Unified Growth Theory

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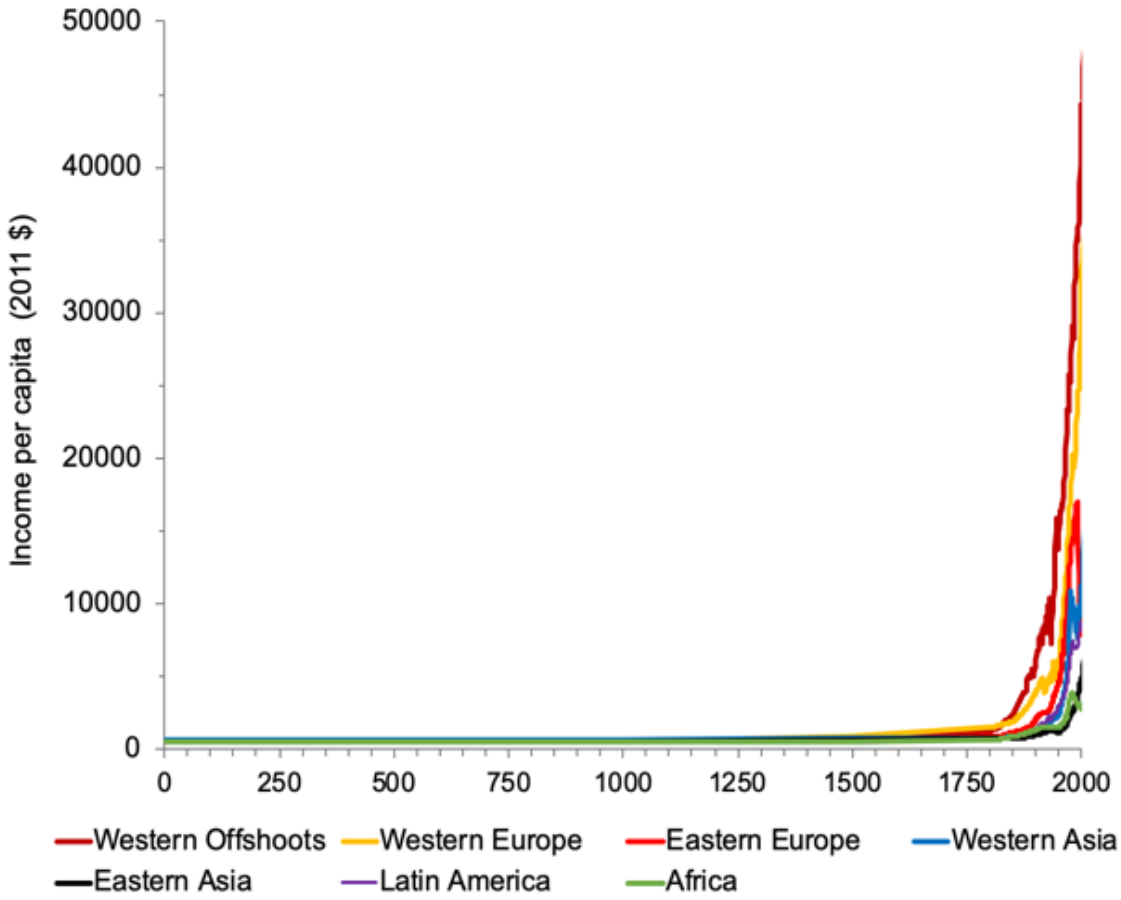
Two Mysteries

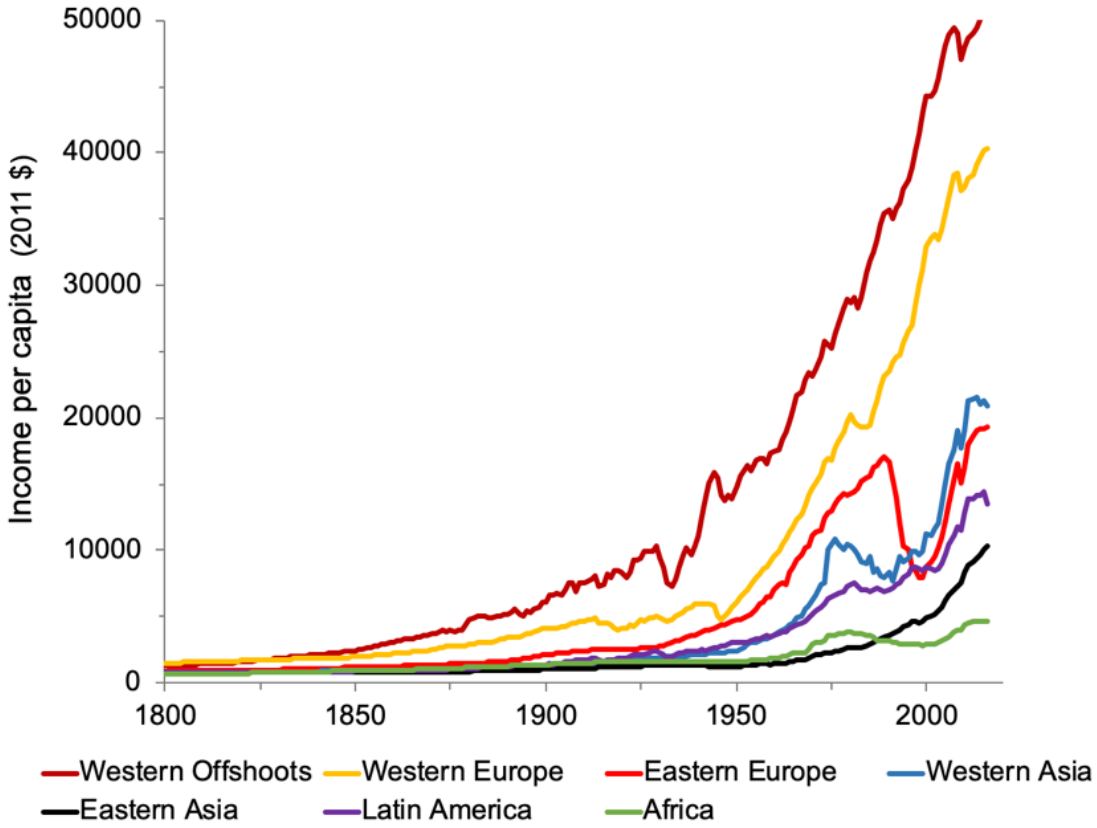
- *The Mystery of Growth*:
  - Why economic growth emerged only in the past two centuries, after hundreds of thousands of years of stagnation?
- *The Mystery of Inequality*
  - What is the origin of the vast inequality in income per capita across countries and regions?

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



Data Source: Maddison Project (2020)

Great Divergence: 1800–2018



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Resolution of these Mysteries

- Requires the identification of The 'Wheels of Change' that:
  - Governed the journey of humanity over the entire course of history
  - Led to an epoch of Malthusian stagnation
  - Triggered the transition from stagnation to growth
  - Contributed to the differential timing of the transition across the globe

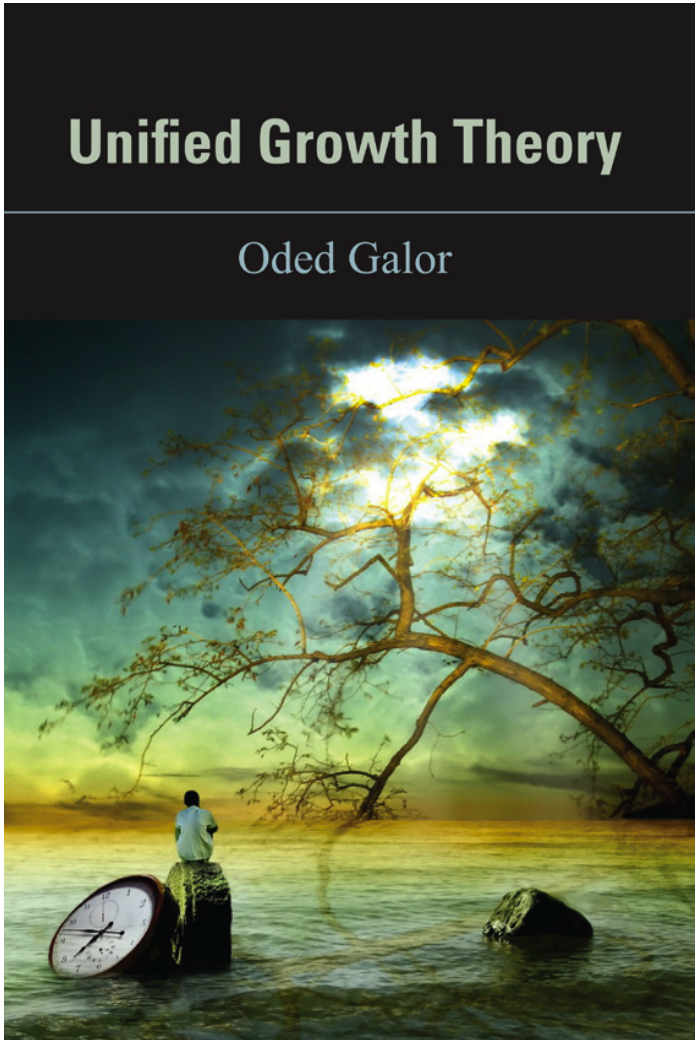
Phases of Development

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

Neoclassical Growth Theory

- Does 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 inequality

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:
    - Their desirable number of children
    - 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

