R&D-based Growth in the Post-modern Era

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Optimal Fertility in Ageing Societies
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Motivation

All developed countries have to face very low fertility rates:

Table 1: TFR for the G-8: 2005

USA	2.05	France	1.89
U.K.	1.82	Canada	1.53
Italy	1.38	Germany	1.36
Russia	1.34	Japan	1.24

The consequences are

- Aging societies
- Declining and even negative population growth

Main question:

What are the effects of these developments on long-run economic growth perspectives?

Theoretical Considerations

- Endogenous growth literature (e.g. Romer, 1990):
  - Positive linear association between population **size** and productivity (TFP) growth
- Semi-endogenous growth literature (e.g. Jones, 1995):
  - Positive linear association between population **growth** and TFP growth
  - However, the model cannot deal with negative population growth and therefore below replacement fertility

Altogether:

Facing declining population growth these models give a **very pessimistic economic outlook**.

Empirical Evidence

- Negative association between population growth and income growth:
  - Brander and Dowrik (1994)
  - Kelley and Schmidt (1995)
  - Ahituv (2001)
  - Herzer et al. (2010)
- Negative association between population growth and productivity growth:
  - Bernanke and Guerkaynak (2001)

Our aim:

Our aim is to introduce **more realistic demographic settings** into the **dynamic general equilibrium frameworks** used to analyze R&D based economic growth.

Basic Structure of the Model

- Three overlapping generations: **children**, **young adults**, and **retirees**
- Young adults choose optimal **consumption**, **savings**, **fertility** and **education of offspring**
- Two production factors: **physical** capital and **human** capital
- Three sectors
  - **Final goods sector**: perfectly competitive; produces consumption goods by using intermediate goods and workers
  - **Intermediate goods sector**: Dixit and Stiglitz (1977) monopolistically competitive; produces machines with one blueprint as fixed input and individual savings as variable input
  - **Research and development**: perfectly competitive; produces blueprints using scientists

Optimization Problem of Young Adults

Maximize lifetime utility, i.e.

$$\max_{c_t, s_t, e_t, n_t} u_t = \log c_t^1 + \beta \log(R_{t+1} s_t) + \eta \log n_t + \gamma \log e_t \qquad (1)$$

subject to the wealth constraint

$$w_t h_t (1 - \tau n_t) = c_t^1 + s_t + n_t e_t. \qquad (2)$$

Solution for e_t and n_t:

$$n_t = \frac{\eta - \gamma}{(1 + \beta + \eta)\tau}, \qquad (3)$$

$$e_t = \frac{\gamma \tau w_t h_t}{\eta - \gamma}. \qquad (4)$$

Education

Child expenditure e_t is transformed into human capital of the next generation h_{t+1} according to the "schooling technology"

$$h_{t+1} = \max\left\{A_E \frac{e_t}{w_t},\ 1\right\}. \tag{5}$$

Low of motion for human capital if education is not at the corner solution:

$$h_{t+1} = A_E \frac{\gamma\tau}{\eta - \gamma} h_t. \tag{6}$$

Aggregate human capital which is used to produce in the economy amounts to

$$H_t = h_t L_t, \tag{7}$$

where L_t is the size of the current generation of young adults.

Final goods sector

Production function

$$Y_t = \left(H_t^Y\right)^{1-\alpha} \sum_{i=1}^{A_t} x_{i,t}^{\alpha}. \tag{8}$$

Profit maximization in the perfectly competitive numeraire sector pins down the wage rate and prices of intermediate goods

Factor rewards in the final goods sector

$$w_t = (1-\alpha)\frac{Y_t}{H_t^Y}, \tag{9}$$

$$p_{i,t} = \alpha\left(\frac{H_t^Y}{x_{i,t}}\right)^{1-\alpha}. \tag{10}$$

where the index i can be dropped due to symmetry.

