Unified Growth Theory and Comparative Economic Development

Oded Galor

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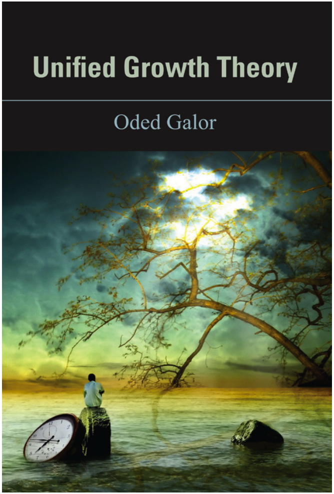
Unified Growth Theory



The Underlying Hypothesis

The understanding of contemporary variations in income per capita across the globe would remain obscured unless growth theory would capture:

- The process of development in its entirety
  - The forces that triggered the transition from stagnation to growth of the currently developed economies
    - $\Longrightarrow$ hurdles faced by LDCs
  - The role played by deep rooted factors in the differential timing of the transition from stagnation to growth
    - $\Longrightarrow$ comparative development

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Virtues of Unified Growth Theory

- Sheds light on historical and contemporary patterns of development
- Identifies the forces the permitted the currently developed economy to transit from an epoch of Malthusian stagnation to sustained economic growth
- Uncovers the hurdles faced by LDCs in their transitions from stagnation to growth
- Derives policies that may expedite the transition of LDCs to sustained economic growth

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- Identifies the persistent effect of initial biogeographical conditions on the growth process
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Development of a unified growth theory that accounts for:

- An epoch of Malthusian stagnation
- The take-off from the Malthusian Regime
- The emergence of human capital as a significant factor
- The demographic transition
- A shift to sustained economic growth
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A dynamical system that permits an escape from a *stable* Malthusian Steady-State:

- A major shock in an environment characterized by multiple locally stable equilibria
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- The evolution of a latent state variable that ultimately affects the qualitative properties of the dynamical system
- The latent evolution of the demand for human capital ultimately changes the dynamical system qualitatively:
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- Transition from Malthusian to Post-Malthusian Regime:
  - Faster rates of technological progress
  - Faster rate of population growth
- Transition from the Post-Malthusian to Modern Growth Regime:
  - Faster rate of technological progress
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- The forces behind these transitions may be hidden therefore in the understanding of how:
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The Basic Structure of the Model

- Overlapping-generations economy
- $t = 0, 1, 2, 3...$
- One homogeneous good
- 2 factors of production:
  - Labor (measured in efficiency units)
  - Land

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- Land is fixed over time
    - e.g., surface of planet earth
- Efficiency units of labor evolves endogenously
    - determined by households' decisions about the number and level of human capital of their children

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- A subsistence consumption constraint
- Positive effect of income on population
  - reflecting household's optimization
- Fixed factor of production - Land
- Output per capita flactuates around a constant level
  - reflecting diminishing returns to labor in agriculture and a positive effect of income on population

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  - $y \uparrow \Longrightarrow L \uparrow$
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  - $L \uparrow \Longrightarrow AP_L \downarrow \ \Longrightarrow y \downarrow$
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Production

- The output produced in period t

$$Y_t = H_t^{\alpha}(A_t X)^{1-\alpha}$$

  - $H_t \equiv$ efficiency units of labor
  - $A_t \equiv$ technological level
  - $X \equiv$ land

- Output per worker produced at time t

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  - $h_t \equiv H_t/L_t$ efficiency units per-worker
  - $x_t \equiv (A_t X)/L_t$ effective resources per worker

The Effect of Technological Progress

- Very short-run (for a given population):
  - $A_t \uparrow \implies y_t \uparrow$ (above $\bar{y}$)
- Short-run:
  - $y_t \uparrow \implies L_t \uparrow$
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  - $L_t \uparrow \implies y \downarrow$ (back to $\bar{y}$)
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Early stage of development

- Population size positively affects technological progress:

$$L_t \uparrow \quad \Longrightarrow \quad A_t \uparrow$$

- Channels:
    - Supply of innovations
    - Demand for innovations
    - Diffusion of knowledge
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$$g_{t+1} \equiv \frac{A_{t+1} - A_t}{A_t} = g(e_t, L_t)$$

