Unified Growth Theory and Comparative Economic Development

Oded Galor

AEA Continuing Education Program

Lecture II – AEA 2014

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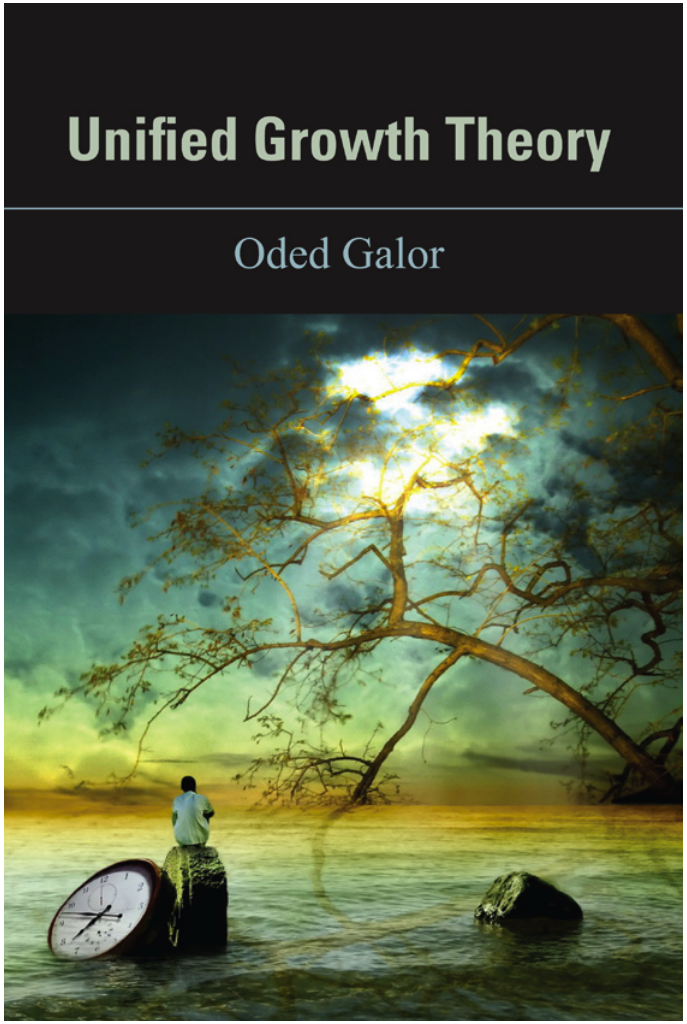
Unified Growth Theory



Fundamental Research Questions

- What is the origin of the vast inequality in income per capita across countries and regions?
- What accounts for the divergence in per-capita income across countries in the past two centuries?
- What are the factors that inhibited the convergence of poor economies toward richer ones in the past decades?
- What is the role of deep-rooted factors in explaining the observed patterns of comparative development?

Limitations of Non-Unified Growth Theory

- Inconsistent with the growth process over most of human history:
- Not designed to shed light on the:
  - Historical origins of vast and persistent inequality across countries
  - Forces that triggered the transition of DCs from stagnation to growth
  - Hurdles faced by LDCs in their take-off from stagnation to growth
  - Factors that hindered convergence across countries
  - Importance of deep-rooted factors in comparative development

Unified Growth Theory

- Captures the:
  - Process of development in its entirety
  - Forces that permitted DCs to transition from the Malthusian Epoch to sustained growth
  - Hurdles faced by LDCs in their transitions from stagnation to growth
  - Persistent effect of initial biogeographical factors on the growth process
- Encompasses:
  - existing hypotheses about the role of geographical, cultural, institutional and genetic factors in comparative development

The Fundamental Challenge

- A unified theory of economic growth that accounts for the:
  - Epoch of Malthusian stagnation
  - Take-off from the Malthusian Regime
  - Emergence of human capital as a significant factor in the growth process
  - Demographic transition
  - Shift to sustained economic growth
  - Emergence of inequality in income per capita across countries

Origins of the Phase Transition

- Design of a dynamical system that permits a phase transition:
  - Escape from a stable Malthusian equilibrium:
- Hypothetical mechanisms:
  - Shock in an economy with multiple stable equilibria
    - Inconsistent with a gradual increase in TFP growth
  - A gradual escape from an absorbing (stable) equilibrium
    - Contradiction to the essence of a stable equilibrium
  - Vanishing Malthusian equilibrium

Origins of the Phase Transition

- Evolution of a latent state variable – the demand for human capital
  - Ultimately changes the dynamical system qualitatively:
    - The Malthusian equilibrium vanishes endogenously
    - The economy gravitates towards the emerging Modern Growth Regime

Characteristics of the Main Transitions

- Transition from Malthusian to Post-Malthusian Regime:
  - Faster rates of technological progress
  - Faster rate of population growth
  - Insignificant investment in human capital
  - Growth of income per capita

- Transition from the Post-Malthusian to Modern Growth Regime:
  - Faster rate of technological progress
  - Faster rate of human capital accumulation
  - Decline in population growth
  - Faster growth of income per capita

Suggestive Evidence

- The underlying forces that govern these transitions:
  - The effect of changes in the technological environment on:
    - population size and quality
  - The effect of changes in the size and the quality of the population on:
    - the rate of technological progress

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

Factor Supply

- Land is fixed over time
  - 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

Main Elements

- The Malthusian Structure
- Sources of Technological Progress
- Origins of Human Capital Formation
- Triggers of the Demographic Transition

The Malthusian Structure

- A subsistence consumption constraint
- Positive effect of income on population
  - $y \uparrow \Longrightarrow L \uparrow$
- Fixed factor of production – Land
  - $L \uparrow \Longrightarrow AP_L \downarrow \Longrightarrow y \downarrow$
- Output per capita fluctuates (with a negligible trend) around a constant level in the long-run
  - Reflecting diminishing returns to labor & positive effect of income on population

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

$$y_t = h_t^{\alpha} x_t^{1-\alpha}$$

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

The Malthusian Structure – Effects of Technological Progress

- Very short-run (for a given population):
  - $A_t \uparrow \implies y_t \uparrow$ (above $\bar{y}$)
- Short-run (initial adjustment of population):
  - $y_t \uparrow \implies L_t \uparrow$
- Long-run (population reaches a new steady-state):
  - $L_t \uparrow \implies y \downarrow$ (back to $\bar{y}$)

Sources of Technological Progress

- Earlier stages of development
  - Population size positively affects technological progress:

$$L_t \uparrow \implies A_t \uparrow$$

  - Channels:
    - Supply of innovations
    - Demand for innovations
    - Diffusion of knowledge
    - Division of labor
    - Extent of trade

Sources of Technological Progress

- Later Stages of Development
  - Human capital positively affects technological progress

$$e_t \uparrow \quad \Longrightarrow \quad A_t \uparrow$$

    - Educated individuals have an advantage in adopting and advancing new technologies

Technological Progress

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

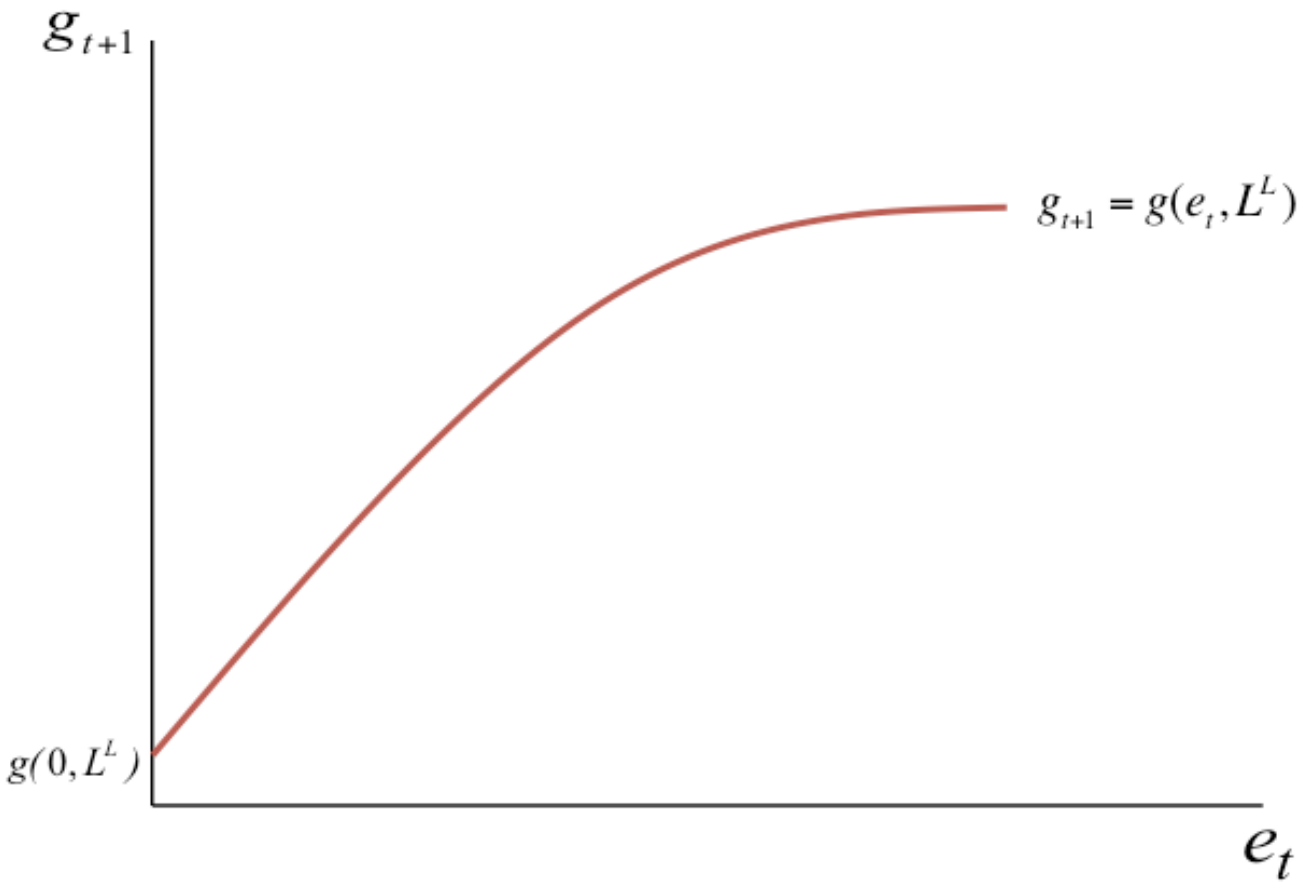
- $g_{t+1} \equiv$ rate of tech progress
- $e_t \equiv$ education
- $L_t \equiv$ population size

Technological Progress

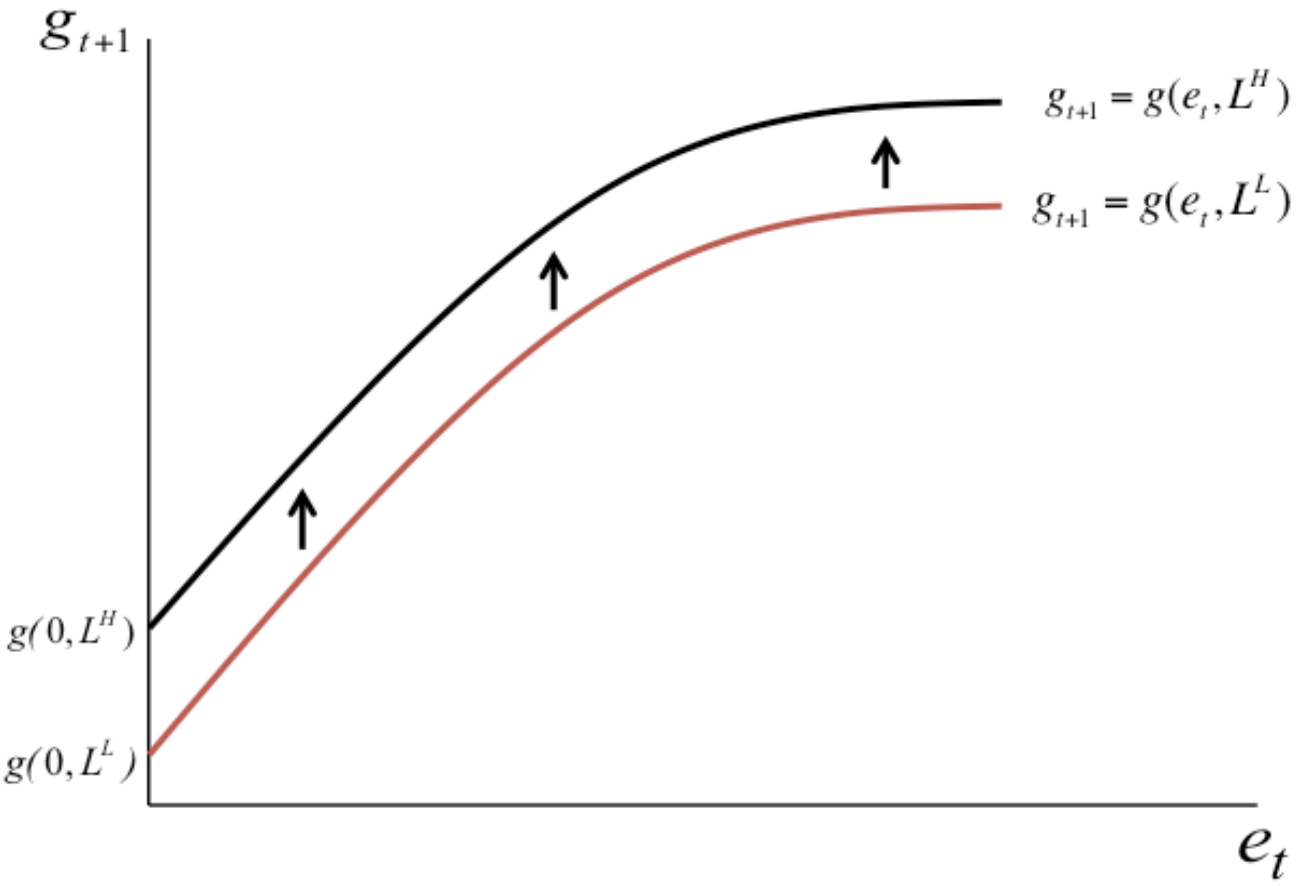
$$g_{t+1} = g(e_t, L_t)$$

- $g_e(e_t, L_t) > 0$ and $g_{ee}(e_t, L_t) < 0$
  - Education has a positive and diminishing effect of technological progress
- $g_L(e_t, L_t) > 0$ and $g_{LL}(e_t, L_t) < 0$
  - The scale of the economy has a positive and diminishing effect on technological progress
- $g(0, L) > 0$ for $L > 0$
  - Technological progress is positive at the outset

Technological Progress



The Effect of Population Size on Technological Progress



Origins of Human Capital Formation

- 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 can be skill-biased or skill-saving in the long run