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

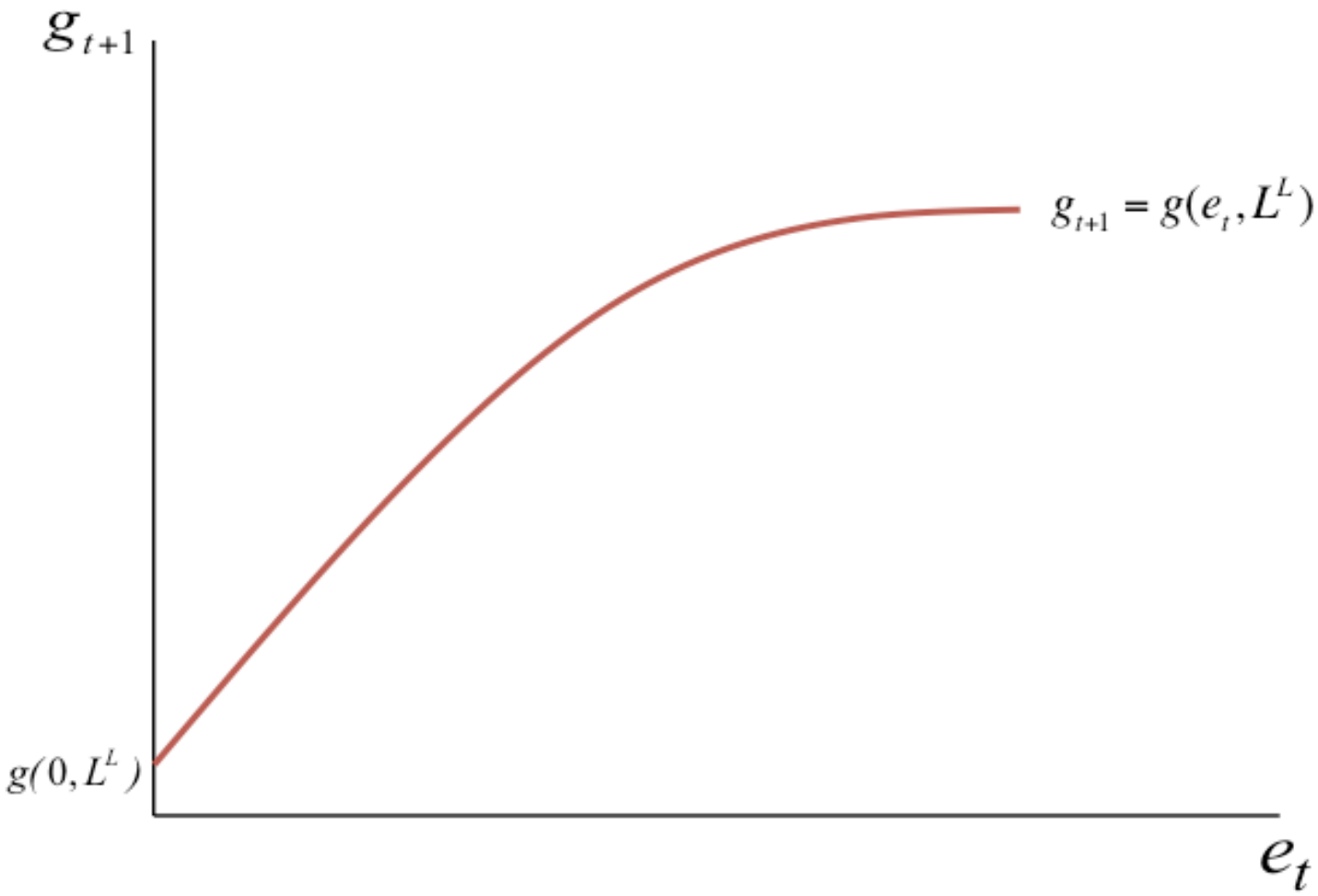
- $g_{t+1} \equiv$ rate of tech progress
- $e_t \equiv$ average level of education
- $L_t \equiv$ population size

Technological Progress

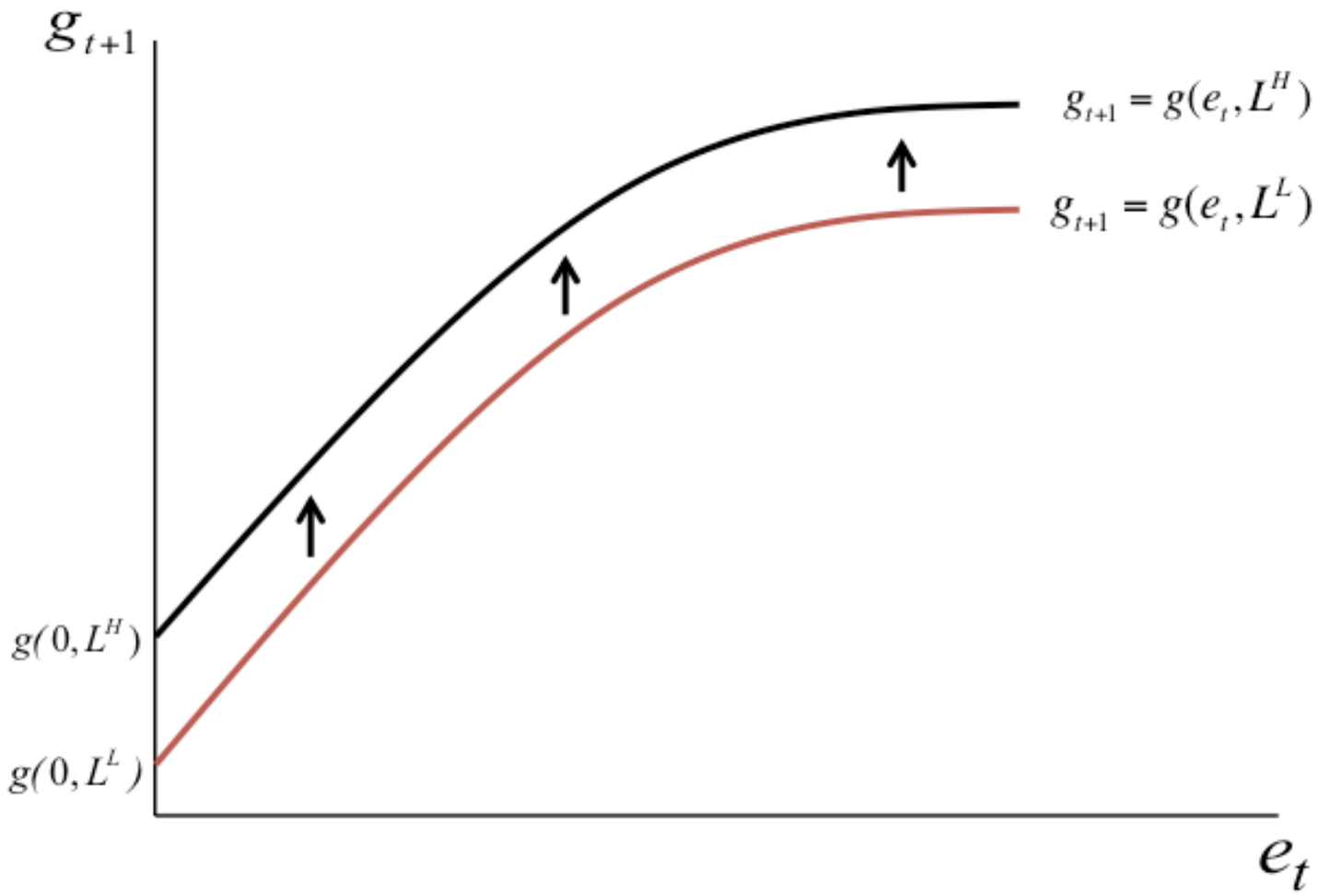
$$g_{t+1} = g(e_t, L_t)$$

- $g_e(e_t, L_t) > 0$ 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 humans 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

Human Capital Formation

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

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

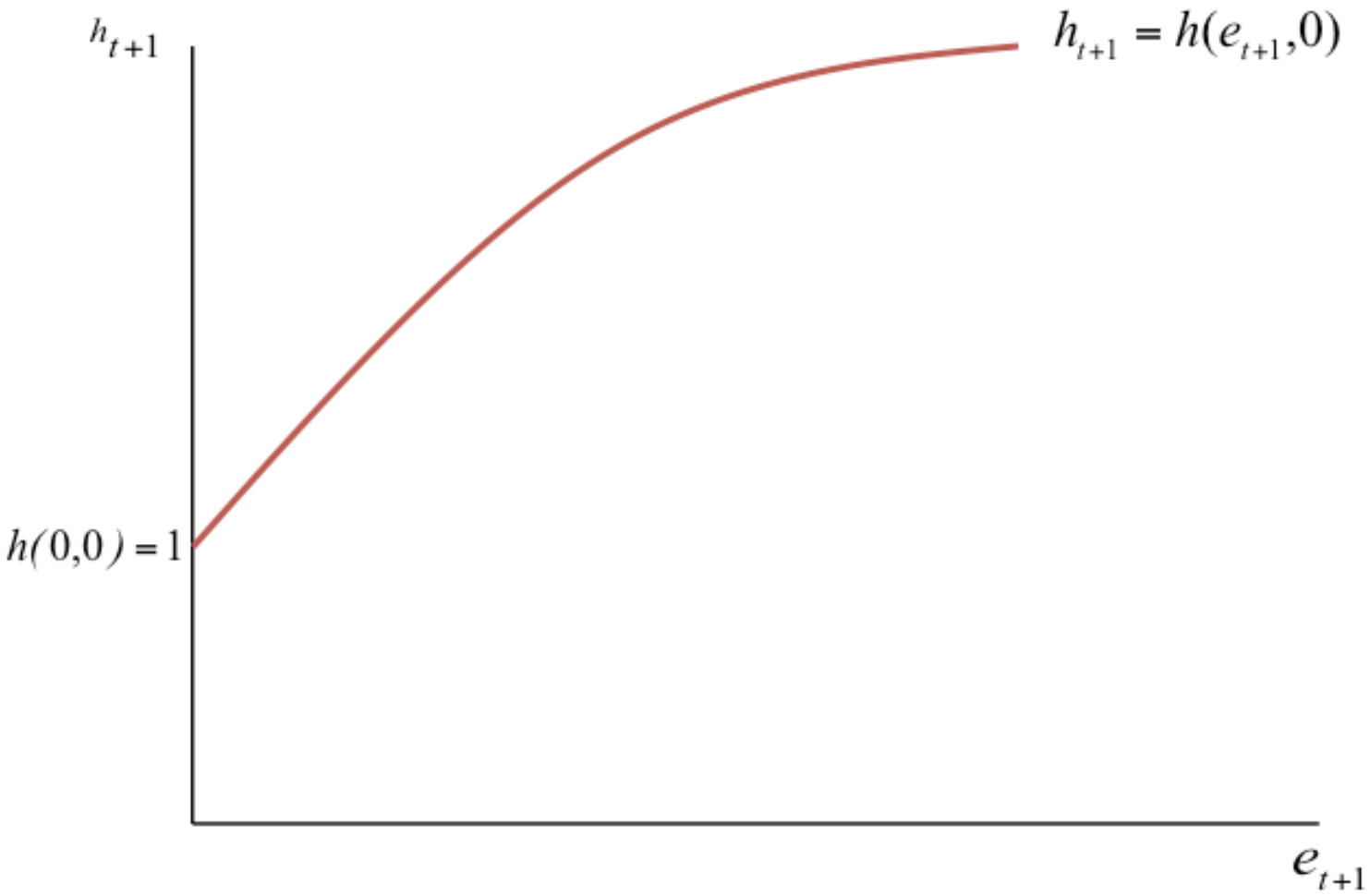
- $e_{t+1} \equiv$ the individual's education level (determined by parental investment, subject to their subsistence constraint, in period t)
- $g_{t+1} \equiv$ rate of tech progress