- $g_{t+1} \equiv$ rate of tech progress
- $e_t \equiv$ education
- $L_t \equiv$ population size

- $g(0, L_t) > 0$
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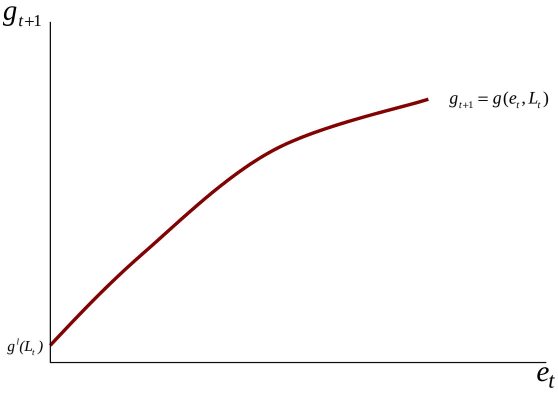
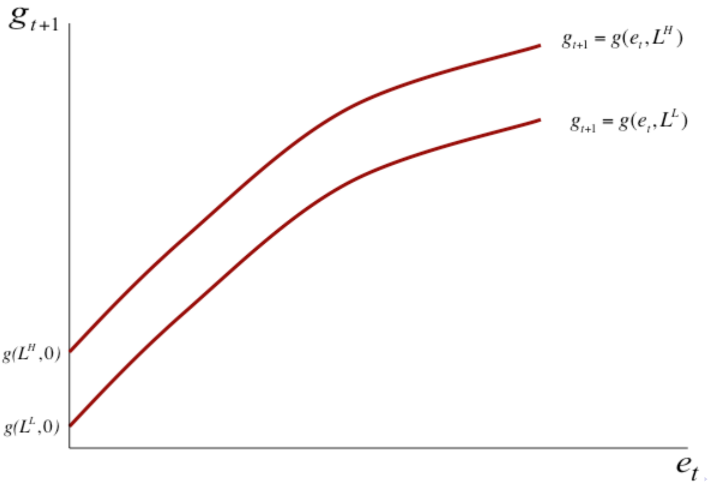


The Effect of Population Size on Technological Progress



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- The increase in the rate of technological progress increases the demand for human capital
  - Human capital permits individuals to better cope with the changes in the technological environment
  - The introduction of new technologies is skill-biased in the short-run, although the nature of the technology is skill-biased or skill-saving in the long run

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Human capital of children of generation t

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Triggers of the Demographic Transition

- The rise in the *demand* for human capital induces parents to substitute quality for quantity of children
- The rise in income along with the rise in the potential return to human capital generates:
  - An income effect - more income to spend on children
  - Substitution effects
    - The opportunity cost of raising children increases
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Later part of the second phase of industrialization:

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- Live for 2 period
- Childhood: (1st Period):
  - Consume a fraction of their parental unit-time endowment
  - The required time increases with children's quality
    - $\tau \equiv$ time required to raise a child, regardless of quality
    - $\tau + e_{t+1} \equiv$ time to raise a child with education e_{t+1}
- Parenthood (2nd Period):
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- $h_{t+1} \equiv$ level of human capital of each child

Preferences

The utility function of individual t

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$$w_t h_t n_t(\tau + e_{t+1}) + c_t \leq w_t h_t$$

- $\tau \equiv$ time required to raise a child, regardless of quality
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Optimization: Quantity and Quality of Children

$$n_t = \begin{cases} \frac{\gamma}{\tau + e(g_{t+1})} \equiv n^b(g_{t+1}) & if \quad z_t \equiv w_t h_t \geq \tilde{z} \\ \frac{1-[\tilde{c}/z_t]}{\tau + e(g_{t+1})} \equiv n^a(g_{t+1}, z(e_t, g_t, x_t)) & if \quad z_t \equiv w_t h_t \leq \tilde{z} \end{cases}$$

