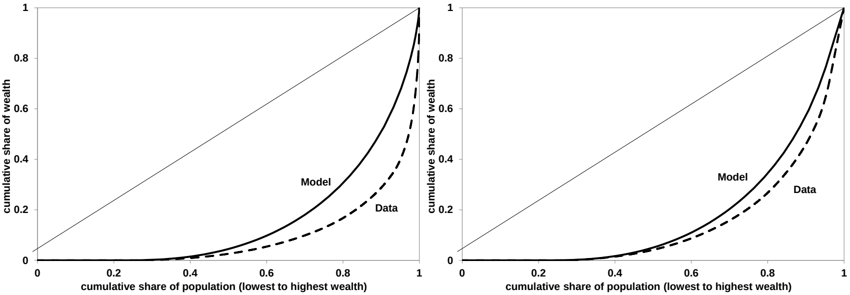
data source: SCF 2007

Distribution of leverage

pctile	25		50		75	
age	model	data	model	data	model	data
21–29	0	0	57	0	98	97
30–38	0	0	45	31	65	73
39–47	0	0	29	15	58	50
48–56	0	0	9	1	38	30
57–65	0	0	0	0	6	12
66–95	0	0	0	0	0	0

Wealth distribution

- Model wealth distribution reasonably similar to the data
- Households with non-positive wealth: 11% (model) vs 10% (data)
- Better if data and model are truncated at $3 million (98th pctile)



data source: SCF 2007

Recession

Great Recession

Great Recession (2007–2010) featured changes in

1. Labor market
    - large decline in disposable labor income (8.7 percent)
    - largest decline for young households
    - increase (decrease) in downard (upward) risk, compared to 2002–2006
2. Asset market
    - risky asset price index falls 23.6 percent
    - increase in expected risky asset volatility
    - real interest rates decreased

Decline in disposable labor income

Table: Large decline in disposable labor income (2007–2010)

age	change (percent)
21–65	-8.7
21–29	-12.0
30–38	-11.0
39–47	-8.0
48–56	-10.1
57–65	-5.6

Source: CPS

Note: Detrended at 2 percent per year, adjusted for inflation

Increase in earnings risk

- PSID available every 2 years
- Compared to 2002-2006, in 2006–2010: graph
  - 4.0 p.p. increase in probability of $\geq$30 percent decrease
  - 4.0 p.p. decrease in probability of $\geq$30 percent increase
  - similar across age groups
- Compared to 2004-2006, in 2008-2010: graph
  - 2.4 p.p. increase in probability of $\geq$30 percent decrease
  - 2.6 p.p. decrease in probability of $\geq$30 percent increase
  - similar across age groups (except for 57–65: no change)
  - reverts to normal in 2010–2012

Labor market changes in the model

- Assume a 3 p.p. increase (decrease) in downward (upward) mobility
- Shock to labor income transition matrix Γ
    - for $i > 1$, $z(i) - z(i-1) \approx 0.3$
    - let $\Delta = \min\{0.03, \Gamma\}$
    - $1 < i < N$: set $\widehat{\Gamma}_{i,i+1} = \Gamma_{i,i+1} - \Delta_{i,i+1}$ and $\widehat{\Gamma}_{i,i-1} = \Gamma_{i,i-1} + \Delta_{i,i+1}$
    - set $\widehat{\Gamma}_{12} = \Gamma_{12} - \Delta_{12}$ and $\widehat{\Gamma}_{11} = \Gamma_{11} + \Delta_{12}$
    - set $\widehat{\Gamma}_{NN} = \Gamma_{NN} - \Delta_{NN}$ and $\widehat{\Gamma}_{N,N-1} = \Gamma_{N,N-1} + \Delta_{NN}$
- Adjust age-profile $\widehat{\eta}_j$ such that average decline matches data
- After 1 period, revert to non-recession Γ and η_j
    - labor market shocks persistent

Decline in risky asset price index ▸ graph

- Risky asset price index: average inflation-adjusted changes of stock and housing prices, weighted by 2004 portfolio share
- 23.6 percent decrease from 2007 to 2010
- Fully recovered in 2014
- Model:
    - 23.6 percent decrease in period 1
    - return to steady state price in period 2

