Unified Growth Theory:

Roots of Growth and Inequality in the Wealth of Nations

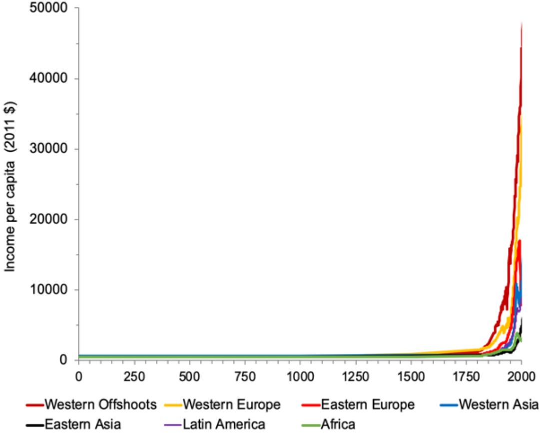
Oded Galor

May 17, 2026

Two Mysteries

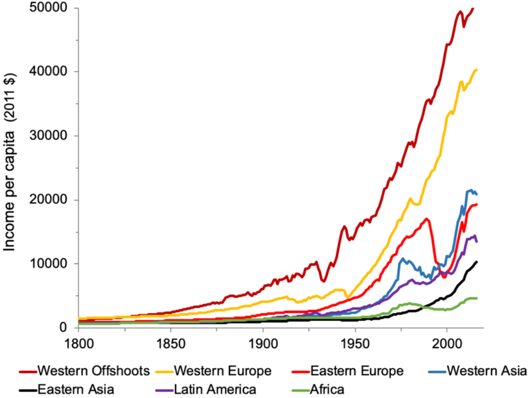
- *The Mystery of Growth*:
    - Why economic growth emerged only in the past two centuries, after hundreds of thousands of years of stagnation?
- *The Mystery of Inequality*
    - What is the origin of the vast inequality in income per capita across countries and regions?

The Mystery of Growth: Income per Capita: 1–2020



Data Source: Maddison Project (2020)

Great Divergence: 1800–2018



Data Source: Maddison Project (2020)

Resolution of these Mysteries

- Requires the identification of:
  - Forces that triggered the transition from stagnation to growth
  - The origins of the differential timing of the transition across the globe
  - The role of historical pre-historical factors in the growth process
    - geographical, cultural, institutional & human characteristics
  - The contribution of human adaptation to process of development
- Provides insights about policies that can:
  - Narrow the vast global inequality

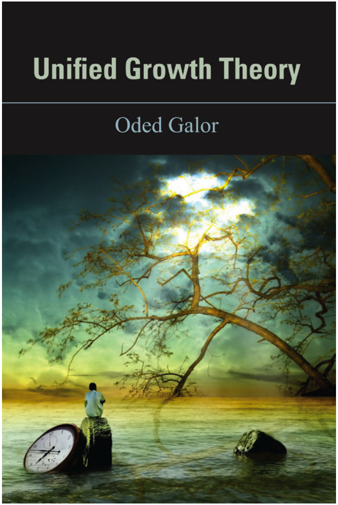
Phases of Development

- The Malthusian Epoch
- The Post-Malthusian Regime
- The Modern Growth Regime

Neoclassical Growth Theory

- Do not shed any light on the two main mysteries of the growth process:
  - Economies are assumed to operate in the modern growth regime
    - No insights about the origins of economic growth
  - Diminishing returns to physical & human capital and technological progress
    - Reduction in inequality & convergence – counter-factual
    - $\Longrightarrow$ No insights about the mystery of the gaps

Unified Growth Theory



Contribution of Unified Growth Theory

- Resolution of the *Mystery of Growth*
  - The origins of economic growth in the past two centuries, after hundreds of thousands of years of stagnation
- Contribution to the understanding of the *Mystery of Inequality*
  - The origin of the vast inequality in income per capita across countries and regions
  - The role of deep-rooted historical and pre-historical factors in global inequality

Unified Growth Theory

- A unified framework that captures the process of development in its entirety:
  - The epoch of Malthusian stagnation
  - The forces that permitted the take-off from the Malthusian epoch
  - The emergence of human capital as a central engine of growth
  - The onset of the demographic transition
  - The emergence of sustained economic growth
  - The rise in inequality in income per capita across countries

Unified Growth Theory - Theoretical Challenges

- Origins of the phase transition:
  - The transition from stagnation to growth
  - The escape from a *stable* Malthusian trap
- 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 mere concept of a *stable* equilibrium

Phase Transition: Origins

- A gradual evolution of a latent force ultimately generates a phase transition:
  - Example: A critical temperature level beyond which a transition from liquid to gas takes place
- Once the latent force reaches a critical level:
  - The dynamical system changes qualitatively (bifurcation of equilibria):
    - The Malthusian equilibrium vanishes
    - The economy gravitates towards the Modern Growth Regime

Phase Transition

Phase Transition: Mechanism

- During the Malthusian epoch
  - Population size & quality $\Rightarrow$ Technological progress
  - Technological progress $\Rightarrow$ Population size & quality
- Technological progress accelerated & ultimately reaches a critical threshold
  - Investment in human capital (HC) became profitable
    - HC enabled individuals to cope with rapid technological change
- Human capital formation triggered a decline in fertility & population growth
  - The Malthusian equilibrium vanishes
  - The growth process freed from the counterbalancing effect of population
- Tech progress, human capital formation & decline in population growth
  - $\Rightarrow$ Sustained economic growth
- Variations in the timing of the take-off
  - $\Rightarrow$ Divergence in income per capita in the past two centuries

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 the quality of the population
  - Onset of growth in income per capita
- Transition from the Post-Malthusian to Modern Growth Regime:
  - Faster rate of technological progress
  - Decline in population growth
  - Investment in the quality of the population
  - Faster growth of income per capita

Suggestive Evidence

- The underlying forces that govern these transitions:
  - The effect of changes in the technological progress on:
    - Population size & quality
  - The effect of changes in the size & quality of the population on:
    - 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
    - The level of human capital of each child

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 around a constant level in the long-run

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:

$$L_t \uparrow \implies A_{t+1} \uparrow$$

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

Sources of Technological Progress

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

$$e_t \uparrow \quad \Longrightarrow \quad A_{t+1} \uparrow$$

    - Educated individuals have a comparative advantage in adopting & advancing new technologies

Technological Progress

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

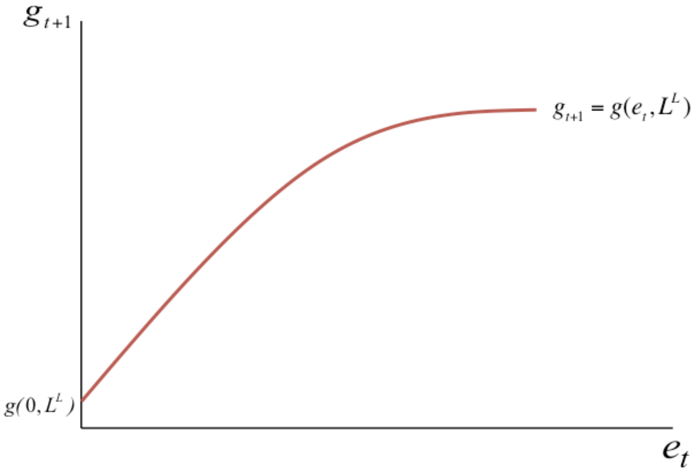
- $g_{t+1} \equiv$ rate of tech progress
- $e_t \equiv$ average level of education
- $L_t \equiv$ population size