Human Capital Formation

Human capital of an individual who joins the labor force in period $t+1$

$$h_{t+1} = h(e_{t+1}, g_{t+1})$$

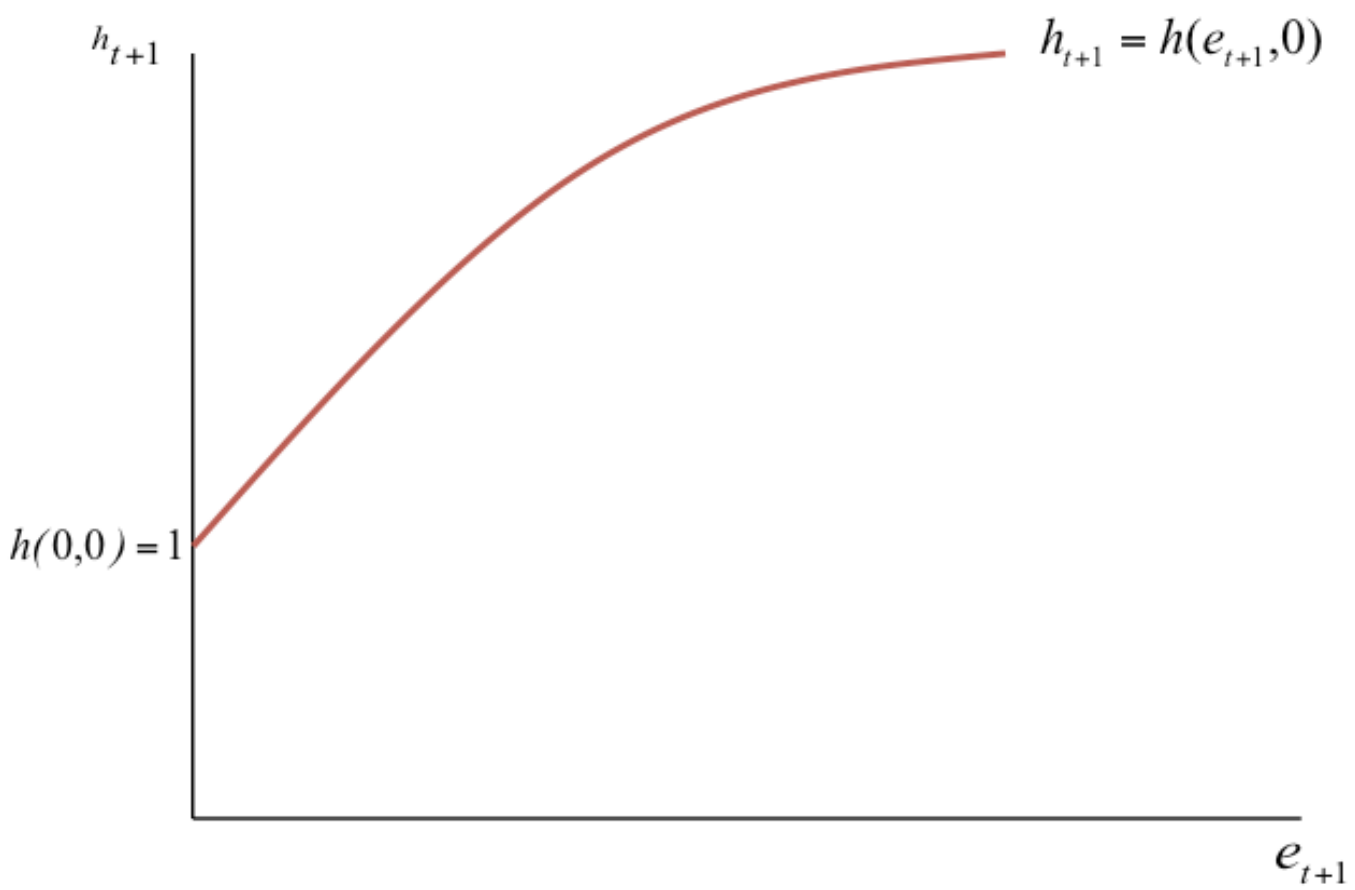
- $e_{t+1} \equiv$ the individual education level (determined by parental investment, subject to their subsistence constraint, in period t)
- $g_{t+1} \equiv$ rate of tech progress

Human Capital Formation

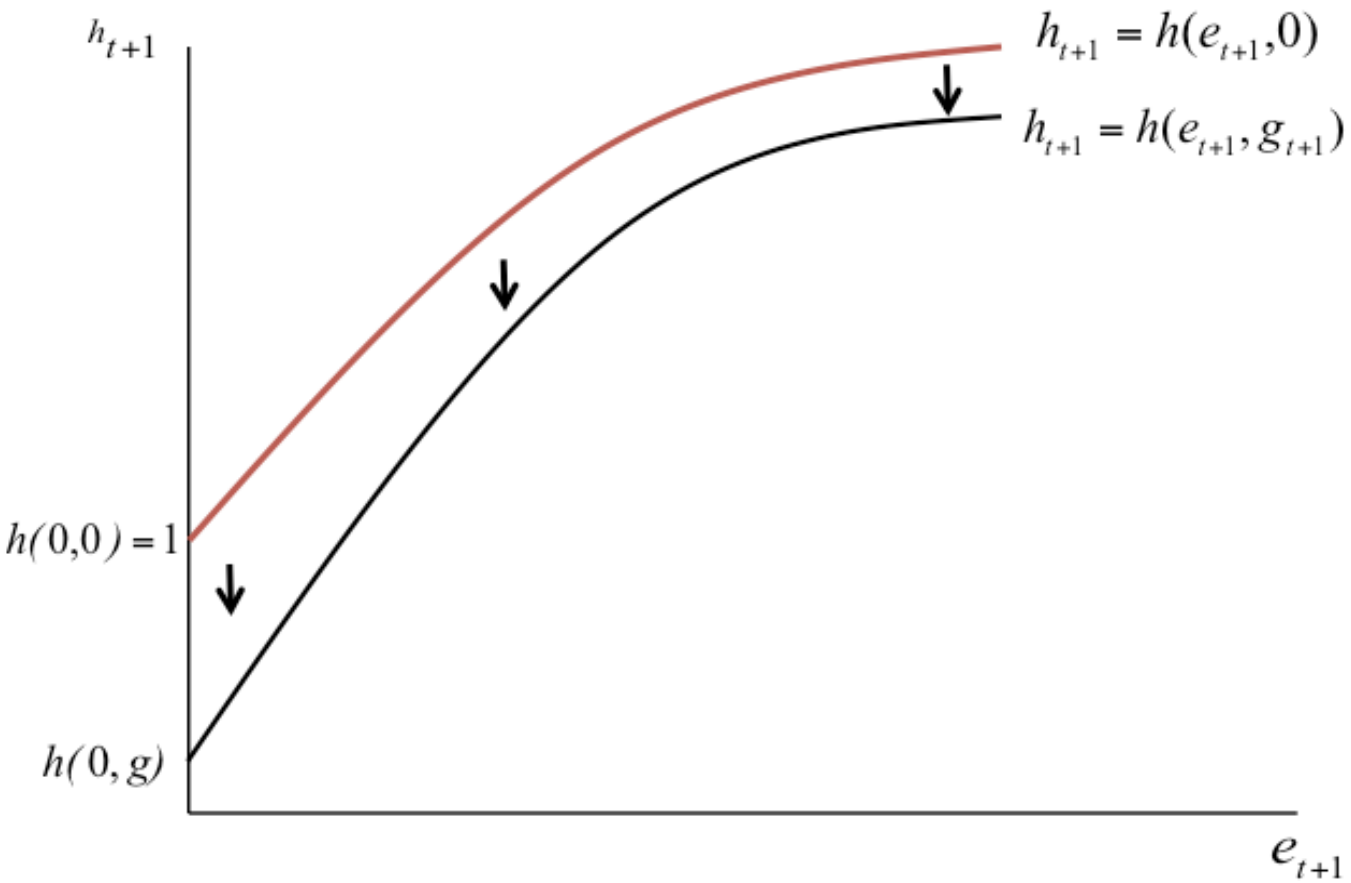
$$h_{t+1} = h(e_{t+1}, g_{t+1})$$

- $h_e(e,g) > 0$ and $h_{ee}(e,g) < 0$
  - HC is increasing (in decreasing rates) in the parental time investment in the education of the child
- $h_g(e,g) < 0$ and $h_{gg}(e,g) > 0$
  - Obsolescence of HC in a changing technological environment
- $h_{eg}(e,g) > 0$
  - Education lessens the obsolescence of HC in a changing technological environment
- $h(0,g) > 0$
  - Basic level of human capital

Human Capital Formation



Human Capital Formation



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
    - Return to investment in child quality increases

Triggers of the Demographic Transition

- Early part of the second phase of industrialization:
  - The income effect dominates (moderate demand for human capital):
    - Population growth & human capital formation increase:
- Later part of the second phase of industrialization:
  - The substitution effect dominates (significant demand for human capital):
    - Population growth declines & human capital formation increases further

Individuals

- Live for 2 periods
- Childhood (1st Period):
  - Consume a fraction of parental time endowment
  - The required time increases with child 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):
  - Allocate the time endowment between childrearing and work
  - Choose the optimal mixture of child quantity and quality
  - Consume

Preferences

- The utility function of individual t (adult at time t)

$$u^t = (1-\gamma)\ln(c_t) + \gamma \ln(n_t h_{t+1})$$

  - $c_t \equiv$ consumption of individual t
  - $n_t \equiv$ number of children of individual t
  - $h_{t+1} \equiv$ level of human capital of each child

Budget and Subsistence Consumption Constraints

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

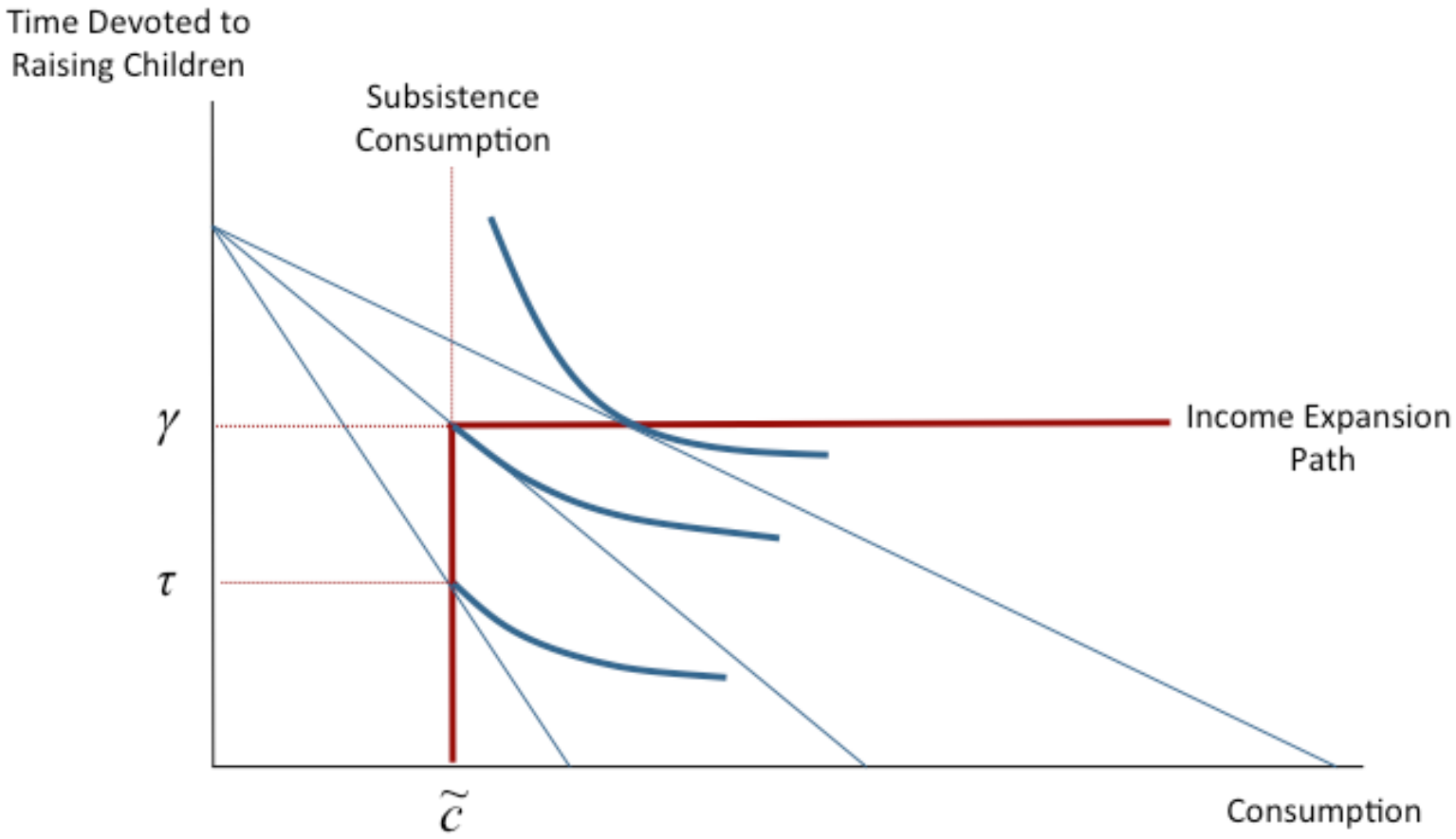
- $z_t \equiv$ potential income of individual t
- $\tau \equiv$ time required to raise a child, regardless of quality
- $\tau + e_{t+1} \equiv$ time needed to raise a child with education e_{t+1}

$$z_t \equiv y_t = h_t^{\alpha} x_t^{1-\alpha} = z(e_t, g_t, x_t)$$

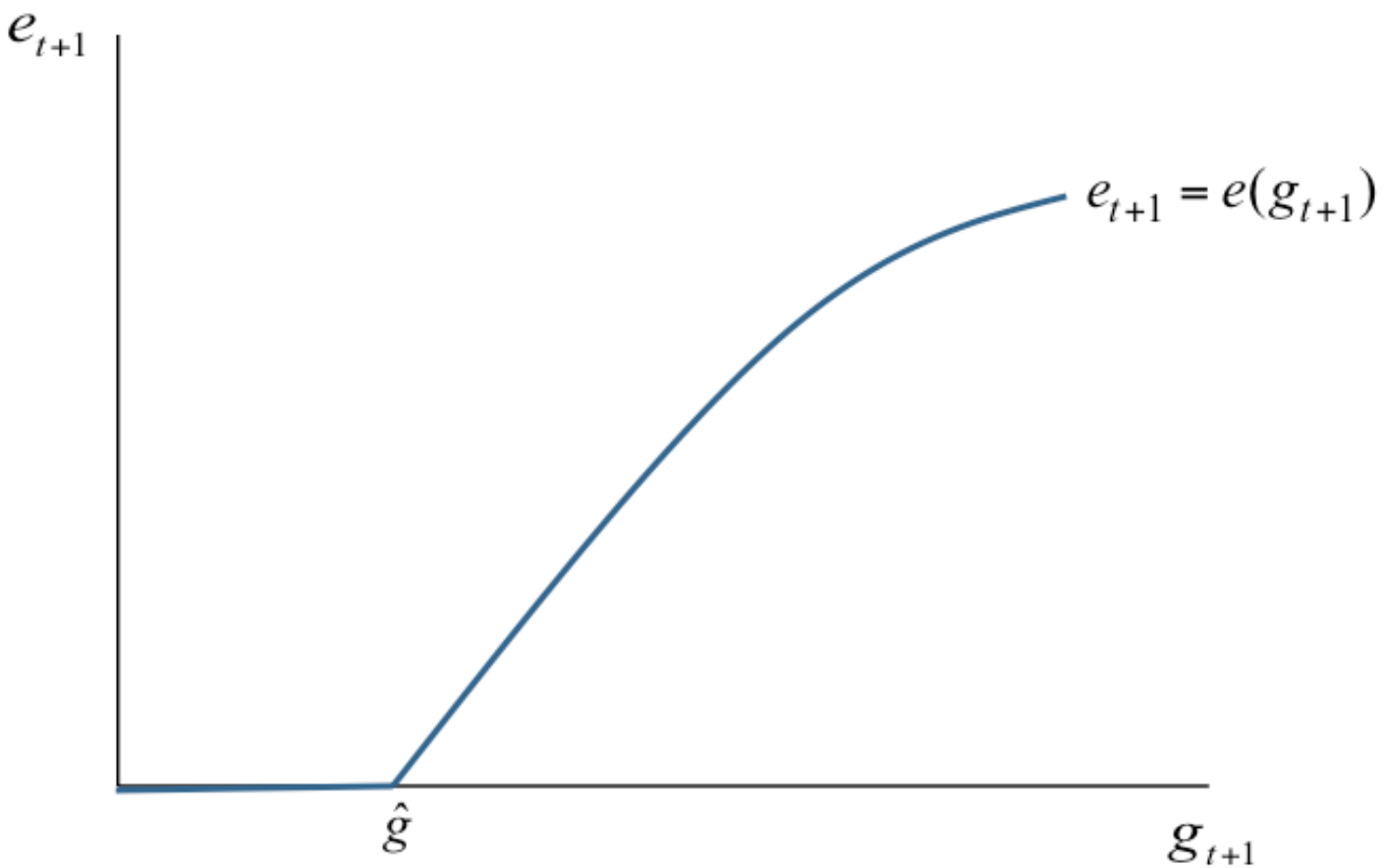
- Subsistence consumption constraint:

$$c_t \geq \tilde{c}$$

Constraint and Optimization



Optimal Investment in Child Quality



Optimization: Quantity and Quality of Children

- Time devoted to children:

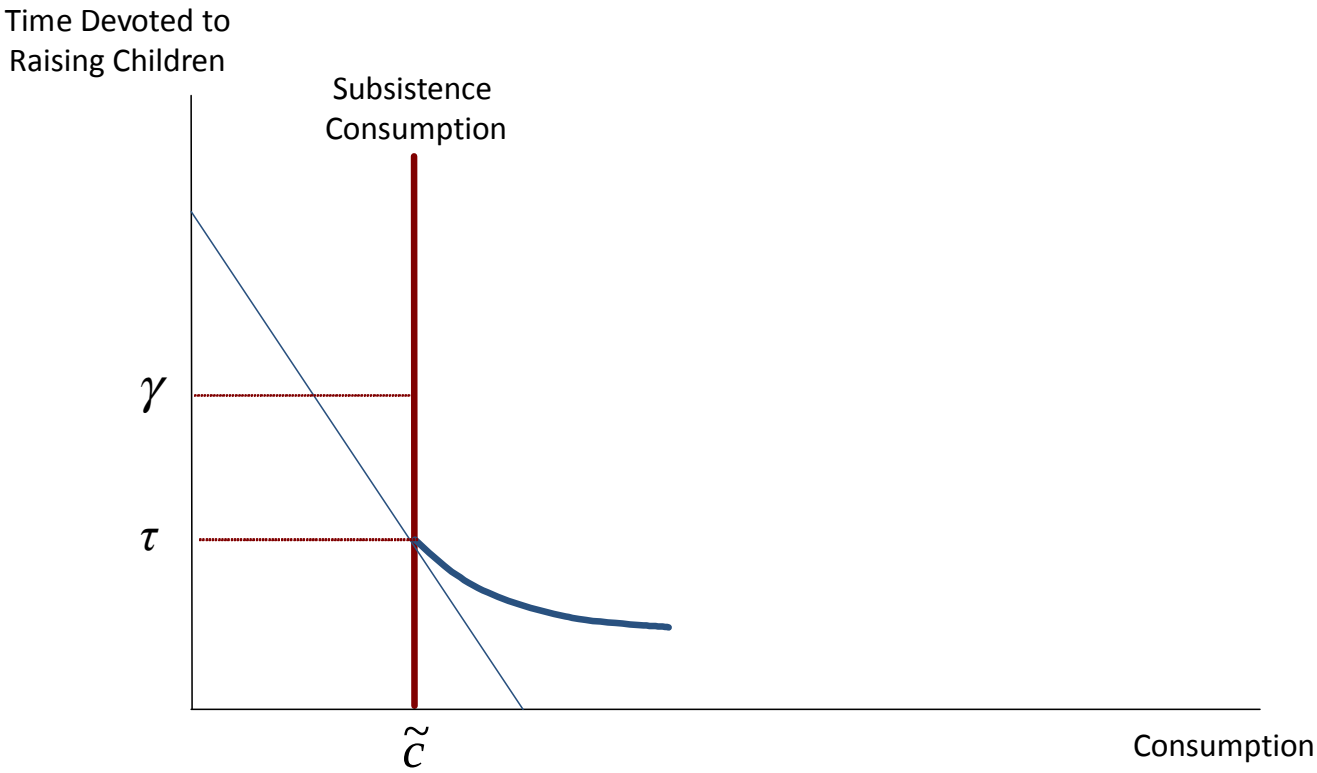
$$n_t(\tau + e_{t+1}) = \begin{cases} \gamma & \text{if} \quad z_t \geq \tilde{z} \\ 1 - \frac{\tilde{c}}{z_t} & \text{if} \quad z_t \leq \tilde{z} \end{cases}$$

- $z_t = \tilde{z}$ is the highest level of potential income such that the subsistence constraint is still binding

$$e_{t+1} = e(g_{t+1}) \implies$$

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

Optimization – Malthusian Epoch



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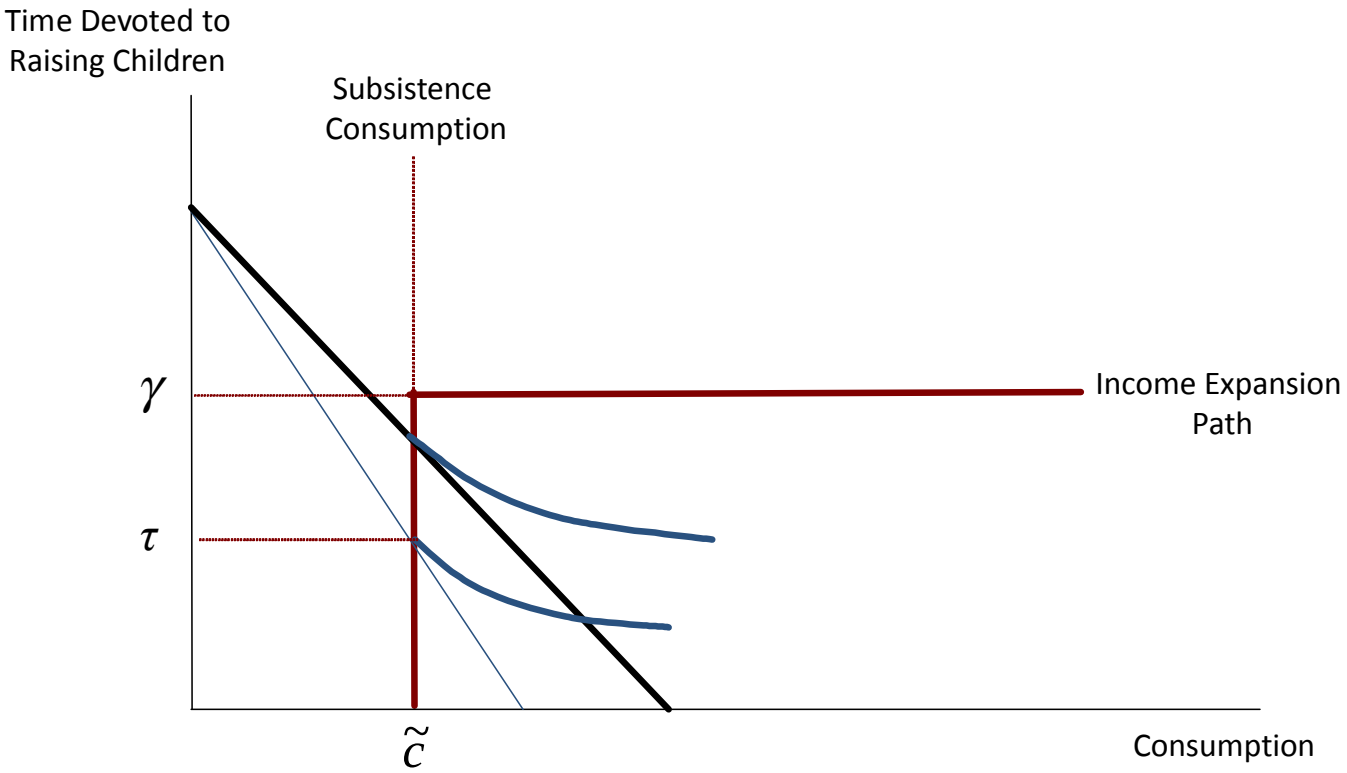

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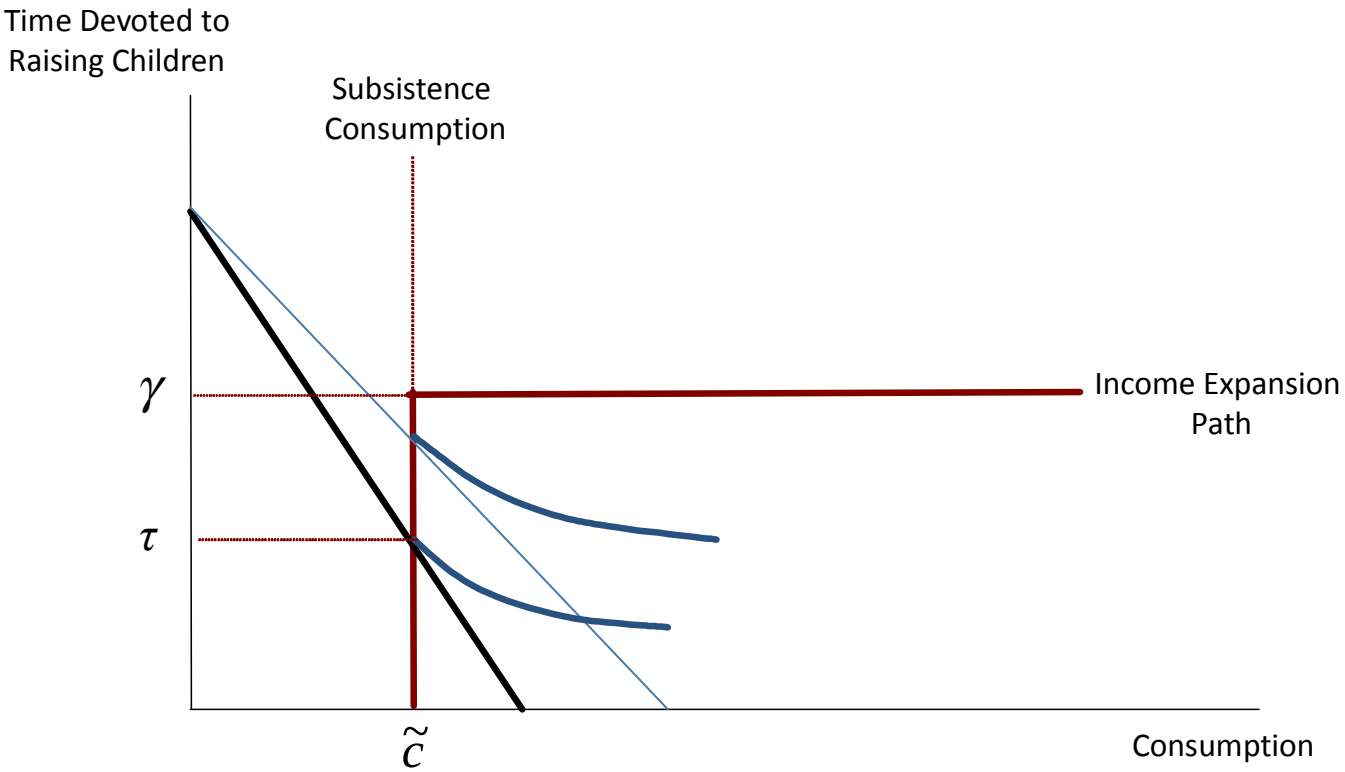

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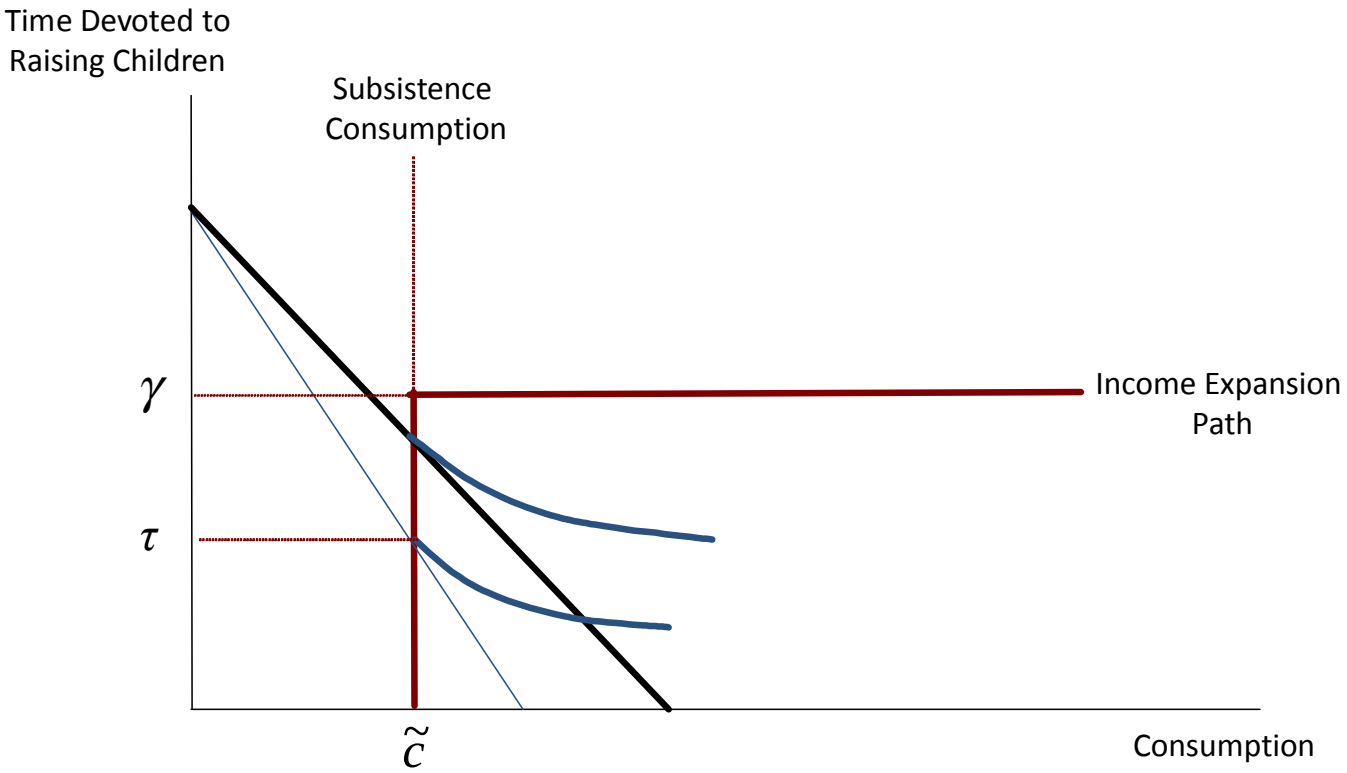

