Global demographic trends and social security reform

Orazio Attanasio, University College London
Sagiri Kitao, University of Southern California
Gianluca Violante, New York University

June 28, 2007
The University of Tokyo
Introduction

Demographic trends

- significant increase in longevity
- decline in fertility
- the retirement of the ‘baby boom’ generations

Global demographic trends are not completely synchronized across countries
Introduction

- Economic implications of the demographic trends
  - large changes in factor prices and welfare
  - sustainability of PAYG pension systems

Question: when thinking about how to reform the social security system in the developed world, does the distinction open vs closed economy matter for
  - factor prices
  - welfare
  - fiscal policy variables?

Contribution: offer an alternative benchmark for policy evaluation.
Introduction

- Social security in closed economy
  - Conesa and Krueger (1999), De Nardi, Imrohoroglu and Sargent (1999), Huggett and Ventura (1999), Abel (2003), Bohn (2003), and many more

- Global demographic trends and current account dynamics
  - Brooks (2003), Domeij and Floden (2004), Attanasio, Kitao and Violante (2006), Krueger and Ludwig (2007) and many more

- Labor flow across regions
Overview

- OLG model calibrated on observed and projected demographic trends
  - two regions: North and South

- Different ways to finance the social security system in the North
  - PAYGO system is maintained
  - The system is privatized to a fully-funded system

- Open and closed economy versions of the model
MODEL
Model

Two regions: \( r = n, s \)
Model

- Two regions: \( r = n, s \)

- Technology
  - CRS production function \( F(Z_t^r, K_t^r, L_t^r) \)
  - TFP \( Z_t^r \) grows exogenously at rate \( \lambda_t^r \)
Model

- Two regions: \( r = n, s \)

Technology
- CRS production function \( F(Z^r_t, K^r_t, L^r_t) \)
- TFP \( Z^r_t \) grows exogenously at rate \( \lambda^r_t \)

Demographics
- OLG of pairs of individuals, indexed by age \( i = 1, 2, \ldots I \)
- dependent for \( I^d \) periods, become adults and start working at \( I^d + 1 \), and retire from work at \( I^R \)
- surviving probability \( s^r_{i,t}, S^r_{i,t} \)
- fertility rate \( \phi^r_{i,t} \)
- number of dependent children \( d^r_{i,t} = \sum_{k=i-I^d+1}^{i} \phi^r_{k,t-(i-k)} S^r_{i-k+1,t} \)
Model: evolution of population

At time $t$, population shares $\mu_t^r$ evolve according to the transition matrix

$$
\Gamma_t^r = \begin{bmatrix}
\phi_{1,t}^r & \phi_{2,t}^r & \cdots & \cdots & \phi_{I,t}^r \\
0 & s_{2,t+1}^r & 0 & \cdots & 0 \\
0 & 0 & s_{3,t+1}^r & 0 & \cdots \\
0 & 0 & \cdots & \cdots & 0 \\
0 & 0 & \cdots & s_{I,t+1}^r & 0
\end{bmatrix}
$$

$$
\mu_{t+1}^r = \Gamma_t^r \mu_t^r
$$
Model: preferences

\[ u^r(c_{i,t}^a, c_{i,t}^d) = \frac{(c_{i,t}^a)^{1-\theta}}{1 - \theta} + d_{i,t}^r \omega(d_{i,t}^r) \frac{(c_{i,t}^d)^{1-\theta}}{1 - \theta} \]
Model: preferences

\[ u^r(c_{i,t}^a, c_{i,t}^d) = \frac{(c_{i,t}^a)^{1-\theta}}{1-\theta} + d_{i,t}^r \omega(d_{i,t}^r) \frac{(c_{i,t}^d)^{1-\theta}}{1-\theta} \]

From F.O.C.

\[ c_{i,t}^d = c_{i,t}^a \omega(d_{i,t}^r)^{\frac{1}{\theta}} \]
Model: preferences

\[ u^r(c_{i,t}^a, c_{i,t}^d) = \frac{(c_{i,t}^a)^{1-\theta}}{1 - \theta} + d_{i,t}^r \omega (d_{i,t}^r) \frac{(c_{i,t}^d)^{1-\theta}}{1 - \theta} \]

From F.O.C.

\[ c_{i,t}^d = c_{i,t}^a \omega (d_{i,t}^r)^\frac{1}{\theta} \]

