Population Aging and Economic Growth: A Generational Equilibrium Approach

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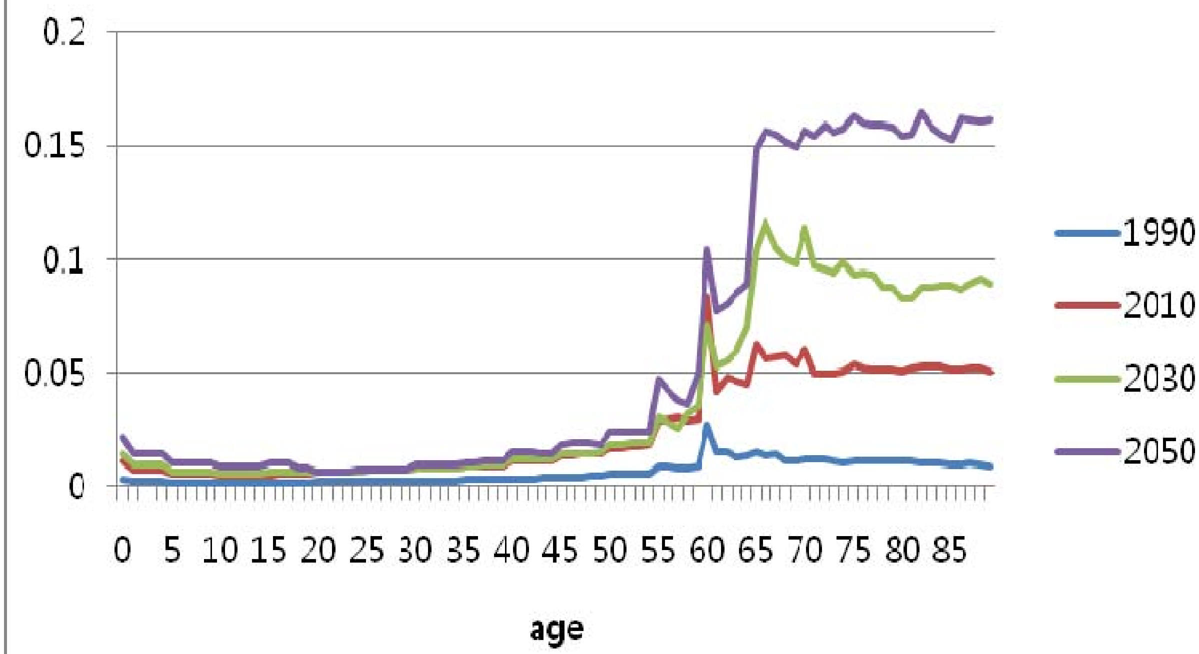
Motivation

- High speed of population aging
  - Low fertility (Total fertility rate as of 2010): 1.24 (Korea)
  - Prolonged life expectancy
- Increase in the social welfare expenditure to the elderly
  - Tax burden is expected to increase

Figure 1. Transfer income from gov. ([1])



