The Demographic Deficit

http://ssrn.com/abstract=3067781

Thomas F. Cooley
NYU Stern School of Business

Espen Henriksen
BI Norwegian Business School and UCSB

Bank of Finland/CEPR Conference on Demographics and the Macroeconomy

October 12th, 2017

Changing Demographics and Secular Growth

- Changing demographics may be an important factor for long-run growth, including the recent slowdown
- Two influential narratives about the recent slowdown:
  - Declining Productivity (Robert Gordon; Bloom et al., and others)
  - Low Interest Rates (Larry Summers, and others)
- May changing demographics have played a role?
- Structural life-cycle models studying demographic have focused on capital accumulation and interest-rate trends
- Changes in capital accumulation are important, but so are also effects of demographic changes on aggregate economic activity
  - Population growth (trivially)
  - Labor-supply changes
    - on the intensive
    - on the extensive margin
  - TFP changes

The Demographic Deficit

- To what extent can secular growth, incl. the "secular stagnation", be accounted for by evolving demographics?
  - Increases in life-expectancy affects life-cycle factor-supply decisions
  - Aging cohorts affects the the aggregation of individual decisions
  - Changes in life expectancy are important for both savings and labor supply, hence also for measured TFP and interest rates
- General-equilibrium model
  - Changes in life expectancy and cohort distributions are slow moving and predictable: possible to make projections
- Case: to what extent can we account for the experience of the U.S. and Japan between 1990 and the onset of the Great Recession?

The Demographic Deficit

- To what extent can secular growth, incl. the "secular stagnation", be accounted for by evolving demographics?
  - Increases in life-expectancy affects life-cycle factor-supply decisions
  - Aging cohorts affects the the aggregation of individual decisions
  - Changes in life expectancy are important for both savings and labor supply, hence also for measured TFP and interest rates
- General-equilibrium model
  - Changes in life expectancy and cohort distributions are slow moving and predictable: possible to make projections
- Case: to what extent can we account for the experience of the U.S. and Japan between 1990 and the onset of the Great Recession?

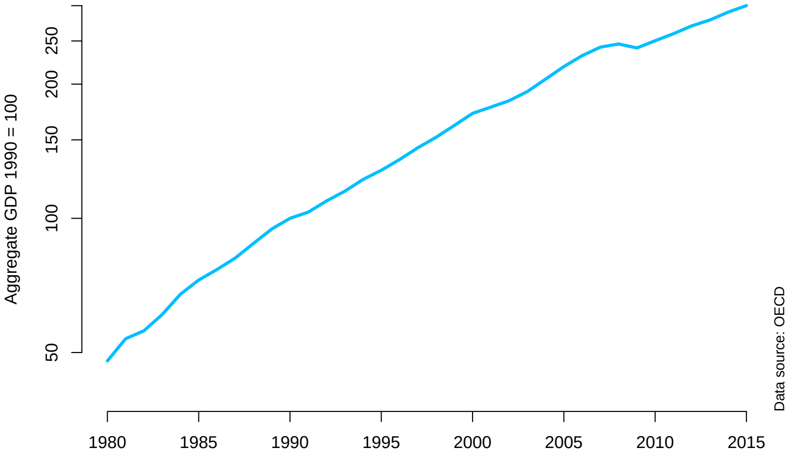
The Demographic Deficit

- To what extent can secular growth, incl. the "secular stagnation", be accounted for by evolving demographics?
  - Increases in life-expectancy affects life-cycle factor-supply decisions
  - Aging cohorts affects the the aggregation of individual decisions
  - Changes in life expectancy are important for both savings and labor supply, hence also for measured TFP and interest rates
- General-equilibrium model
  - Changes in life expectancy and cohort distributions are slow moving and predictable: possible to make projections
- Case: to what extent can we account for the experience of the U.S. and Japan between 1990 and the onset of the Great Recession?

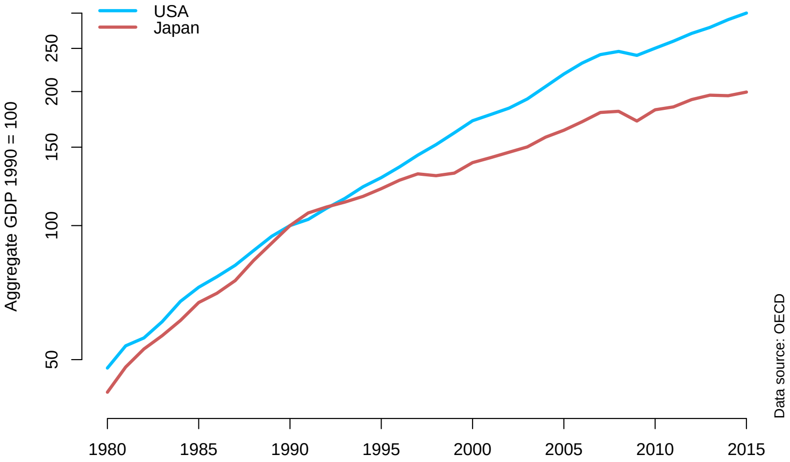
Overview

- "Secular stagnation" facts
  1. Low growth rates since 2010
  2. Falling interest rates
- Growth accounting facts
- Facts about demography
  - Cohorts
  - Life expectancy
- Model economy
- Findings
- Projections
- Conclusion

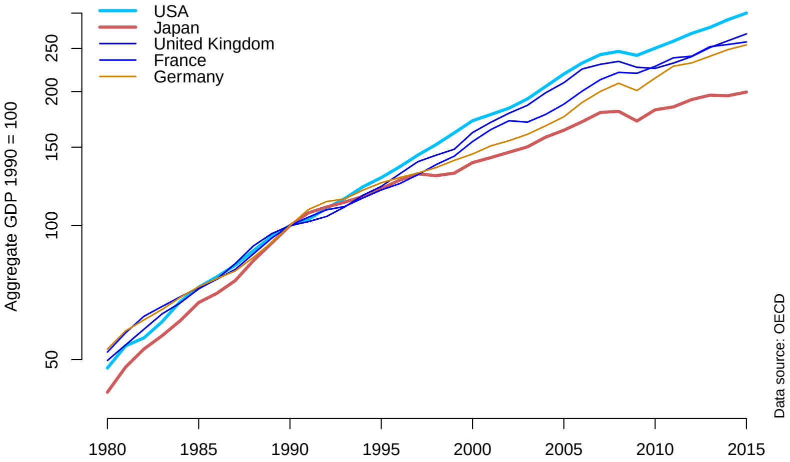
Low growth


Aggregate GDP 1990 = 100
50
100
150
200
250
1980
1985
1990
1995
2000
2005
2010
2015
Data source: OECD