Technological Progress

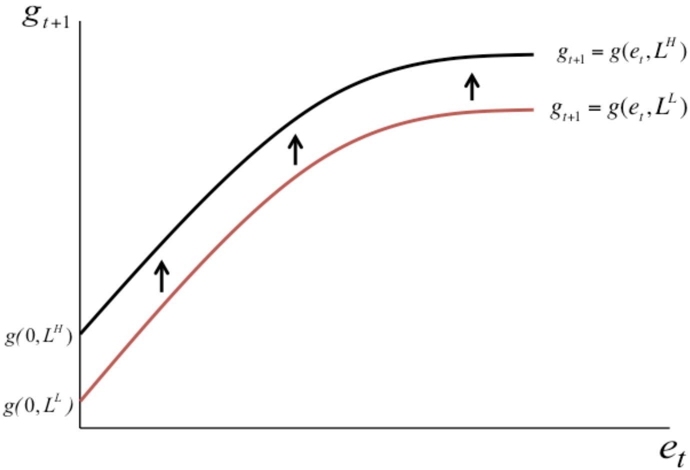
$$g_{t+1} = g(e_t, L_t)$$

- $g_e(e_t, L_t) > 0$ 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 as long as human are present

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 a changing 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 $t+1$

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

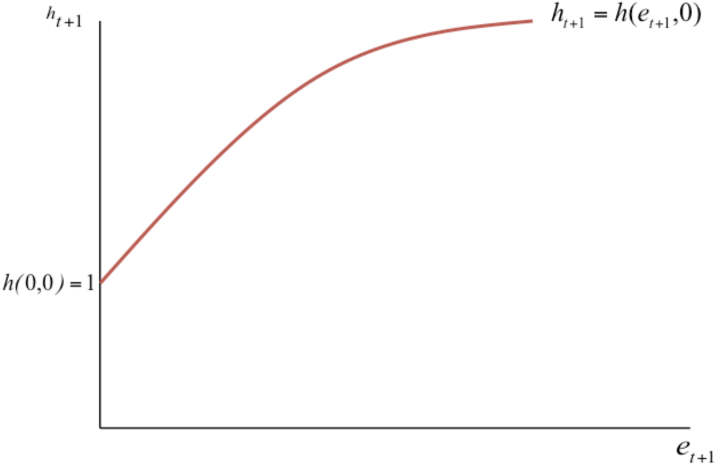
- $e_{t+1} \equiv$ the individual's education level (determined by parental investment, subject to their subsistence constraint, in period t)
- $g_{t+1} \equiv$ rate of tech progress

Human Capital Formation

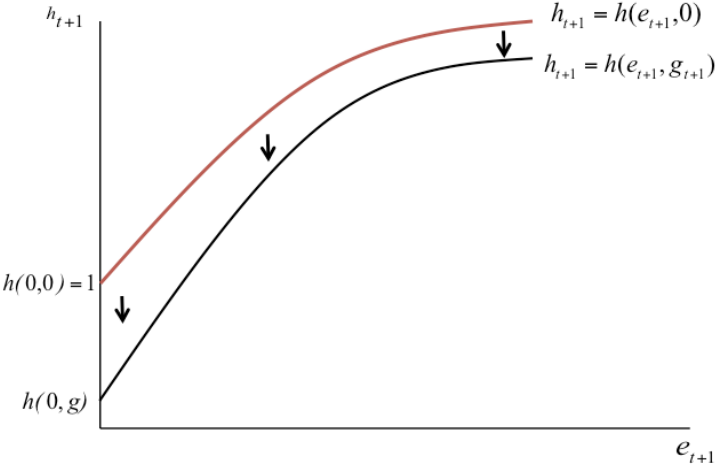
$$h_{t+1} = h(e_{t+1}, g_{t+1})$$

- $h_e(e, g) > 0$ 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 phase of industrialization:
  - The income effect dominates (moderate demand for human capital & subsistence constraint becomes less binding):
    - Population growth & human capital formation increase:
- Later part of the second phase of industrialization:
  - The substitution effect dominates (higher demand for human capital):
    - Population growth declines & human capital formation increases

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

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

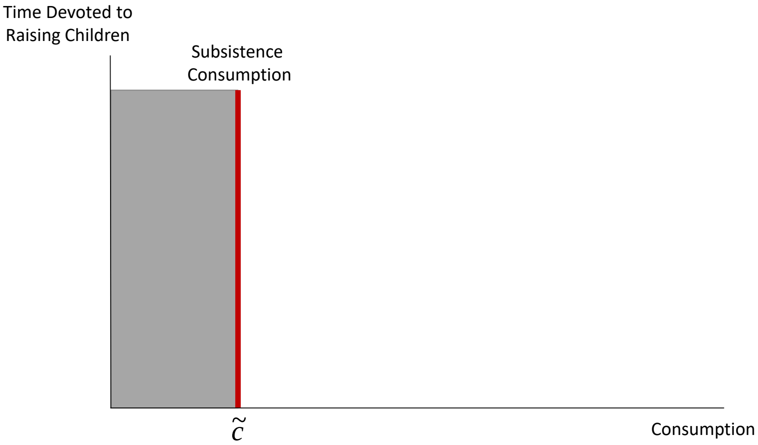
- $z_t \equiv$ potential income of individual t
- $\tau \equiv$ time required to raise a child, regardless of quality
- $\tau + e_{t+1} \equiv$ time needed to raise a child with education e_{t+1}
- $z_t(\tau + e_{t+1}) \equiv$ opportunity cost of raising 1 child with education e_{t+1}

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

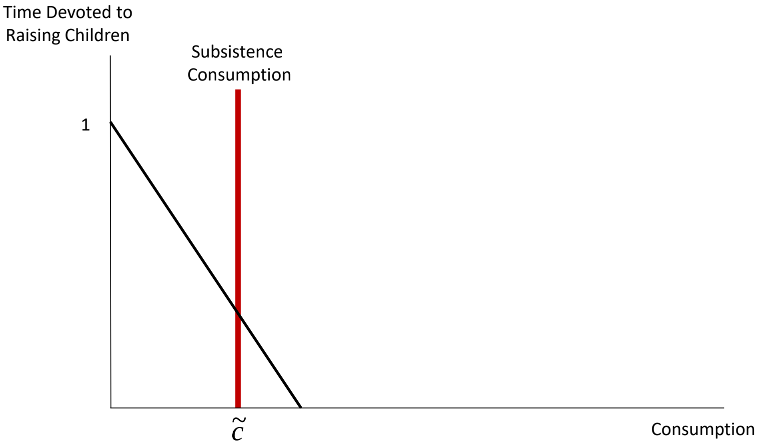
- Subsistence consumption constraint:

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

The Subsistence Consumption Constraint



Subsistence Consumption & Budget Constraints



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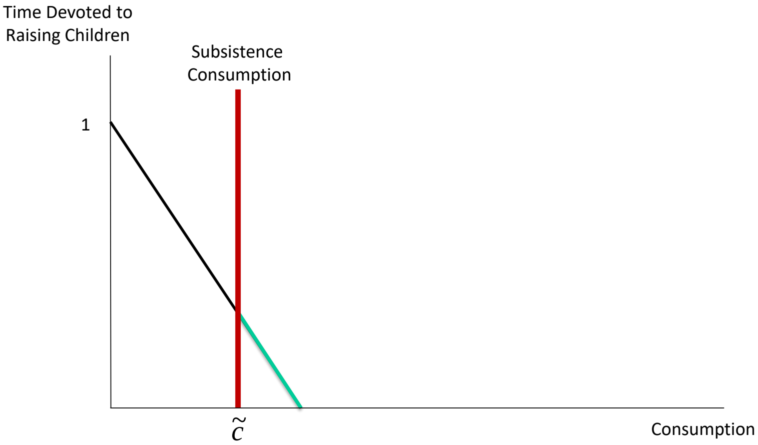
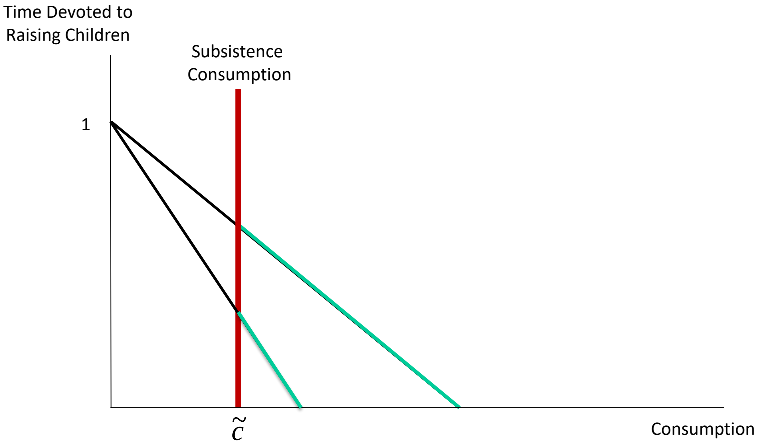
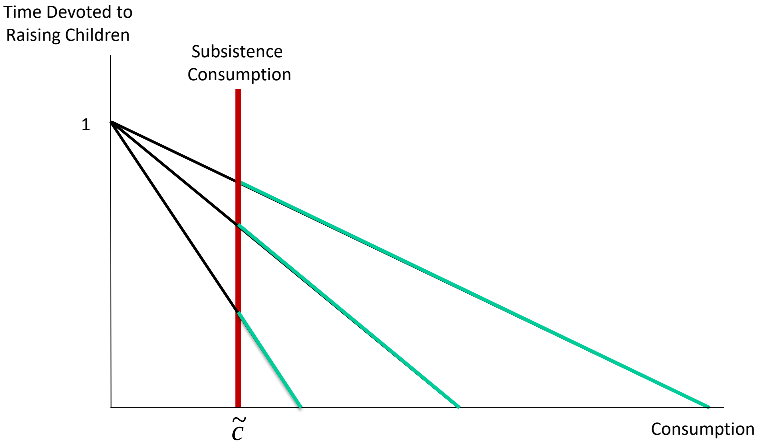


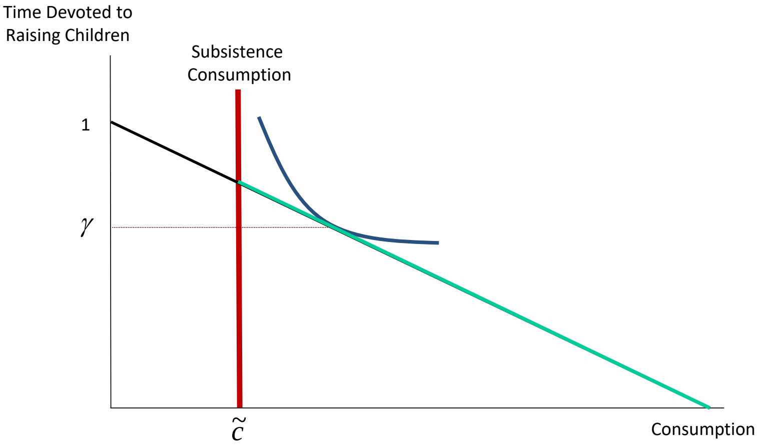
Subsistence Consumption & Budget Constraints



Subsistence Consumption & Budget Constraints



Optimization - Subsistence Constraints is not Binding



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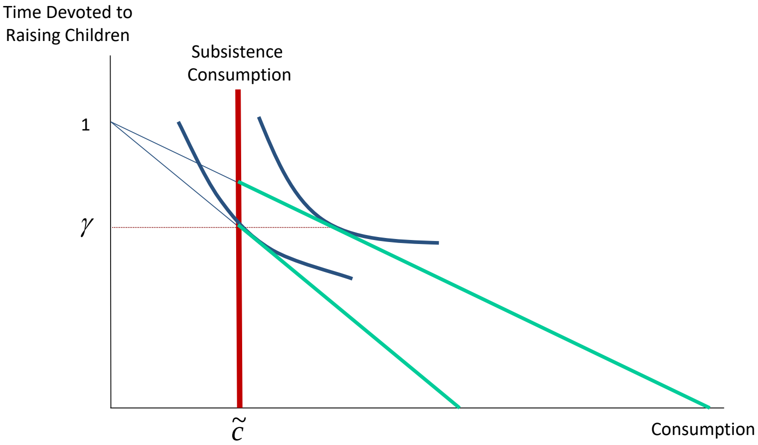

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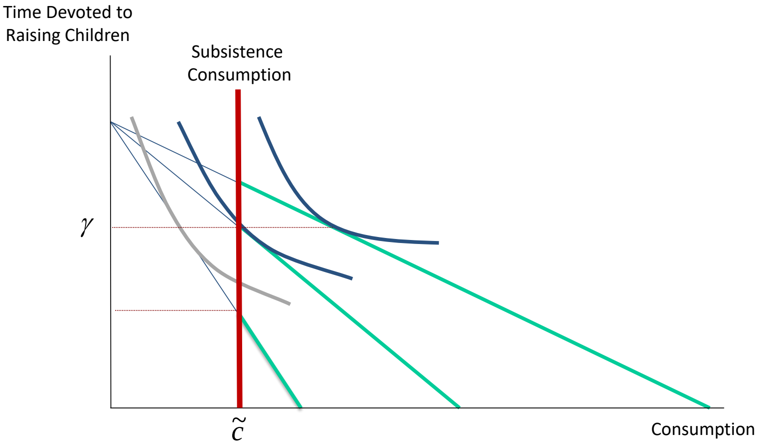
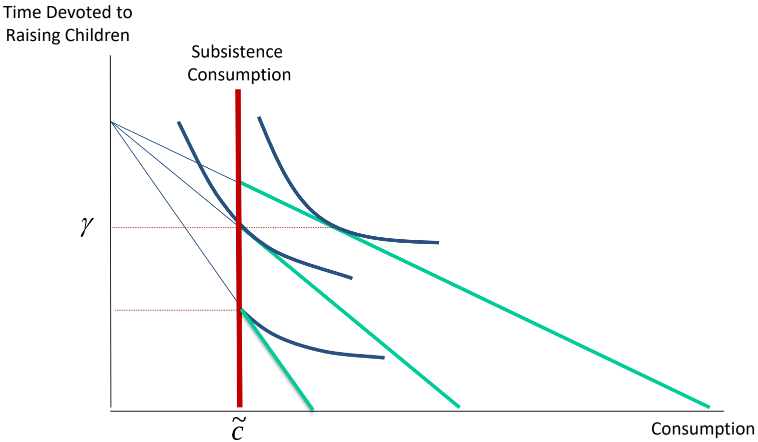
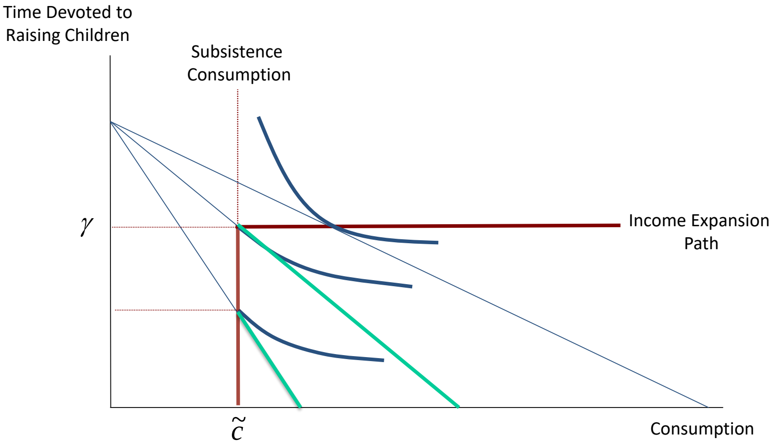