Intermediate goods sector

Firms can transform one unit of savings into one machine ($x = k$) after having purchased a certain blueprint from the R&D sector. Operating profits of intermediate goods producers are therefore:

$$\pi = \alpha \left(\frac{H_Y}{k} \right)^{1-\alpha} k - rk. \tag{11}$$

Profit maximization yields prices of intermediates

Prices of intermediates

$$p = \frac{r}{\alpha}. \tag{12}$$

Research and development sector

The number of blueprints evolves according to

$$A_{t+1} - A_t = \delta A_t^{\phi} L_t^{-\nu} H_t^A, \tag{13}$$

where with $0 < \phi < 1$ being the standing-on-shoulders effect and $0 \leq \nu < 1$ the stepping-on-toes effect. Profit maximization of research firms

$$p_t^A \delta A_t^{\phi} L_t^{-\nu} H_t^A - w_t H_t^A, \tag{14}$$

pins down wages in the research sector to

Wages of scientists

$$w_t = \delta A_t^{\phi} L_t^{-\nu} p_t^A. \tag{15}$$

Equilibrium I

Imposing labor market clearing and solving for the general equilibrium provides us with a four-dimensional system in A_t, L_t, K_t and h_t:

Equilibrium Dynamics

$$A_{t+1} = \delta A_t^{\phi} h_t L_t^{1-\nu} - \frac{1-\alpha}{\alpha} A_t, \tag{16}$$

$$L_{t+1} = n_t L_t, \tag{17}$$

$$K_{t+1} = B K_t^{\alpha} A_t^{1-\alpha-\alpha(1-\phi)} h_t L_t, \tag{18}$$

$$h_{t+1} = A_E \frac{\gamma\tau}{\eta-\gamma} h_t. \tag{19}$$

with $B \equiv \beta(1-\alpha)(\alpha\bar{\delta})^{\alpha}/(1+\beta+\eta)$.

Equilibrium II

Along a balanced growth path, we know that the growth rates of A, L, K, and h have to be constant. Therefore we obtain that

$$\left(\frac{A_{t+1}}{A_t}\right)^{1-\phi} = \left(\frac{h_{t+1}}{h_t}\right) n_t^{1-\nu}. \qquad (20)$$

Superficial inspection thus *seemingly* suggests that TFP growth and population growth are positively correlated.

Central Results I

The most positive role of population growth is for no congestion in research, i.e. for $\nu = 0$. Then we have

$$g_A = \left(\frac{\gamma A_E}{1+\beta+\eta}\right)^{1/(1-\phi)} - 1 \quad (21)$$

$$g_L = \frac{\eta-\gamma}{(1+\beta+\eta)\tau} - 1. \quad (22)$$

and we can state the following result

Proposition

If parents want better educated children, this leads to increasing TFP growth and decreasing population growth.

Economic Intuition

The economic intuition is rooted in the effects of changing preferences towards education on the **aggregate** human capital in an economy:

$$\begin{aligned} \frac{H_{t+1}}{H_t} &= \frac{\eta-\gamma}{(1+\beta+\eta)\tau}\cdot\frac{\gamma\tau A_E}{\eta-\gamma} = \frac{\gamma A_E}{1+\beta+\eta} \\ \Rightarrow \frac{\partial(H_{t+1}/H_t)}{\partial\gamma} &= \frac{A_E}{1+\beta+\eta} > 0. \end{aligned} \quad (23)$$

If there is congestion in R&D, i.e. if $\nu > 0$ we can even state the following result

Proposition

Increasing time costs for rearing children lead to lower population growth and higher TFP growth.

Central Results III

For per capita income growth we can even state more generally that

Proposition

A higher parent's desire for education increases growth in income per capita and decreases population growth.

Proposition

An increase in child-rearing costs increases growth in income per capita and decreases population growth.

The reason we do not need congestion in research for the latter proposition is the neoclassical capital dilution effect.

Conclusions

Central results

1. Decreasing fertility due to quantity-quality substitution is positive for TFP growth and per capita income growth
2. Increasing child costs are positive for per capita income growth
3. Increasing child costs are positive for TFP growth if there is congestion in R&D

The model

- can deal with negative population growth
- fits to the empirical findings

Thank you for your attention!

Questions?

Remarks?

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