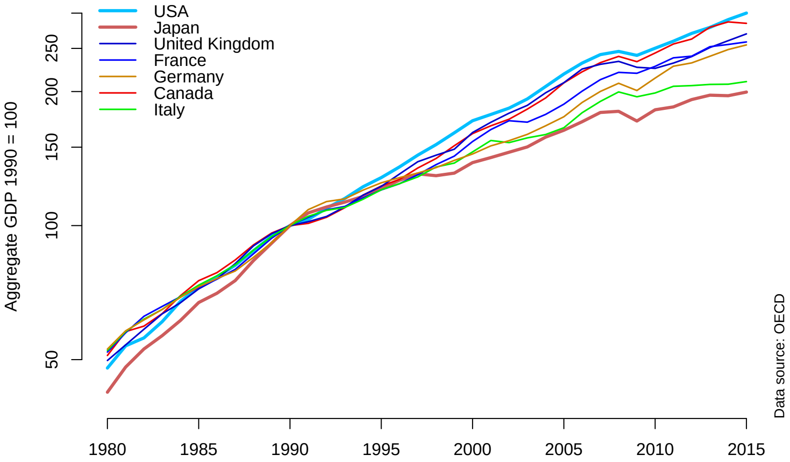
Low growth


USA
Japan
Aggregate GDP 1990 = 100
50
100
150
200
250
1980
1985
1990
1995
2000
2005
2010
2015
Data source: OECD

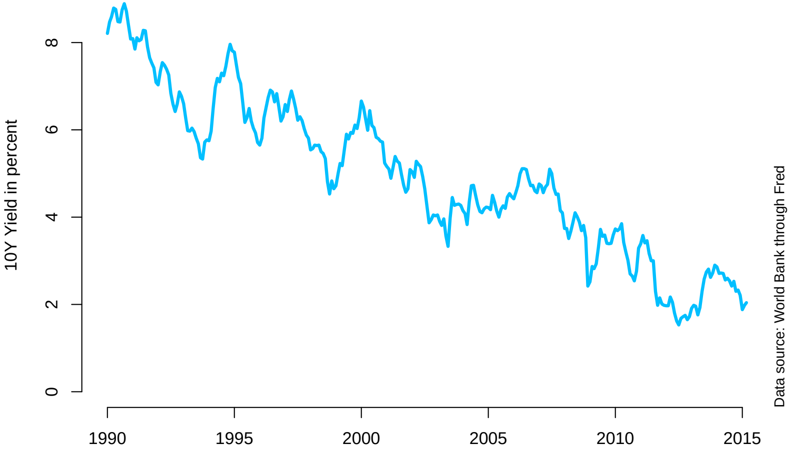
Low growth


USA
Japan
United Kingdom
France
Germany
Aggregate GDP 1990 = 100
50
100
150
200
250
1980
1985
1990
1995
2000
2005
2010
2015
Data source: OECD

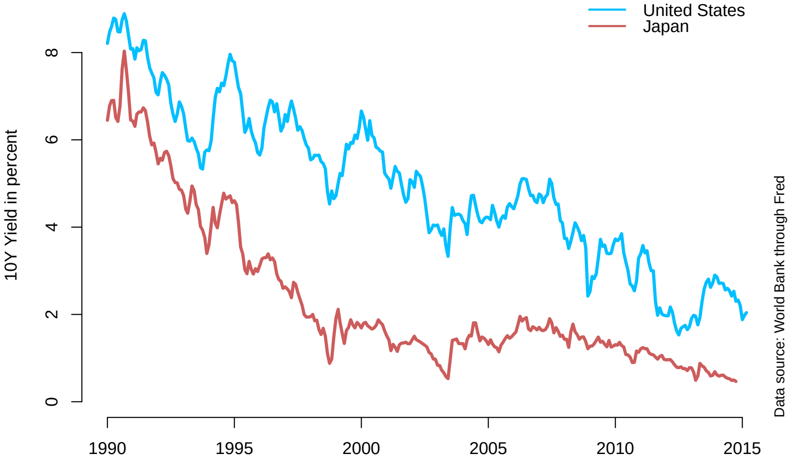
Low growth


USA
Japan
United Kingdom
France
Germany
Canada
Italy
Aggregate GDP 1990 = 100
50
100
150
200
250
1980
1985
1990
1995
2000
2005
2010
2015
Data source: OECD

Declining interest rates



Declining interest rates



Growth Accounting

- The standard production function

$$Y_t = A_t \cdot {K_t}^{\alpha} \cdot (L_t h_t)^{1-\alpha}$$

- Separate labor input on the intensive and extensive margin

$$Y_t = A_t \cdot \left(\frac{K_t}{L_t}\right)^{\alpha} \cdot Pop_t \cdot \frac{L_t}{Pop_t} \cdot h_t^{1-\alpha}$$

- Growth accounting

$$\gamma_Y = \gamma_A + \alpha\gamma_{K/L} + \gamma_{Pop} + \gamma_{L/Pop} + (1-\alpha)\gamma_h$$

Growth Accounting: G7

The 18-year period (1990-2008) leading up to the financial crisis

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	γ_{Pop}	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	2.76	1.28	0.52	1.10	-0.10	-0.05
Canada	2.61	0.45	0.80	0.99	0.52	-0.15
UK	2.48	1.53	0.72	0.40	0.09	-0.25
France	1.78	0.97	0.45	0.54	0.19	-0.36
Germany	1.67	1.03	0.55	0.18	0.28	-0.38
Italy	1.30	0.30	0.54	0.32	0.26	-0.13
Japan	1.11	0.75	0.83	0.17	-0.16	-0.47

Growth Accounting: the United States and Japan

The 18-year period (1990-2008) leading up to the financial crisis

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	γ_{Pop}	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	2.76	1.28	0.52	1.10	-0.10	-0.05
Japan	1.11	0.75	0.83	0.17	-0.16	-0.47
Difference	1.65	0.53	-0.31	0.93	0.06	0.42

Growth Accounting:

The 18-year period (1990-2008) leading up to the financial crisis

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	γ_{Pop}	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	2.76	1.28	0.52	1.10	-0.10	-0.05
Japan	1.11	0.75	0.83	0.17	-0.16	-0.47
Difference	1.65	0.53	-0.31	0.93	0.06	0.42

This paper:

> To what extent can we account for the growth experience of Japan and the United States in this period by modeling individual decisions in the face of demographic change?

Potentially due to evolving demographics?