Express utility as a function of household consumption \( c_{i,t} = c_{i,t}^a + d_{i,t} c_{i,t}^d \)

\[ u^r(c_{i,t}) = \Omega_{i,t}^r \frac{c_{i,t}}{1 - \theta}, \quad \Omega_{i,t}^r = \left[ 1 + \omega (d_{i,t}^r)^\frac{1}{\theta} d_{i,t}^r \right]^\theta \]
Model: preferences

\[
ur^r (c^a_{i,t}, c^d_{i,t}) = \frac{(c^a_{i,t})^{1-\theta}}{1-\theta} + d^r_{i,t} \omega (d^r_{i,t}) \frac{(c^d_{i,t})^{1-\theta}}{1-\theta}
\]

From F.O.C.

\[
c^d_{i,t} = c^a_{i,t} \omega (d^r_{i,t})^{1/\theta}
\]

Express utility as a function of household consumption \(c_{i,t} = c^a_{i,t} + d_{i,t} c^d_{i,t}\)

\[
ur^r (c_{i,t}) = \Omega^r_{i,t} \frac{c^a_{i,t}}{1-\theta}, \quad \Omega^r_{i,t} = \left[ 1 + \omega (d^r_{i,t})^{1/\theta} d^r_{i,t} \right]^{\theta}
\]

\[
Ur^r = \sum_{i=1}^{I} \beta^{i-1} S^r_{i,t+i-1} \Omega^r_{i,t+i-1} \frac{c^a_{i,t+i-1}}{1-\theta}
\]
(1 + \tau_{c,t}^r) c_{i,t}^r + s_{i+1,t+1}^r a_{i+1,t+1}^r = y_{i,t}^r + [1 + (1 - \tau_{a,t}^r) r_t] a_{i,t}^r
Model: budget constraint

\[
(1 + \tau_{c,t}^r) c_{i,t}^r + s_{i+1,t+1}^r a_{i+1,t+1}^r = y_{i,t}^r + [1 + (1 - \tau_{a,t}^r) r_t] a_{i,t}^r
\]

\[
y_{i,t}^r = \begin{cases} 
(1 - \tau_{w,t}^r) w_{t}^r \varepsilon_{i,t}^r l_{i,t}^r = (1 - \tau_{w,t}^r) \tilde{y}_{i,t}^r & \text{if } i < I^R, \\
 p_{i,t}^r = \kappa_t^r \frac{W_{i,t}^r}{I^R - 1} & \text{if } i \geq I^R
\end{cases}
\]
Model: budget constraint

\[(1 + \tau^r_{c,t}) c^r_{i,t} + s^r_{i+1,t+1} a^r_{i+1,t+1} = y^r_{i,t} + [1 + (1 - \tau^r_{a,t}) r_t] a^r_{i,t} \]

\[y^r_{i,t} = \begin{cases} 
(1 - \tau^r_{w,t}) w^r_{i,t} \in^r_{i,t} l^r_{i,t} = (1 - \tau^r_{w,t}) \tilde{y}^r_{i,t} & \text{if } i < I^R, \\
\rho^r_{i,t} = \kappa^r_t \frac{W^r_{i,t}}{I^R - 1} & \text{if } i \geq I^R 
\end{cases} \]

\[W^r_{i,t} = \begin{cases} 
\tilde{y}^r_{1,t} & \text{if } i = 1 \\
\tilde{y}^r_{i,t} + W^r_{i-1,t-1} & \text{if } 1 < i < I^R \\
W^r_{i-1,t-1} & \text{if } i \geq I^R.
\]
Model: government

\[ G_t^r + (1 + r_t) B_t^r + \sum_{i=1}^{I} P_{i,t}^r \mu_{i,t}^r = \]

\[ \tau_{w,t}^r \sum_{i=1}^{I} \mu_{i,t}^r \varepsilon_{i,t}^r \tau_{i,t}^r + \sum_{i=1}^{I} \mu_{i,t}^r \left( \tau_{a,t}^r r_{a,t,i,t}^r + \tau_{c,t}^r c_{i,t}^r \right) + B_{t+1}^r \]
Equilibrium