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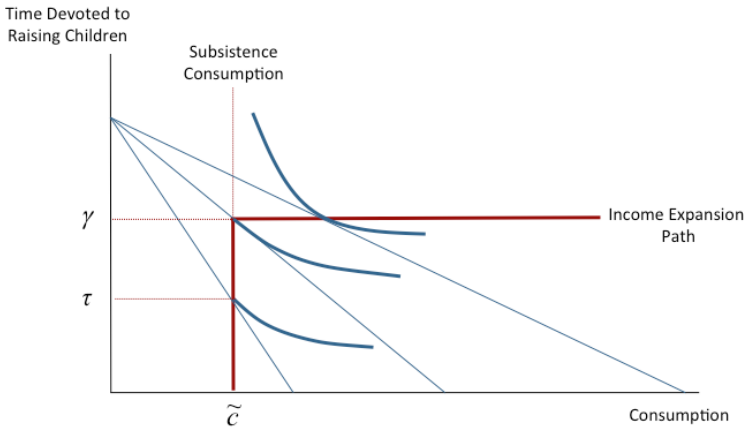
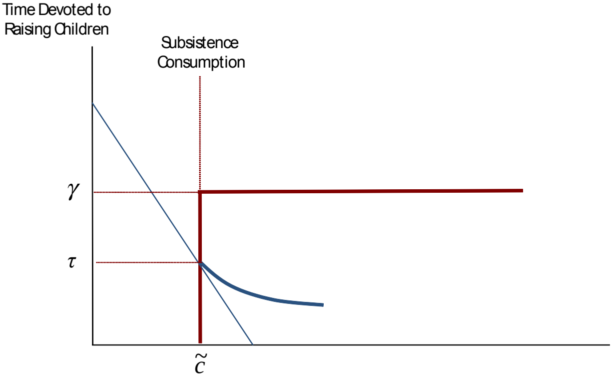
Optimization: Income Expansion Path



Optimization - Malthusian Epoch



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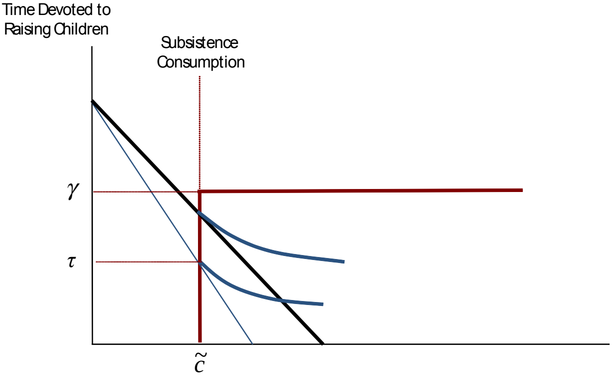

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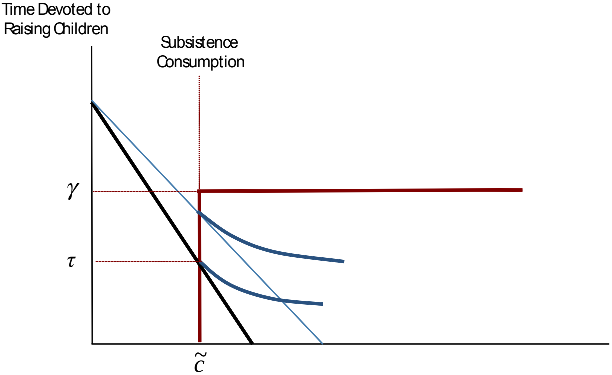

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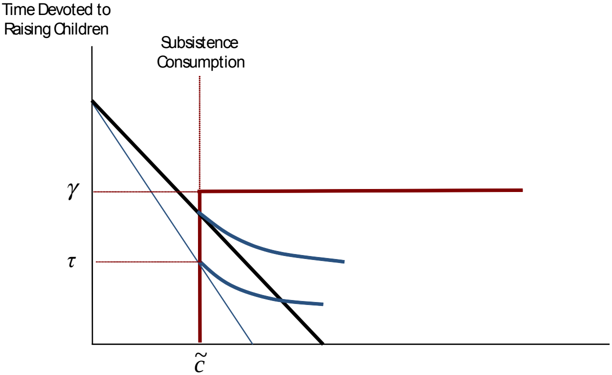