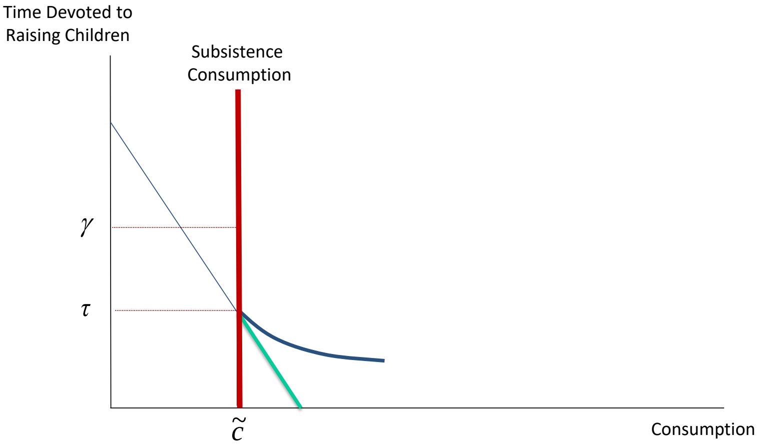
Optimization - Subsistence Constraints is Binding



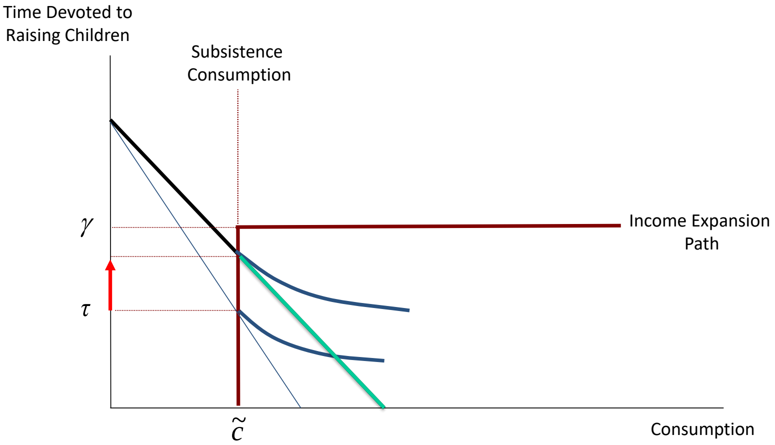
Optimization - Income Expansion Path



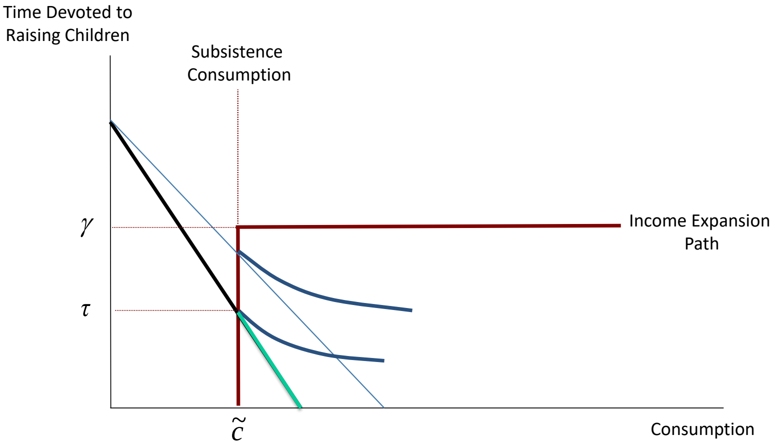
Optimization - Malthusian Steady-State Equilibrium



Optimization - Impact of Tech Progress in the Malthusian Epoch (SR)



Optimization - Impact of Tech Progress in the Malthusian Epoch (LR)



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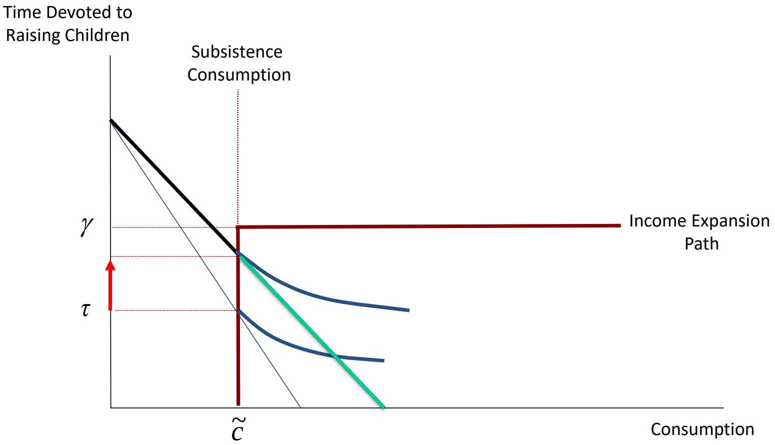