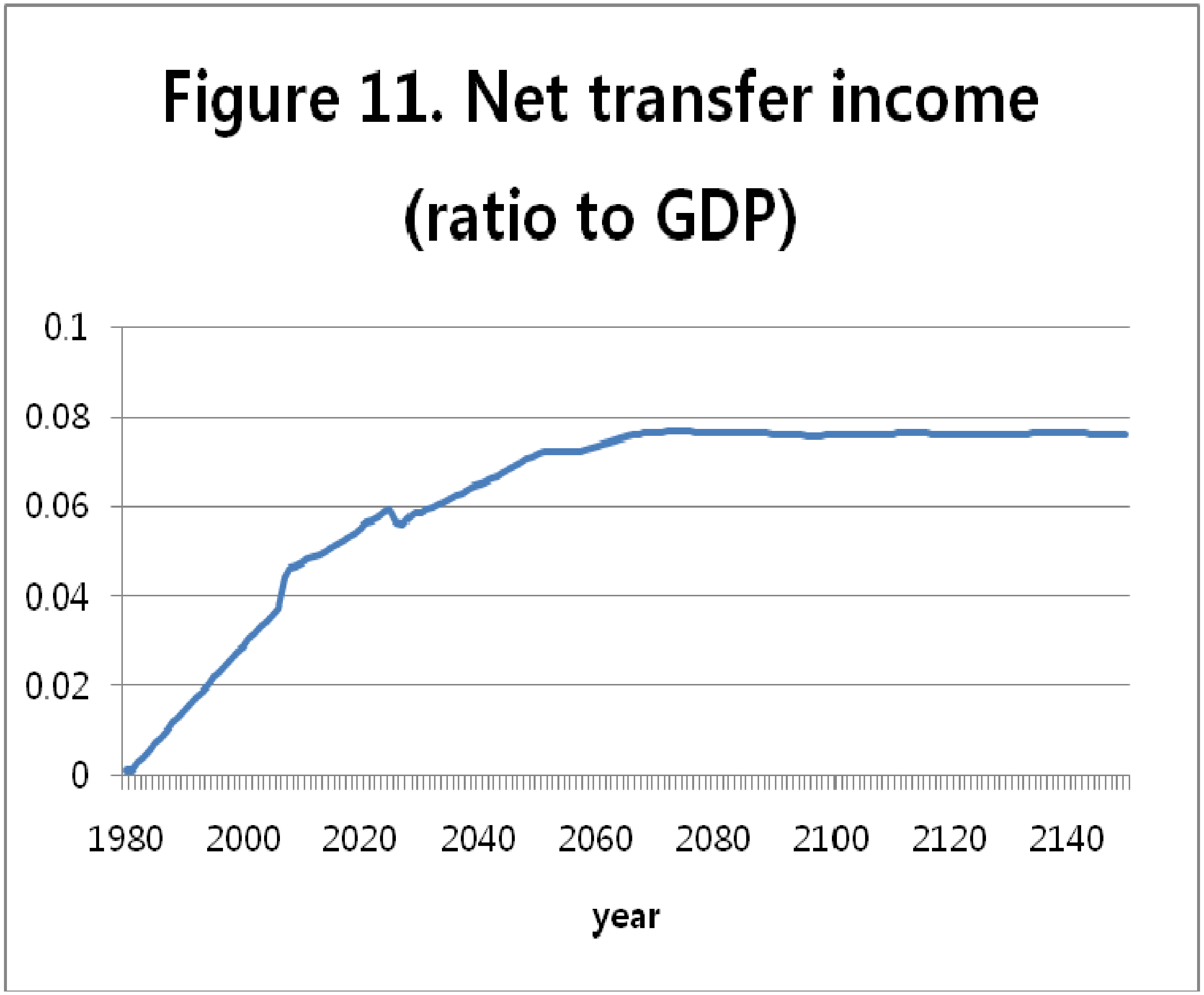


Figure 11. Net transfer income
(ratio to GDP)
0.1
0.08
0.06
0.04
0.02
0
1980
2000
2020
2040
2060
2080
2100
2120
2140
year

- Effects of low fertility rate, population decrease, population aging on economic growth?
  - Decrease in Labor supply and capital delays quantitative economic growth
    - Weil (2011), Auerbach and Kotlikoff (1987), Kotlikoff et al. (1996), Chun (2007)
  - The reduction of the quantitative growth delays the technological progress.
    - The reduction of the quantitative growth implies the reduction of market size and production which reduces the return from R&D
    - Aghion and Howitt (1992), Grossman and Helpman (1991), Arrow (1962), Romer (1990), Jones (1998), Kremer (1993)
      - The economy with large population has high change of new idea and because of the non-rivalry of the idea, technology progress is accelerated.

- Population aging increases in transfer to the elderly and tax burden.
  - Delays the quantitative growth

    Gruber et al (1998), Auerbach and Kotlikoff (1987)
  - Delays the technological progress
- Increase in the educational expenditure improves the economic growth.
  - Decrease in number of children increases the educational expenditure per child, which will increase the human capital accumulation.
  - Simultaneous determination of fertility and educatonal expenditure: Becker (1973), Hock and Weil (2006),
  - Effect of exogenous fall in fertility rate: Ashraf et al. (2011)

Purpose

- Investigate the effects of the fall in fertility rate, population aging, population reduction on economic growth
  - Using general equilibrium model
  - Take into account the growth promoting as well as the growth reduction effects
- Policy simulations
  - Effects of subsidy to R&D and education
  - Identify the optimal subsidy rate.

The Model

- Household sector:
  - Parents and children coexist.
  - Parents make decision on their labor supply, the consumption of parents and children, educational expenditure for children.
- Firms:
  - Maximizes the value of the firms
  - Decides on R&D, production
  - Endogeneize the technological progress
- Government sector:
  - Reflect the transfer payment policies.