A Competitive Equilibrium of the Two-Region Economy, for given sequences of demographic matrices \( \{ \Gamma^r_t \}_{t=1}^{\infty} \), TFP \( \{ Z^r_t \}_{t=1}^{\infty} \) and fiscal variables \( \{ G^r_t, \kappa^r_t, \tau^{a,r}_t, \tau^{c,r}_t, B^r_t \}_{t=1}^{\infty} \), is such that:

1. household allocations
2. wage tax rates
3. wage rates (in North and South)
4. world interest rate
5. aggregate variables
6. external wealth of the North
Equilibrium

A Competitive Equilibrium of the Two-Region Economy, for given sequences of demographic matrices \( \{ \Gamma^r_t \}_{t=1}^\infty \), TFP \( \{ Z^r_t \}_{t=1}^\infty \) and fiscal variables \( \{ G^r_t, \kappa^r_t, \tau^r_{a,t}, \tau^r_{c,t}, B^r_t \}_{t=1}^\infty \), is such that:

1. households and firm maximize
2. regional labor markets clear
3. regional bond markets and international capital market clear
4. government budget constraints are satisfied
5. allocations are feasible
CALIBRATION
Calibration

Model period: five years
Calibration

Model period: five years

Demographics
- demographic variables: UN projections (2005-2200)
  - North “more developed regions" US, Canada, Europe, Japan, Australia and NZ
  - South “less developed regions" Africa, Asia (ex-Japan), Latin America, and the rest

\[ I^d = 3, \quad I = \bar{I} - I^d = 24 - 3 = 21, \quad I^R = 11, \]
Calibration

Model period: five years

Demographics
- demographic variables: UN projections (2005-2200)
  - North “more developed regions" US, Canada, Europe, Japan, Australia and NZ
  - South “less developed regions" Africa, Asia (ex-Japan), Latin America, and the rest
- \( I_d^d = 3, I = \bar{I} - I_d^d = 24 - 3 = 21, I^R = 11, \)

Technology
- Cobb-Douglas with 0.3 share of capital
- growth of \( Z_t^r \): match historical growth of income per capita and converge to the same rate in the long-run
- \( Z_0^r \) to match the North-South income per capita ratio of 7 in 2000
Calibration

Preference

- risk-aversion coefficient $\sigma = 2$
- preference weight for children $\omega(d_{i,t}^r)$ calibrated to match equivalence scale (Fernandez-Villaverde and Krueger, 2006)
Calibration

**Preference**
- risk-aversion coefficient $\sigma = 2$
- preference weight for children $\omega(d_{i,t}^r)$ calibrated to match equivalence scale (Fernandez-Villaverde and Krueger, 2006)

**Endowment and labor supply**
- efficiency units calibrated using micro data for US and Mexico
- males assumed to work full time
- female participation rates calibrated as a function of fertility and trend using data for US (North) and Brazil, India, Korea and Mexico (South)

$$P_{i,t}^r(d_{i,t}^r) = \beta_0^r + (\bar{P} + \bar{T}_i - \beta_0^r)\{1 - \exp[-\beta_1^r \ast (t-1)]\} + \sum_{j=1}^{I^d} \alpha_j d_{i,j,t}^r$$
## Calibration

### Government

<table>
<thead>
<tr>
<th></th>
<th>$B_t/Y_t$</th>
<th>$G_t/Y_t$</th>
<th>$\tau_c$</th>
<th>$\tau_a$</th>
<th>$\rho$</th>
<th>$\tau_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>35.5%</td>
<td>26.5%</td>
<td>9%</td>
<td>38%</td>
<td>46.6%</td>
<td>26.3%</td>
</tr>
<tr>
<td>South</td>
<td>50%</td>
<td>20%</td>
<td>15%</td>
<td>38%</td>
<td>10.1%</td>
<td>6.0%</td>
</tr>
</tbody>
</table>
Policy simulations

- Assume that the world economy is in the initial steady state characterized by the demographic parameters of 1950.

- Then, the world experiences a demographic shock and a gradual change through the actual and projected demographic transitions, eventually reaching the final steady state.