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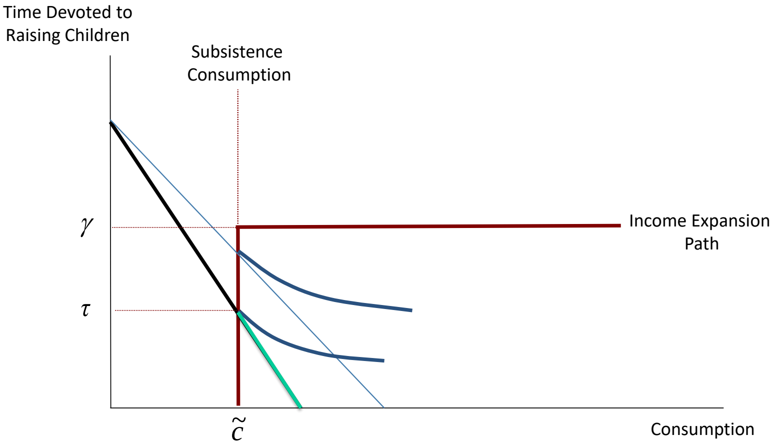
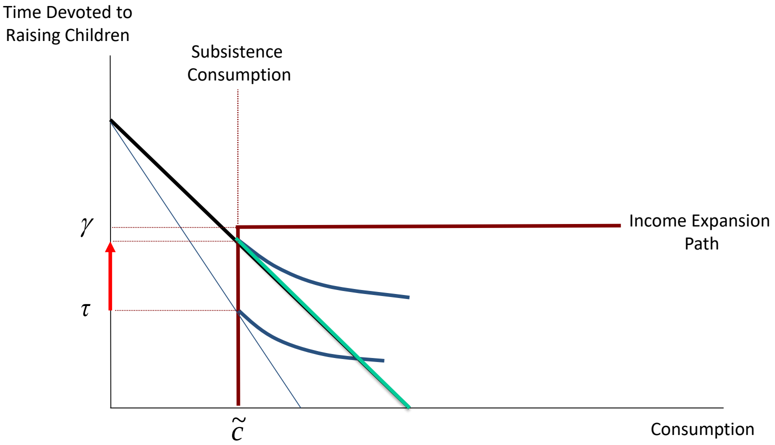
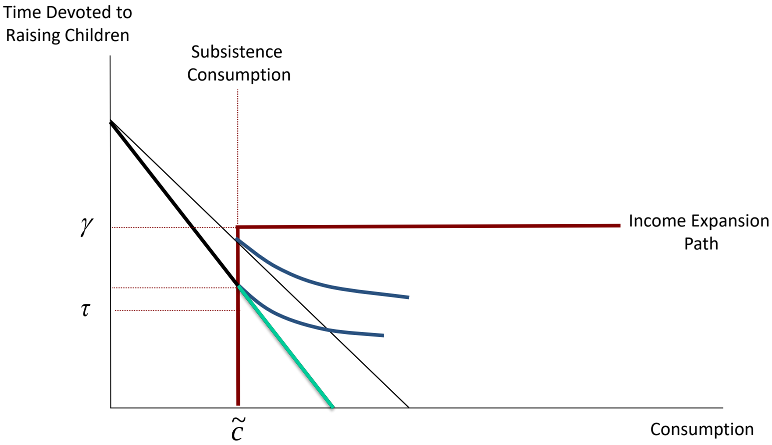


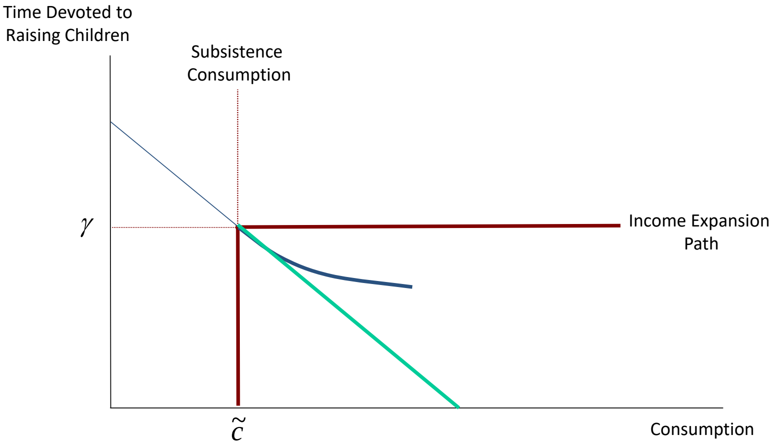
Optimization - Additional Tech Progress in the Malthusian Epoch (SR)



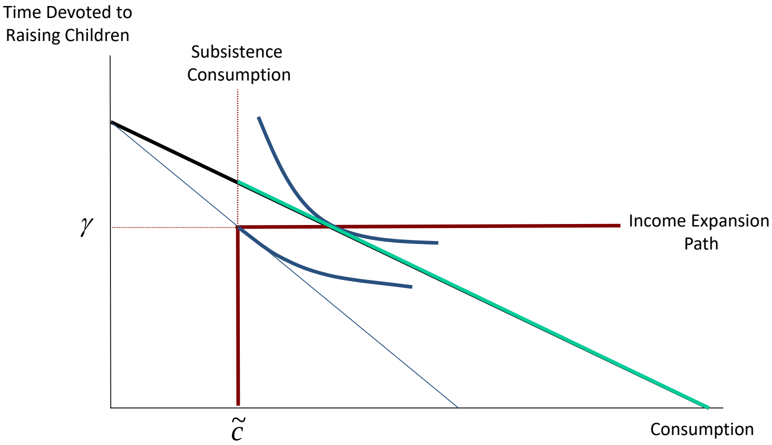
Optimization - Additional Tech Progress in the Malthusian Epoch (LR)



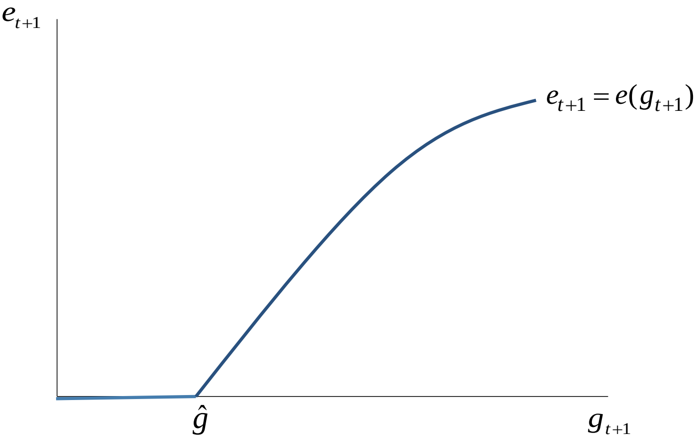
Optimization - Impact of Technological Progress (Eve of the Take-off)



Optimization - Escape from the Malthusian Trap



Optimization - Investment in Child Quality



Optimization: Quantity and Quality of Children

- Time devoted to children $(z_t n_t(\tau + e_{t+1}) + c_t \leq z_t)$

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

  - $z_t = \tilde{z}$ highest potential income s.t. subsistence constraint is still binding

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

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

Optimization: Quantity and Quality of Children

- Number of children

$$n_t = n(e_t, g_t, x_t, L_t)$$

- Quality of children

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

Population Dynamics

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

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

$$L_{t+1} = n(e_t, g_t, x_t, L_t)$$

Dynamics of the Level of Resources per Worker

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

$$x_{t+1} = \phi(e_t, g_t, x_t, L_t)$$

The Dynamical System

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

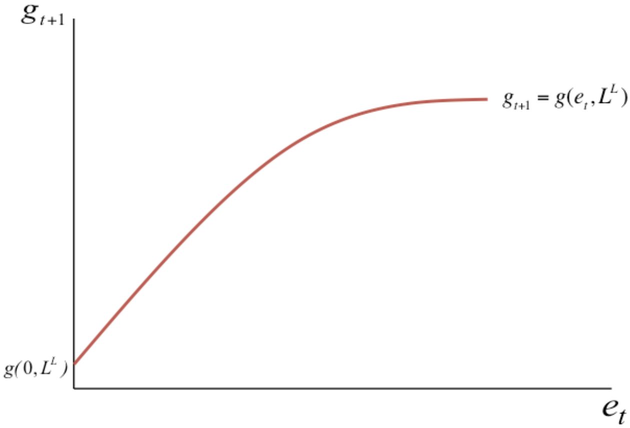
$$\begin{cases} g_{t+1} = g(e_t, L_t) \\ e_{t+1} = e(g(e_t, L_t)) \\ x_{t+1} = \phi(e_t, g_t, x_t, L_t) \\ L_{t+1} = n(e_t, g_t, x_t, L_t) \end{cases}$$