Household

- Households consist of:
  - Parents: aged 25-90
  - Children: aged 0-24
  - People become parents at age 25, and the number of children is determined at that time.
- Parents make decision on their labor supply, the consumption of parents and children, educational expenditure for children.
  - At aged 25-49 (Children aged 0-24): decide on children's consumption
  - At aged 31-49 (Children aged 6-24): decide on the educational expenditure for the children

- Life-cycle preference

$$\sum_{a=26}^{90} \beta^{a-1} u(c_a, l_a, ncf_{a-25}, E_{a-25})$$

$$u(c, l, cf, E) = \frac{1}{1-\gamma}\left(c^{1-\alpha-\psi_i-\epsilon_i} l^{\alpha} (ncf)^{\psi_i} E^{\epsilon_i}\right)^{1-\gamma}$$

- Budget constraint

$$\sum_{a=26}^{90}\left(\prod_{s=26}^{a} \frac{1}{1+r_s(1-\tau_{ys}-\tau_{ks})}\right)\left(w_a(1-l_a)(1-\tau_{ls}-\tau_{ys}) + tr_{as} - c_a(1+\tau_{ca})\right)$$

$$+\sum_{a=26}^{50}\left(\prod_{s=26}^{a} \frac{1}{1+r_s(1-\tau_{ys}-\tau_{ks})}\right)\left(ntrf_{a-26} - ncf_{a-26}\right)$$

$$-\sum_{a=31}^{50}\left(\prod_{s=26}^{a} \frac{1}{1+r_s(1-\tau_{ys}-\tau_{ks})}\right) n(1-\rho_a) E_{a-26} \qquad \geq 0$$

- Educational expenditure determines the productivity of the children.

$$e_{as} = \left(\sum_{j=a-20}^{a-1} E_{j,s-24+j} \right)^{\alpha_E}$$

- Optimization conditions:

$$l_a = \frac{\alpha}{1-\alpha-\psi_i-\epsilon_i}\frac{1+\tau_{ca}}{w_a(1-\tau_{la}-\tau_{ya})}c_a$$

$$cf_{a-25} = \frac{\psi_i}{1-\alpha-\psi_i-\epsilon_i}c_a$$

$$E_{a-25} = \frac{\epsilon_i}{1-\alpha-\psi_i-\epsilon_i}\frac{1+\tau_{ca}}{n(1-\rho_{a-25})}c_a$$

$$\frac{c_{a+1}}{c_a} = \beta(1+r(1-\tau_{ya+1}-\tau_{ka+1}))^{\frac{1}{\gamma}}\left(\frac{1+\tau_{ca+1}}{1+\tau_{ca}}\right)^{(\alpha+\psi_i+\epsilon_i)\frac{(1-\gamma)}{\gamma}}\left(\frac{w_a(1-\tau_{la}-\tau_{ya})}{w_{a+1}(1-\tau_{la+1}-\tau_{ya+1})}\right)^{\alpha\frac{(1-\gamma)}{\gamma}}$$

Firms

- Maximize the value of the firms

$$V_t = \sum_{s=t}^{\infty} \left(\prod_{j=t}^{s} \frac{1}{1+r_j} \right) (Y_s - w_s L_s - r_s K_s - I_s - (1-\zeta) y_{Rs})$$

$$Y_s = K_s^{1-\theta} (A_s L_s)^{\theta}$$

$$K_{s+1} = I_s + (1-\delta_K) K_s$$

$$A_{s+1} = A_s (1-\delta_A) + \phi A_s^{\sigma} y_s^{\nu}$$

$$K_s^{1-\theta}(A_s L_s)^{\theta-1}\theta A_s - w_s = 0$$

$$(1-\theta)K_s^{-\theta}(A_s L_s)^{\theta} = r_s + \delta_K$$

$$\xi_s = (1+r)^{-1}\xi_{s+1}\left(1-\delta_A \phi A_{s+1}^{\sigma-1}\sigma y_{s+1}^{\nu}\right) + (1+r)^{-1}\left(K_{s+1}^{1-\theta}(A_{s+1}L_{s+1})^{\theta-1}\theta L_{s+1}\right)$$

$$\sum_{s=t}^{\infty}\left(\prod_{j=t}^{s}\frac{1}{1+r_j}\right)(-(1-\zeta)) + \xi_s\left(\phi A_s^{\sigma}\nu y_s^{\nu-1}\right) = 0$$

Government

- Government Policies
  - Subsidy to education and R&D
  - Transfer payment: Social Welfare
  - Balanced budget
    - taxes: income tax, labor income tax, capital income tax, consumption tax

$$\sum_{a=6}^{25} \rho_a E_a \mu_a + \zeta y_R + \sum_{a=6}^{25} trf_a \mu_a + \sum_{a=26}^{95} tr_a \mu_a = (\tau_l + \tau_y) wN + (\tau_k + \tau_y) rW + \tau_c C$$