Increase in risky asset volatility

graph

- 28.6 percent increase in VIX (expected 30-day standard deviation, annualized) from 2007 to 2010
- Returns to 2007 levels by 2013
- Model:
  - set $\widehat{\sigma}_\xi = 1.286 \times \sigma_\xi$
  - after 1 period, revert to non-recession σ_ξ

Change in real interest rates

▸ graph

Table: Change in real rates (percent, relative to 2007)

	2010
10-year treasury	-0.7
15-year mortgage	-1.2
credit card	1.3

- Model:
  - feed in exact changes in period 1
  - return to steady state rates in period 2

Timing and Information

- Sequence of events
  1. start $t = 0$ in steady state
  2. MIT shock in $t = 1$: transition matrix $\widehat{\Gamma}$ from $t = 0$ to $t = 1$, income profile $\widehat{\eta}_j$ and risky asset price $\widehat{p}_x$ in $t = 1$, risky asset $\widehat{\sigma}_\xi$ from $t = 1$ to $t = 2$
  3. return to steady state transition processes and prices in $t = 2$
- Information set: households believe
  - θ probability that prices recover
  - $1 - \theta$ probability that prices persist forever
- Baseline: set θ such that quantity of risky assets remains unchanged
- Alternatives: set $\theta = 1$ or $\theta = 0$

Household problem in recession

- Household of age j, wealth a, endowment shock z, and past earnings k solves:

$$\widehat{v}(j,a,z,k) =$$

$$\max_{c,b',x'} \left\{ \begin{array}{r} u_j(c) + \beta\psi_j \sum_{z'\in Z}\sum_{\xi'\in\Xi} \Gamma^j_{z,z'}\widehat{\pi}(\xi')\Big[\theta v(j+1,\widehat{a}'(p_x),z',\widehat{k}') \\ +(1-\theta)v(j+1,\widehat{a}'(\widehat{p}_x),z',\widehat{k}')\Big] \end{array} \right\}$$

$$\text{s.t. } c + \widehat{p}_x x' + b' \leq \widehat{y}_j(z,k) - \mathbb{1}_{x'>0} f + a$$

$$\widehat{a}'(p) = b'(1+\widehat{r}(b',x',j)) + px'e^{\xi'}$$

$$\widehat{k}' \text{ follows } (\widehat{1})$$

$$c \geq 0,\ x' \geq 0$$

- Policy functions: $\widehat{b}', \widehat{x}', \widehat{c}$

Ex post value function

- Risky asset prices recover in period $t = 2$
- Based on $t = 1$ decisions, compute ex post value function:

$$v^*(j, a, z, k) = u_j(\widehat{c}(j, a, z, k)) + \beta\psi_j \sum_{z' \in Z} \sum_{\xi' \in \Xi} \Gamma^j_{z,z'} \widehat{\pi}(\xi') v(j+1, \widehat{a}'(p_x), z', k')$$

where

$$\widehat{a}'(p) = \widehat{b}'(j, a, z, k)(1 + \widehat{r}(b', x', j)) + p\widehat{x}'(j, a, z, k)e^{\xi'}$$

$\widehat{k}'$ follows $(\widehat{1})$

Conditional welfare change (ex post)

- Utility function is homogeneous to degree $1 - \sigma$
- Conditional welfare change (remaining lifetime consumption):

$$\delta(j, a, z, k) =$$

$$\left[\frac{u_j\left(c(j, a, z, k)\right) + \beta \psi_j \sum_{z' \in Z} \sum_{\xi' \in \Xi} \widehat{\Gamma}^j_{z,z'} \pi(\xi') v^*(j+1, a'(\widehat{p}_x), z', k')}{v(j, a, z, k)} \right]^{\frac{1}{1-\sigma}} - 1$$

where

$$a'(p) = b'(j, a, z, k)(1 + r(b', x', j)) + px'(j, a, z, k)e^{\xi'}$$

k' follows (1)