The Conditional Evolution of Technology and Education

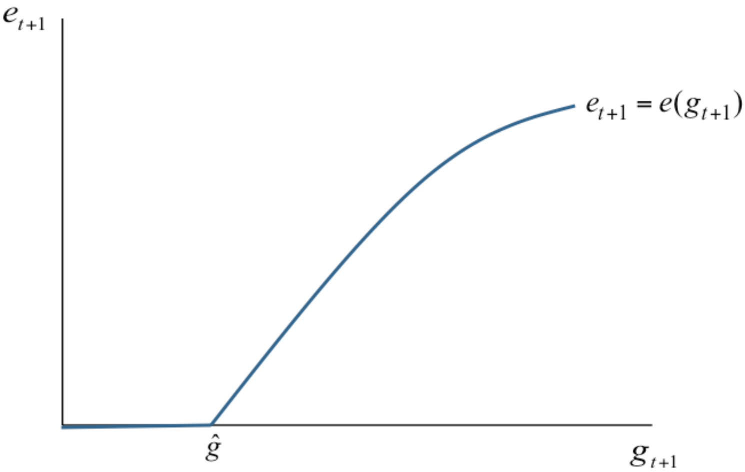
A sequence $\{g_t, e_t; L\}_{t=0}^{\infty}$ such that:

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

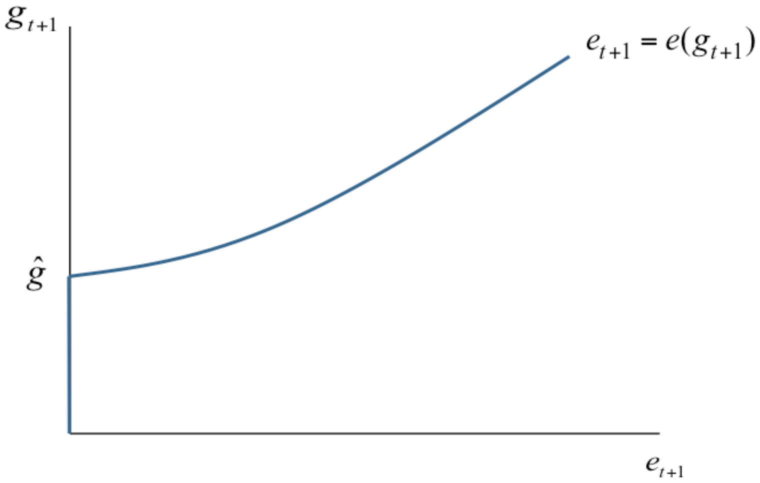
The Effect of Education on Technology



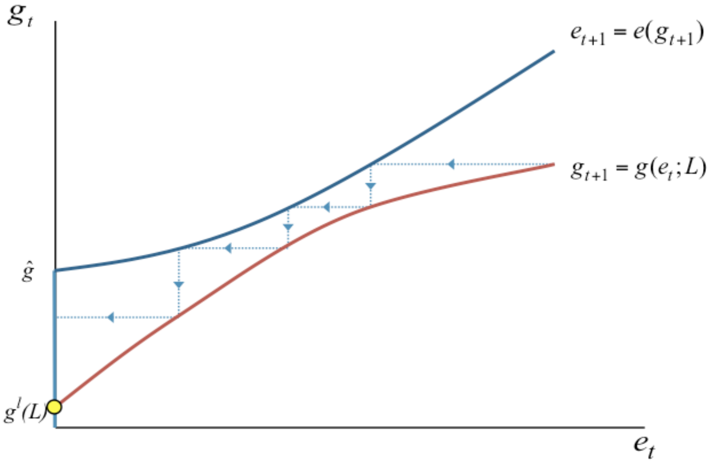
The Effect of Technology on Education



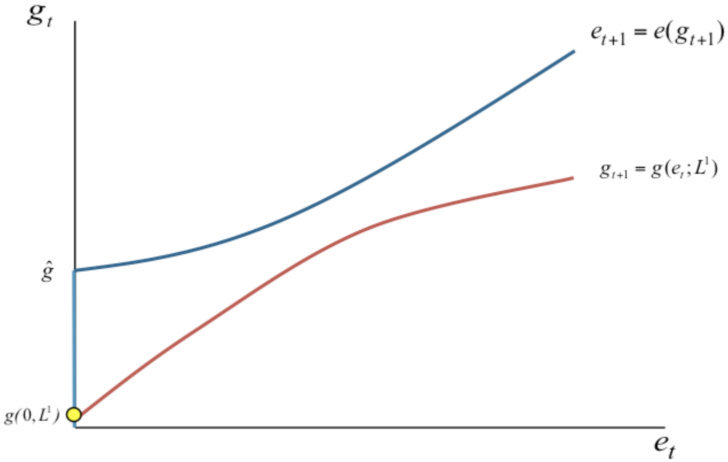
The Effect of Technology on Education: Flipped Axis



The Evolution of Education and Technology: For a Given L



The Evolution of Education and Technology



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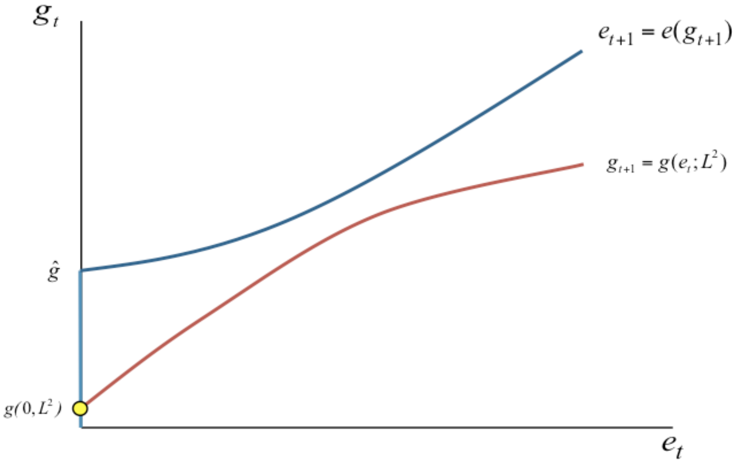