Calibration

- α: 0.55, β: 0.98, γ: 0.25, φ: 0.08, ε: 0.08
- Fertility rate:
  - Fall from 2 (1980) to 1.2 (2010)
  - Rise to 1.4 (2050)
  - Stays at 1.4 thereafter
- Production function
  - Labor income share: 60%
  - Depreciation rate (physical capital): 5% per annum

- Production or new technology
  - depreciation: 4% per annum,
    - Heckman (1976): 연 4-9%
    - Haley (1976): 1-4%
  - σ: 0.5, υ: 0.1
    - Elasticity of technological progress with respect to R&D investment: 0.2 (Lee et al. (2010))

$$\frac{A_{s+1} - A_s(1-\delta_A)}{A_s} = \phi A_s^{\sigma-1} y_{Rs}^{\nu}$$

$$\frac{\Delta A / A}{\Delta y_R / y_R} = \frac{\nu}{1-\sigma}$$

- Contribution of eduction to labor productivity

  α_E : 0.2

  – Rate of return from education: 8.8% (on average)
    - First 4 years 13.4%
    - Next 4 years 10.1%
    - Further educations 6.8%

- Tax proportion:
  – consumption: labor income: income: capital income

  = 40: 10: 35: 15

Table 2. Policy Scenarios

Scenario	Contents
[1]	Medium fertility[1] No transfer income from government ζ , ρ=0, α_E=0.2
[2]	Medium fertility Transfer income from government is included ζ , ρ=0, α_E=0.2
[3]	High fertility[2] Transfer income from government is included ζ , ρ=0, α_E=0.2
[4]	Low fertility[3] Transfer income from government is included ζ , ρ=0, α_E=0.2
[5]	Medium fertility Transfer income from government is included ζ=40%[4], ρ=0, α_E=0.2
[6]	Medium fertility Transfer income from government is included ζ=0, ρ=40%, α_E=0.2
[7]	Medium fertility Transfer income from government is included ζ , ρ=0, α_E=0.4
[8]	Medium fertility Transfer income from government is included ζ , ρ=0, α_E=0

Note: 1) Fertility rate rise from 1.2 to 1.4 until 2050.
2) Fertility rate rise from 1.2 to 1.8 (2.0) until 2050.
3) Fertility rate stays at current level (1.2).
4) The subsidy is provided from 2011.

Benchmark economy

Table 3. Resource allocation (Initial period of benchmark economy)

Capital-Output ratio	3.05
Labor hour (worker)	0.342
Savings Rate (%)	14.3
Ratio of consumption (except for educational exp) to GDP (%)	80.5
Ratio of educational expenditure to GDP (%)	5.1
Ratio of educational expenditure to household consumption (for households with children %)	12.7
Ratio of educational expenditure to household consumption (for the whole household, %)	5.9
R&D investment / GDP (%)	4.7%

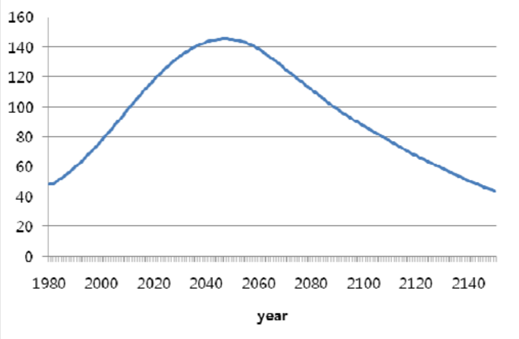


Figure 2. GDP ([1])

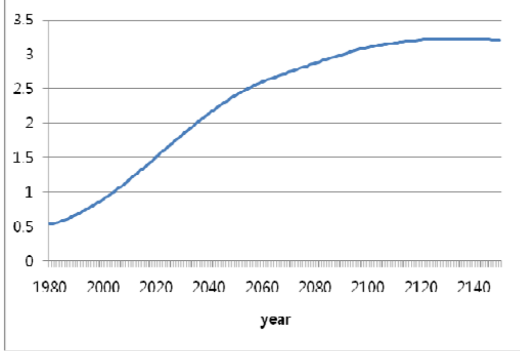


Figure 3. GDP per capia ([1])