One-period consumption equivalent

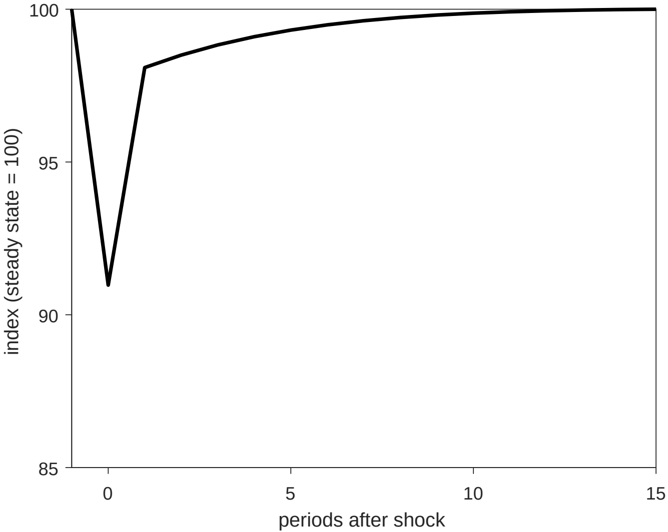
- Agents have different remaining lifetime
- Compute one-period consumption equivalent $\delta^p(j,a,z,k)$ such that:

$$u_j\left(c(j,a,z,k)(1+\delta^p)\right)+\beta\psi_j\sum_{z'\in Z}\sum_{\xi'\in\Xi}\Gamma^j_{z,z'}\pi(\xi')v(j+1,a'(p_x),z',k')$$

$$=u_j\left(c(j,a,z,k)\right)+\beta\psi_j\sum_{z'\in Z}\sum_{\xi'\in\Xi}\widehat{\Gamma}^j_{z,z'}\pi(\xi')v^*(j+1,a'(\widehat{p}_x),z',k)$$

where k' follows (1)

Aggregate income



Young suffer largest decline in net wealth

age	model	data
	(percent change)	
21–29	−47.3	−59.2
30–38	−37.3	−44.1
39–47	−29.1	−18.9
48–56	−25.7	−19.6
57–65	−21.3	−11.7
66–74	−20.5	−20.0
75–83	−20.6	−9.2
84–92	−19.5	21.5

Young risky participants suffer largest welfare loss

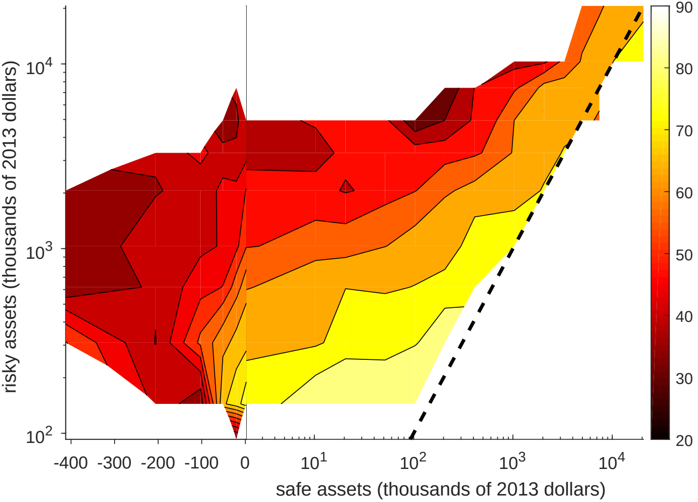
age	remaining lifetime cons. equivalent (percent)	one-period cons. equivalent (percent)		
		all	risky participant	risky non-participant
21–29	−6.2	−18.1	−37.1	−9.2
30–38	−9.2	−22.3	−32.6	−6.4
39–47	−15.1	−24.2	−29.4	−2.5
48–56	−12.4	−21.5	−24.1	5.3
57–65	−5.1	−19.8	−21.4	15.2
66–74	−4.8	−19.9	−21.7	2.1
75–83	−4.8	−16.3	−19.3	0.0
84–92	−4.3	−10.0	−16.4	−0.1