- γ_{Pop} : Population Growth
- $(1-\alpha)\cdot\gamma_h$: Hours of work (Intensive Margin of Labor Supply)
- $\gamma_{L/Pop}$: Labor Force Participation (Extensive Margin of L.S.)
- $\alpha\cdot\gamma_{K/L}$: Contribution of Capital Intensity
- γ_A : Total Factor Productivity Growth

Potentially due to evolving demographics?

- ✓ γ_{Pop} : Population Growth
- $(1-\alpha)\cdot\gamma_h$: Hours of work (Intensive Margin of Labor Supply)
- $\gamma_{L/Pop}$: Labor Force Participation (Extensive Margin of L.S.)
- $\alpha\cdot\gamma_{K/L}$: Contribution of Capital Intensity
- γ_A : Total Factor Productivity Growth

Potentially due to evolving demographics?

- ✓ γ_{Pop} : Population Growth
- ✓ $(1-\alpha)\cdot\gamma_h$: Hours of work (Intensive Margin of Labor Supply)
- $\gamma_{L/Pop}$: Labor Force Participation (Extensive Margin of L.S.)
- $\alpha\cdot\gamma_{K/L}$: Contribution of Capital Intensity
- γ_A : Total Factor Productivity Growth

Potentially due to evolving demographics?

- ✓ γ_{Pop} : Population Growth
- ✓ $(1-\alpha)\cdot\gamma_h$: Hours of work (Intensive Margin of Labor Supply)
- ✓ $\gamma_{L/Pop}$: Labor Force Participation (Extensive Margin of L.S.)
- $\alpha\cdot\gamma_{K/L}$: Contribution of Capital Intensity
- γ_A : Total Factor Productivity Growth

Potentially due to evolving demographics?

- ✓ γ_{Pop} : Population Growth
- ✓ $(1-\alpha)\cdot\gamma_h$: Hours of work (Intensive Margin of Labor Supply)
- ✓ $\gamma_{L/Pop}$: Labor Force Participation (Extensive Margin of L.S.)
- ✓ $\alpha\cdot\gamma_{K/L}$: Contribution of Capital Intensity
- γ_A : Total Factor Productivity Growth

Potentially due to evolving demographics?

- ✓ γ_{Pop} : Population Growth
- ✓ $(1-\alpha)\cdot\gamma_h$: Hours of work (Intensive Margin of Labor Supply)
- ✓ $\gamma_{L/Pop}$: Labor Force Participation (Extensive Margin of L.S.)
- ✓ $\alpha\cdot\gamma_{K/L}$: Contribution of Capital Intensity
- ✓ γ_A : Total Factor Productivity Growth

Literature Review

- Stagnating growth rates: Gordon (2016), Summers (2013), Teulings & Baldwin (2014), et al.
- Demographics and growth: Hansen (1939), Lindh & Malmberg (1999), Feyrer (2007), Favero & Galasso (2015), Maestas, Mullen, & Powell (2016), Jones (2016), Acemoglu & Restrepo (2017), et al.
- Demographics and capital accumulation: Feroli (2003), Krueger & Ludwig (2007), Backus, Cooley, & Henriksen (2014), Gagnon, Johannson, & Lopez-Salido (2016), Carvalho, Ferrero, & Nechio (2016), Ikeda & Saito (2014), et al.
- Trends in participation rates and hours worked: Aguiar & Hurst (2007), Aaronson et al. (2014), Aguiar, Bils, Hurst, & Charles (2016), Bick, Fuchs-Schündeln, & Lagakos, 2016, et al.
- Reconciling micro and macro labor supply elasticities: Cho and Cooley (1993), Keane & Rogerson (2011), Prescott, Rogerson, & Wallenius (2009), Llosa, Ohanian, Raffo, & Rogerson (2012), Rogerson and Wallenius (2013), Boppart and Krusell (2016), et al.
- Productivity and earnings life-cycle profiles: Murphy & Welch (1990), Hansen (1993), Kambourov & Manovski (2009), Casanova (2013), Rupert & Zanella (2015), et al.

Literature Review

- Stagnating growth rates: Gordon (2016), Summers (2013), Teulings & Baldwin (2014), et al.
- Demographics and growth: Hansen (1939), Lindh & Malmberg (1999), Feyrer (2007), Favero & Galasso (2015), Maestas, Mullen, & Powell (2016), Jones (2016), Acemoglu & Restrepo (2017), et al.
- Demographics and capital accumulation: Feroli (2003), Krueger & Ludwig (2007), Backus, Cooley, & Henriksen (2014), Gagnon, Johannson, & Lopez-Salido (2016), Carvalho, Ferrero, & Nechio (2016), Ikeda & Saito (2014), et al.
- Trends in participation rates and hours worked: Aguiar & Hurst (2007), Aaronson et al. (2014), Aguiar, Bils, Hurst, & Charles (2016), Bick, Fuchs-Schündeln, & Lagakos, 2016, et al.
- Reconciling micro and macro labor supply elasticities: Cho and Cooley (1993), Keane & Rogerson (2011), Prescott, Rogerson, & Wallenius (2009), Llosa, Ohanian, Raffo, & Rogerson (2012), Rogerson and Wallenius (2013), Boppart and Krusell (2016), et al.
- Productivity and earnings life-cycle profiles: Murphy & Welch (1990), Hansen (1993), Kambourov & Manovski (2009), Casanova (2013), Rupert & Zanella (2015), et al.

Literature Review

- Demographics and capital accumulation: Feroli (2003), Krueger & Ludwig (2007), Backus, Cooley, & Henriksen (2014), Gagnon, Johannson, & Lopez-Salido (2016), Carvalho, Ferrero, & Nechio (2016), Ikeda & Saito (2014), et al.

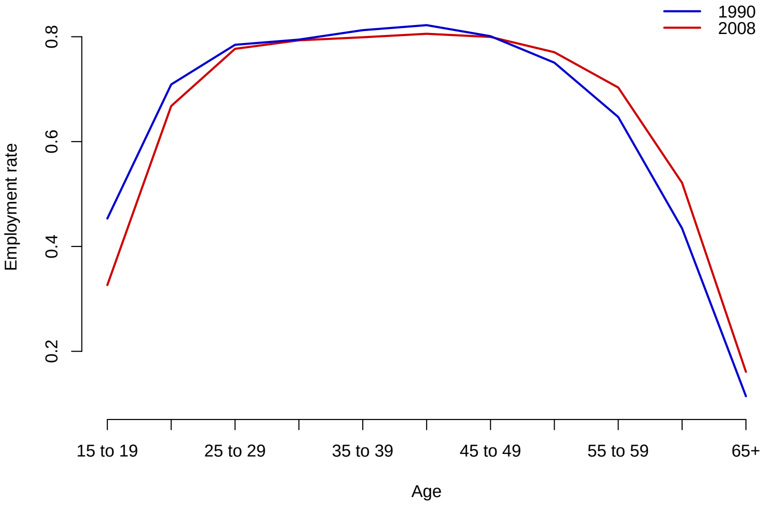
Literature Review

- Demographics and capital accumulation: Feroli (2003), Krueger & Ludwig (2007), Backus, Cooley, & Henriksen (2014), Gagnon, Johannson, & Lopez-Salido (2016), Carvalho, Ferrero, & Nechio (2016), Ikeda & Saito (2014), et al.