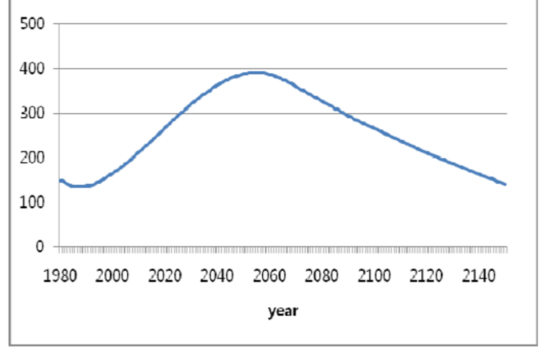


Figure 4. Capital ([1])

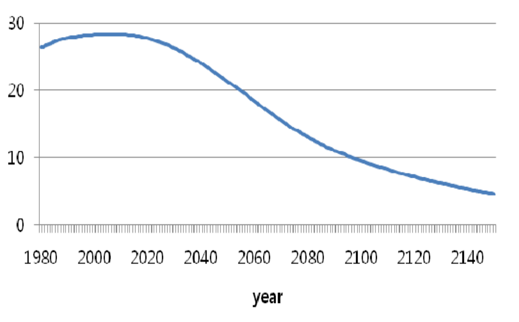


Figure 5. Labor supply ([1])

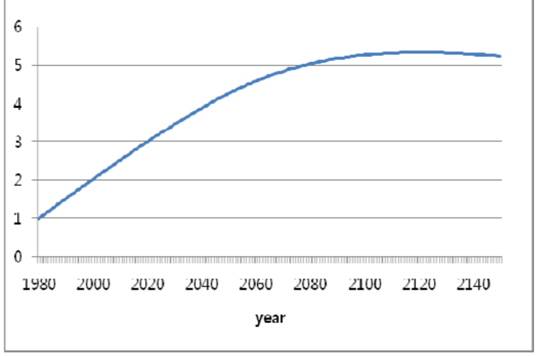


Figure 6. Productivity ([1])

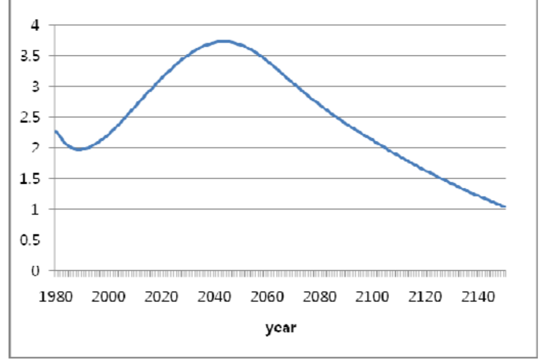


Figure 7. R&D investment ([1])

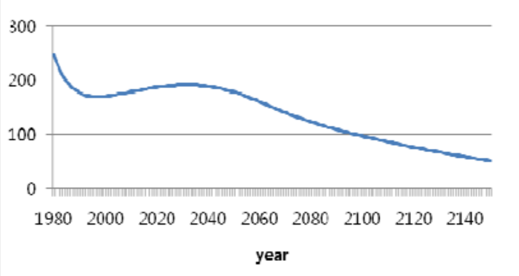


Figure 8. Retrun from R&D ([1])

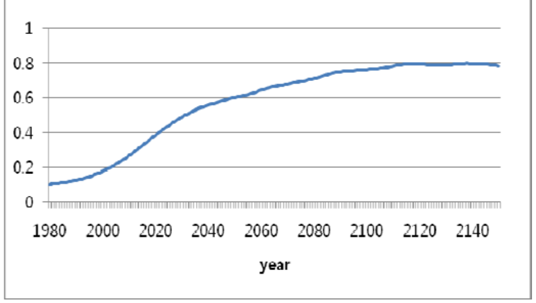


Figure 9. Edu. Exp. per child ([1])

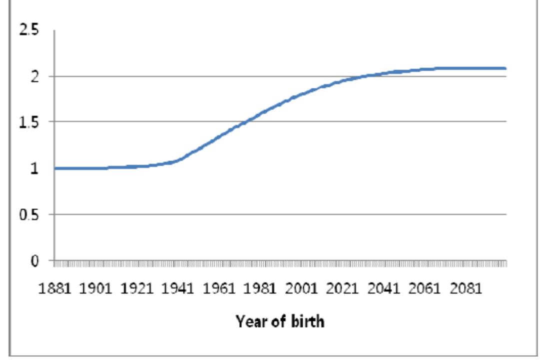


Figure 10. Welfare ([1])