Decomposition of welfare losses

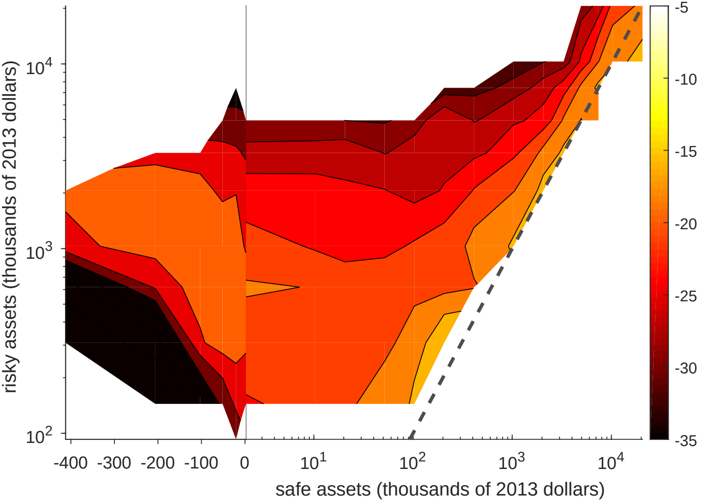
age	labor market changes			risky asset changes			safe asset change		
	all	risky		all	risky		all	risky	
		>0	$=0$		>0	$=0$		>0	$=0$
21–29	78	32	136	24	67	−29	−2	2	−7
30–38	54	25	161	51	77	−47	−5	−3	−14
39–47	42	26	204	68	83	−85	−10	−9	−18
48–56	42	32	−902*	76	84	728*	−19	−15	274*
57–65	16	14	−24*	102	101	84*	−18	−15	40*
66–74	0	0	0*	113	112	58*	−13	−12	42*
75–83	0	0	n.a.	109	109	n.a.	−9	−9	n.a.
84–92	0	0	0	104	105	−43	−4	−5	143
all	39	19	179	71	90	−61	−10	−9	−18

* : decomposition of welfare gains.

Young are more leveraged



Biggest losers: the highly leveraged

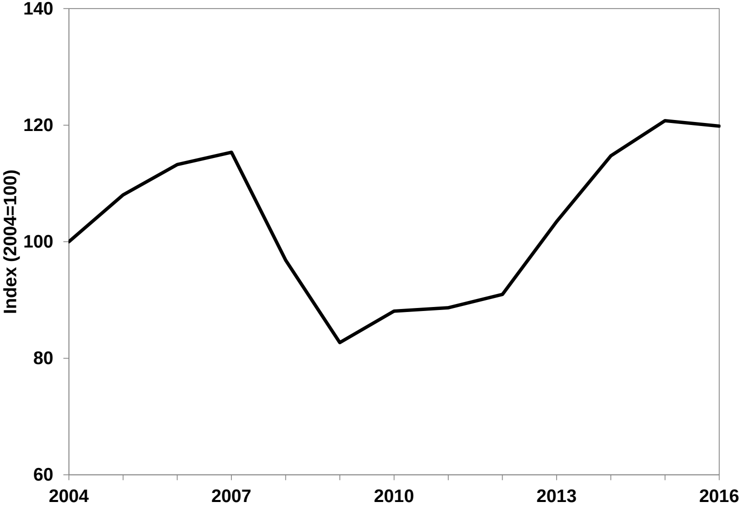


Conclusion

- Developed a model consistent with
  - age profiles of wealth, risky assets, risky asset participation, and leverage
  - distributions of household leverage and wealth
- Changes in labor and asset markets resembling Great Recession
- Results
  - young risky participants suffer the largest welfare losses
  - pre-retirement non-participants have the largest welfare gains