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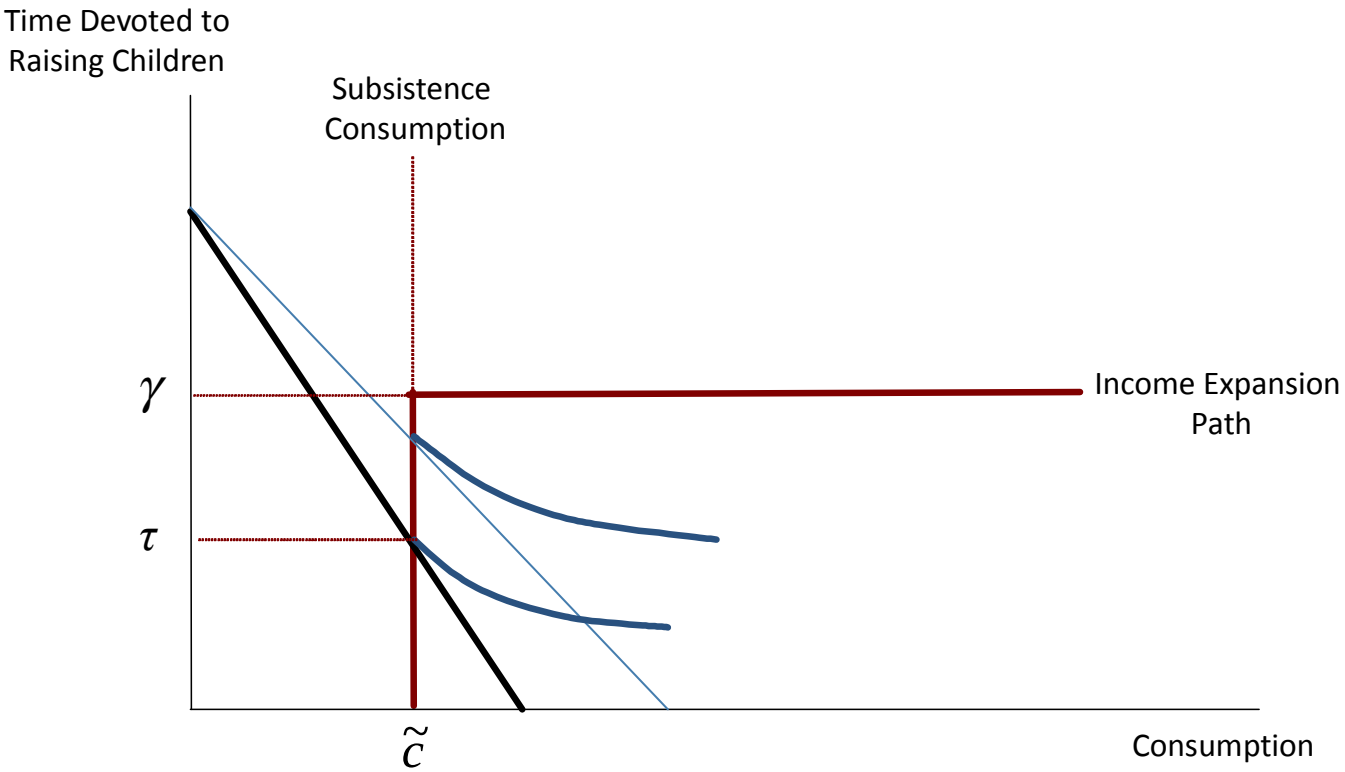
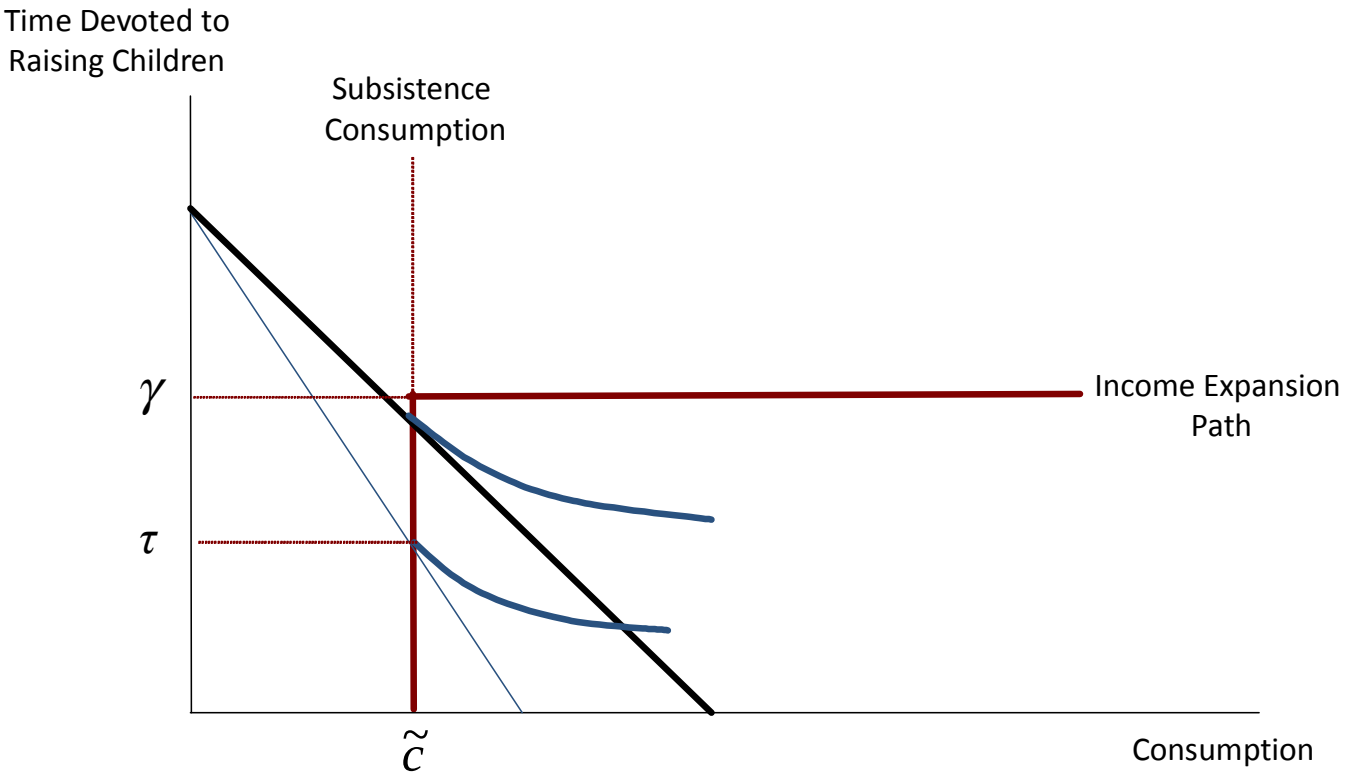
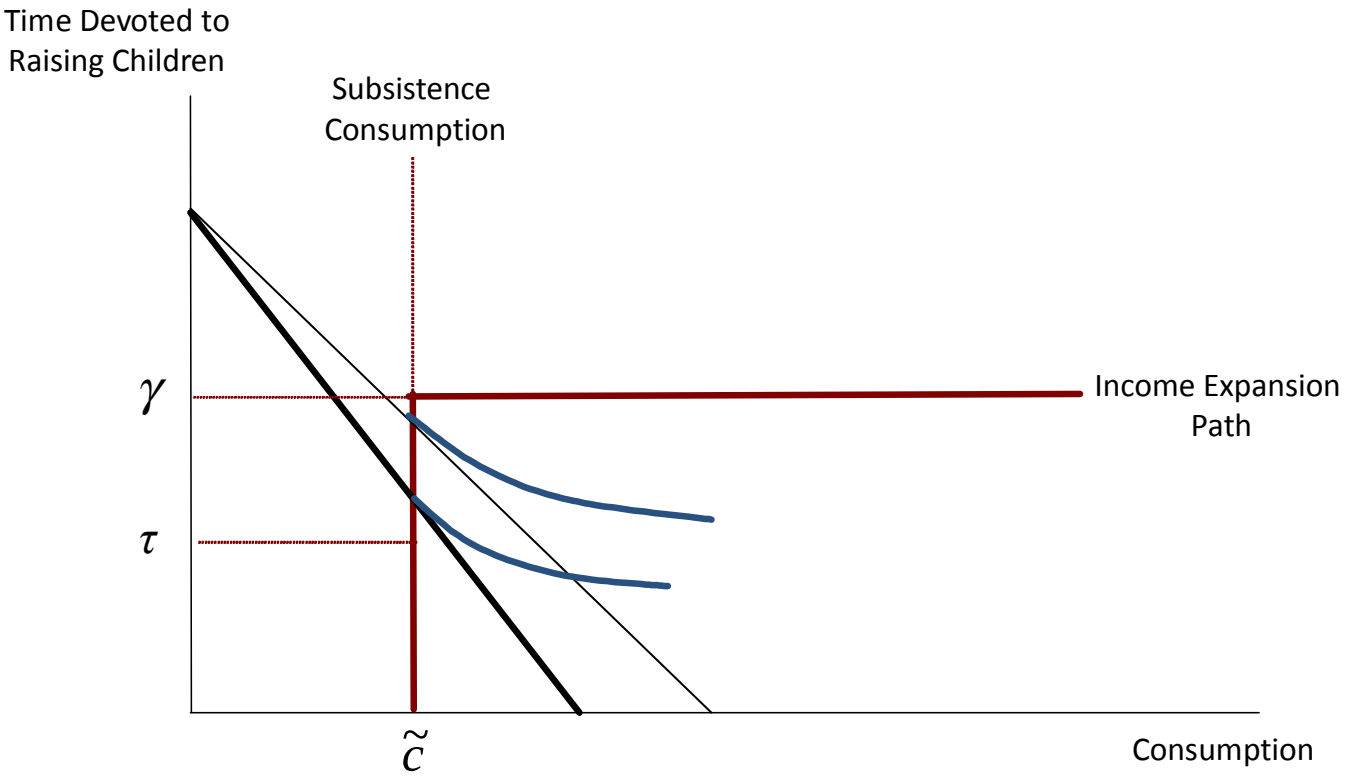


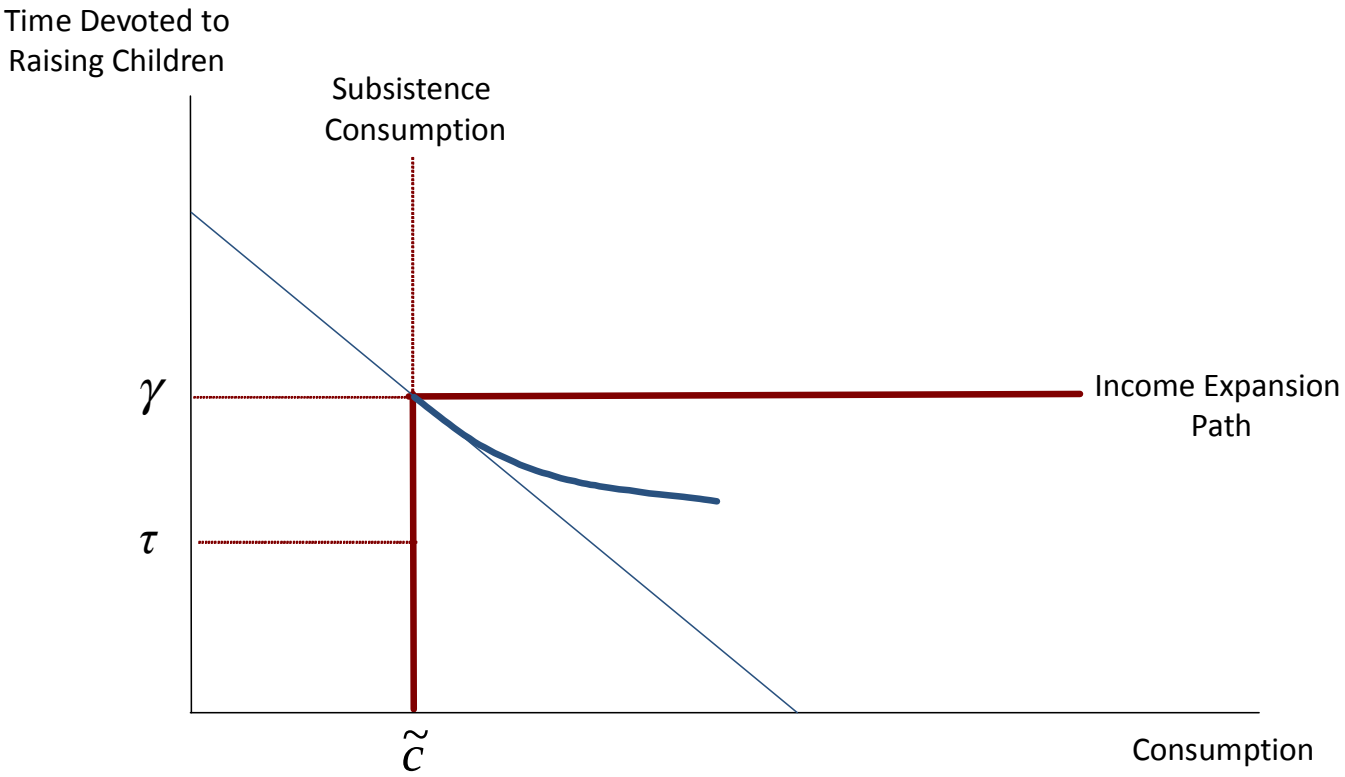
Income Expansion Path – Malthusian Epoch



Income Expansion Path – Malthusian Epoch



Income Expansion Path – Post-Demographic Transition



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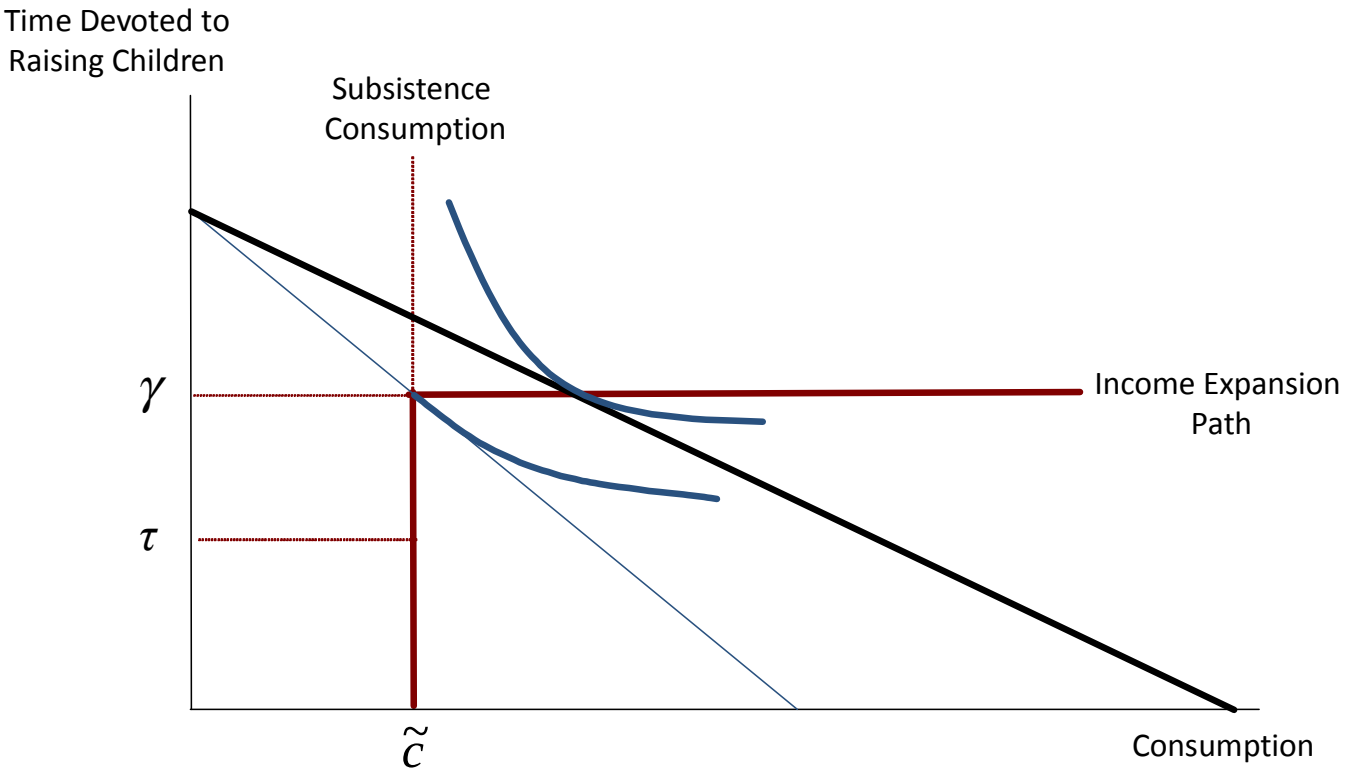


Population Dynamics

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

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

Dynamics of the Level of Resources per Worker

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

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

The Dynamical System

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

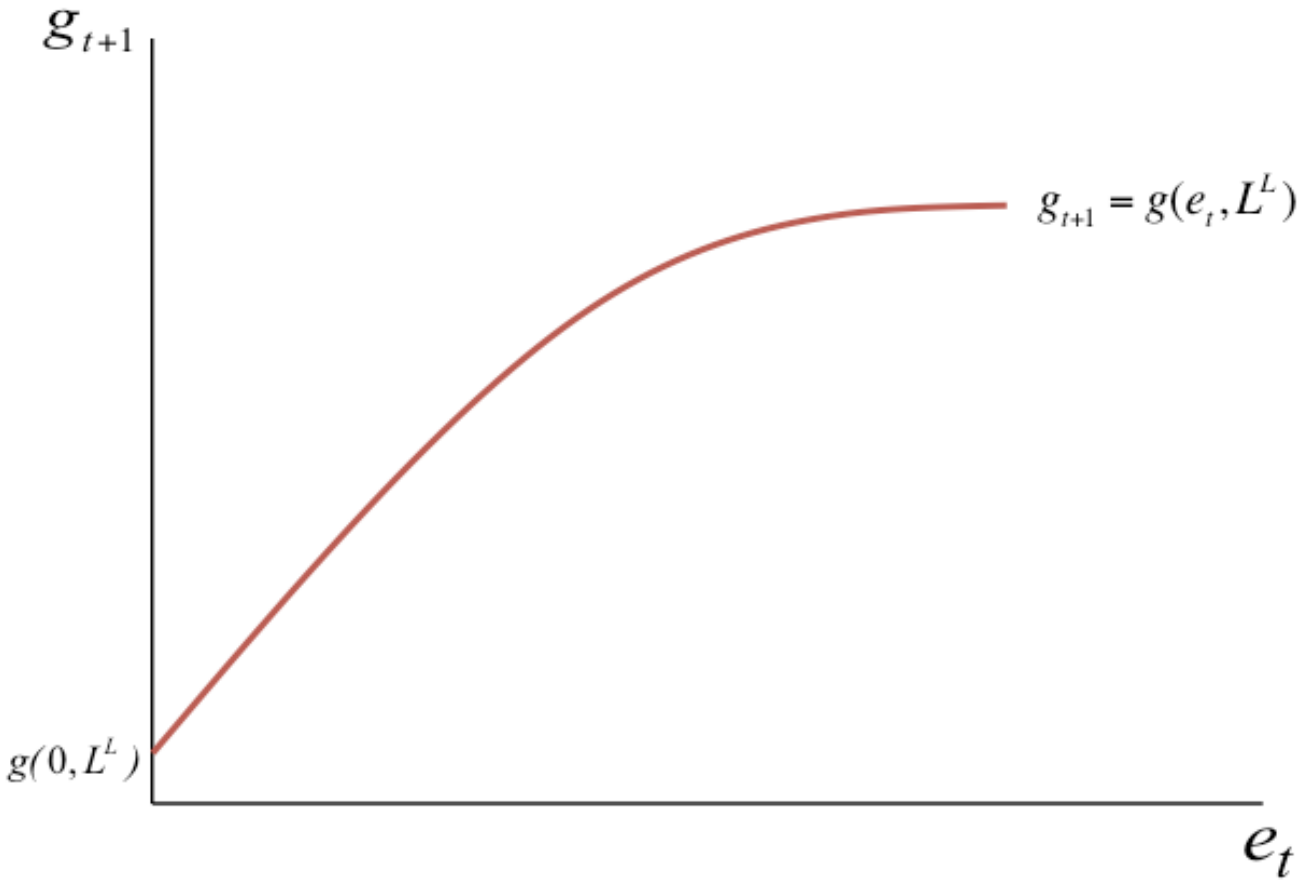
$$\begin{cases} x_{t+1} = \phi(e_t, g_t, x_t, L_t)x_t \\ e_{t+1} = e(g(e_t, L_t)) \\ g_{t+1} = g(e_t, L_t) \\ L_{t+1} = n(e_t, g_t, x_t, L_t)L_t \end{cases}$$

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 Effect of Education on Technology