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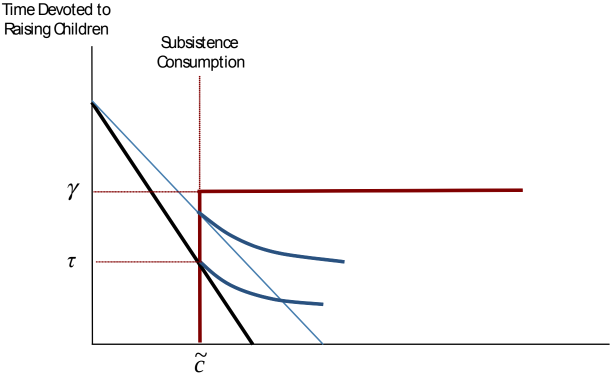

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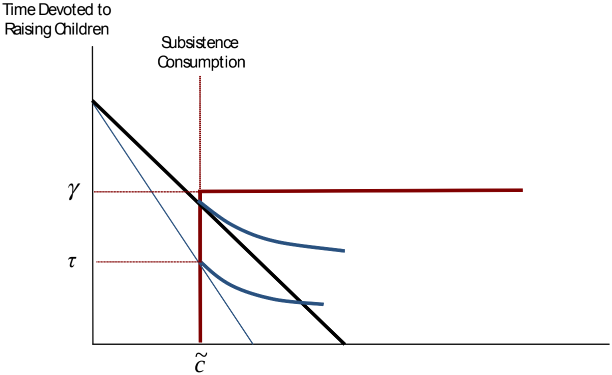

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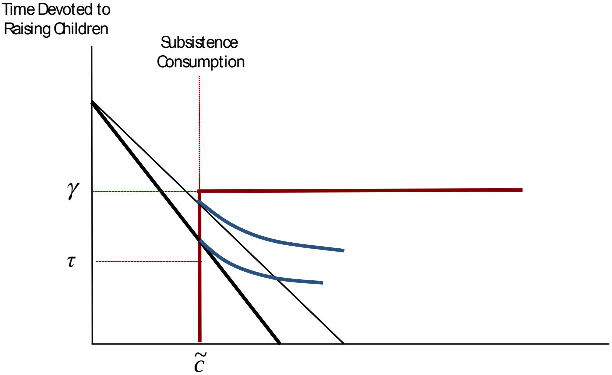
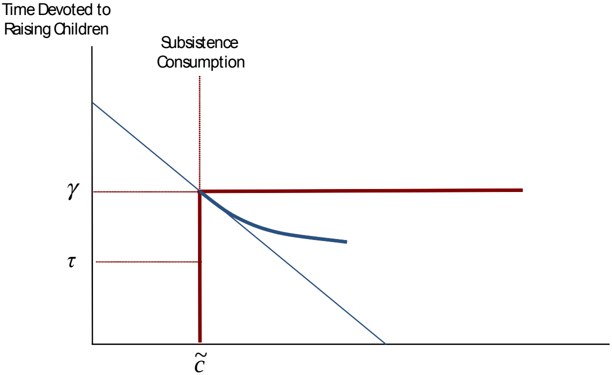


Income Expansion Path - Post-Demographic Transition



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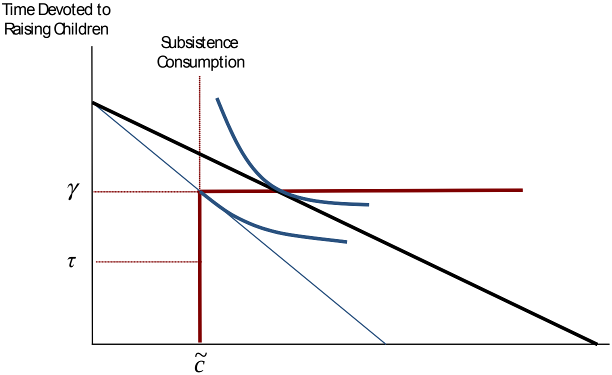
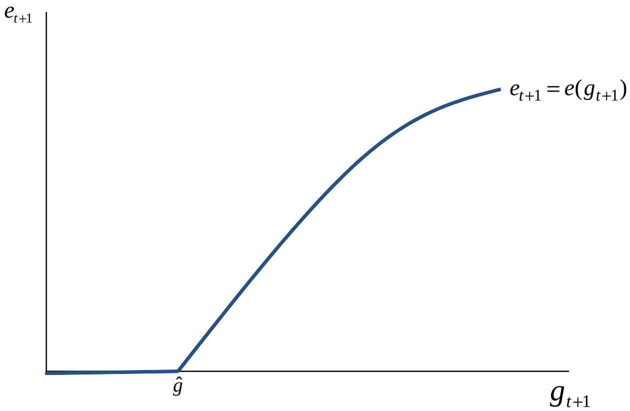