Human Capital Formation

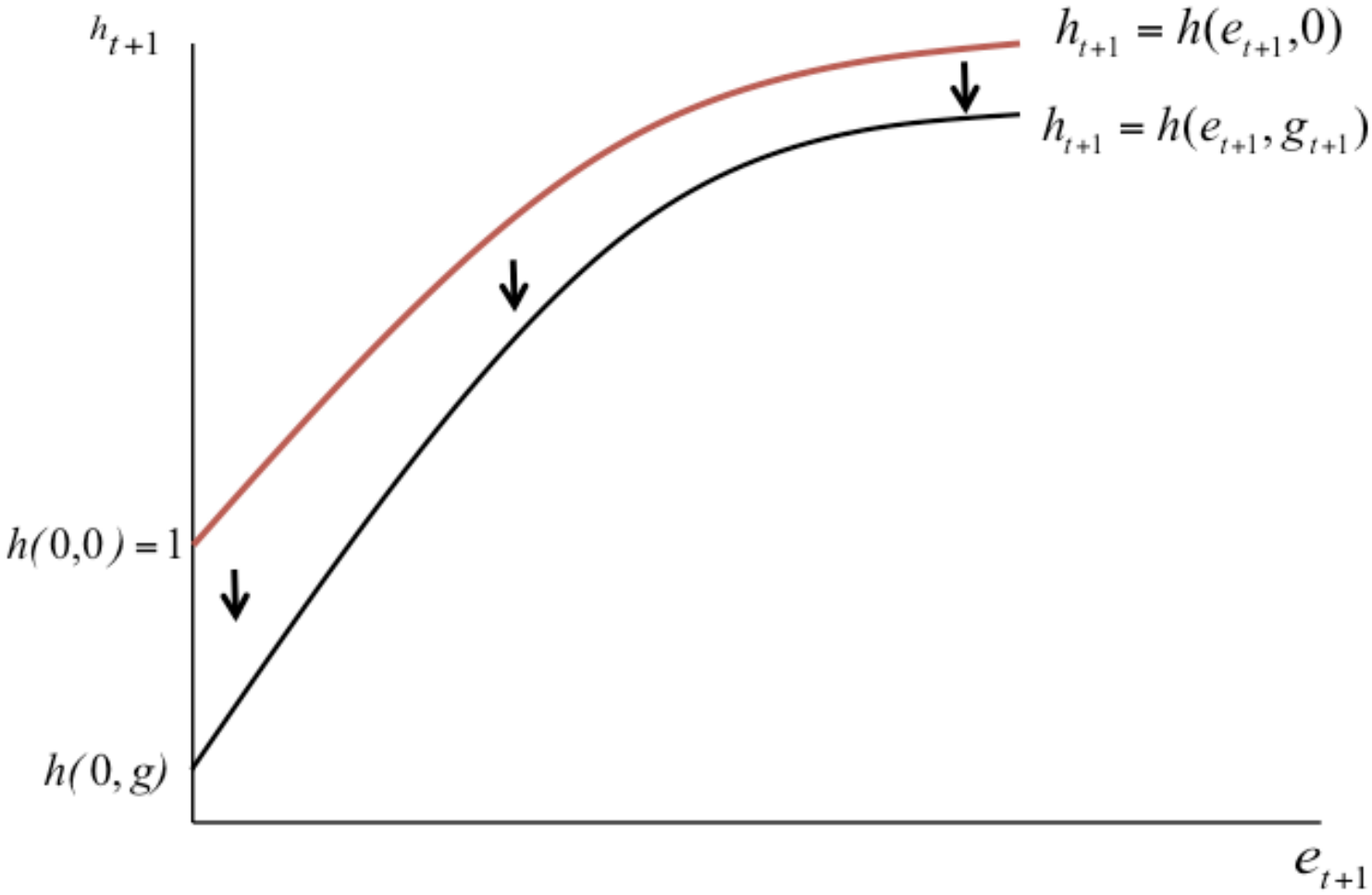
$$h_{t+1} = h(e_{t+1}, g_{t+1})$$

- $h_e(e,g) > 0$ 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)

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

  - $c_t \equiv$ 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

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

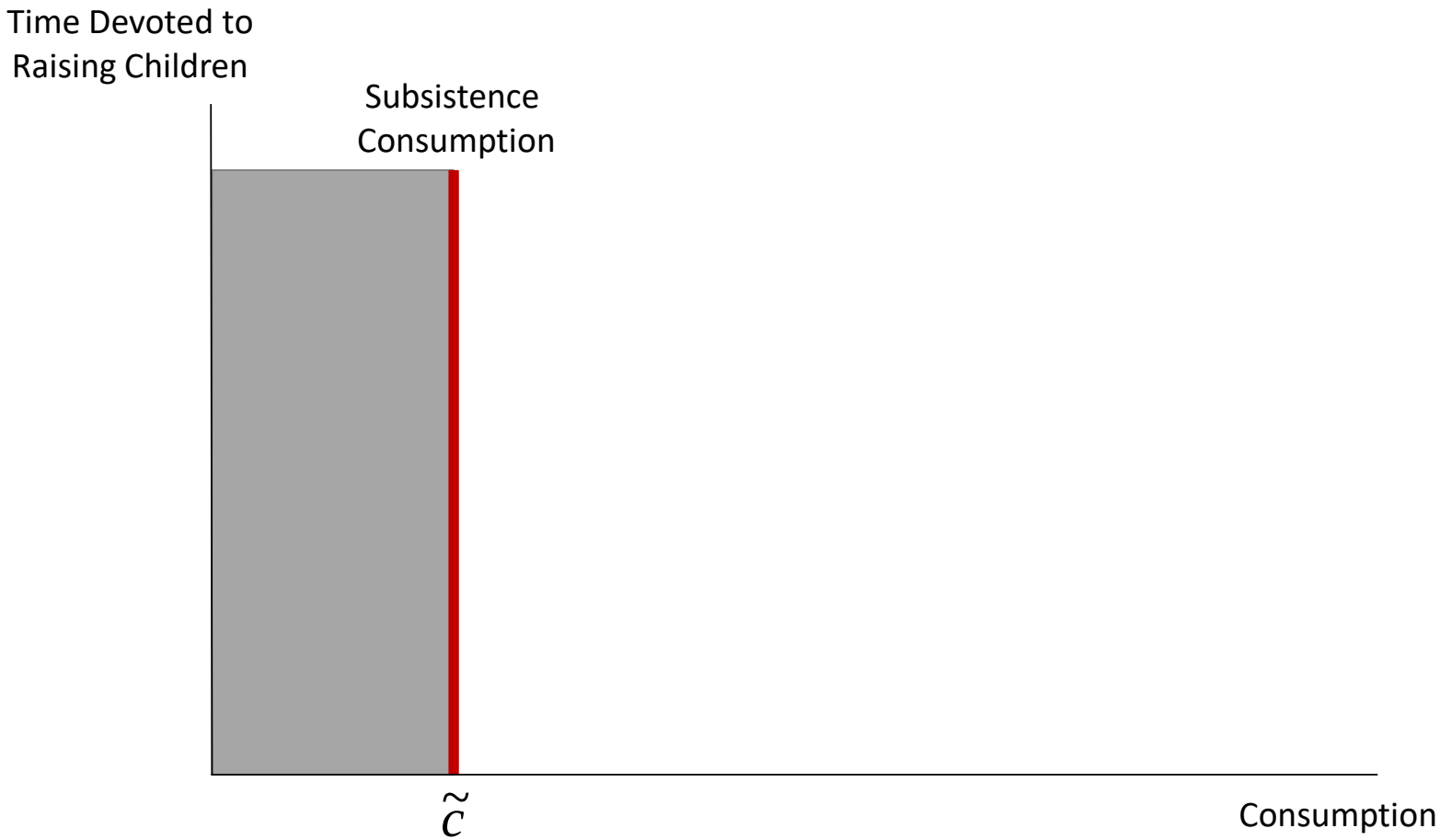
- $z_t \equiv$ potential income of individual t
- $\tau \equiv$ time required to raise a child, regardless of quality
- $\tau + e_{t+1} \equiv$ time needed to raise a child with education e_{t+1}
- $z_t(\tau + e_{t+1}) \equiv$ opportunity cost of raising 1 child with education e_{t+1}