⇒ Consumption-savings choice (endogenous capital accumulation). Assumption: Labor supply inelastic both on the intensive and the extensive margin.

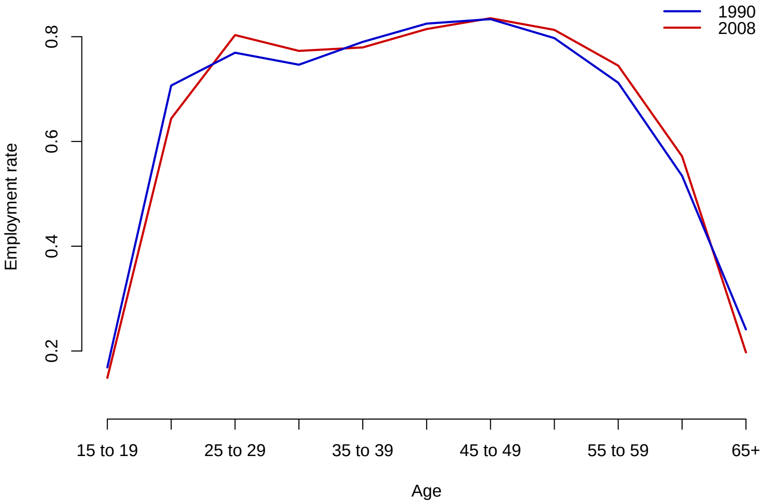
Labor Force Participation

United States



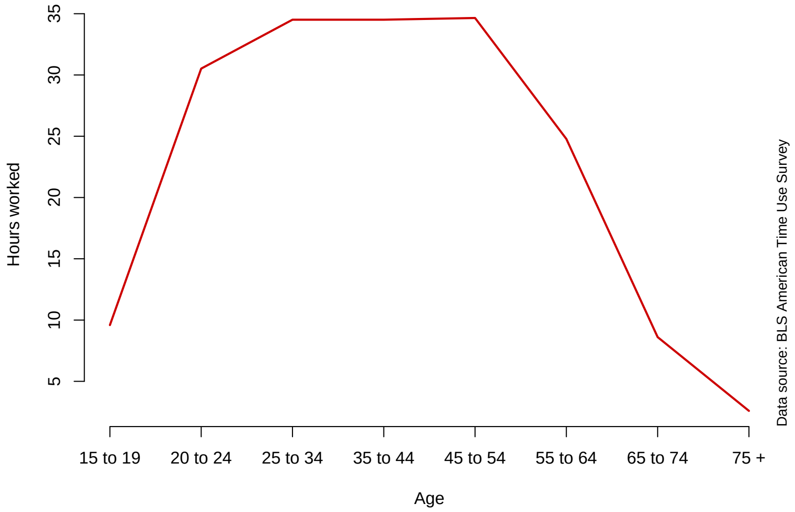
Labor Force Participation

Japan



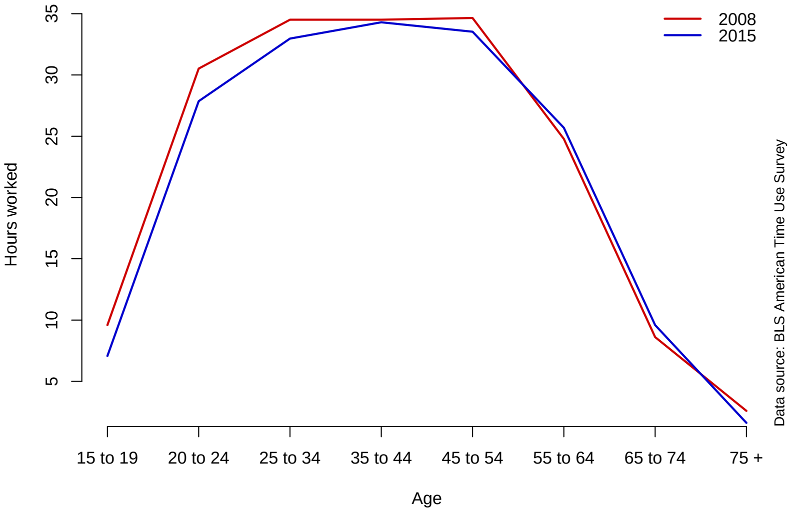
Hours worked

Average, United States



Hours worked

Average, United States



Features of the Model Economy

- Standard life-cycle economies do not account for labor supply decisions on the intensive and extensive margin
- Growth accounting showed that these two margins are crucial for the differential growth histories
- Need a framework where
  1. There is a role for demographics
  2. Individuals make life-cycle choices with respect to
     - consumption-savings
     - labor supply on the extensive margin
     - labor supply on the intensive margin
  3. Market clearing; endogenous factor prices

What features of demographics?

The law of motion for a population may be written

$$x_{t+1} = \hat{\Gamma}_t x_t + m_t.$$

where

- $x_t \in \mathbb{R}^I$ is a vector of number of members in each cohort in period t.
- Transition matrix

$$\hat{\Gamma} = \begin{pmatrix} \varphi_1 & \varphi_2 & \varphi_3 & \cdots & \varphi_I \\ s_1 & 0 & 0 & \cdots & 0 \\ 0 & s_2 & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ 0 & 0 & \cdots & s_{I-1} & 0 \end{pmatrix},$$

  where

  - φ: fertility rates
  - s: survival probabilities
- m: net migration rates

Why some demographic features may be important

Organizing framework – "Competitive equilibrium"

1. Households' supply and demand decisions:
    1. Decisions: Individuals at every age solve their optimization problems given aggregate price functions and conditional on their conditional life expectancy.
    2. Composition: The decisions of individuals of different ages are aggregated by the relative cohort sizes
2. Firms supply and demand decisions:
   Firms demand inp ut factors and supply goods and services given price functions
3. Prices are set competitively.