Optimal Investment in Child Quality



Technological Progress

Technological progress over time

$$g_{t+1} \equiv \frac{A_{t+1} - A_t}{A_t} = g(e_t, L_t)$$

- $g(0, L_t) > 0$
- $g_i(e_t, L_t) > 0$ and $g_{ii}(e_t, L_t) < 0, \quad i = e, L$

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Population Dynamics

$$L_{t+1} = n_t L_t$$

$$L_{t+1} = \begin{cases} n^b(g_{t+1})L_t & \text{if} \quad z_t \geq \tilde{z} \\ n^a(g_{t+1}, z(e_t, g_t, x_t))L_t & \text{if} \quad z_t \leq \tilde{z} \end{cases}$$

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Dynamics of the Level of Resources per Worker

$$x_{t+1} = \frac{A_{t+1}X}{L_{t+1}} = \frac{(1+g_{t+1})A_tX}{n_tL_t} = \frac{1+g_{t+1}}{n_t}x_t$$

$$x_{t+1} = \begin{cases} \frac{[1+g(e_t,L_t)][\tau^q+\tau^e e(g(e_t,L_t))]}{\gamma}x_t \equiv \phi^b(e_t;L)x_t & z_t \geq \tilde{z} \\ \frac{[1+g(e_t,L_t)][\tau+e(g(e_t,L_t))]}{1-[\tilde{c}/z(e_t,g_t,x_t)]}x_t \equiv \phi^a(e_t,g_t,x_t,L_t)x_t & z_t \leq \tilde{z}, \end{cases}$$

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The Dynamical System

A sequence $\{x_t, e_t, g_t, L_t\}_{t=0}^{\infty}$ such that:

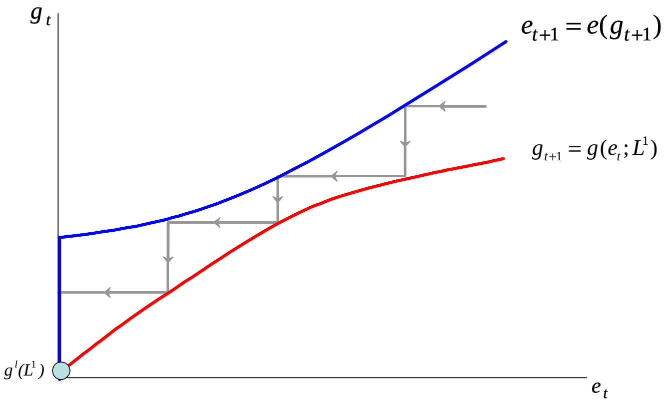
$$\begin{cases} x_{t+1} = \phi(e_t, g_t, x_t, L_t)x_t \\ e_{t+1} = e(g(e_t, L_t)) \\ g_{t+1} = g(e_t, L_t) \\ L_{t+1} = n(e_t, g_t, x_t, L_t)L_t \end{cases}$$