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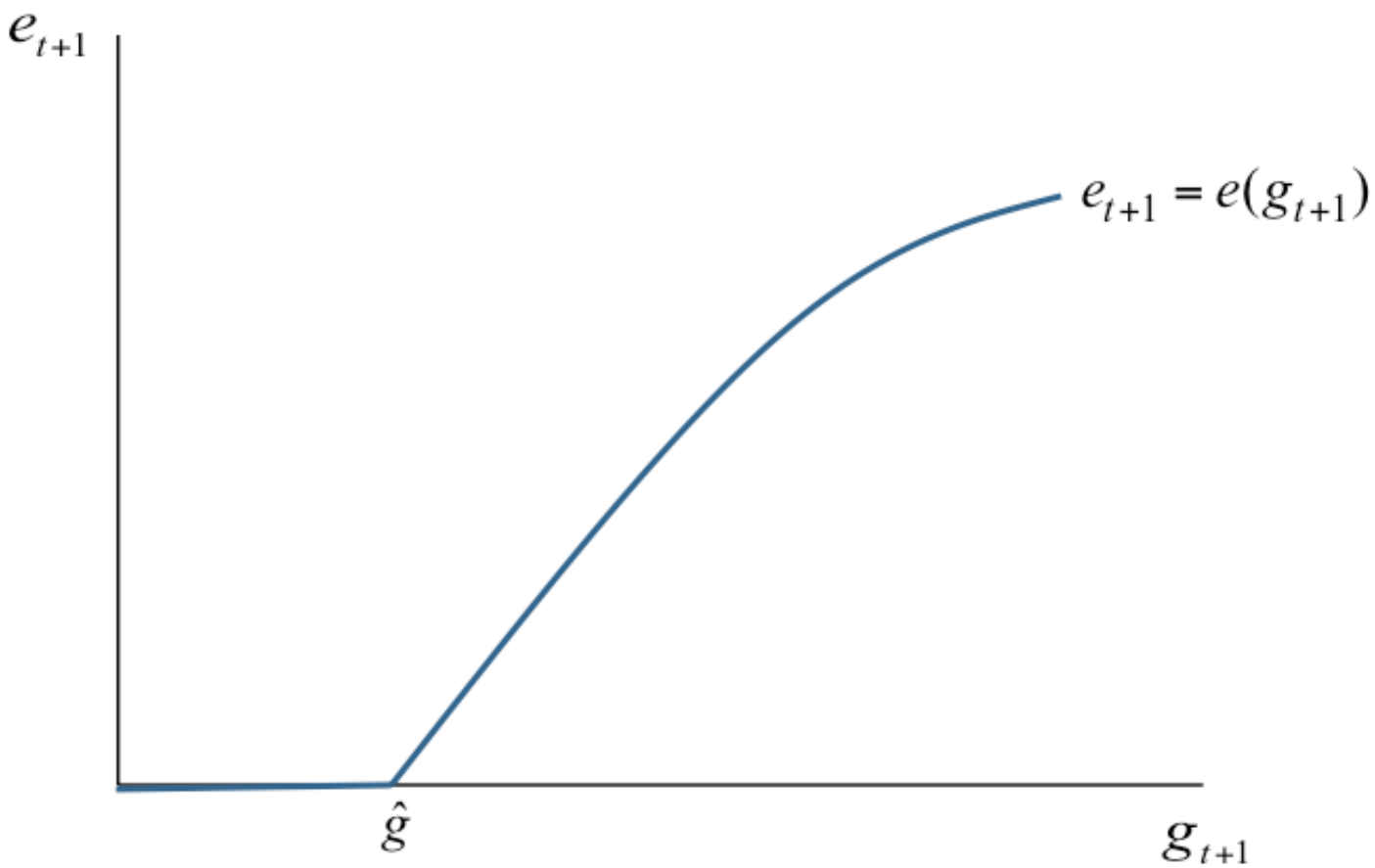
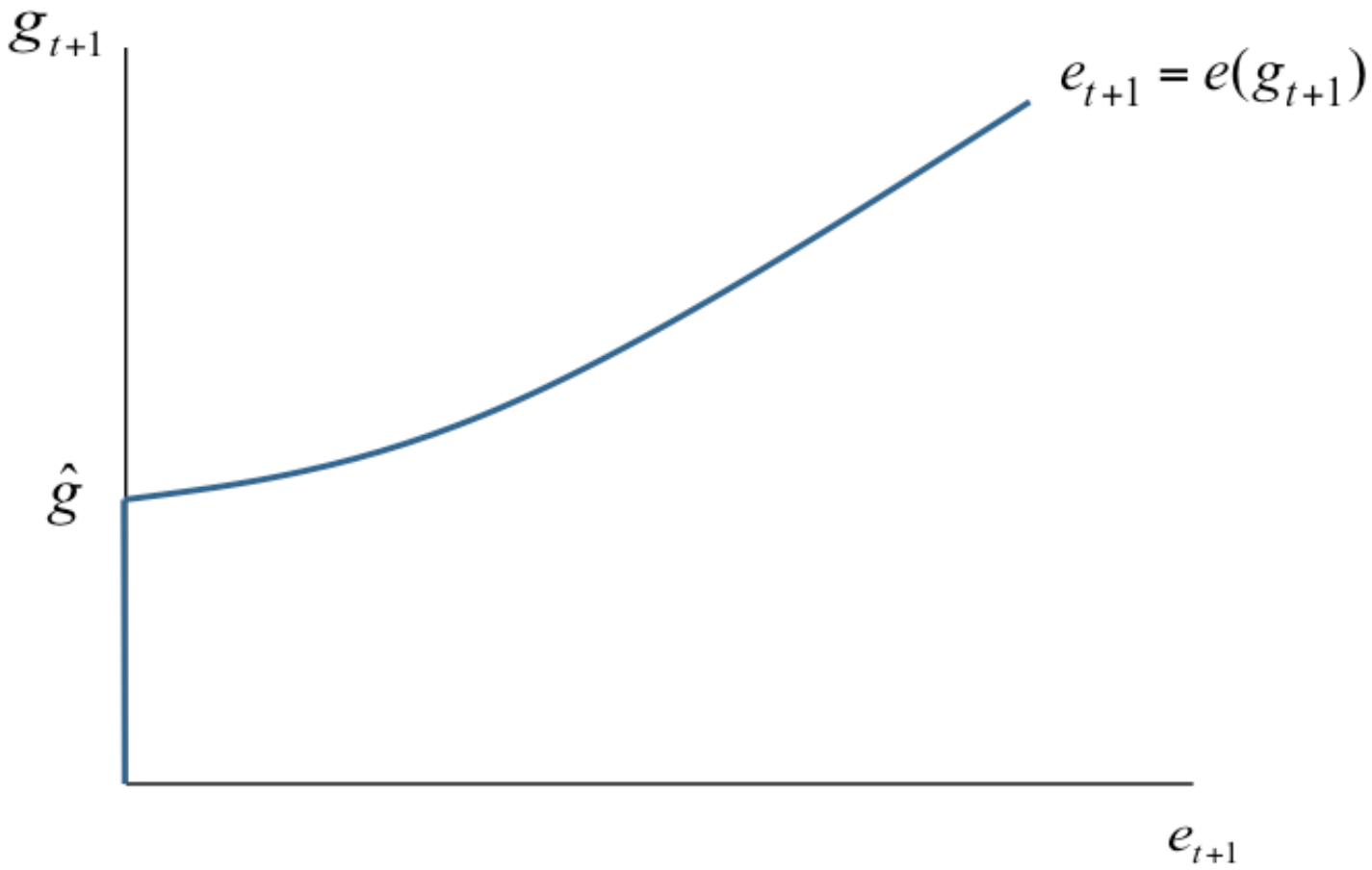
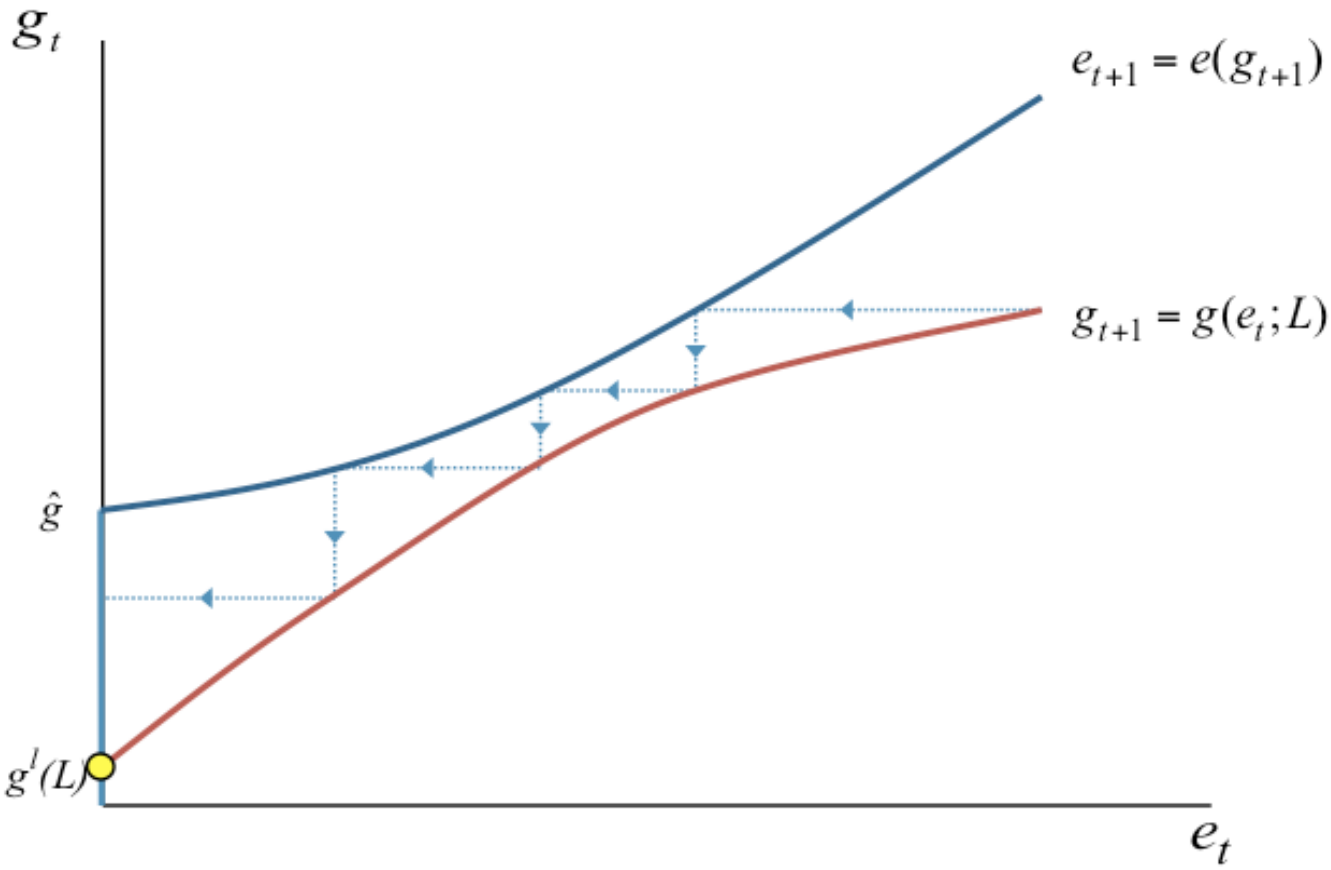


The Effect of Technology on Education: Flipped Axis



The Evolution of Education and Technology: For a Given Population Size



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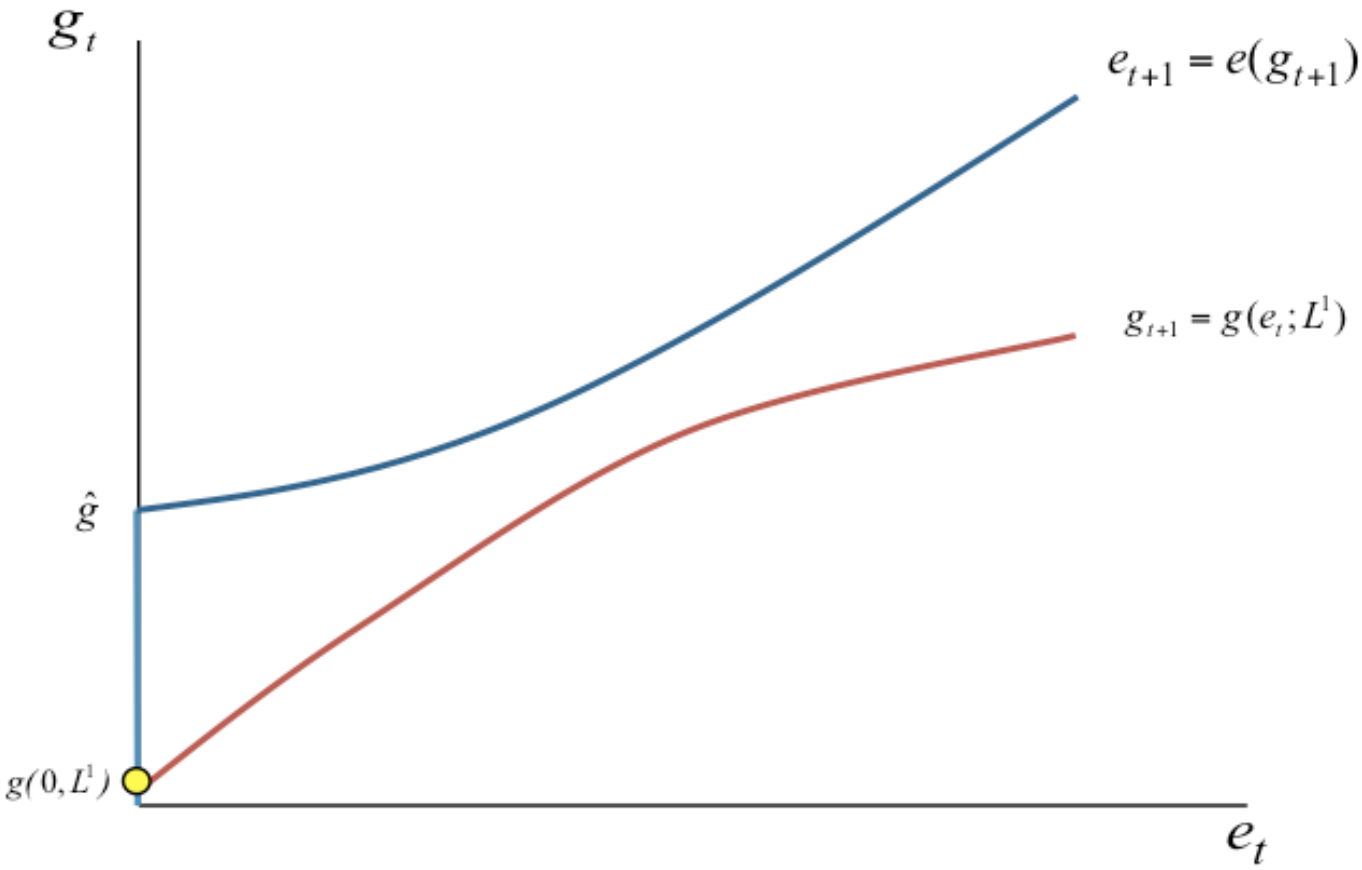