- Agents have perfect foresight on the demographic path.
Policy simulations

Two sets of experiments

1. alternative policies to sustain PAYG system in the North
   - wage tax (benchmark)
   - consumption tax
   - retirement age
   - government debt
   - retirement benefit

   ⇒ policy change is announced in 2005 and implemented in 2010

2. privatization with ‘recognition bonds’

Each experiment is performed in closed and open economy
Benchmark simulation

Interest rates in open and closed economies
Benchmark simulation

Current account of the North (% of GDP)
Benchmark simulation

Current account of the North (% of GDP)

Reversal of capital flow
Benchmark simulation

Current account of the North (% of GDP)

External assets of the South
(\% of total wealth) 1970–90
Model: \(-40\%\)
Data: \(-10\%\) (Kraay, et al)
Solid lines represent closed economy and dotted lines represent open economy.
Benchmark simulation

- Demographic transition induces higher capital accumulation and lower interest rates
- Capital flows first North to South and then South to North
- Factor prices in open and closed economies differ substantially, but the paths of wage tax are similar
  - increase in wage (and the wage tax revenue) is offset by the decline in interest rates (and the capital tax revenue)
Consumption tax

Solid lines represent closed economy and dotted lines represent open economy.
The government announces in 2005 that the retirement age is raised by one period (=5 years) starting in 2020.

The transition is financed by the adjustment of wage tax.
Solid lines represent closed economy and dotted lines represent open economy.
Government debt

Solid lines represent closed economy and dotted lines represent open economy.
Pension benefits

Solid lines represent closed economy and dotted lines represent open economy.
Welfare comparison: PAYG system

![Graph showing consumption equivalent variation (%)](image-url)
Welfare comparison: PAYG system

**Closed Economy**

- Consumption tax
- Government debt
- Replacement ratio

**Open Economy**

- Consumption tax
- Government debt
- Replacement ratio
Privatizing social security

- Privatization of the pension system as an alternative policy
- Issue of how to finance the transition
- Reform is announced in 2005 and implemented in 2015
  - retired: honor payments under PAYG
  - in labor force but not retired: issue "recognition bond" for accumulated pension rights (Chile)
  - not yet in labor force in 2015: no PAYG
Privatizing social security

Every year $t > t^* = 2015$, a ‘recognition bond’ $\Omega_t$ is paid to the retiring cohort that was age $i^*$ at time $t^*$

$$\Omega_t = \left[ \kappa^{old} \frac{W_{i^*,t^*}}{I^R - 1} \right] \left[ 1 + \sum_{i=1}^{I-I^R} \prod_{j=1}^{i} \left( \frac{S_{I^R+j,t+j}}{R_{t+j}^{old}} \right) \right]$$

- $W_{i^*,t^*}$: wage accumulated up to age $i^*$ and time $t^*$
- $\kappa^{old} \frac{W_{i^*,t^*}}{I^R - 1}$: benefit they would have been entitled to under the previous system
- $\Omega_t$: PDV of such stream of payment at retirement
Privatizing social security

The transition is financed by:

- wage tax
- consumption tax
- government debt
Privatization: wage tax

Solid lines represent closed economy and dotted lines represent open economy.
Privatization: wage tax

- The North accumulates capital faster

- The paths of prices in closed and open economy are similar
  - capital flow from the South is replaced by an increase in domestic life-cycle savings

- The paths of policy variables are similar in closed and open (again, but for different reasons)
Privatization: consumption tax

Solid lines represent closed economy and dotted lines represent open economy.
Privatization: government debt

Solid lines represent closed economy and dotted lines represent open economy.
Welfare comparison: privatization
Welfare comparison: privatization

Closed Economy

Open Economy
Conclusions

Does the distinction open vs closed economy matter?

- NO, in terms of the evolution of fiscal variables
- YES, in terms of factor prices during the transition
- YES, if concerned about welfare effects
Benchmark simulation

External assets of the South (% of total wealth)
Benchmark simulation

External assets of the South (% of total wealth)

Benchmark simulation

External assets of the South (% of total wealth)
Robustness analysis (1)

- Endogenous labor supply
- Development process and TFP growth
  - immediate catch up of the TFP in the South with the North
  - full convergence of per-capita GDP in the South to the North
- Risk aversion
  - alternative values of CRRA
- The role of China and India
  - findings of Fehr, Jokisch and Kotlikoff (2006)
Robustness analysis (2)

- Frictional capital markets
  - transaction cost of capital invested by the North
- Population projection
- Capital income tax in the South
Robustness analysis: endogenous labor supply