The Conditional Evolution of Technology and Education

A sequence $\{g_t, e_t; L\}_{t=0}^{\infty}$ such that:

$$\begin{cases} g_{t+1} = g(e_t; L) \\ e_{t+1} = e(g_{t+1}) \end{cases}$$

The Evolution of Education and Technology



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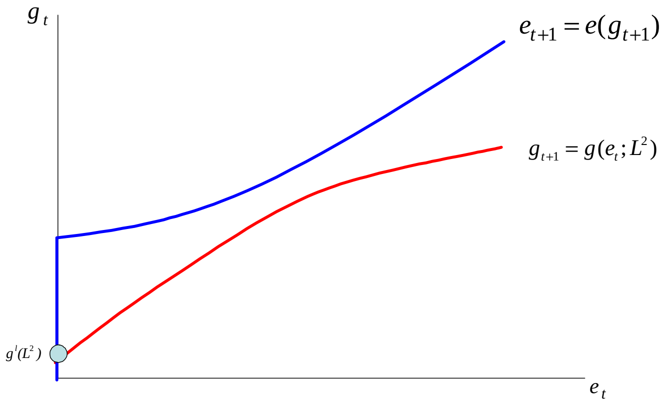

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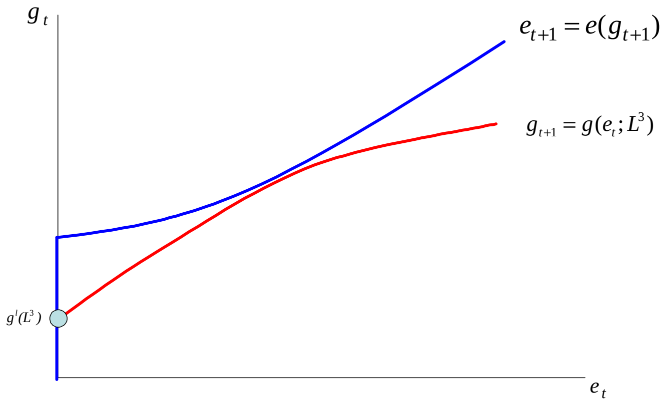

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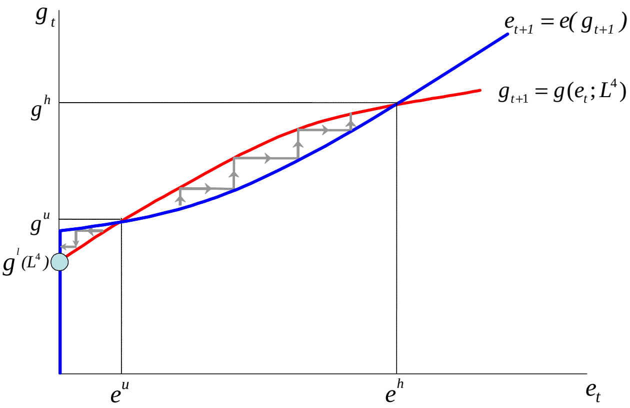

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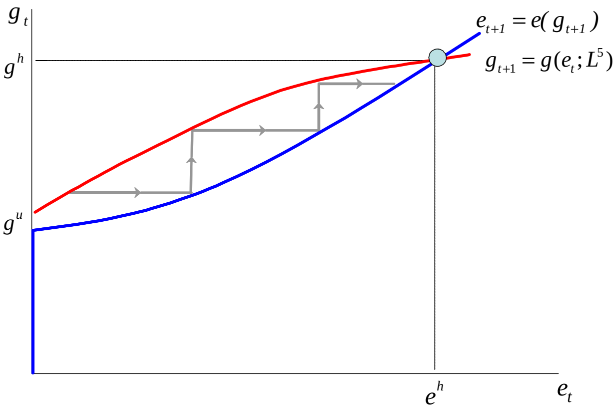
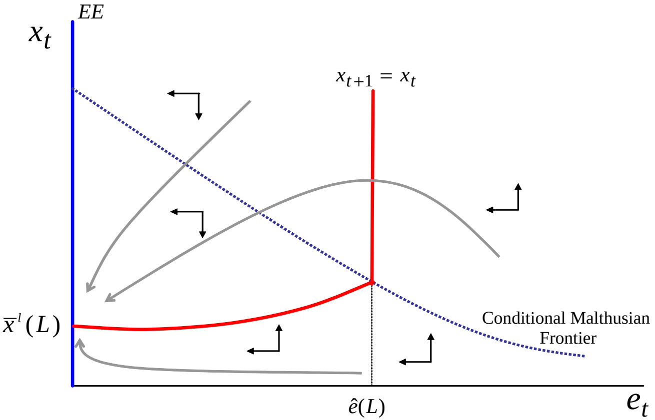
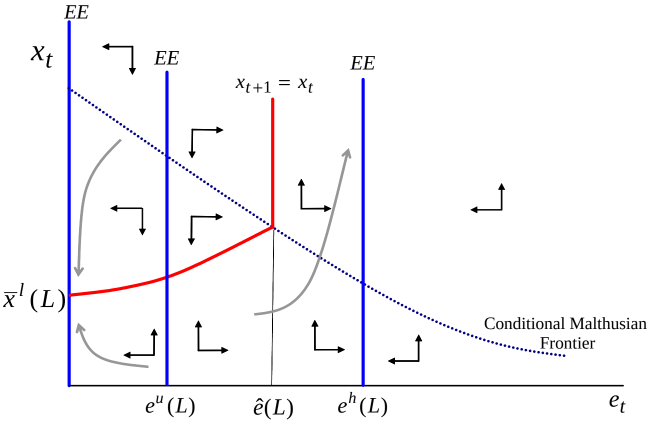