Effects of Transfer Payment

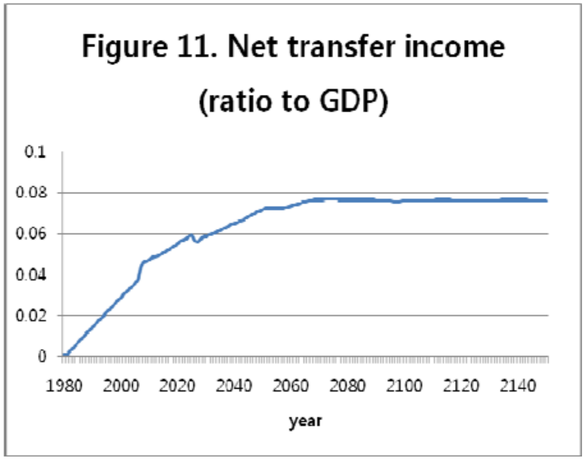


Figure 11. Net transfer income (ratio to GDP)

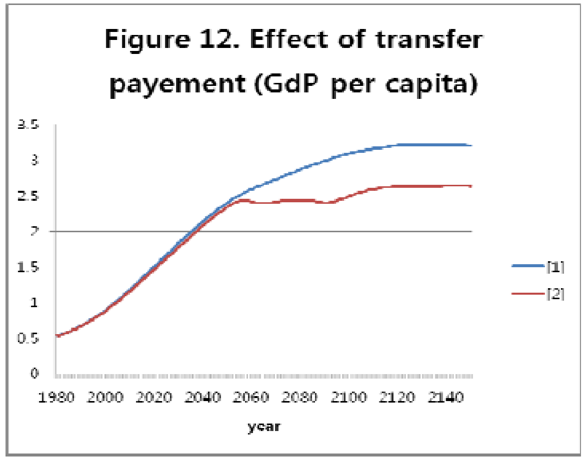


Figure 12. Effect of transfer payement (GdP per capita)

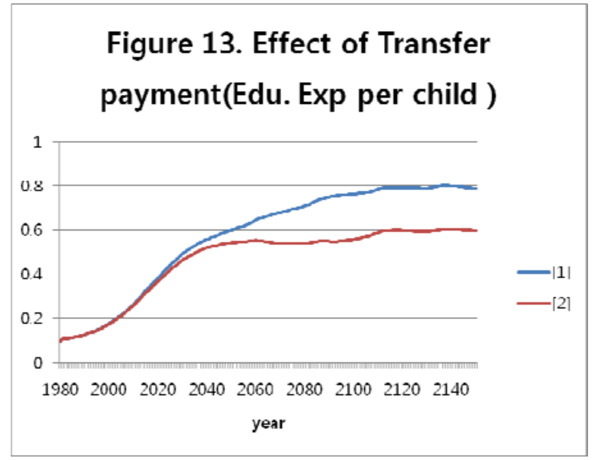


Figure 13. Effect of Transfer payment(Edu. Exp per child)

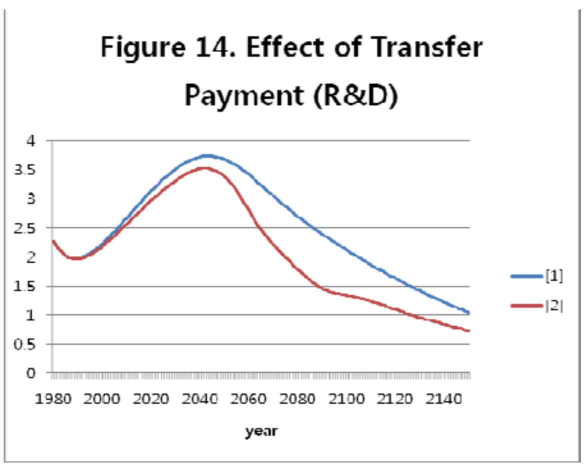
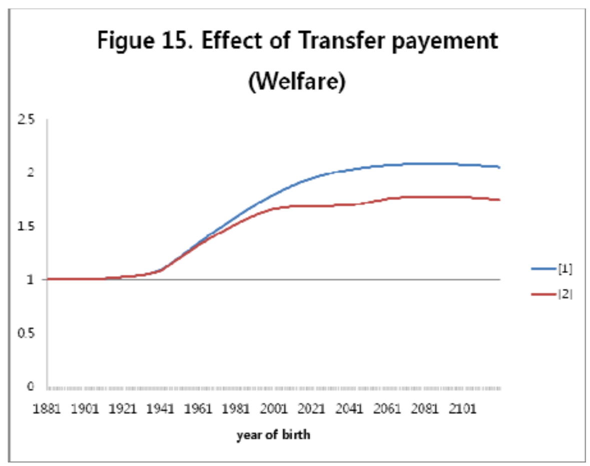