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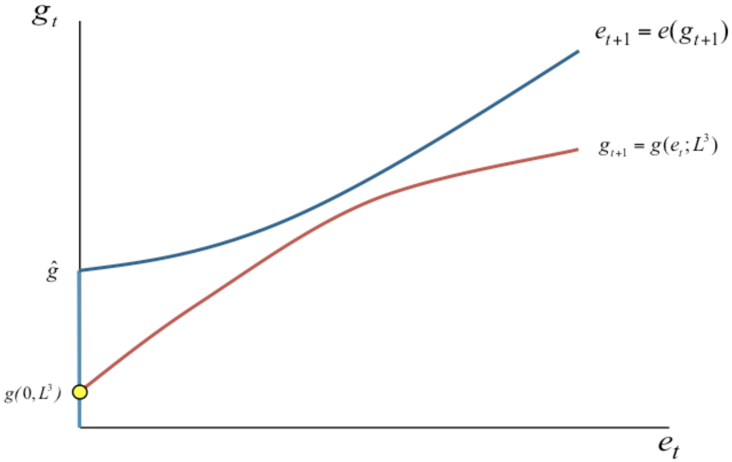

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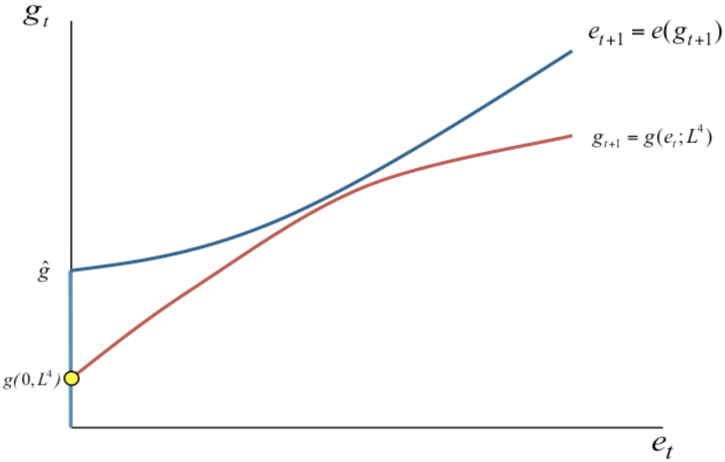

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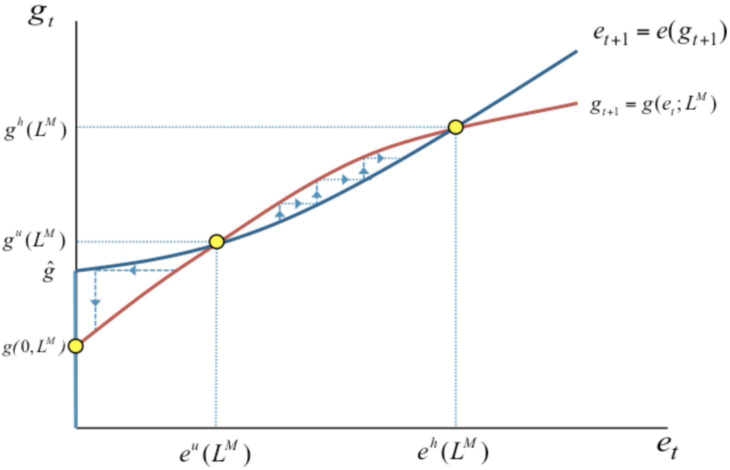
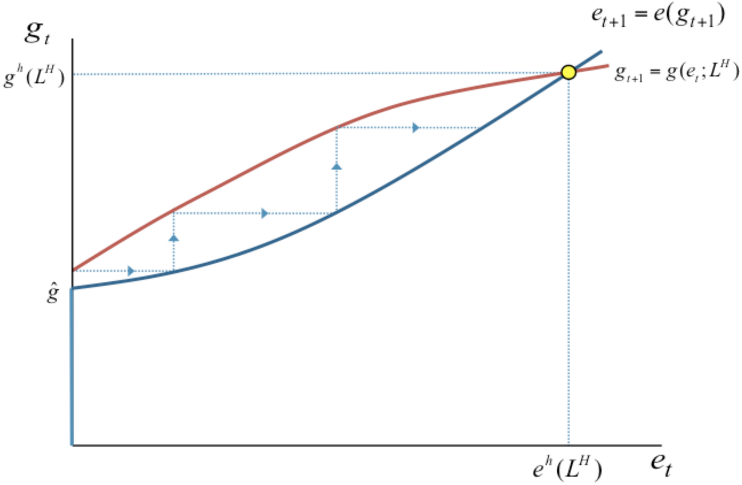
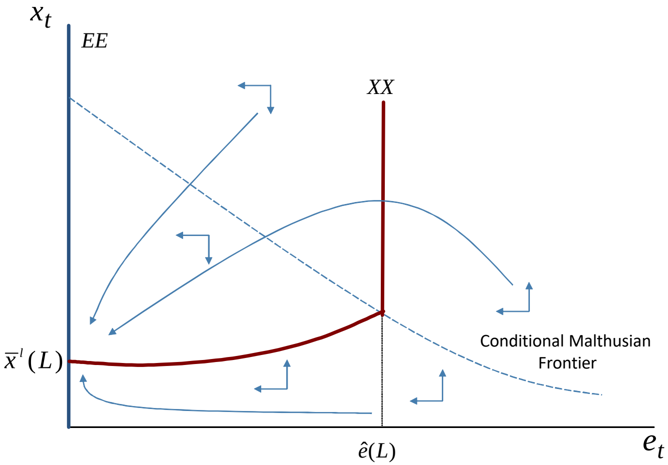


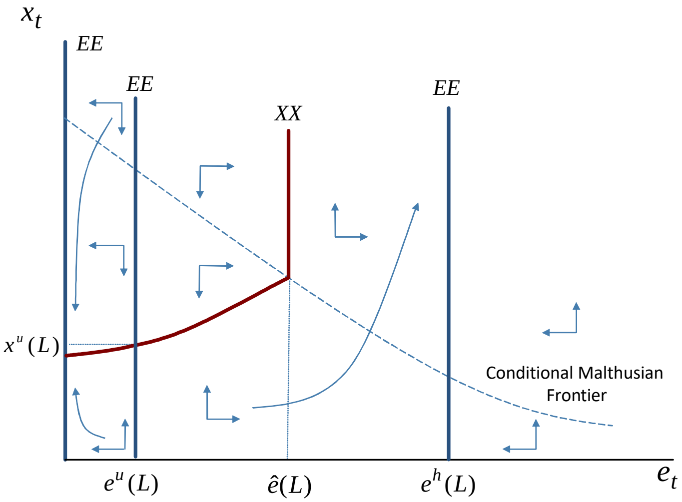
The Evolution of Education and Technology



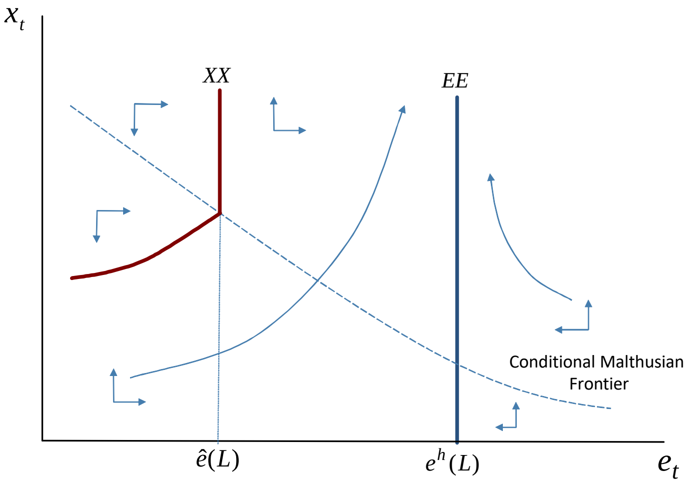
The Evolution of Education and Resources per Capita