The Evolution of Education and Resources Per Worker: Small Population



The Evolution of Education and Resources Per Worker: Intermediate Population



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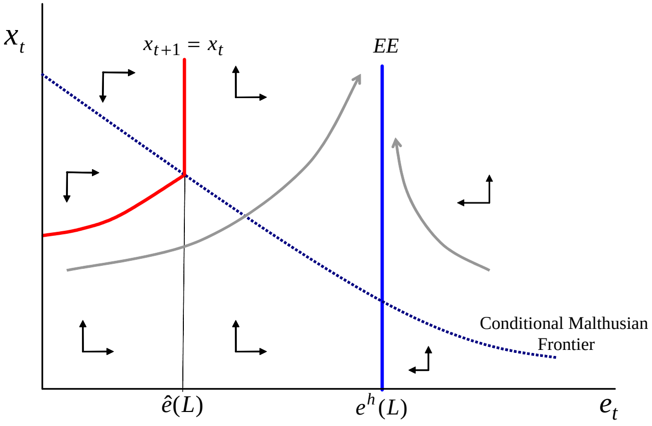
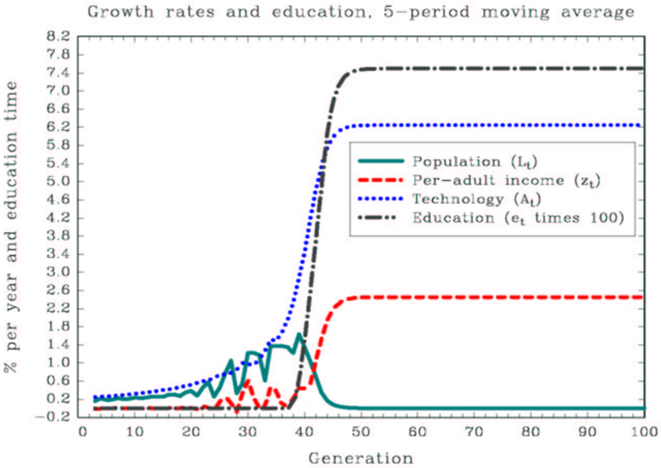


Calibrations



Implications

- The transition from stagnation to growth is an *inevitable* by-product of the process of development
- The inherent Malthusian interaction between technology and population, accelerated the pace of technological progress, and eventually brought an industrial demand for human capital
- Human capital formation, triggered a demographic transition, enabling economies to convert a larger share of the fruits of factor accumulation and technological progress into growth of income per capita
- Variations in the timing of the take-off contributed significantly to the divergence in income per capita in the past two centuries

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Differences in the economic performance across countries reflect:

- Variations in country-specific characteristics that affect:
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$$g_{t+1}^i = g(e_t^i, L_t^i, \Omega_t^i)$$

$\Omega_t^i \equiv$ characteristics affecting tech progress in country i:

- Protection of intellectual property rights (policy)
- The stock of knowledge within a society
- The propensity of a country to trade (geography & policy)
    - Technological diffusion
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- Cultural and religious composition in society
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- The composition of interest groups in society
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Variation in Characteristics Conducive for Human Capital Formation