$$z_t \equiv y_t$$

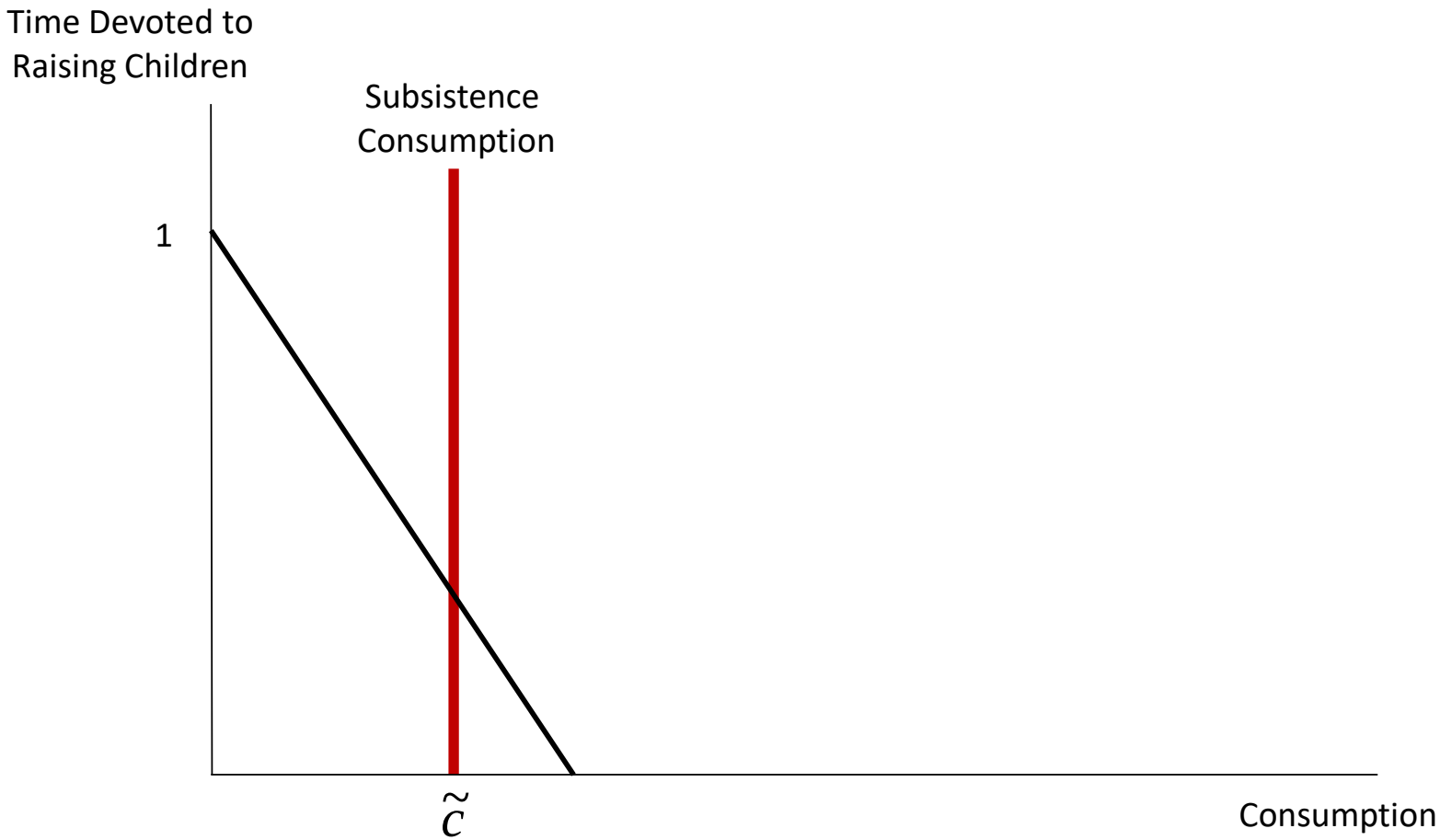
- Subsistence consumption constraint:

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

The Subsistence Consumption Constraint



Subsistence Consumption & Budget Constraints



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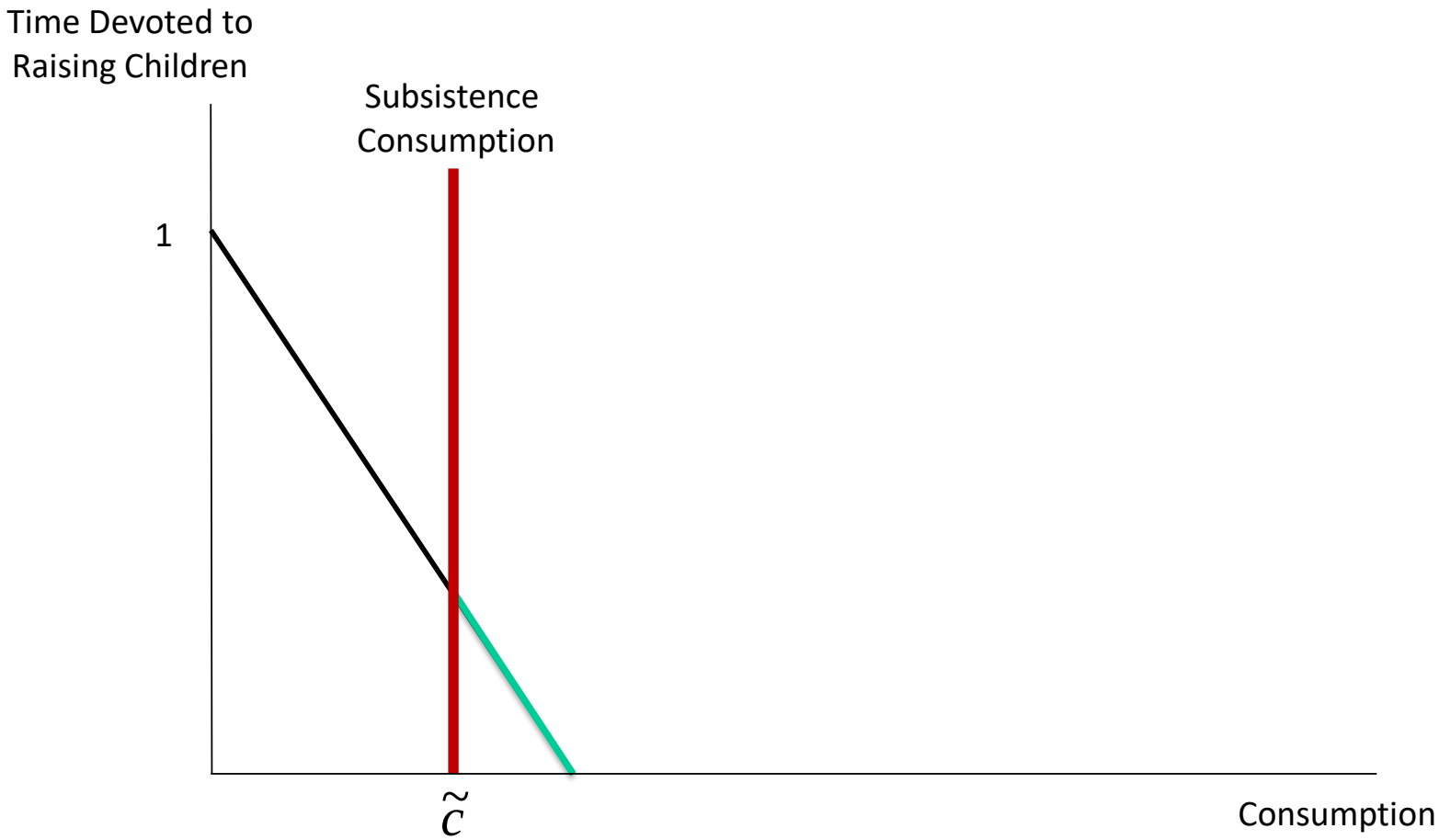