Appendix

Asset price index



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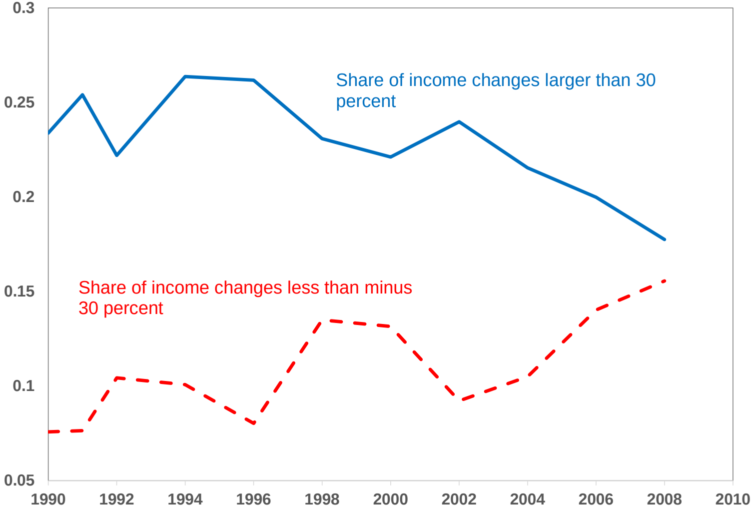
4-year changes in log real disposable income



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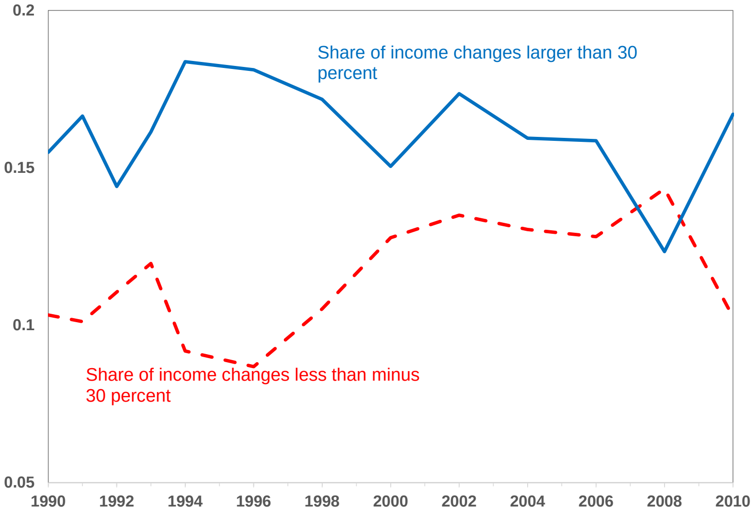
2-year changes in log real disposable income



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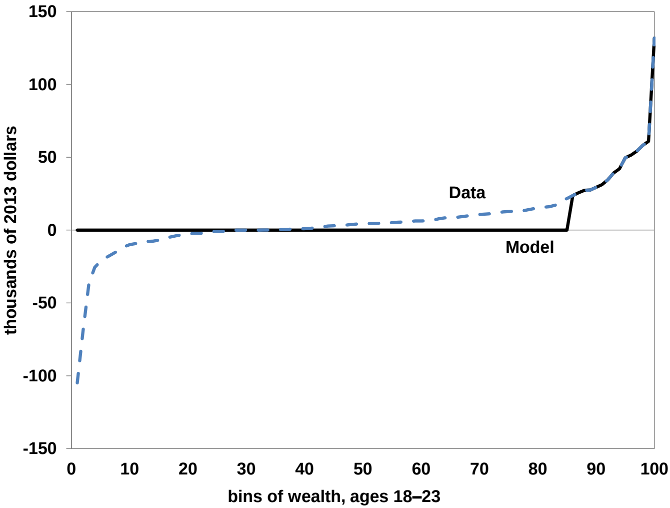
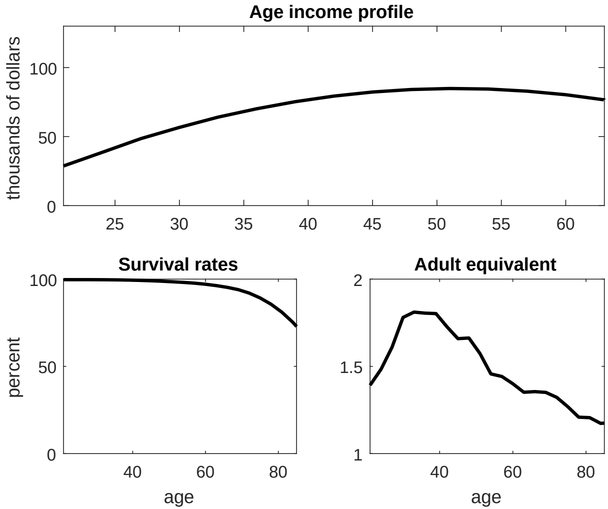
Initial wealth endowments