Why some demographic features may be important

Organizing framework – "Competitive equilibrium"

1. Households' supply and demand decisions:
   1. Decisions: Individuals at every age solve their optimization problems given aggregate price functions and conditional on their conditional life expectancy.
   2. Composition: The decisions of individuals of different ages are aggregated by the relative cohort sizes
2. Firms supply and demand decisions:
   Firms demand inp ut factors and supply goods and services given price functions
3. Prices are set competitively.

Why some demographic features may be important

Organizing framework – "Competitive equilibrium"

1. Households' supply and demand decisions:
    1. Decisions: Individuals at every age solve their optimization problems given aggregate price functions and conditional on their conditional life expectancy.
    2. Composition: The decisions of individuals of different ages are aggregated by the relative cohort sizes
2. Firms supply and demand decisions:
   Firms demand inp ut factors and supply goods and services given price functions
3. Prices are set competitively.

Why some demographic features may be important

Organizing framework – "Competitive equilibrium"

1. Households' supply and demand decisions:
   1. Decisions: Individuals at every age solve their optimization problems given aggregate price functions and conditional on their conditional life expectancy.
   2. Composition: The decisions of individuals of different ages are aggregated by the relative cohort sizes
2. Firms supply and demand decisions:
   Firms demand inp ut factors and supply goods and services given price functions
3. Prices are set competitively.

Why some demographic features may be important

Organizing framework – "Competitive equilibrium"

1. Households' supply and demand decisions:
   1. Decisions: Individuals at every age solve their optimization problems given aggregate price functions and conditional on their conditional life expectancy.
   2. Composition: The decisions of individuals of different ages are aggregated by the relative cohort sizes.

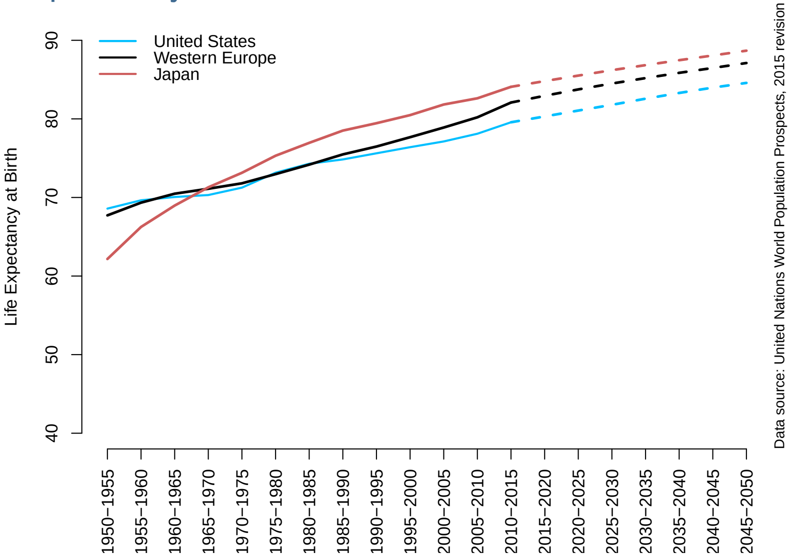
Why some demographic features may be important

Organizing framework – "Competitive equilibrium"

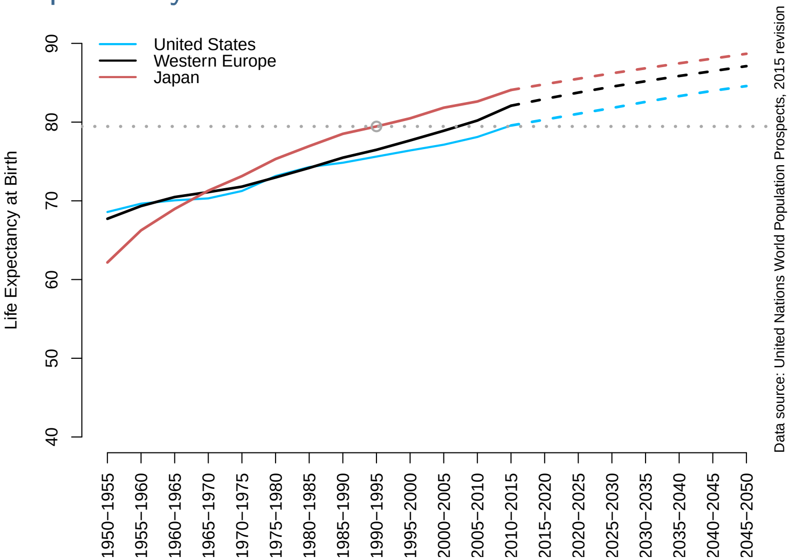
1. Households' supply and demand decisions:
    1. Decisions: Individuals at every age solve their optimization problems given aggregate price functions and conditional on their conditional life expectancy.
    2. Composition: The decisions of individuals of different ages are aggregated by the relative cohort sizes.

$\Rightarrow$ Sufficient set of demographic variables to compute equilibrium
s : changes in survival probabilities / life expectancies
x : changes in cohort distributions

Life expectancy

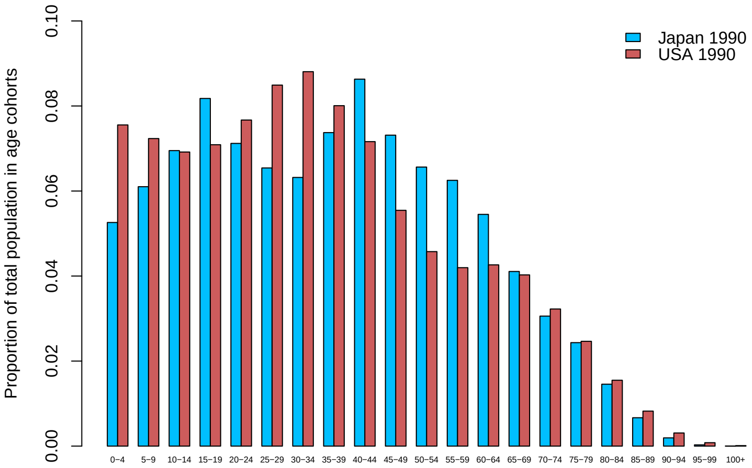


Life expectancy



Cohort distributions

United States 1990 and Japan 1990



Individuals' preferences and optimization problem

$$\max_{\{c_j, h_j\}} \mathrm{E}_{t_0} \left\{ \sum_{j=j_0}^{J} \beta^{j-j_0} s_j u(c_{j,t_0+j}, h_{j,t_0+j}) \right\}$$

where
$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} + \chi \frac{(1-h-\theta_j \cdot i_p)^{1-\gamma}}{1-\gamma}$$

and subject to
$$c_{j+1,t+1} + a_{j+1,t+1} = (1+r_t)a_{j,t} + w_t \cdot h_{j,t} \cdot \eta_{j,t} \cdot \psi_j$$

where

- s_j – conditional survival probability from age j to $j+1$
- θ_j – fixed, age-dependent cost of labor-market participation
- η – idiosyncratic shocks to labor productivity
- ψ_j – age-dependent labor productivity