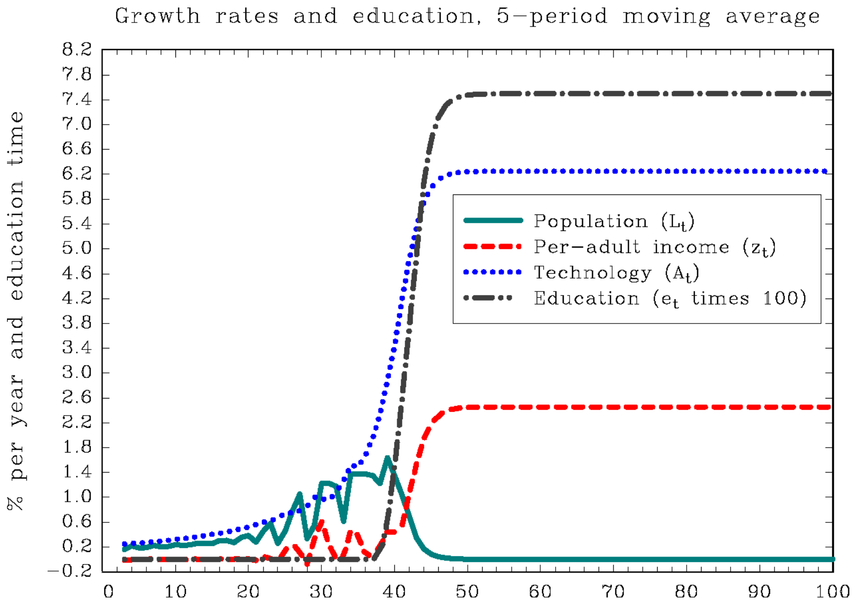
The Evolution of Education and Resources per Capita



The Evolution of Education and Resources per Capita



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
Population (L_t)
Per−adult income (z_t)
Technology (A_t)
Education (e_t times 100)

Implications

- 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

$$g_{t+1}^{i} = g(e_t^i, L_t^i, \Omega_t^i)$$

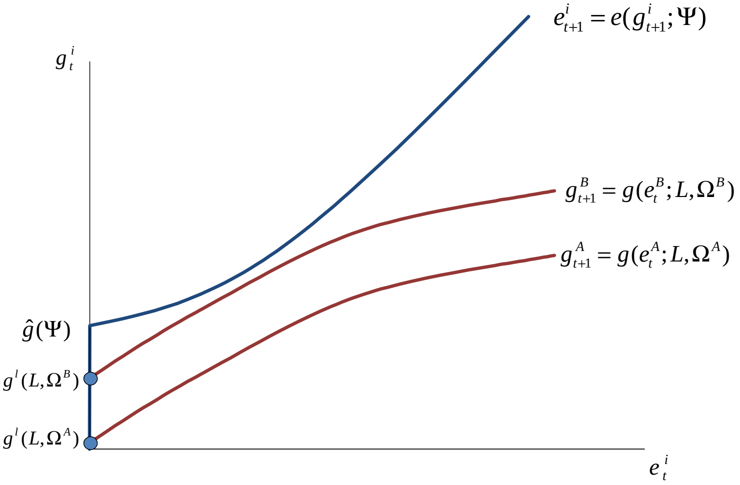
$\Omega_t^i \equiv$ characteristics affecting tech progress in country i:

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

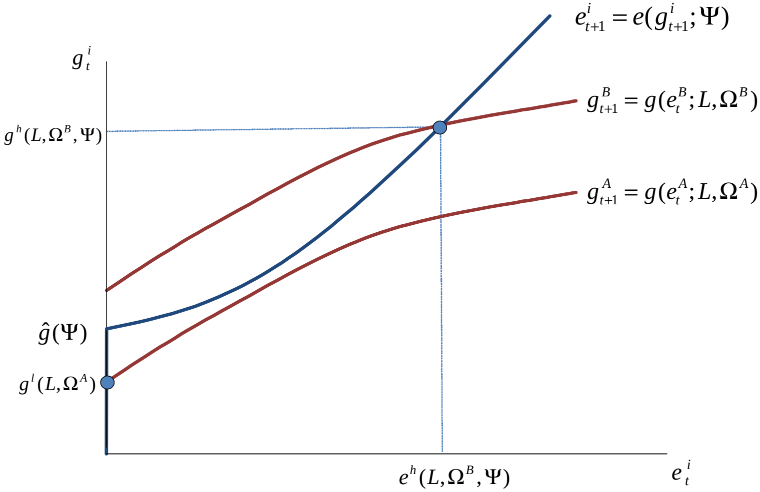
Variations in Country-Specific Characteristics Conducive for Technological Progress

- 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

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

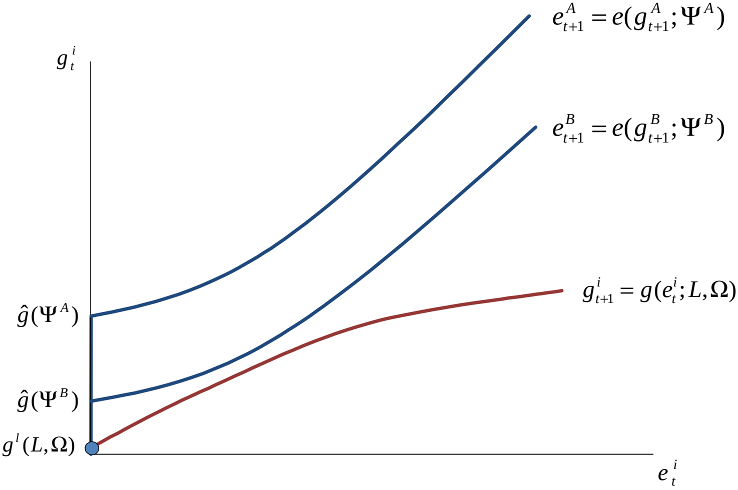
Variation in Characteristics Conducive for Human Capital Formation

- 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

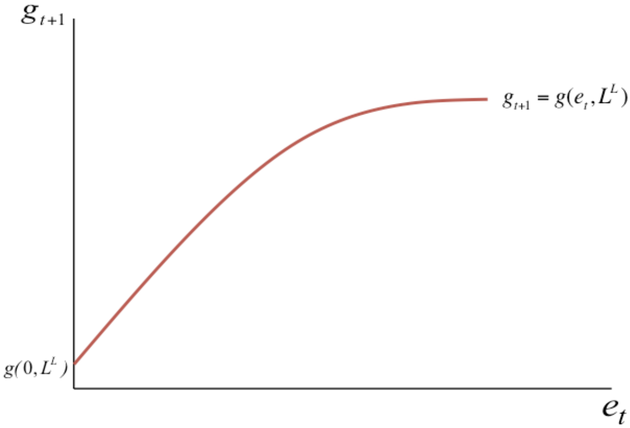
Variation in Characteristics Conducive for Human Capital Formation

- 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 uncovers:
  - 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