- preference over consumption and leisure

\[ u(c_{it}, l_{it}) = \frac{\left[ c_{it}^{\eta} \left( \bar{L}_{it} - l_{it} \right)^{1-\eta} \right]^{1-\theta}}{1 - \theta} \]

- pension benefit

\[ p_{k,t} = \frac{\kappa_{t}}{I^R - 1} \sum_{j=1}^{I^R-1} w_{t-k+j} \varepsilon_{j,t-k+j} \phi \bar{L}_{j,t-k+j} \]

- calibrate \( \beta \) and \( \eta \)

  - capital-output ratio of 2.5
  - average work hours 40% (also set \( \phi = 0.4 \))
  - implied Frisch elasticity of 0.8 and IES of 0.45
Robustness analysis: endogenous labor supply

Solid lines represent the closed economy and dotted lines represent open economy.
Robustness analysis: endogenous labor supply

- little effect on equilibrium
- what matters is the wage net of taxes – the effects of higher wage and higher labor income tax offset each other
- labor supply increase only in the open economy towards 2100, when the payroll tax levels off and wage keeps rising
Robustness analysis: TFP growth

Benchmark

- TFP growth in the North higher than in the South during 1950-2000
- the South catches up during 2000-2050
- GDP per capita of the South 1/7 of the North to 1/5

Experiments

1. TFP of the South converge to the level of the North in 2000
   - almost no effect
2. the South grows to fully catch up with the North in terms of per-capita output, i.e. it grows much faster than in the benchmark
   - no significant effect on experiment results
   - with faster growth of labor productivity, interest rates are higher in the South
   - the South is larger and open economy interest rates are closer to South
Robustness analysis: risk aversion

*benchmark* $\theta = 2$

*experiments* $\theta = 1.5$ and $2.5$

*higher* $\theta$ implies lower *IES*

$\Rightarrow$ more saving and output, slightly lower interest rate and higher wage. no significant effect on the policy variables.
Robustness analysis: role of China and India

Fehr, Jokisch and Kotlikoff (2005) allowing for the capital flow between the US and China, the US wage 8% higher in 2100

Experiment: open economy with and without China and India capital flow to the North halved and wages lower by 6% in 2070
Robustness analysis: role of China and India

Solid lines represent the open economy without China and India.
Robustness analysis: frictional capital markets

- Transaction cost as a function of the external wealth, reducing the return to the capital *invested by the North in the South*

\[
\chi (N_t) = \begin{cases} 
\bar{\chi} N_t^{0.5} & \text{if } N_t > 0, \\
0 & \text{if } N_t \leq 0.
\end{cases}
\]

- Calibrate \(\bar{\chi}\) so that we match the fraction of external wealth in the South as in Kraay, et al (2004)

- Interest rate in the South is higher in the open economy

- No effect on the results after the capital flow reverses
Robustness analysis: frictional capital markets

Solid lines represent the open economy with transaction costs and dotted lines represent the economy with perfect international capital markets.
Robustness analysis: population variants

- Use alternative variants of UN population projections.
- The low and high variants differ from the medium variants with respect to the assumption about total fertility.
  - Medium variants (benchmark): total fertility in (almost) all countries is assumed to converge eventually toward a below-replacement level of 1.85 by 2050 and remain there for about 100 years. It will then return to the replacement level (2.1) and remain there until 2300
  - High variants: 0.5 (and 0.25) children above the medium variant before (and after) 2050
  - Low variants: 0.5 (and 0.25) children below the medium variant before (and after) 2050
Robustness analysis: HIGH variants

- Wage rate
- Interest rate (%)
- Capital per capita
- Output per capita
- Wage tax (%)
- Current account (% of GDP)
Robustness analysis: LOW variants
Robustness analysis

- in the high variant, the demographic trends are not too severe
- rise in the wage tax is smaller
- qualitative effects are the same
Robustness analysis: Capital tax in South

Benchmark
- capital tax rate same as the North 38%
- too little capital and higher interest rate in the South? → more capital flow before the reversal?

Experiment
- find $\tau_a^s$ so that we match the capital flow as in Kraay, et al (2004) ⇒ 20%
Robustness analysis: Capital tax in South = 20%

Solid lines represent closed economy and dotted lines represent open economy.
Robustness analysis: Capital tax in South = 20%

External assets of the South (% of total wealth)


South K tax=20%

South K tax=38%