Figure 14. Effect of Transfer Payment (R&D)



Figue 15. Effect of Transfer payement (Welfare)

Effects of change in fertility

Figure 16. Effect of fertility rate (GDP per capita)

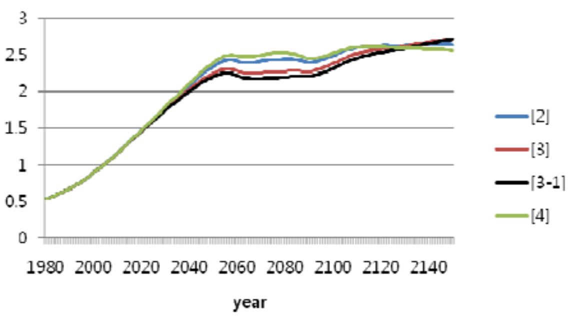


Figure 17. Effect of fetility rate (labor productivity)

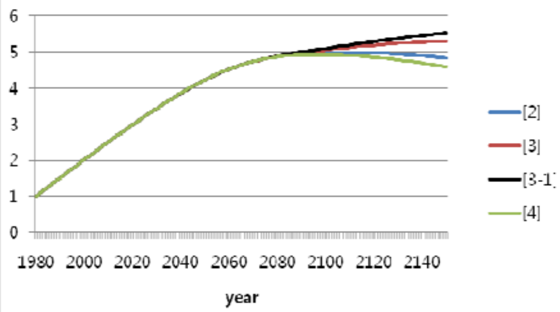


Figure 18. Effect of fertilit rate (R&D)

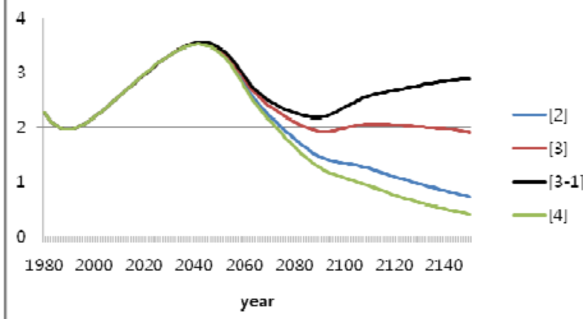


Figure 19. Effect of fertility rate (Edu. Exp. per child)

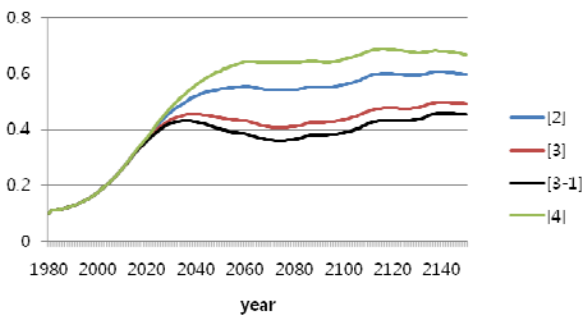
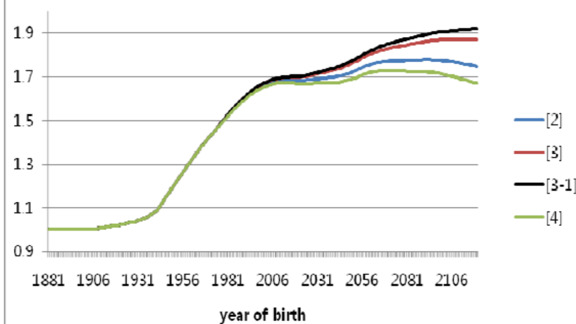
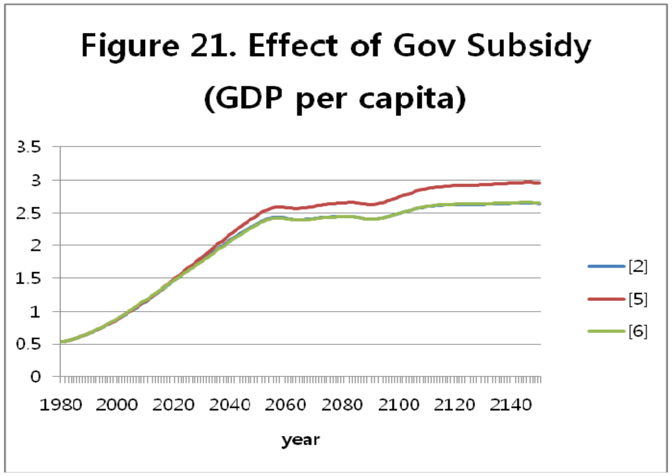
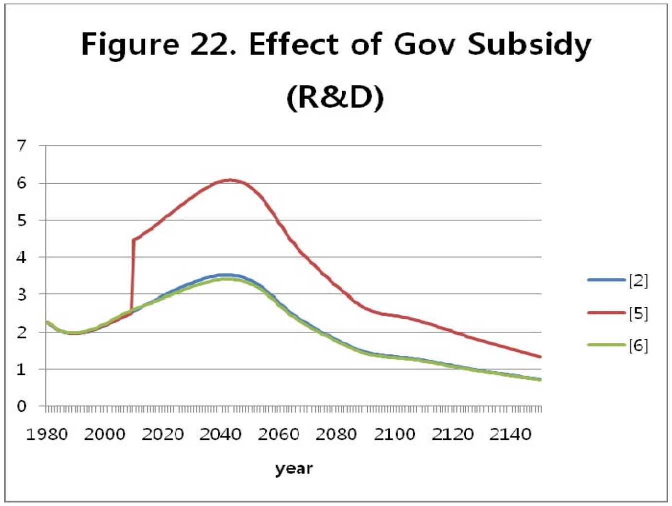