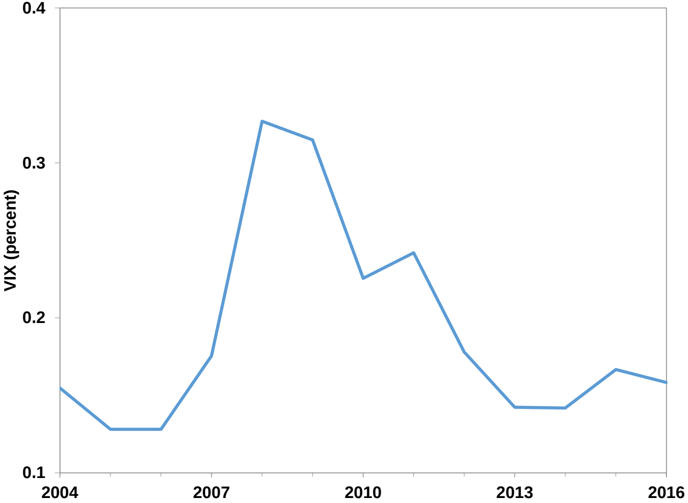
parameters

Age income profile



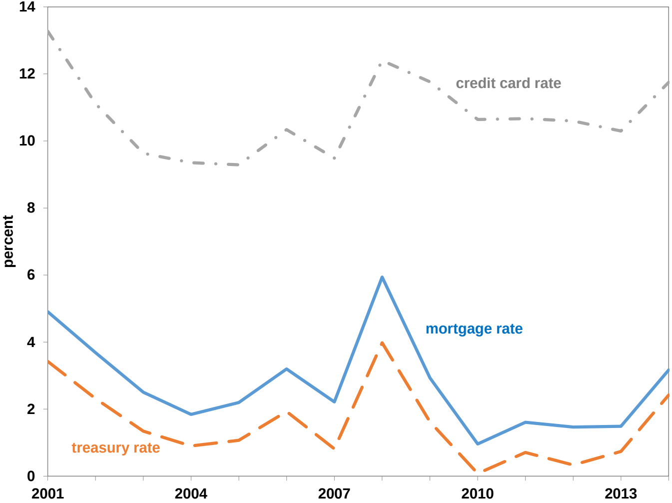
parameters

Stock Martket Volatility Index



back

Real interest rates



back

Sensitivity for $\lambda = 0.745$ back

- Model recalibrated

age	all	risky>0	risky$=0$
21–29	-17.9	-35.4	-9.1
30–38	-22.2	-29.7	-7.7
39–47	-23.2	-27.4	-3.1
48–56	-20.4	-22.3	3.2
57–65	-19.3	-20.3	10.8
66–74	-19.7	-21.0	2.3
75–83	-16.2	-18.4	0.0
84–92	-10.5	-15.9	-0.1
all	-19.6	-23.7	-5.5

Sensitivity for σ back

- Model recalibrated

	$\sigma = 2.5$			$\sigma = 3.5$		
age	all	risky>0	risky$=0$	all	risky>0	risky$=0$
21–29	−21.5	−41.5	−10.5	−16.7	−32.1	−9.4
30–38	−26.0	−34.8	−8.3	−20.2	−28.7	−7.1
39–47	−26.2	−30.8	−2.3	−21.8	−26.3	−4.3
48–56	−22.0	−24.0	4.4	−22.1	−24.4	0.3
57–65	−19.7	−20.8	11.5	−20.5	−21.9	10.3
66–74	−18.9	−20.3	2.6	−20.4	−22.2	1.2
75–83	−15.1	−17.6	0.3	−17.1	−20.1	0.4
84–92	−9.6	−15.3	−0.1	−11.1	−16.8	−0.1
all	−21.2	−25.6	−6.1	−19.5	−24.2	−5.7