Individuals' preferences and optimization problem

$$\max_{\{c_j,h_j\}} \mathrm{E}_{t_0}\left\{\sum_{j=j_0}^{J}\beta^{j-j_0}\mathbf{s_j}u(c_{j,t_0+j},h_{j,t_0+j})\right\}$$

where

$$u(c,h)=\frac{c^{1-\sigma}}{1-\sigma}+\chi\frac{(1-h-\theta_j\cdot i_p)^{1-\gamma}}{1-\gamma}$$

and subject to

$$c_{j+1,t+1}+a_{j+1,t+1}=(1+r_t)a_{j,t}+w_t\cdot h_{j,t}\cdot\eta_{j,t}\cdot\psi_j$$

where

- s_j – conditional survival probability from age j to $j+1$
- θ_j – fixed, age-dependent cost of labor-market participation
- η – idiosyncratic shocks to labor productivity
- ψ_j – age-dependent labor productivity

Individuals' preferences and optimization problem

$$\max_{\{c_j, h_j\}} \mathrm{E}_{t_0} \left\{ \sum_{j=j_0}^{J} \beta^{j-j_0} s_j u(c_{j,t_0+j}, h_{j,t_0+j}) \right\}$$

where

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} + \chi \frac{(1-h-\theta_{\mathbf{j}} \cdot i_p)^{1-\gamma}}{1-\gamma}$$

and subject to

$$c_{j+1,t+1} + a_{j+1,t+1} = (1+r_t)a_{j,t} + w_t \cdot h_{j,t} \cdot \eta_{j,t} \cdot \psi_j$$

where

- s_j – conditional survival probability from age j to $j+1$
- θ_j – fixed, age-dependent cost of labor-market participation
- η – idiosyncratic shocks to labor productivity
- ψ_j – age-dependent labor productivity

Individuals' preferences and optimization problem

$$\max_{\{c_j,h_j\}} \mathrm{E}_{t_0} \left\{ \sum_{j=j_0}^{J} \beta^{j-j_0} s_j u(c_{j,t_0+j}, h_{j,t_0+j}) \right\}$$

where

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} + \chi \frac{(1-h-\theta_j \cdot i_p)^{1-\gamma}}{1-\gamma}$$

and subject to

$$c_{j+1,t+1} + a_{j+1,t+1} = (1+r_t)a_{j,t} + w_t \cdot h_{j,t} \cdot \eta_{\mathbf{j,t}} \cdot \psi_j$$

where

- s_j – conditional survival probability from age j to $j+1$
- θ_j – fixed, age-dependent cost of labor-market participation
- η – idiosyncratic shocks to labor productivity
- ψ_j – age-dependent labor productivity

Individuals' preferences and optimization problem

$$\max_{\{c_j, h_j\}} \mathrm{E}_{t_0} \left\{ \sum_{j=j_0}^{J} \beta^{j-j_0} s_j u(c_{j,t_0+j}, h_{j,t_0+j}) \right\}$$

where

$$u(c,h) = \frac{c^{1-\sigma}}{1-\sigma} + \chi \frac{(1-h-\theta_j \cdot i_p)^{1-\gamma}}{1-\gamma}$$

and subject to

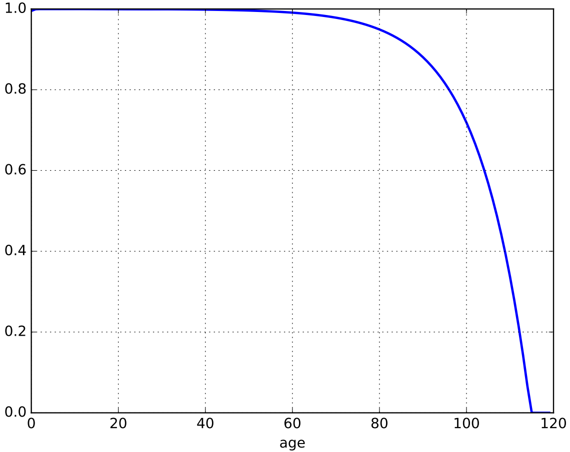
$$c_{j+1,t+1} + a_{j+1,t+1} = (1+r_t)a_{j,t} + w_t \cdot h_{j,t} \cdot \eta_{j,t} \cdot \psi_{\mathbf{j}}$$

where

- s_j – conditional survival probability from age j to $j+1$
- θ_j – fixed, age-dependent cost of labor-market participation
- η – idiosyncratic shocks to labor productivity
- ψ_j – age-dependent labor productivity

Inspecting the crucial elements

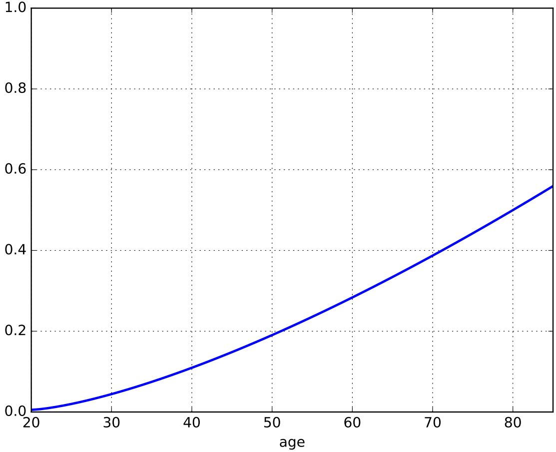
Survival probabilities



Inspecting the crucial elements

Fixed cost of labor-market participation

Given by the following functional form: $\theta_j = \kappa_1 + \kappa_2 j^{\kappa_3}$



Inspecting the crucial elements

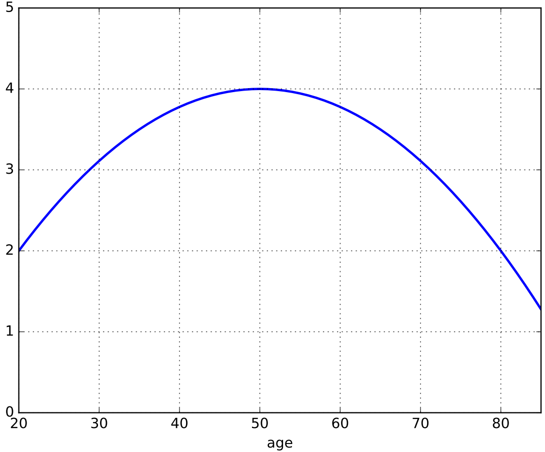
Idiosyncratic shocks to labor productivity