- For country-specific characteristics $\Psi_t^i \equiv [\phi_t^i, \mu_t^i]$

$$e_{t+1}^i = e(g_{t+1}^i; \Psi_t^i) \begin{cases} = 0 & \text{if} \quad g_{t+1}^i \leq \hat{g}(\Psi_t^i), \\ > 0 & \text{if} \quad g_{t+1}^i > \hat{g}(\Psi_t^i) \end{cases}$$

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Variations in Characteristics that Promote Human Capital Formation

- Ability of individuals to finance the cost of education and the forgone earnings
  - Extent of under-investment in education
- The availability, accessibility, and quality of public education (policy & interest groups)
  - Extent of human capital formation
- Cultural and religious composition in society
  - Attitude towards education affect the availability, quality and desirability of education
- The stock of knowledge in society
  - Productivity of human capital formation

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  - Skill-intensity in production and its effect on the demand for human capital
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  - Return to investment in human capital (e.g., Malaria, Hookworm)
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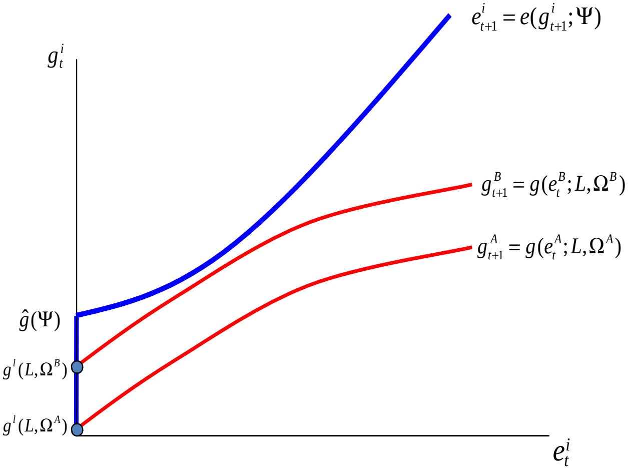
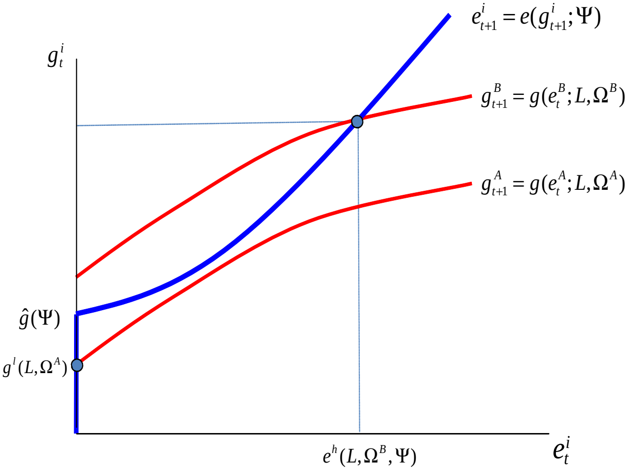
Variations in Characteristics that Stimulate Technological Progress



Earlier Take-off in Country B



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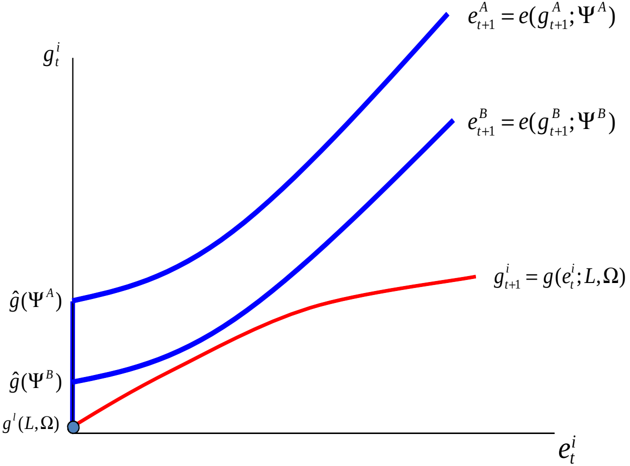

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