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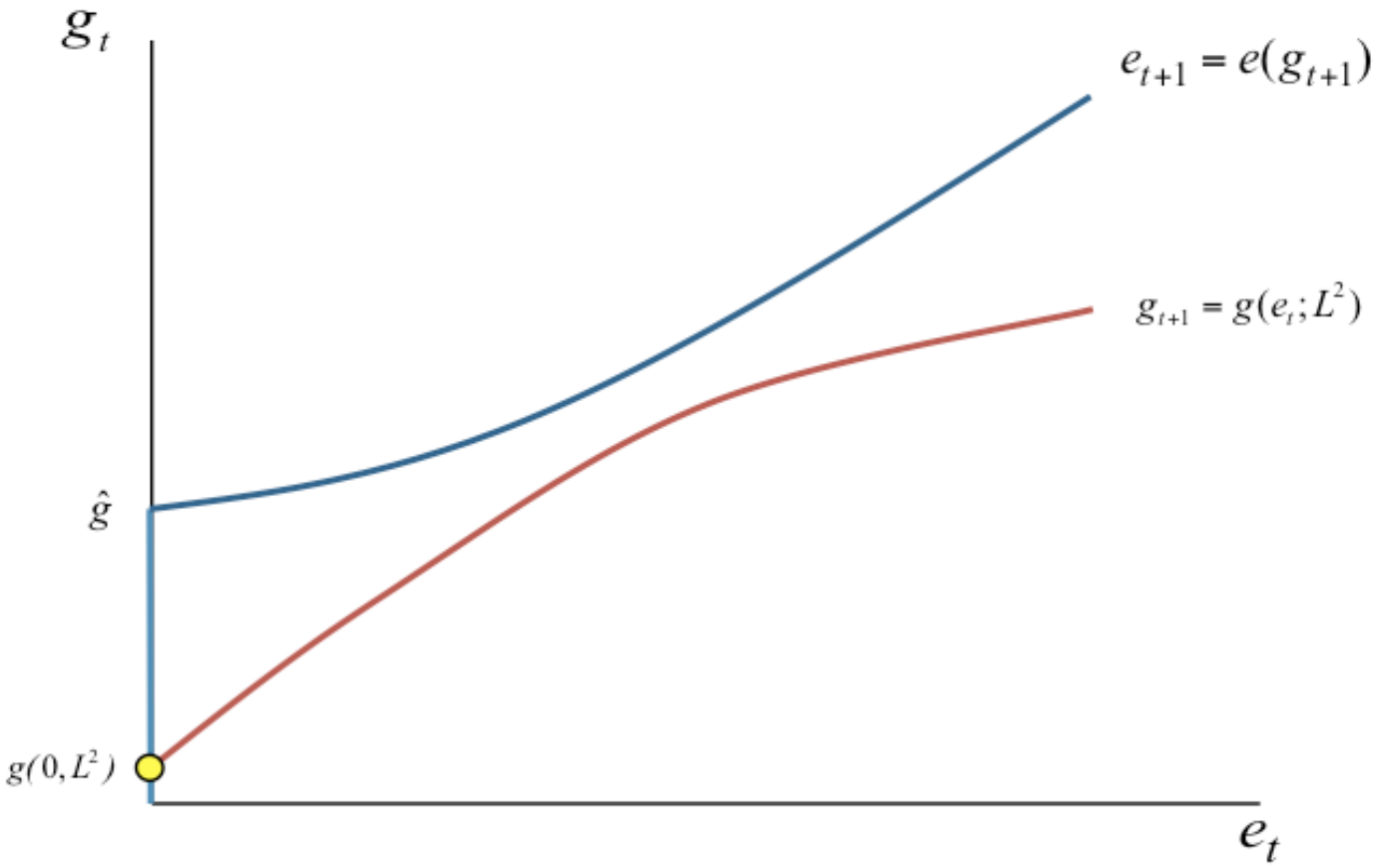

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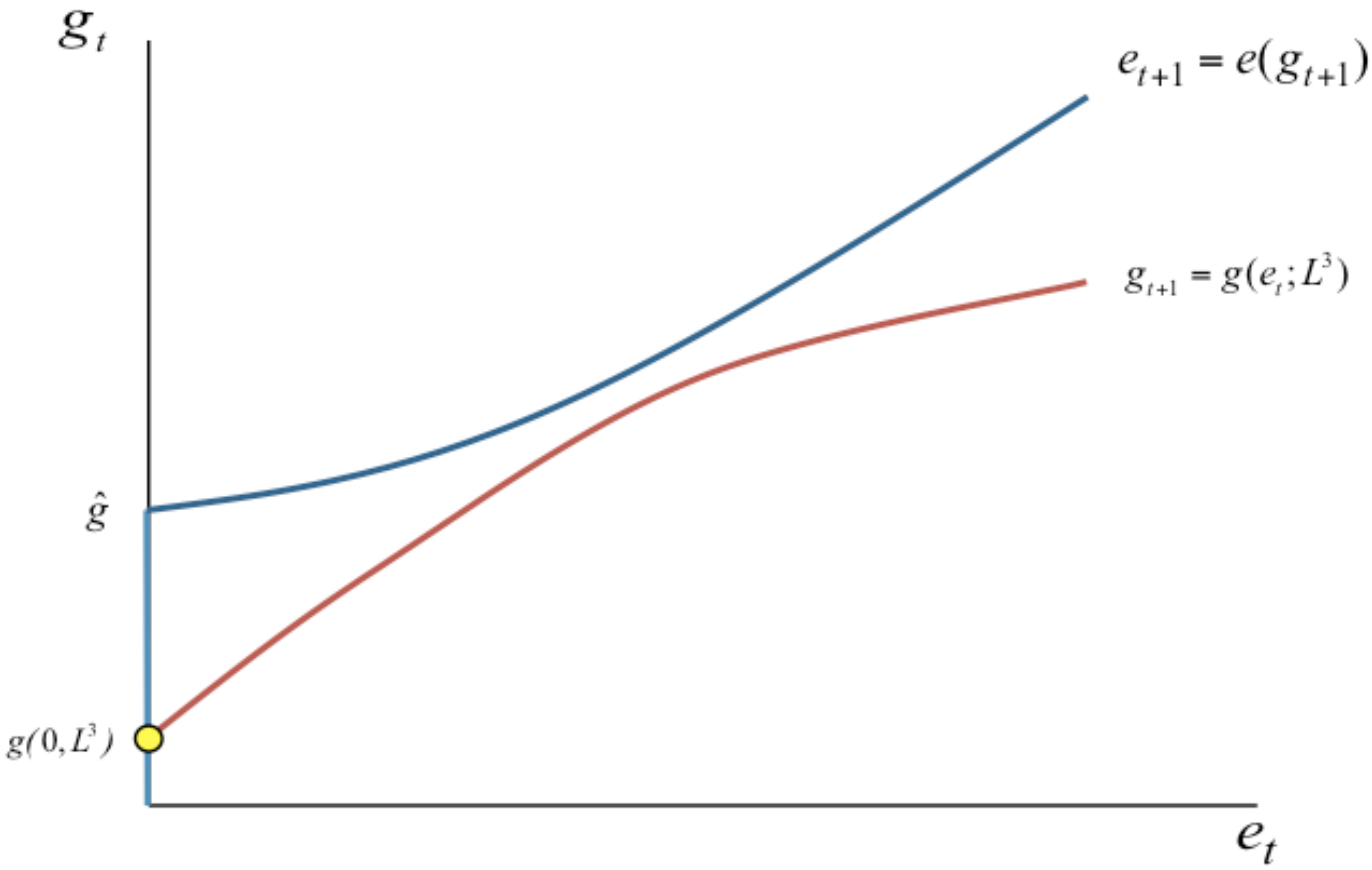

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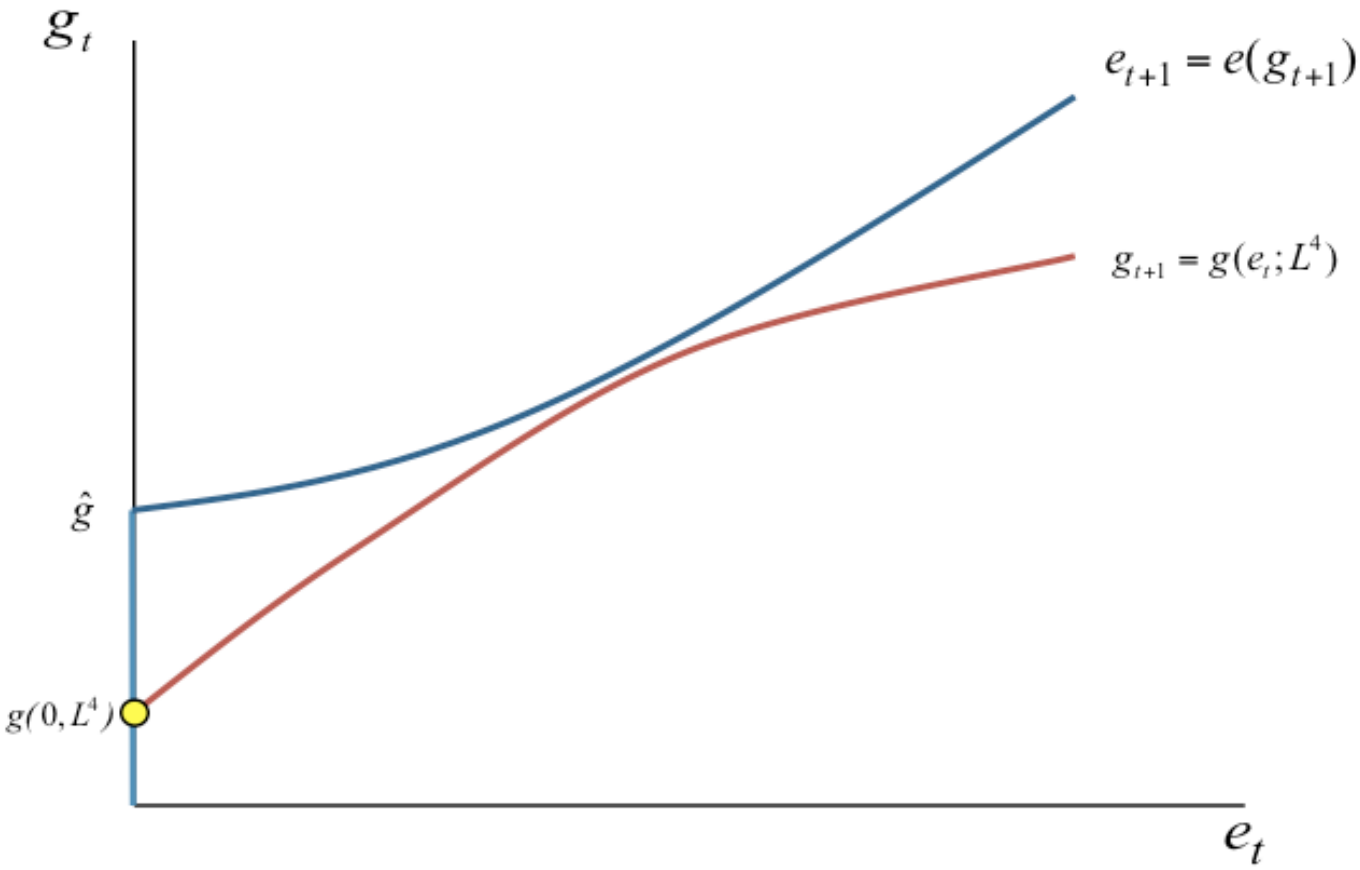

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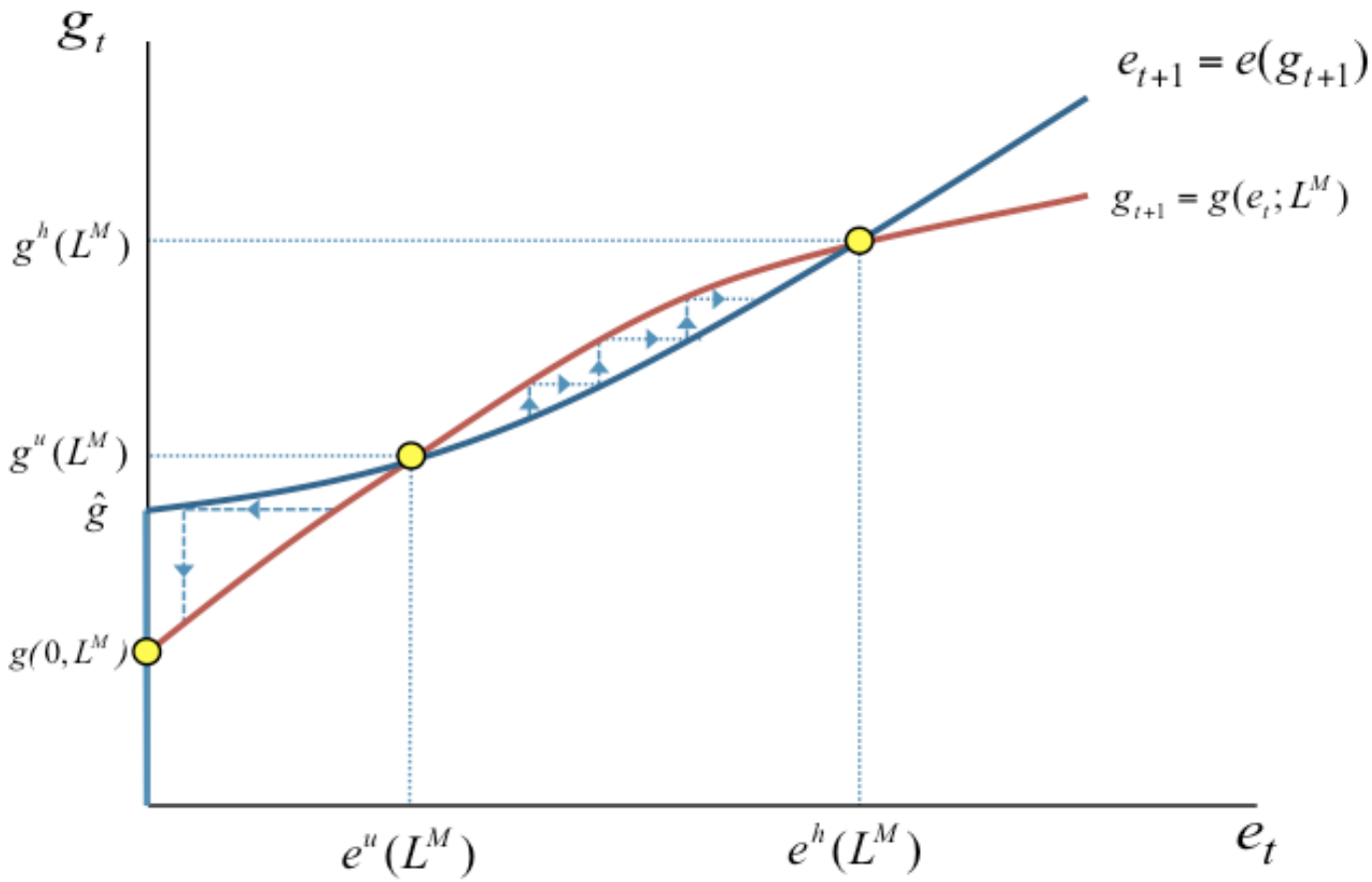
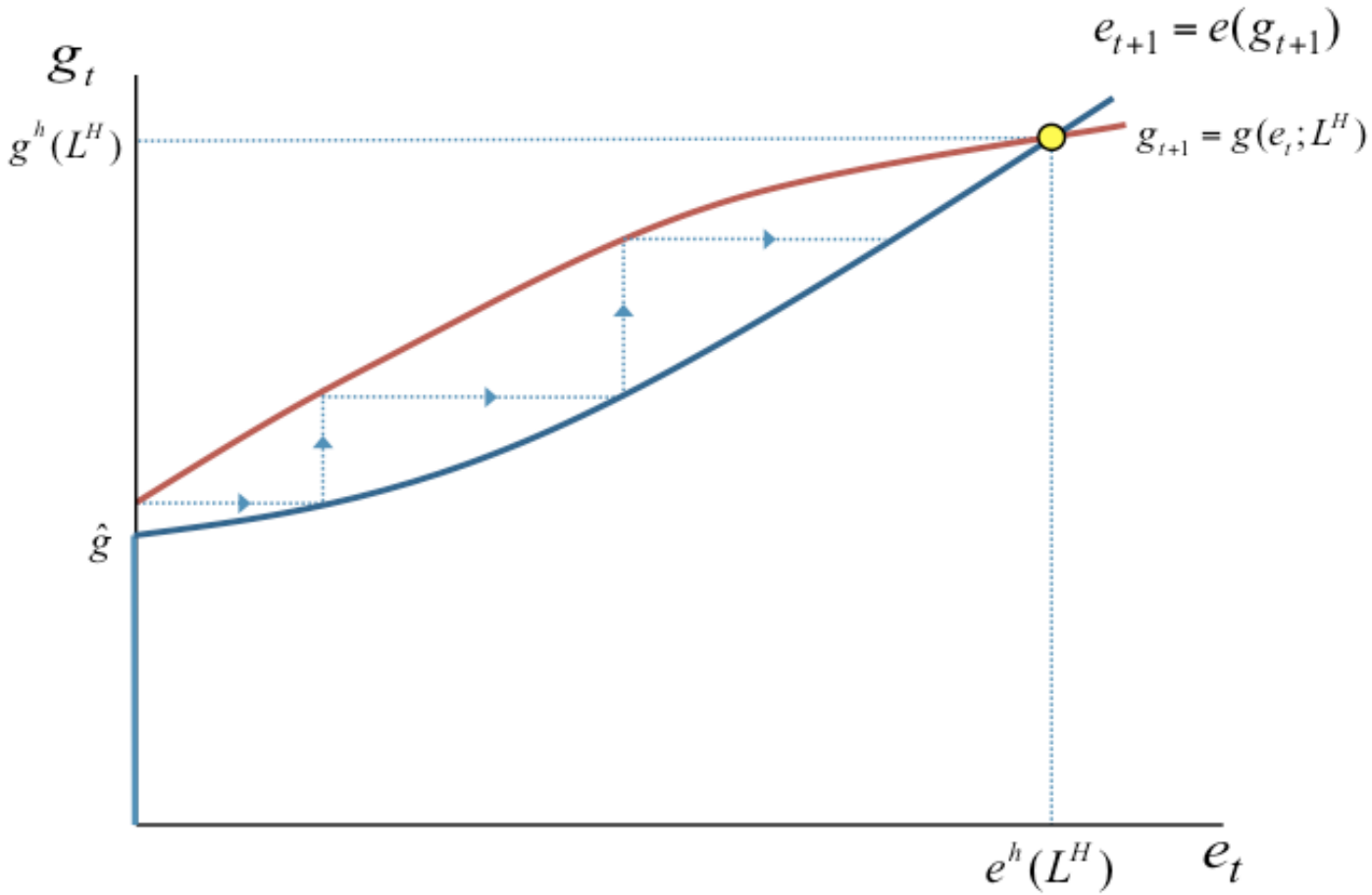
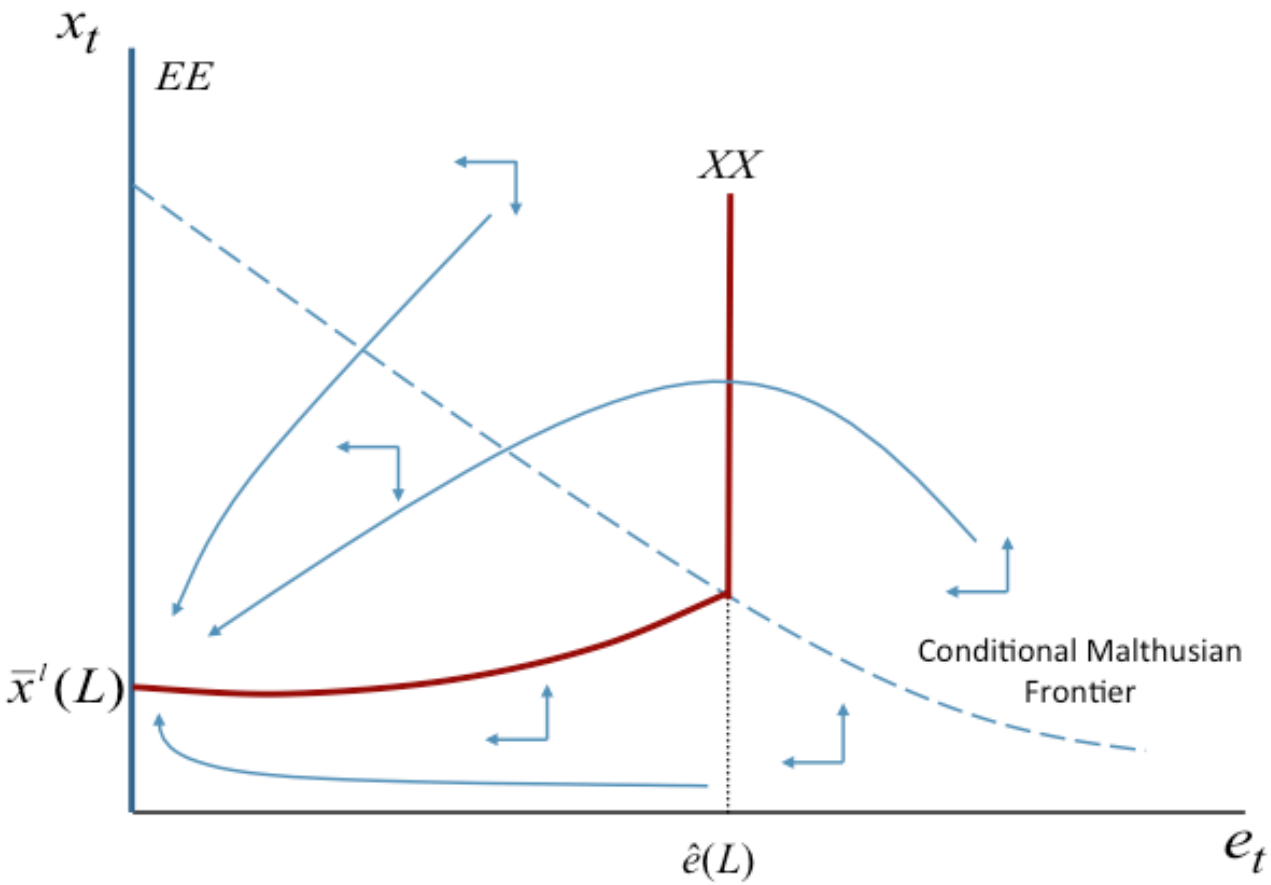