Given by a first-order autoregressive process

$$\eta_{j+1} = \rho \eta_j + \varepsilon_{j+1} \qquad \text{where } \varepsilon \sim \mathcal{N}(0, \sigma^2).$$

Inspecting the crucial elements

Age-dependent labor productivity



Equilibrium

1. Households' decisions
   - Individual household optimization

$$v(j,a,\eta) = \max_{h,a'} \left\{ u(c,h) + \beta \cdot s \cdot \mathrm{E}_{\eta'|\eta} v(j+1, a', \eta') \right\}$$

   - Aggregation: Individuals' quantity choices are aggregated by the number of individuals in each cohort

$$K_t^s = \sum_i x_i \int_{a \times \psi} a \, \mathrm{d}\mu(a, \psi \mid i, t)$$

and

$$L_t^s = \sum_i x_i \int_{a \times \psi} h \, \psi \, \eta_i \, \mathrm{d}\mu(a, \psi \mid i, t)$$

where $\mu(a, \psi \mid i, t)$ is the stationary distribution over a and ψ conditional on i and t.

2. Firms' decisions

$$\max_{K_t^d, L_t^d} \left\{ \left(K_t^d\right)^\alpha \left(L_t^d\right)^{1-\alpha} - r_t K_t^d - w_t L_t^d \right\}$$

3. Market clearing

$$\{r_t, w_t\} \; : \; K_t^s = K_t^d \quad \& \quad L_t^s = L_t^d$$

Parametrization

Demographics		
s	conditional survival probabilities	UN and ego (2016)
x	cohort sizes	UN
J	maximum age	120
Preferences		
β	subjective discount factor	0.969
σ	consumption utility curvature	1.0
χ	weight on leisure	0.4123
γ	leisure utility curvature	4.0
$\kappa_1, .., \kappa_3$	cost of labor force participation	0.0531, 0.00149, 1.4178
Labor productivity process		
ρ	persistence parameter	0.97
σ^2	variance	0.02
ψ	age-dependent productivity	PSID
Technology and production		
α	capital share of output	1/3
δ	depreciation rate of capital	6.0 %

Experiment

- Calibrate to steady-state associated with life expectancies and cohort distributions in the United States 1990
- Compute the closed-economy steady-states associated with life expectancies and cohort distributions in
  - Japan 1990
  - Japan 2008
  - United States 1990
  - United States 2008

  Computing and comparing steady-states makes the model more parsimonious and accountable than computing a transition between steady states
- Growth accounting
  - Japan 1990 and Japan 2008
  - United States 1990 and United States 2008

  No exogenous TFP growth
- Compare with data

Results

Data:

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	γ_{Pop}	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	2.76	1.28	0.52	1.10	-0.10	-0.05
Japan	1.11	0.75	0.83	0.17	-0.16	-0.47
Difference	1.65	0.53	-0.31	0.93	0.06	0.42

Results

Data:

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	1.66	1.28	0.52	-0.10	-0.05
Japan	0.94	0.75	0.83	-0.16	-0.47
Difference	0.72	0.53	-0.31	0.06	0.42

Results

Data:

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	1.66	1.28	0.52	-0.10	-0.05
Japan	0.94	0.75	0.83	-0.16	-0.47
Difference	0.72	0.53	-0.31	0.06	0.42

Model: total growth rates

	$\gamma_{Y/Pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	4.34	1.86	2.61	3.28	-3.41
Japan	1.62	0.54	4.33	-1.03	-2.22

Results

Data:

	γ_Y	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	1.66	1.28	0.52	-0.10	-0.05
Japan	0.94	0.75	0.83	-0.16	-0.47
Difference	0.72	0.53	-0.31	0.06	0.42

Model: annual growth rates:

	$\gamma_{Y/Pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
United States	0.26	0.11	0.15	0.19	-0.20
Japan	0.10	0.03	0.25	-0.06	-0.13

Measured TFP

- Real labor supply

$$\tilde{L}_t = \sum_i x_i \cdot h_i \cdot e^{\eta} \cdot \psi_i$$

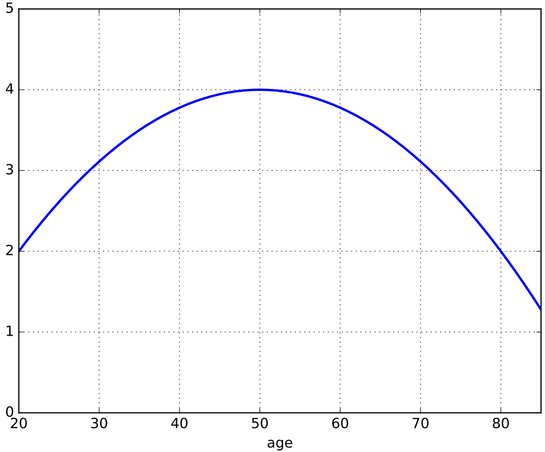
- Measured labor supply

$$L_t = \sum_i x_i \cdot h_i$$

- Partly
  - mechanical age/cohort effect
  - selection effect

Measured TFP

Age-dependent labor productivity



The Frisch elasticity

An “M.I.T. shock”, i.e., as an unexpected, never-again-to-occur departure from an initial steady state. Given the solution to the value function,

$$\{h, a'\} = \underset{h,a'}{\arg\max} \left\{ u(c, h \mid w = \bar{w}) + \beta \cdot s \cdot \mathrm{E}_{\eta'|\eta} v(j+1, a', \eta') \right\}$$

and

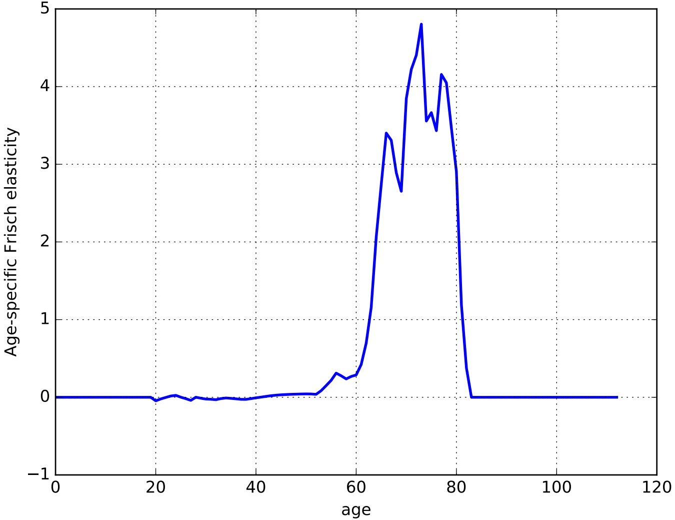
$$\{h, a'\} = \underset{h,a'}{\arg\max} \left\{ u\left(c, h \mid w = \bar{w} \cdot (1+\varepsilon)\right) + \beta \cdot s \cdot \mathrm{E}_{\eta'|\eta} v(j+1, a', \eta') \right\}$$

aggregate these individual labor supply decisions by the stationary distribution over age, asset holdings and individual productivity.