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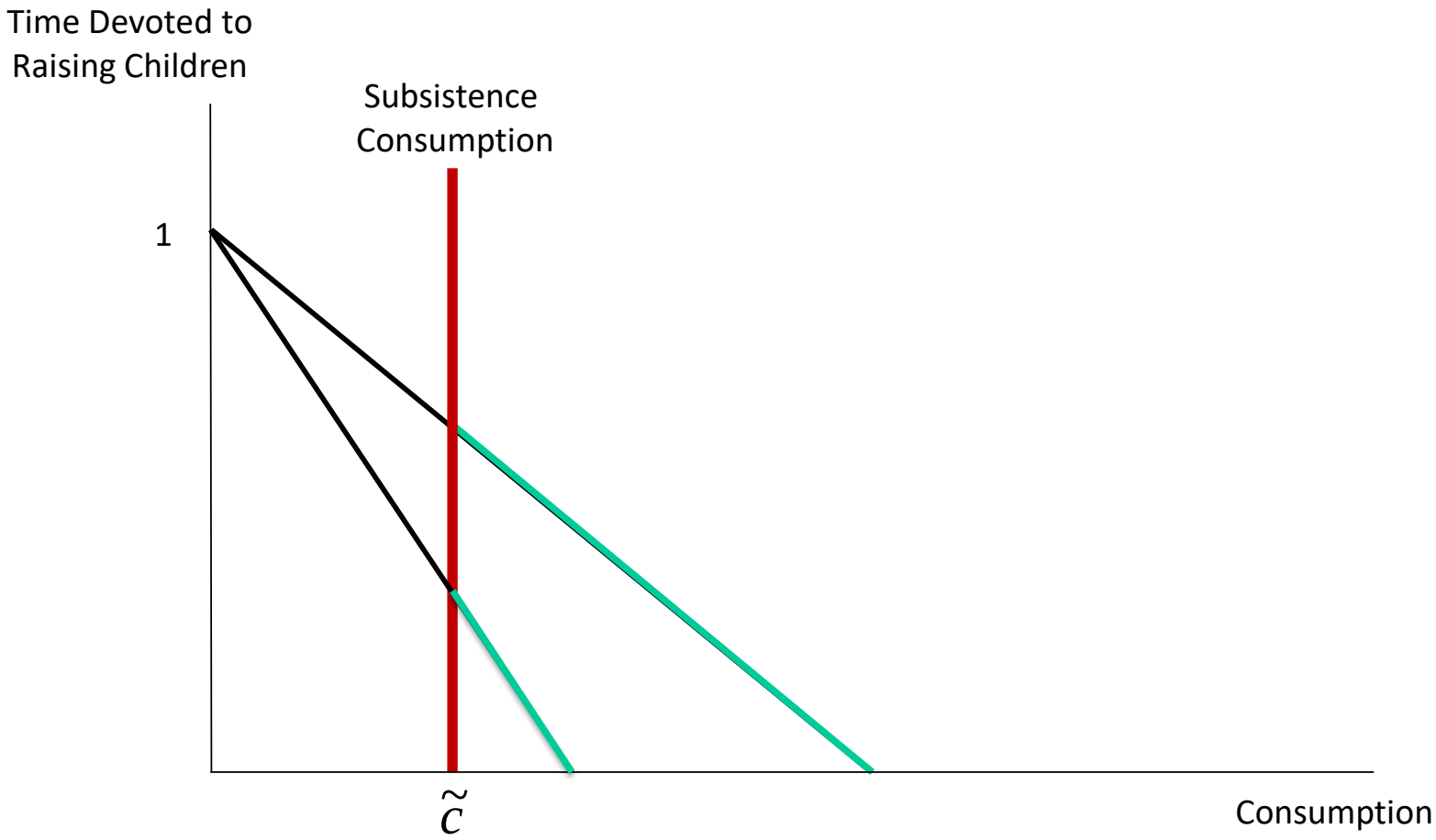
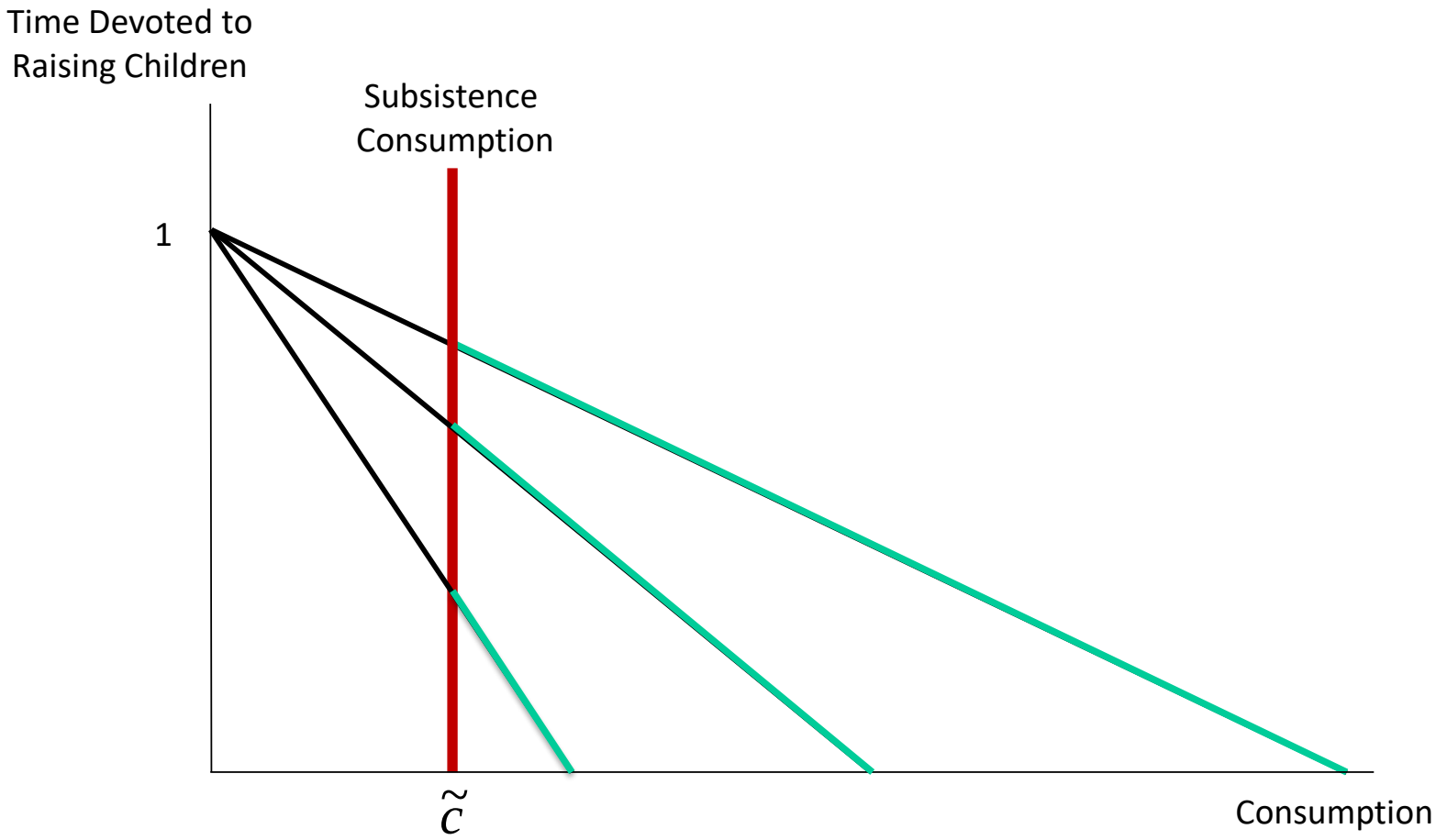
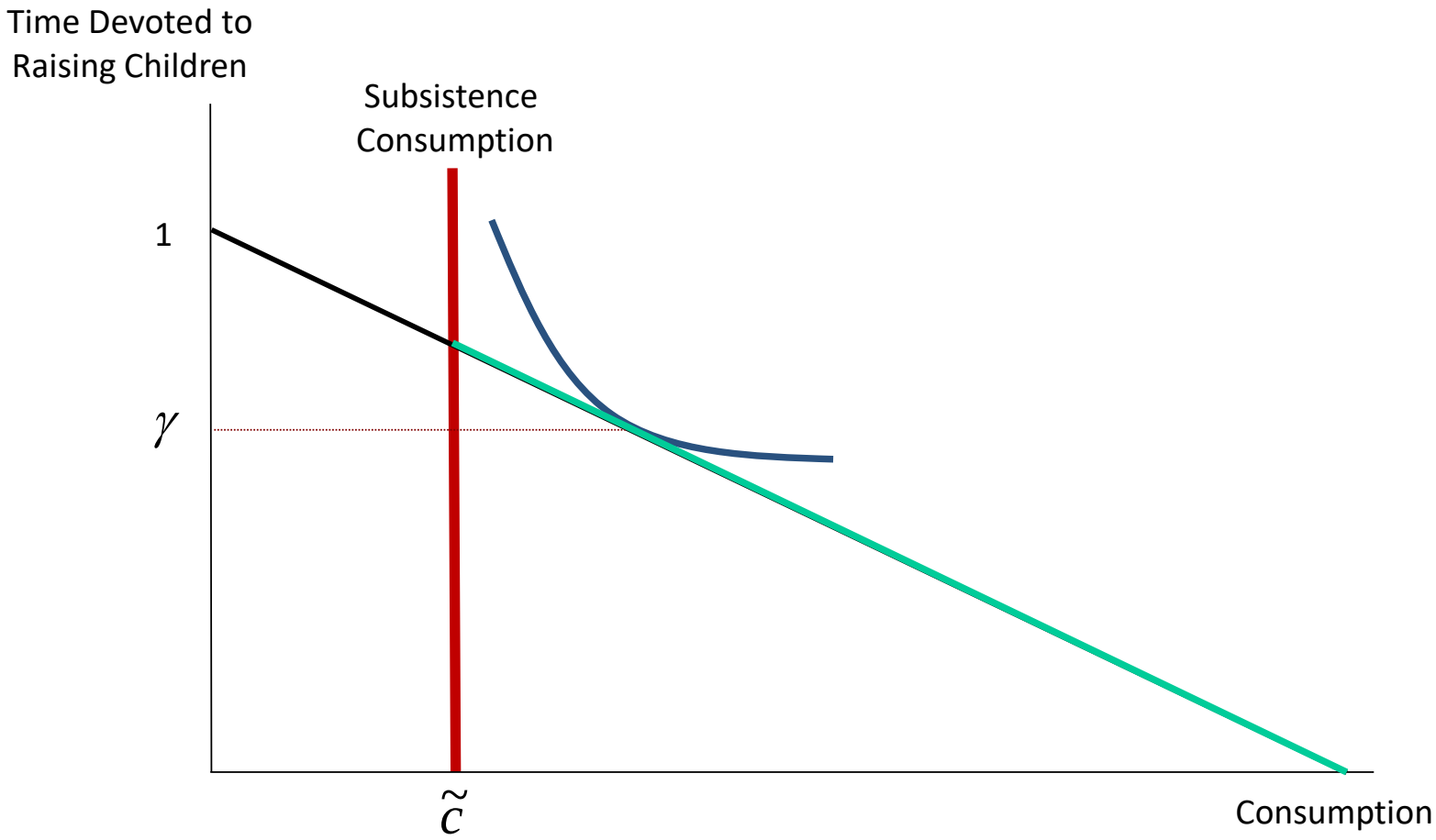