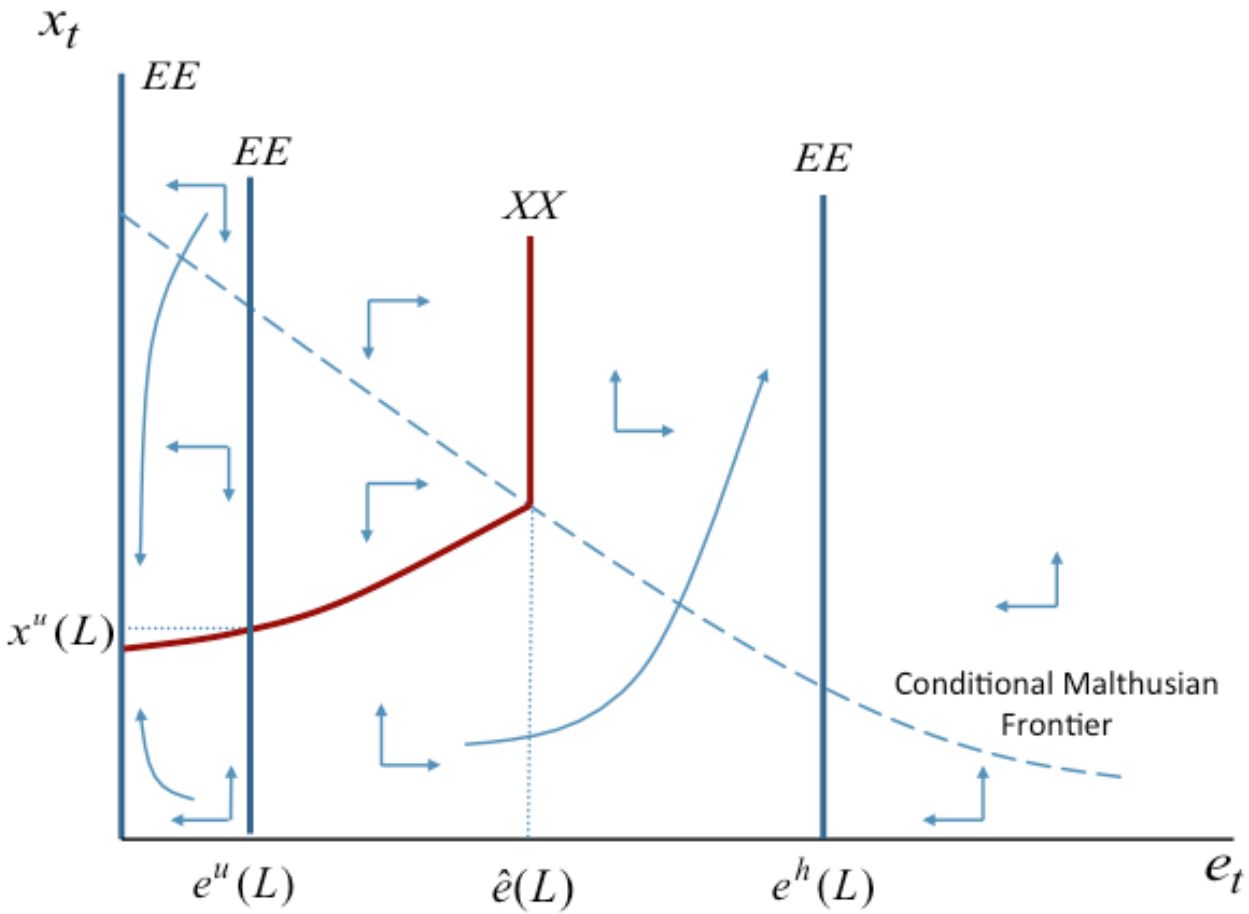
The Evolution of Education and Technology



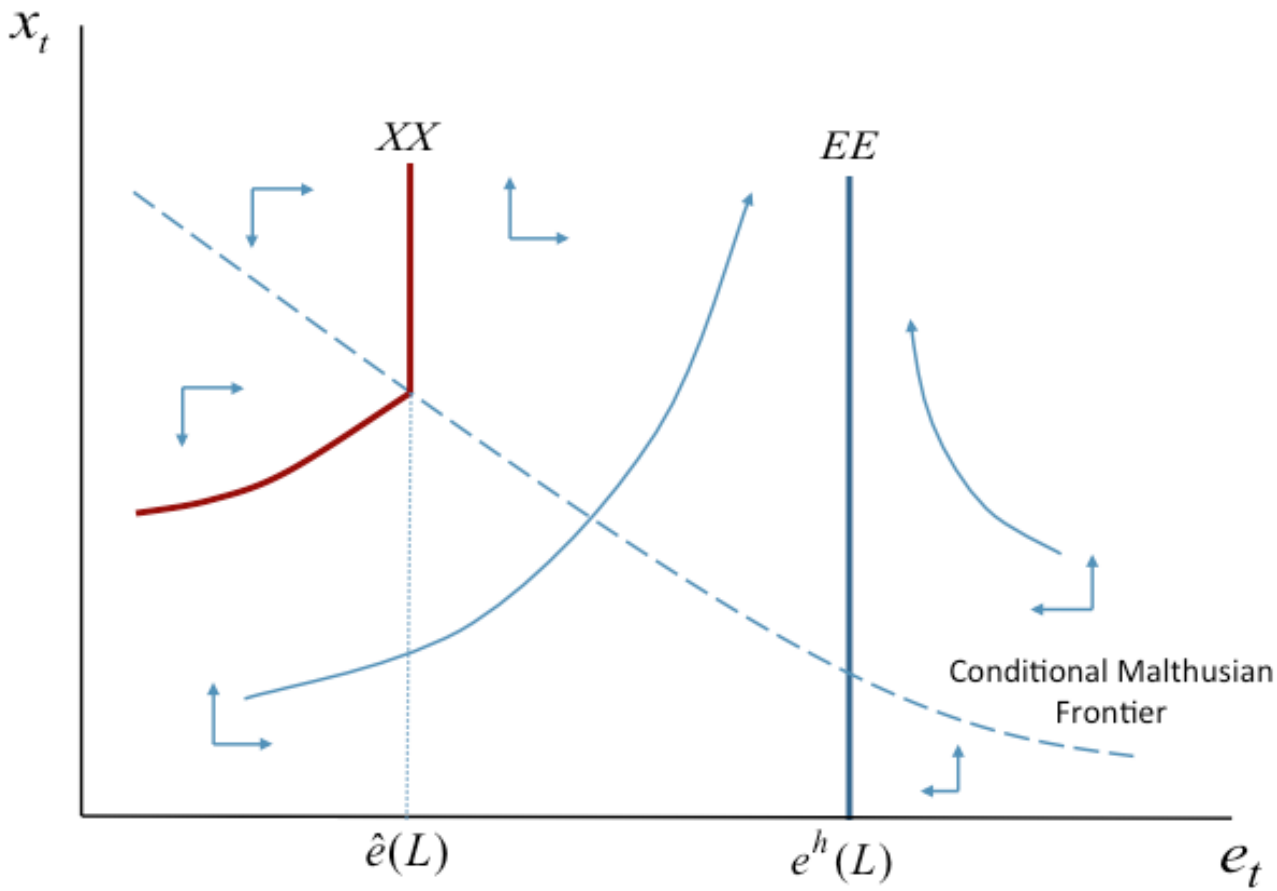
The Evolution of Education and Resources Per Worker: Small Population



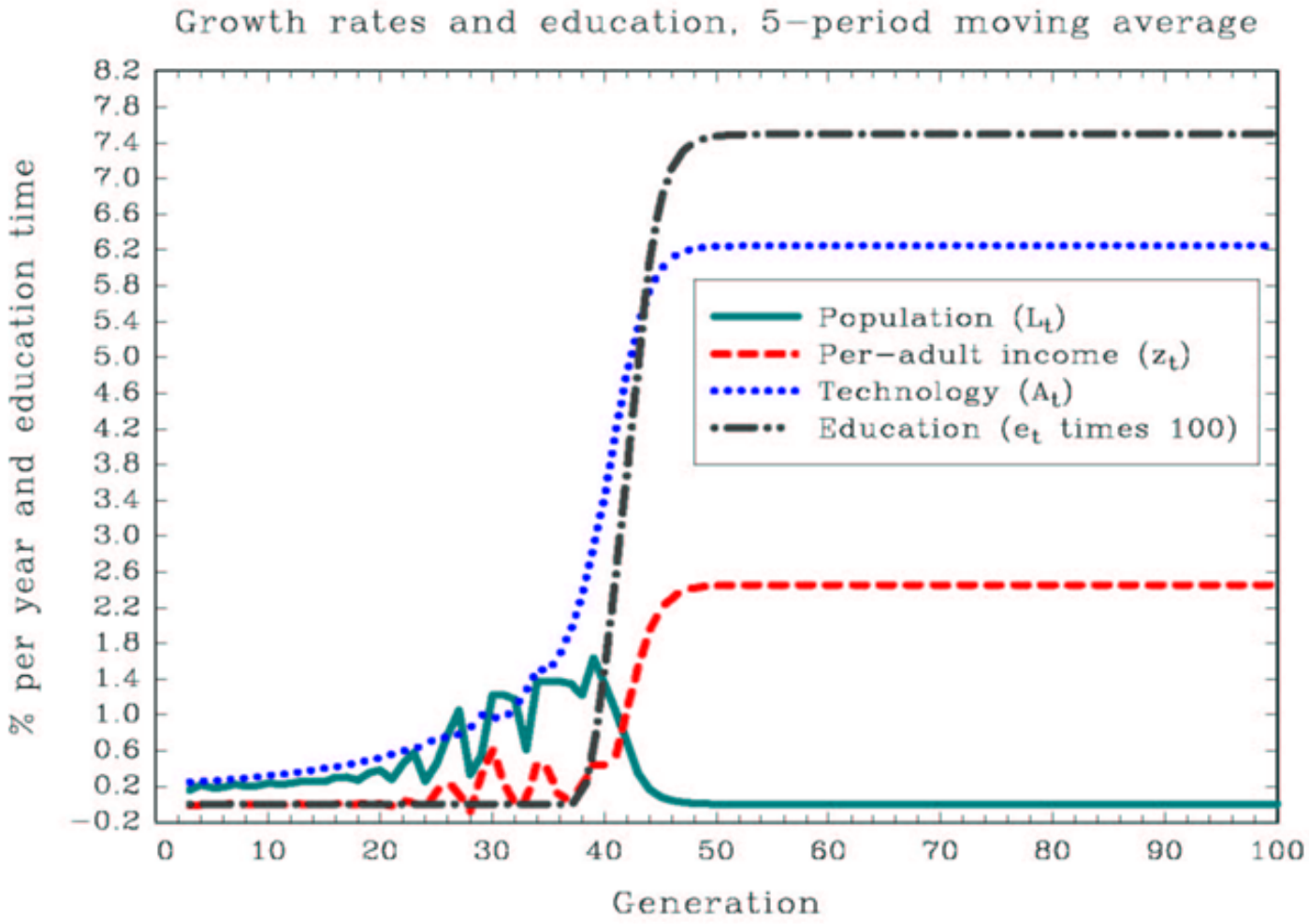
The Evolution of Education and Resources Per Worker: Intermediate Population



The Evolution of Education and Resources Per Worker: Large Population



Simulation


Growth rates and education, 5−period moving average
% per year and education time
8.2
7.8
7.4
7.0
6.6
6.2
5.8
5.4
5.0
4.6
4.2
3.8
3.4
3.0
2.6
2.2
1.8
1.4
1.0
0.6
0.2
−0.2
0
10
20
30
40
50
60
70
80
90
100
Generation
Population (L_t)
Per−adult income (z_t)
Technology (A_t)
Education (e_t times 100)

The Transition from Stagnation to Growth

- The Malthusian interaction between technology & population
  - Acceleration in technological progress
    - $\Longrightarrow$ Industrial demand for human capital
  - Human capital formation
    - $\Longrightarrow$ Decline in fertility rates
    - $\Longrightarrow$ Further technological progress
  - Decline in population growth
    - $\Longrightarrow$ Economic growth is freed from counterbalancing effects of population
  - Technological progress, human capital & decline in population growth
    - $\Longrightarrow$ Sustained economic growth

Implications for Comparative Development

- Variations in the timing of the take-off contributed significantly to the divergence in income per capita in the past two centuries
- Differences in the economic performance across countries reflect:
  - Variations in country-specific characteristics that affect:
    - The pace of technological progress
    - The intensity of human capital formation