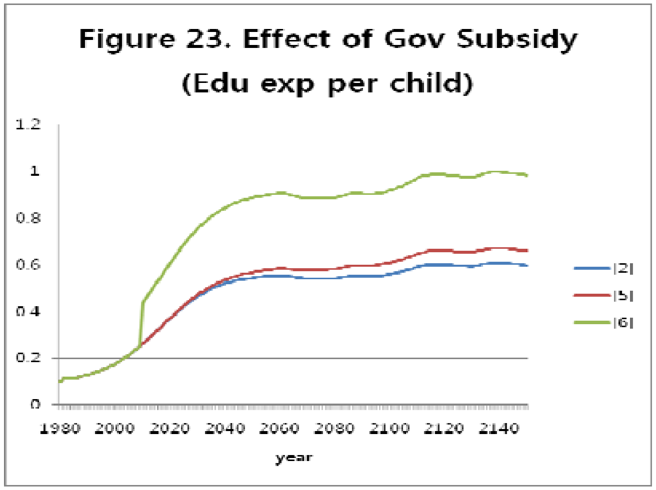
Figure 20. Effect of fertility rate (Welfare)

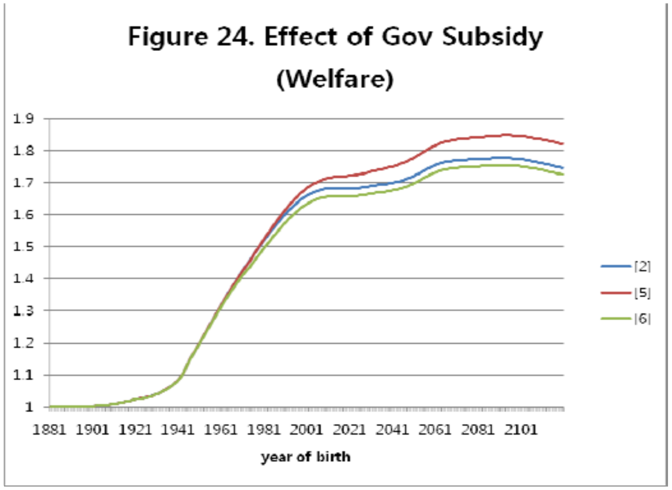


Effect of Subsidy to R&D, Education









Optimal subsidy rate

- Utilitarian social welfare fuction
  - Discount rate for future generations: 2%, 1.5%, 1%
- Optimal subsidy rate for R&D: 60-70% (benchmark case)
- Optimal subsidy rate for education: 0%
  - Because:
    - Low degree of contribution of education to productivity
    - High tax rates

Summary

- Population Aging reduces the technological progress as well as the quantitative economic growth.
  - Effect of the R&D decrease dominates that of increase in educational expenditure.
- Transfer payment through social welfare policies reduces the technological progress as well as the quantitative economic growth.
- The optimal subsidy rate for R&D is quite high, while that for education is very low.

Further study

- Effects of the prolonged life expectancy?
  - Delay of the retirement may reduce the growth delaying effect.
- Effects of the on-the-job training
- Spillover effect of the educational expenditure?
  - How the optimal subsidy rate to the educational expenditure is affected?
  - How much human capital investment is needed to overcome the population aging?