The estimated Frisch elasticity in the benchmark calibration is 0.095

The Frisch elasticity

By age



Bequests

To study whether introduction of bequests would quantitatively affect our results we study a particular type of "impure altruism" where households derive utility from their bequest, so called "warm glow preferences".
The households Bellman equation then takes the form

$$v(j, a, \eta) = \max_{h, a'} \left\{ u(c, h) + \beta \left[s \cdot \mathrm{E}_{\eta' | \eta} v(j+1, a', \eta') + (1-s) \cdot \tilde{u}(a') \right] \right\},$$

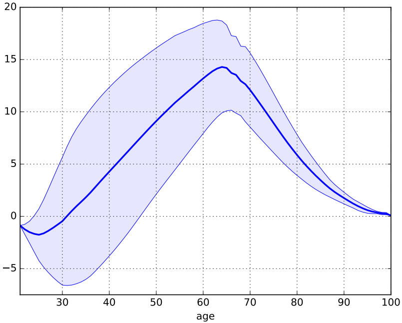
where $\tilde{u}(a') = (a')^{1-\sigma}/(1-\sigma)$.

With these preferences, we have to recalibrate the model. In order to match the initial capital-output ratio of 3 for the United States in 1990, the time preference parameter is recalibrated to 0.949.

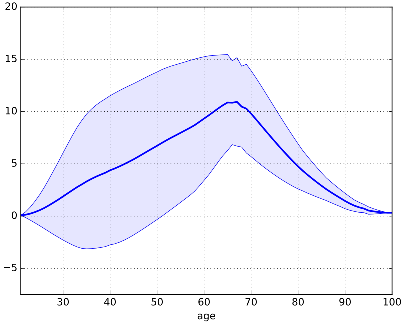
After recalibration, quantitative results hardly change.

Asset profile over the life cycle

Given US life expectancy and equilibrium factor prices in 1990.
The shaded area is on standard deviation in each direction.



Benchmark model



Model with warmglow pref., recalibrated

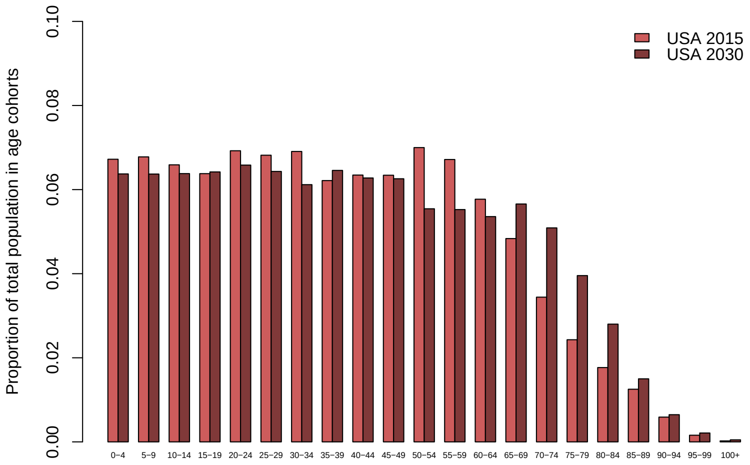
Growth projections

- Use the same calibration
- Compute steady-states associated with life expectancies and cohort distributions projected by the United Nations for
    - Japan 2015
    - Japan 2030
    - United States 2015
    - United States 2030
- Life expectanctancies at birth:
  Japan: 84.09 $\rightarrow$ 86.21 years.
  United States: 79.57 $\rightarrow$ 81.79 years.
- Growth accounting
    - Japan 2015 and Japan 2030
    - United States 2015 and United States 2030

No exogenous TFP growth

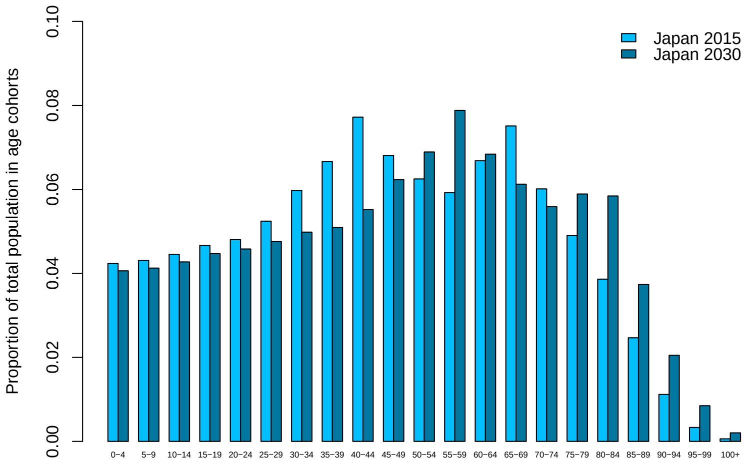
Cohort distributions

US



Cohort distributions

Japan



Model projections: annual growth rates

	$\gamma_{Y/Pop}$	γ_A	$\alpha \cdot \gamma_{K/L}$	$\gamma_{L/Pop}$	$(1-\alpha) \cdot \gamma_h$
Japan	-0.27	0.01	0.17	-0.45	0.01
United States	-0.33	0.02	0.15	-0.38	-0.12

Conclusions

- Among the G7s, (i) Japan has had the lowest growth rates and the US the highest, and (ii) Japan is aging fastest and the US slowest.
- A structural model of demographic change may account for a substantial portion of growth experienced for Japan and the United States in recent decades
- To see the full effect of demographic changes on economic growth we need to look at how these demographic changes affect
  - individual decisions on
    - consumption-savings
    - labor supply on the extensive margin
    - labor supply on the intensive margin
  - how these decisions are aggregated
- In addition, the joint dynamics of those individual decisions and changes in the cohort distribution affect *measured* TFP
- According to the model, in the future the demographic contribution to growth rates will decrease further
- Within this parsimonious framework it is possible to analyze the effects of policy responses both on aggregate growth and on welfare