Subsistence Consumption & Budget Constraints



Optimization - Subsistence Constraints is not Binding



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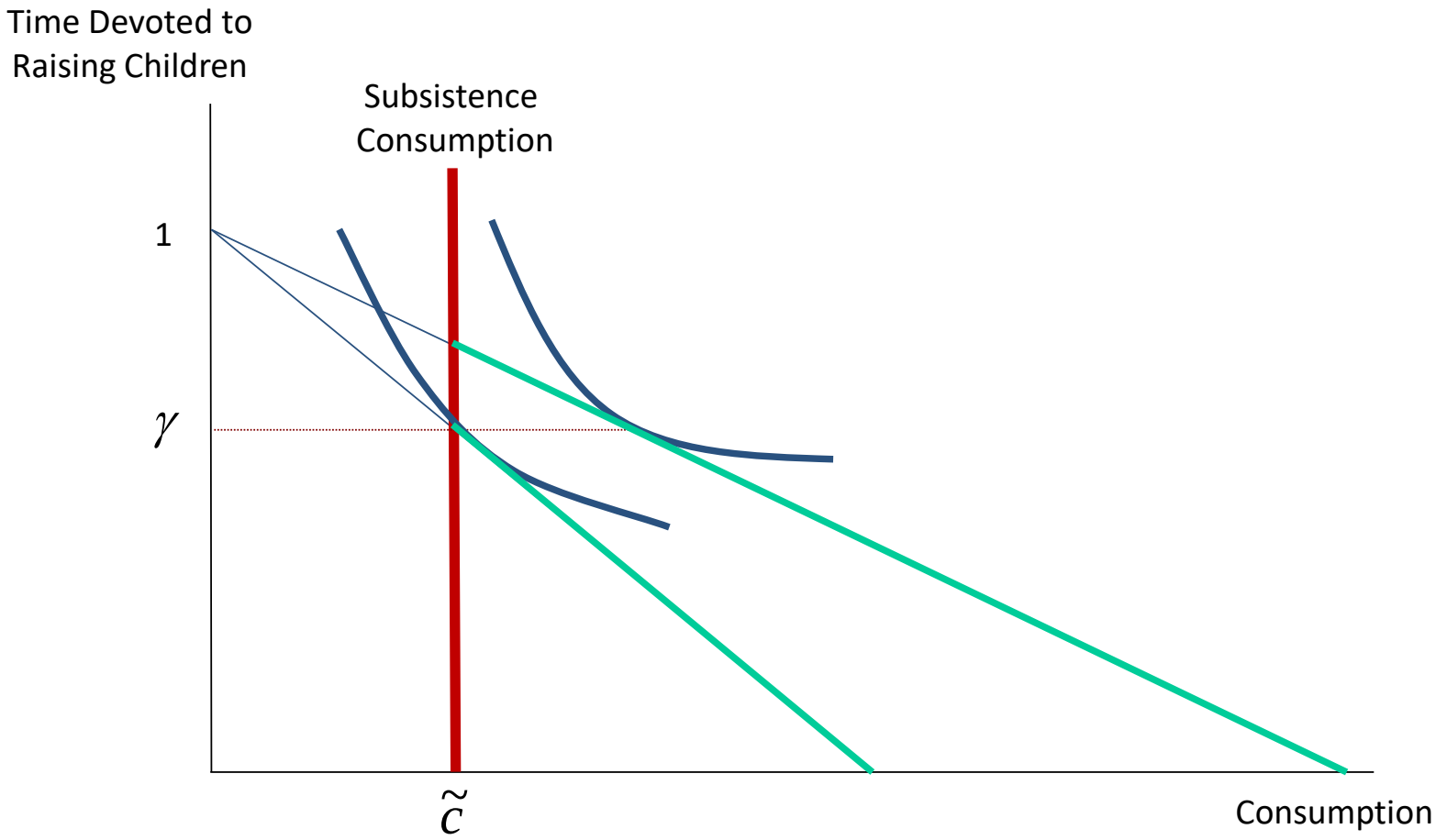

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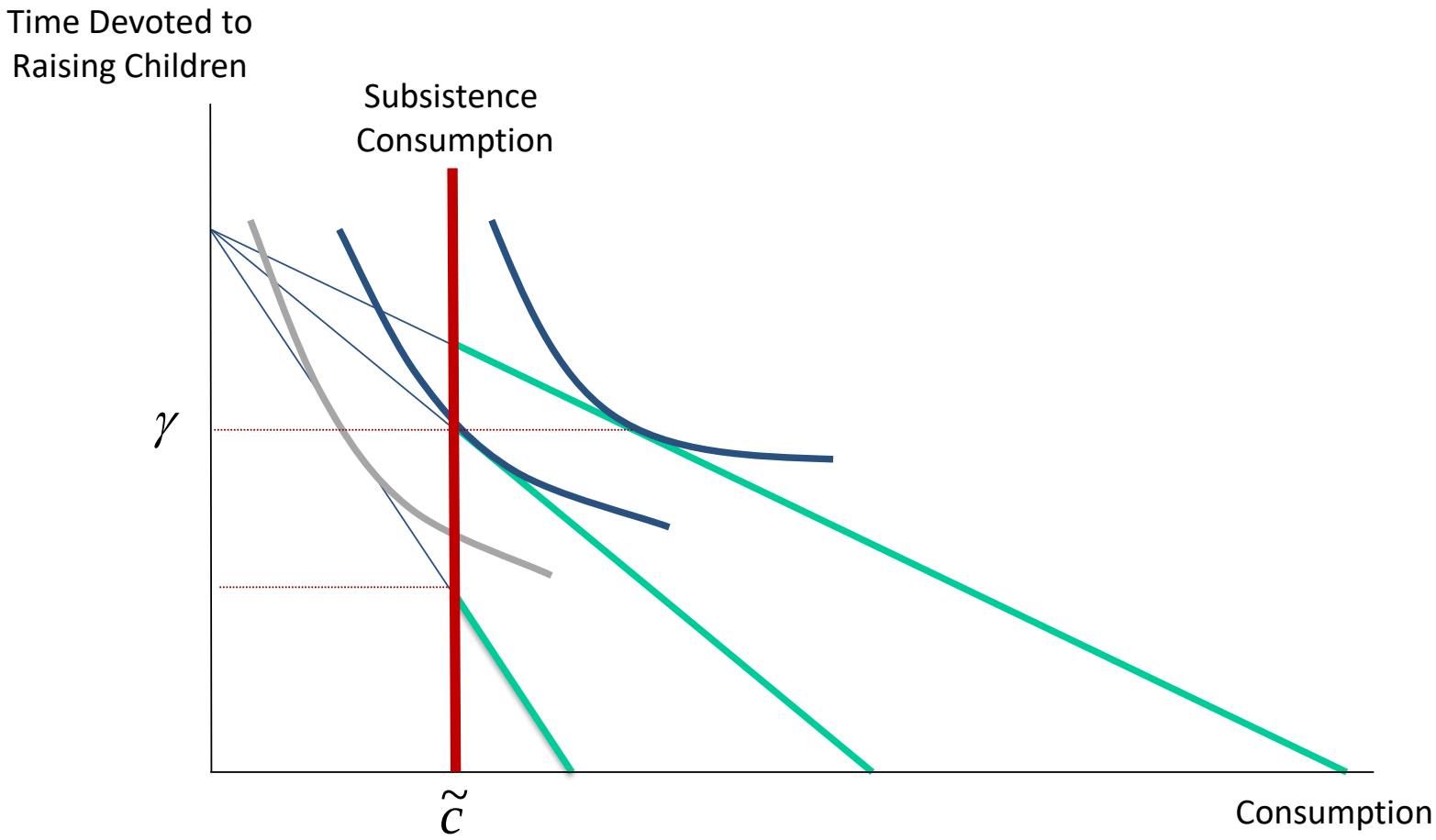