Variations in Country-Specific Characteristics Conducive for Technological Progress

$$g^i_{t+1} = g(e^i_t, L^i_t, \Omega^i_t)$$

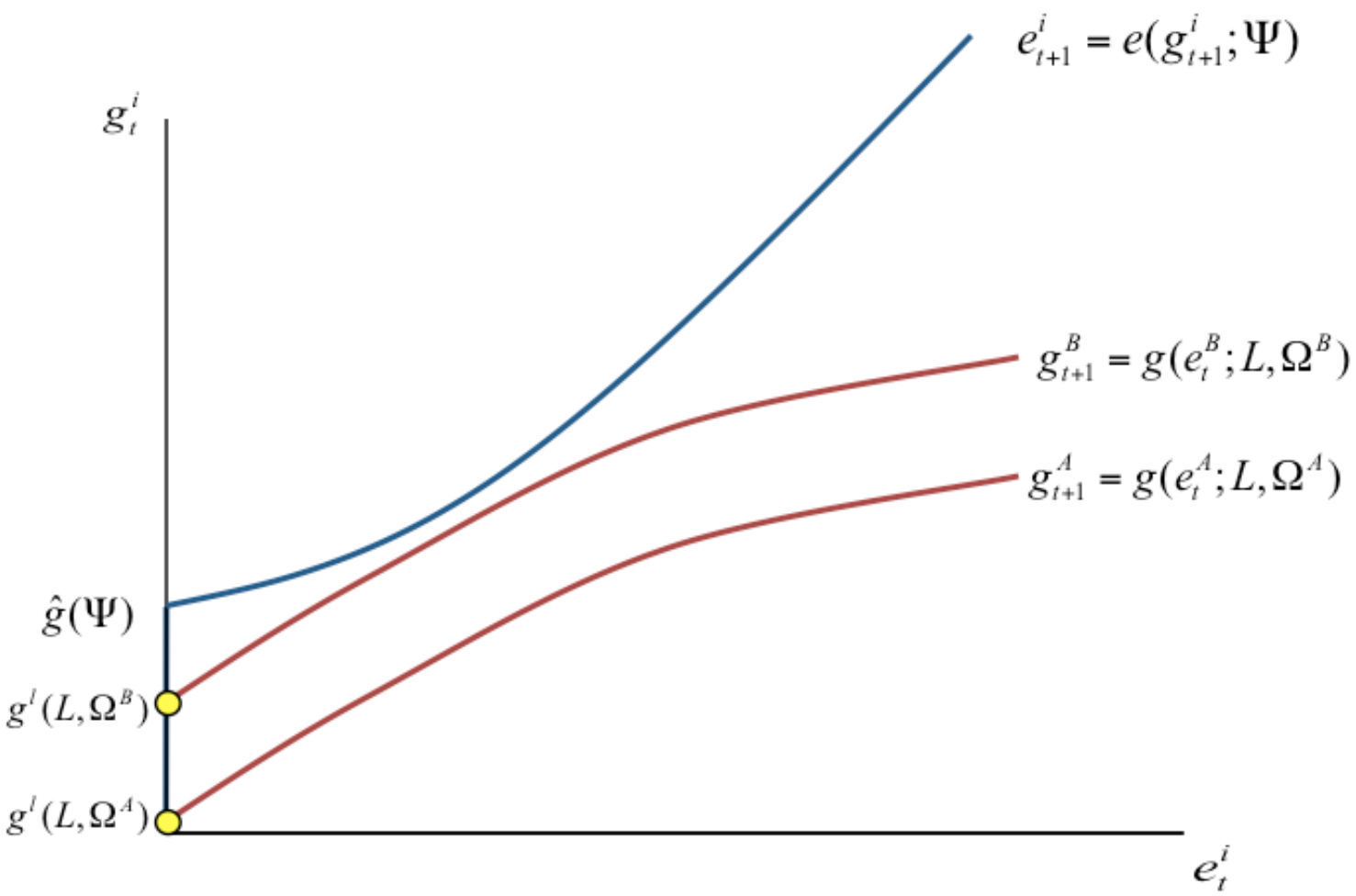
$\Omega^i_t \equiv$ characteristics affecting tech progress in country i:

- Protection of intellectual property rights (policy)
- The stock of knowledge within a society
- The propensity of a country to trade (geography & policy)
  - Technological diffusion
  - Specialization and technological progress via learning by doing

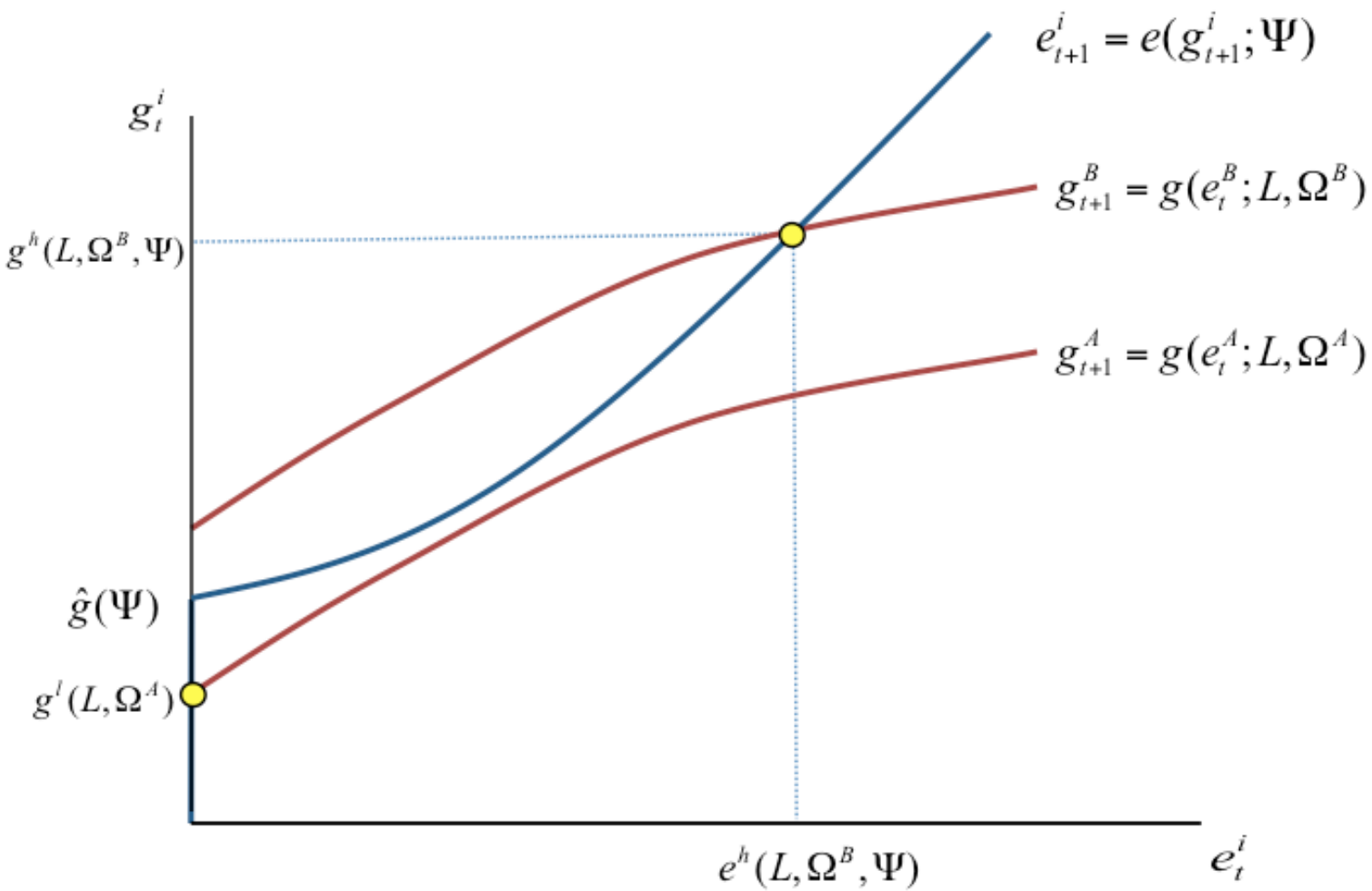
Variations in Country-Specific Characteristics Conducive for Technological Progress

- Cultural and religious composition of society
  - Attitude toward knowledge creation and diffusion (e.g., The Inquisition)
- The composition of interest groups in society
  - Incentives to block or promote technological innovation (e.g., Luddites; landowners)
- Cultural and genetic diversity
  - Wider spectrum of traits are more likely to contain the ones complementary to the adoption or implementation of new technologies
- Abundance of natural resources
  - complementary for industrialization (e.g., Coal & Steam engine)

Variations in Country-Specific Characteristics Conducive for Technological Progress



Earlier Take-off in Country B



Variation in Characteristics Conducive for Human Capital Formation

- For country-specific characteristics Ψ_t^i

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

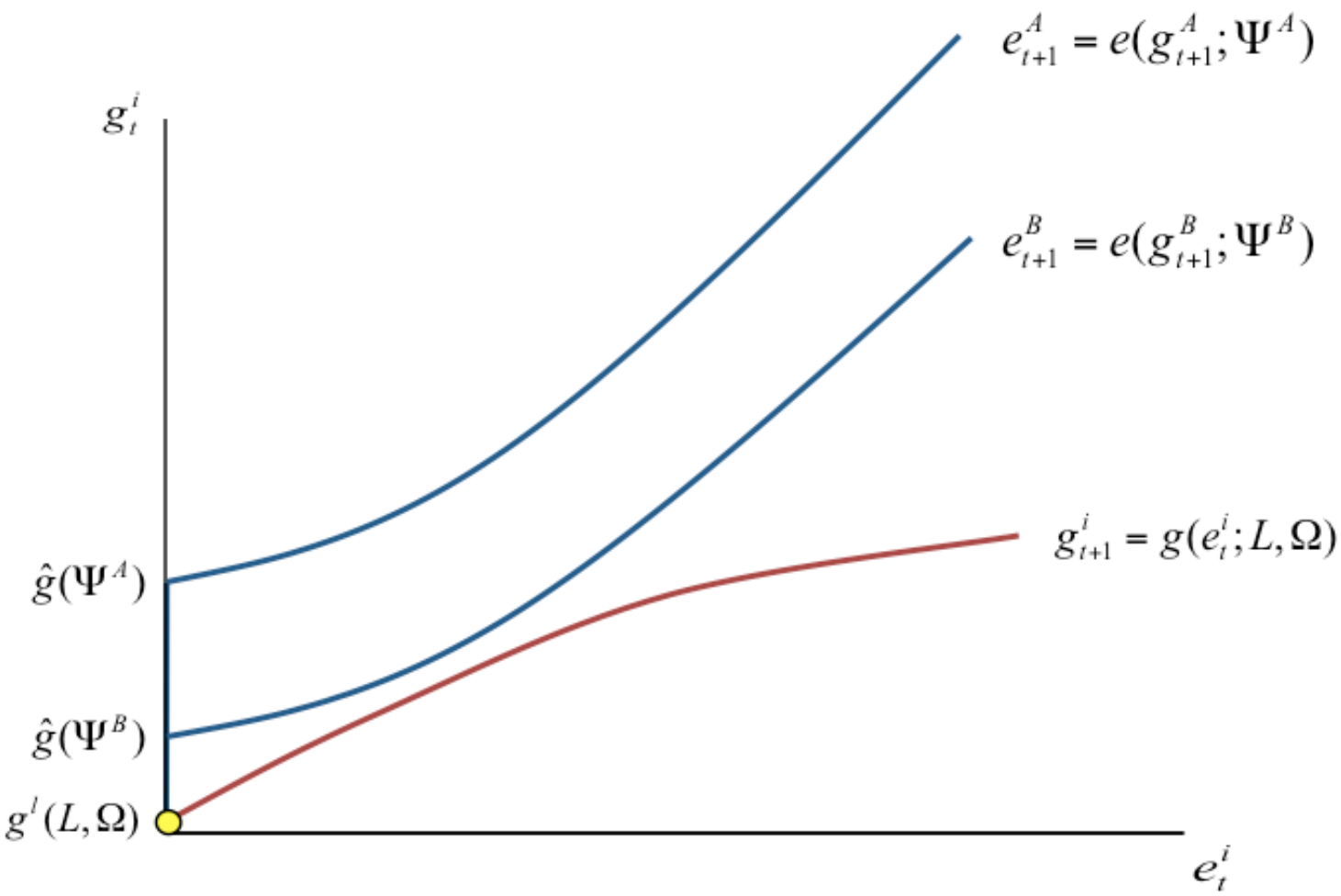
Variation in Characteristics Conducive for Human Capital Formation

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

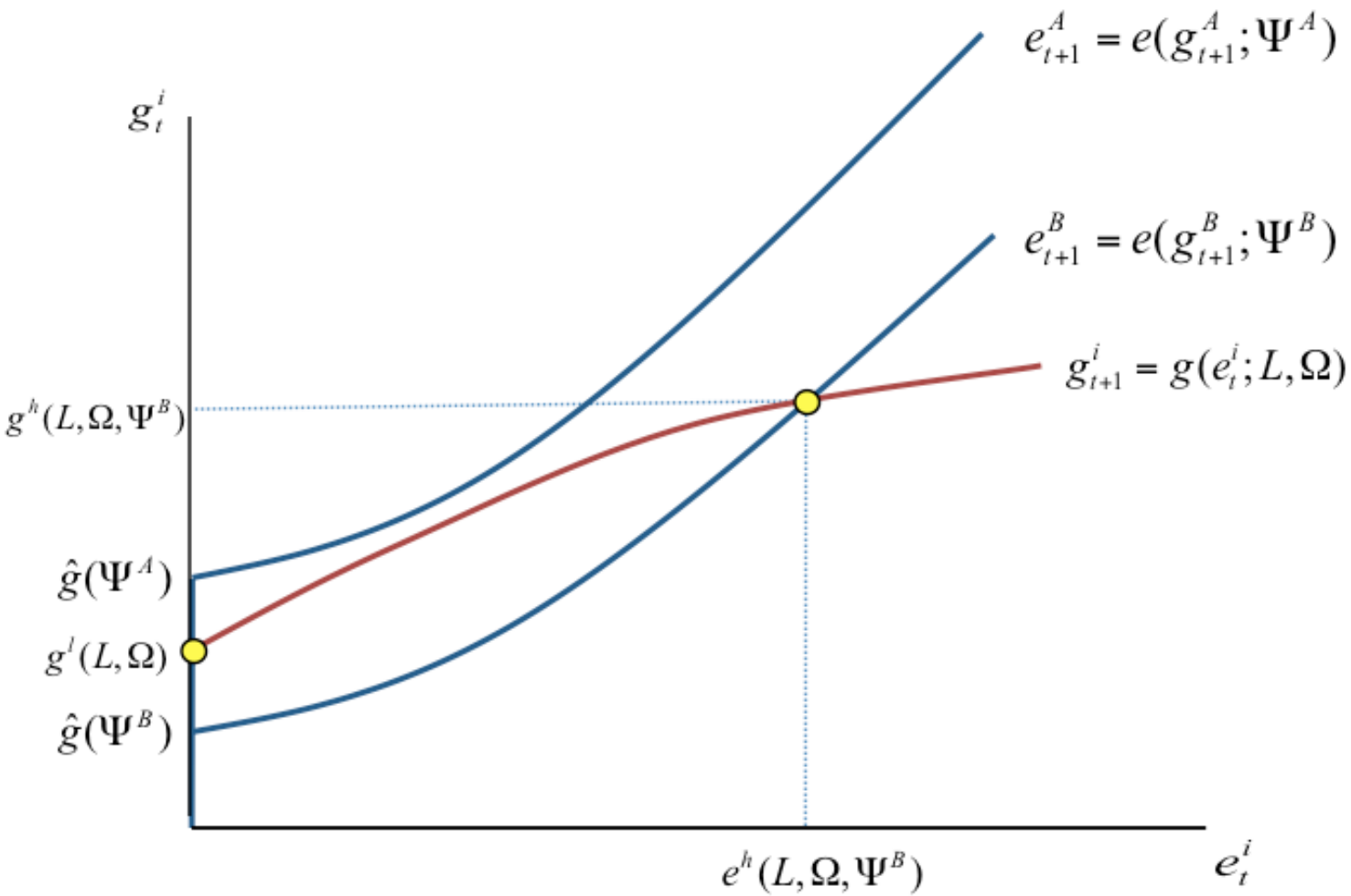
Variation in Characteristics Conducive for Human Capital Formation

- The propensity of a country to trade
  - Skill-intensity in production and its effect on the demand for human capital
- The effect of geographical attributes on health
  - Return to investment in human capital (e.g., Malaria, Hookworm)
- Composition of religious groups within a society and their attitude towards literacy (e.g., Judaism, Protestantism)
- Social status associated with education

Variation in Characteristics Conducive for Human Capital Formation



Earlier Take-off in Country B



Concluding Remarks

- UGT suggests that:
  - The transition from stagnation to growth was 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

Concluding Remarks

- UGT sheds light on:
  - The historical origins of vast and persistent inequality across countries
  - The forces that triggered the transition of DCs from stagnation to growth
  - The hurdles faced by LDCs in their take-off from stagnation to growth
  - The factors that hindered convergence across countries
  - The role of deep rooted factors in comparative development