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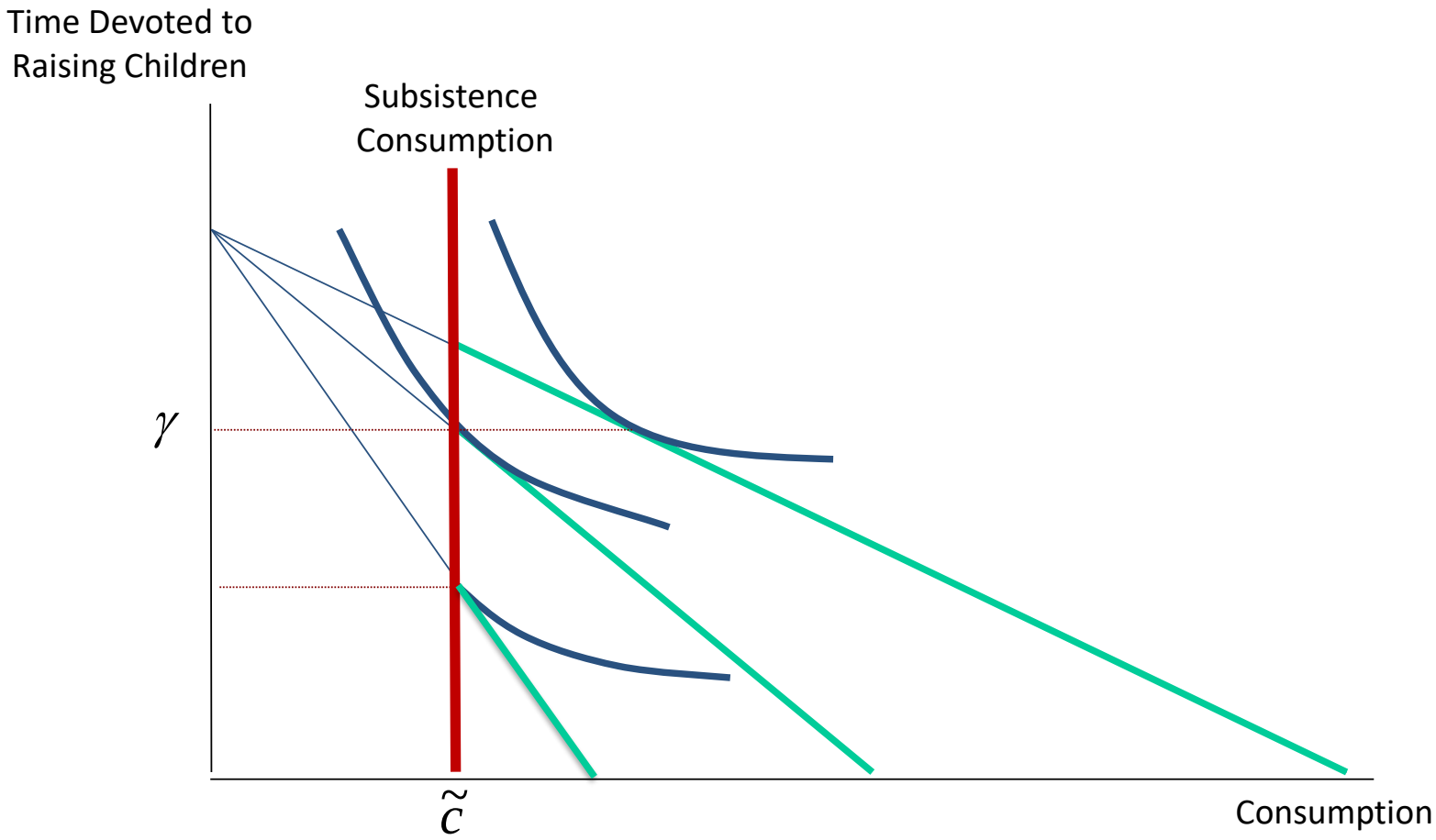
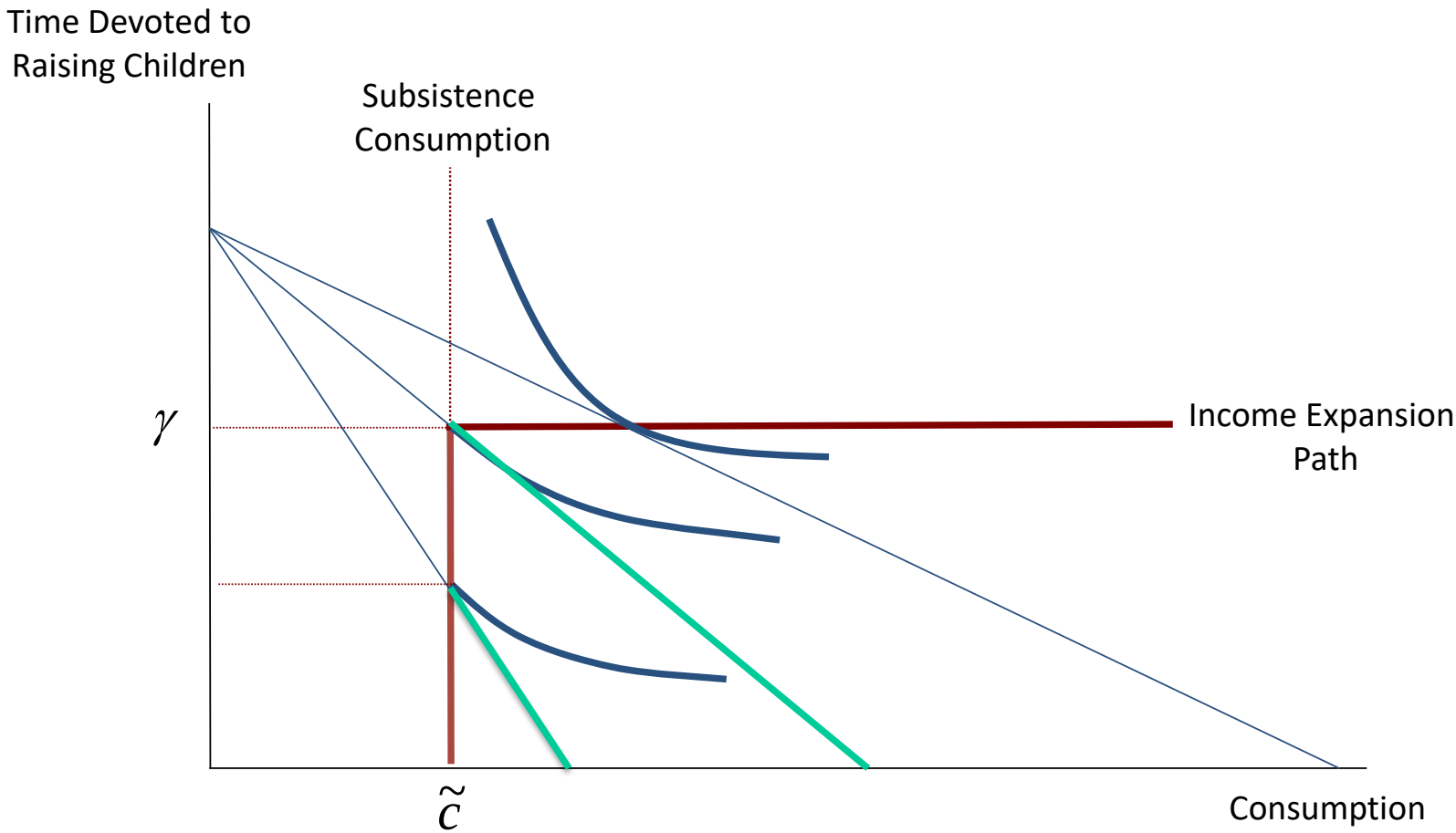
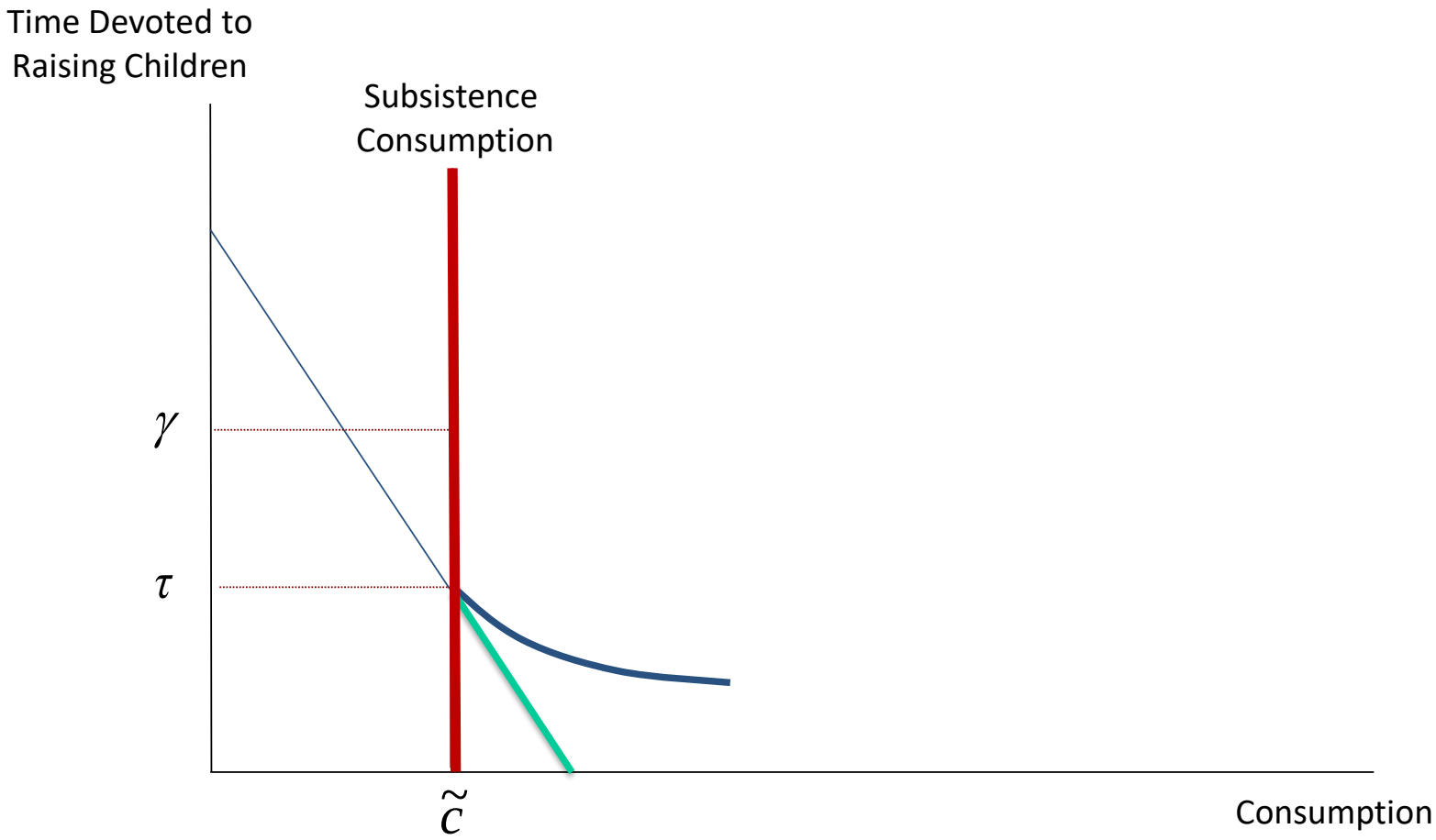


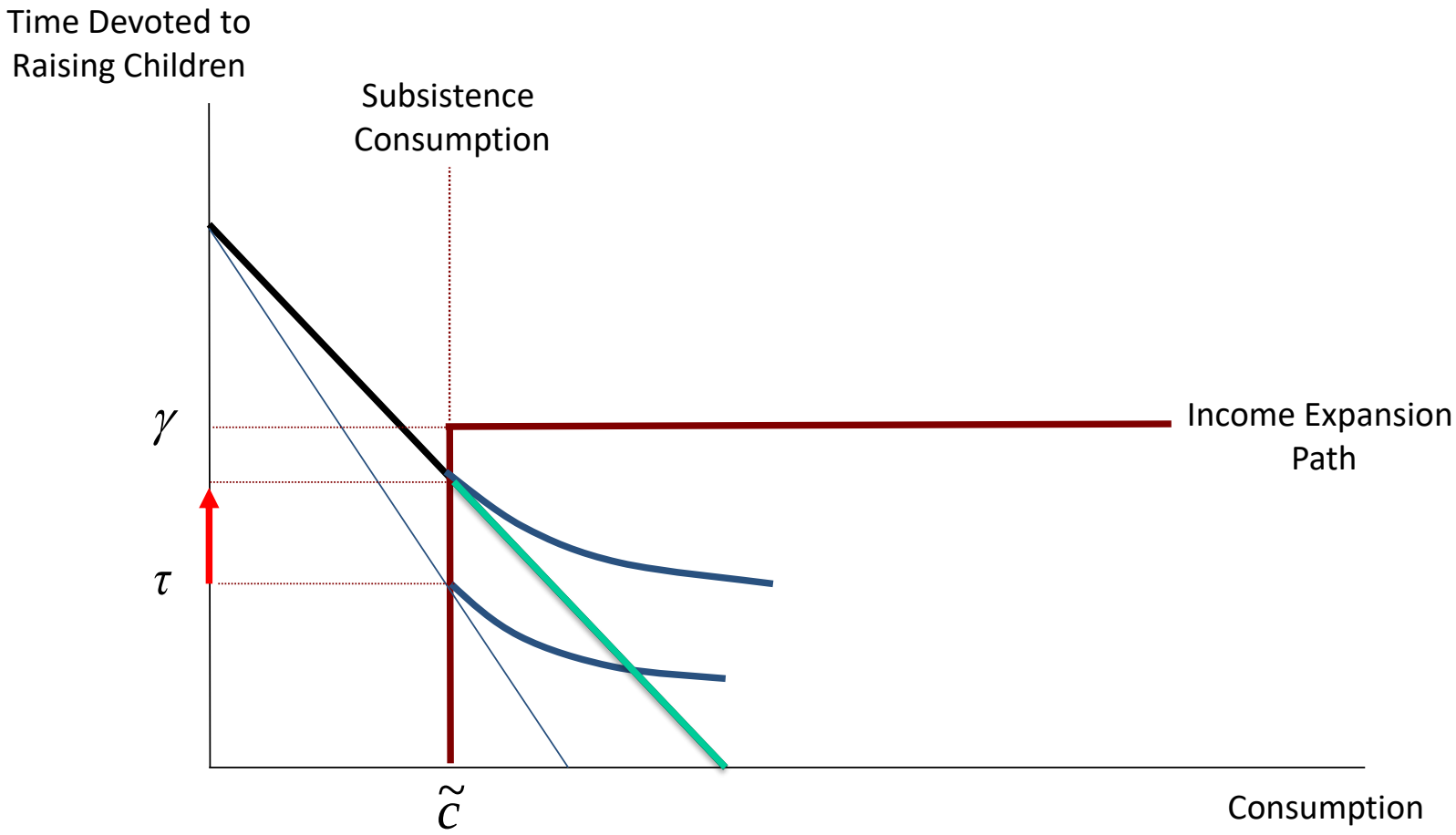
Optimization - Income Expansion Path



Optimization - Malthusian Steady-State Equilibrium



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



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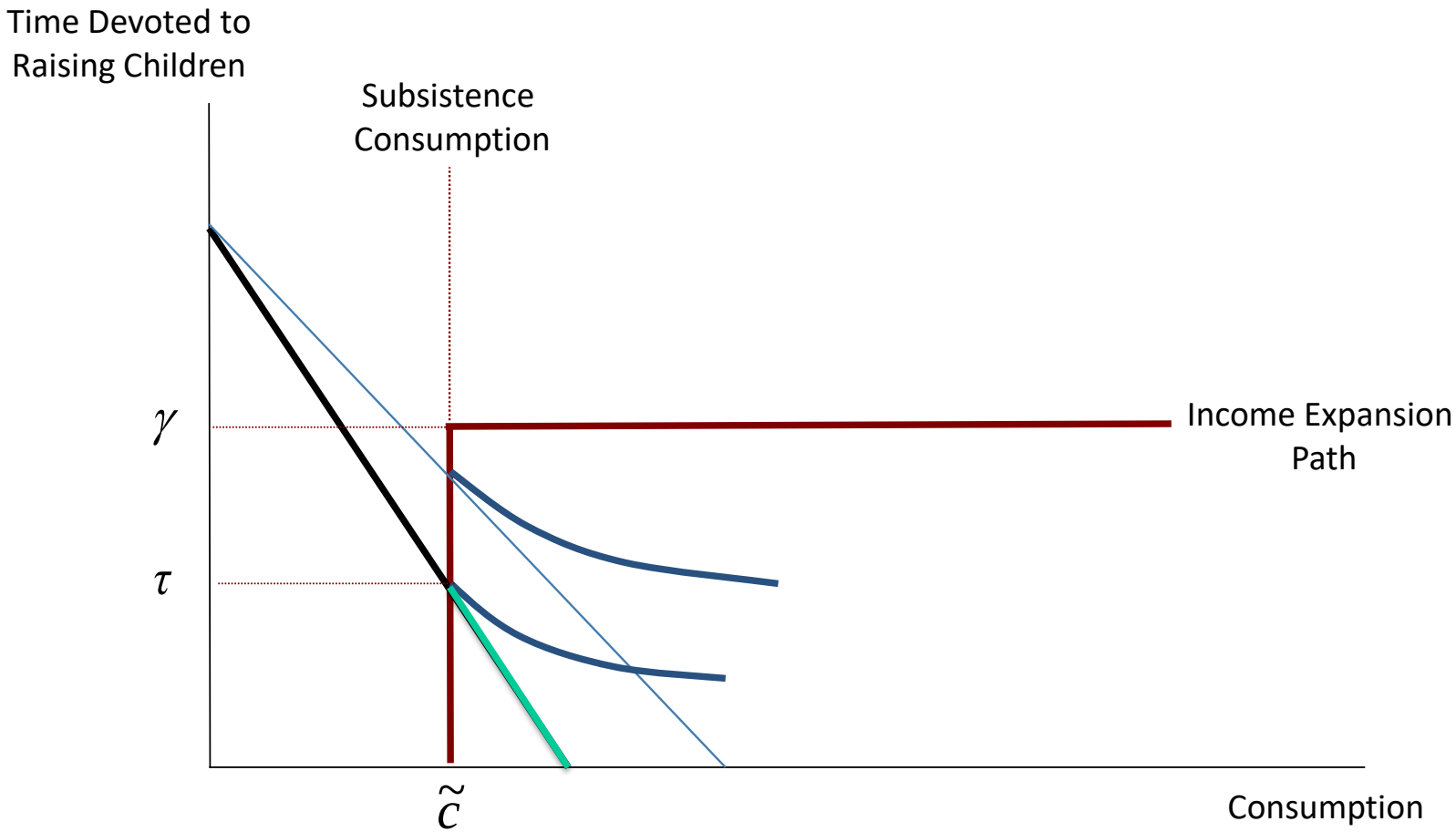

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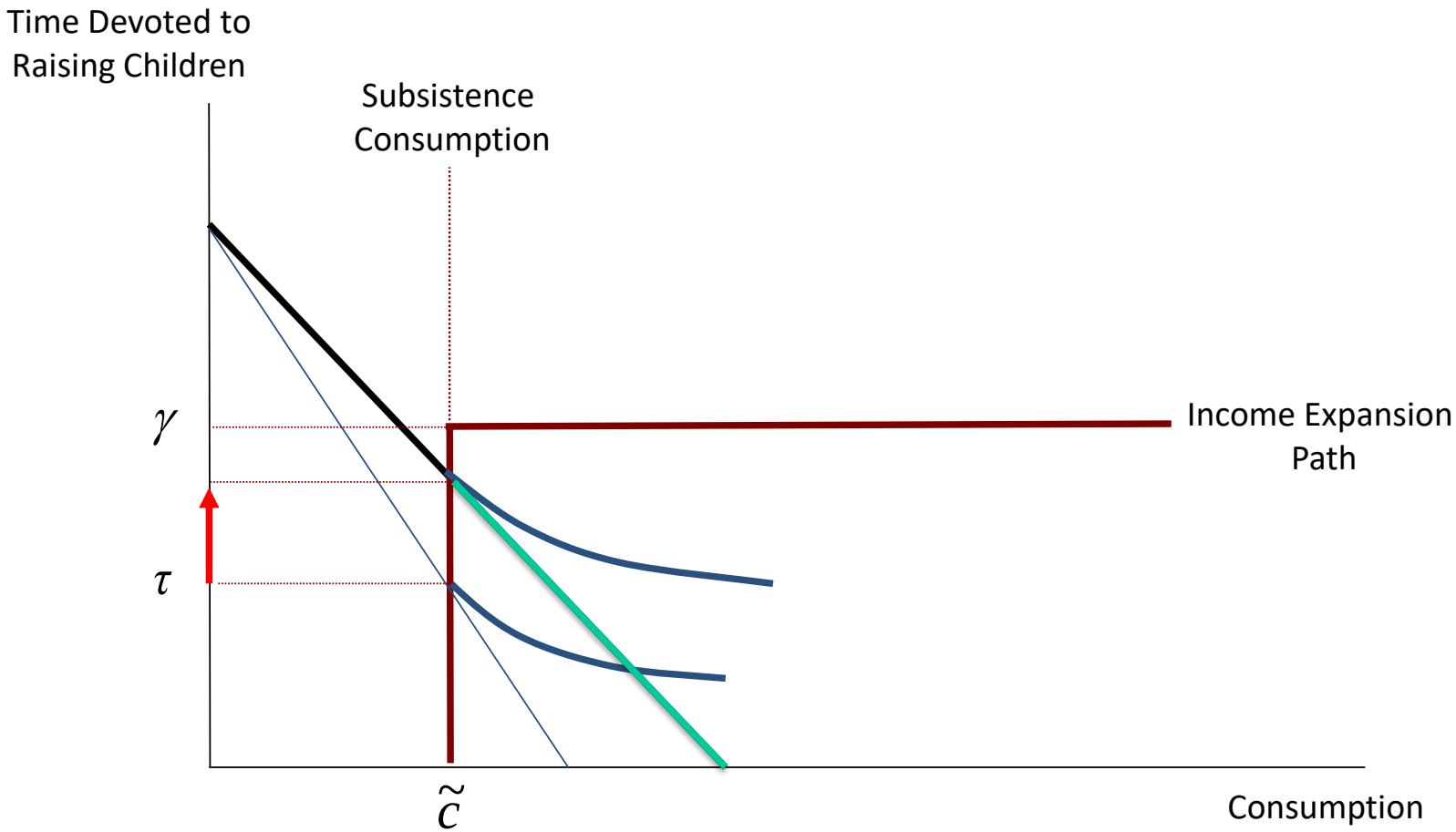

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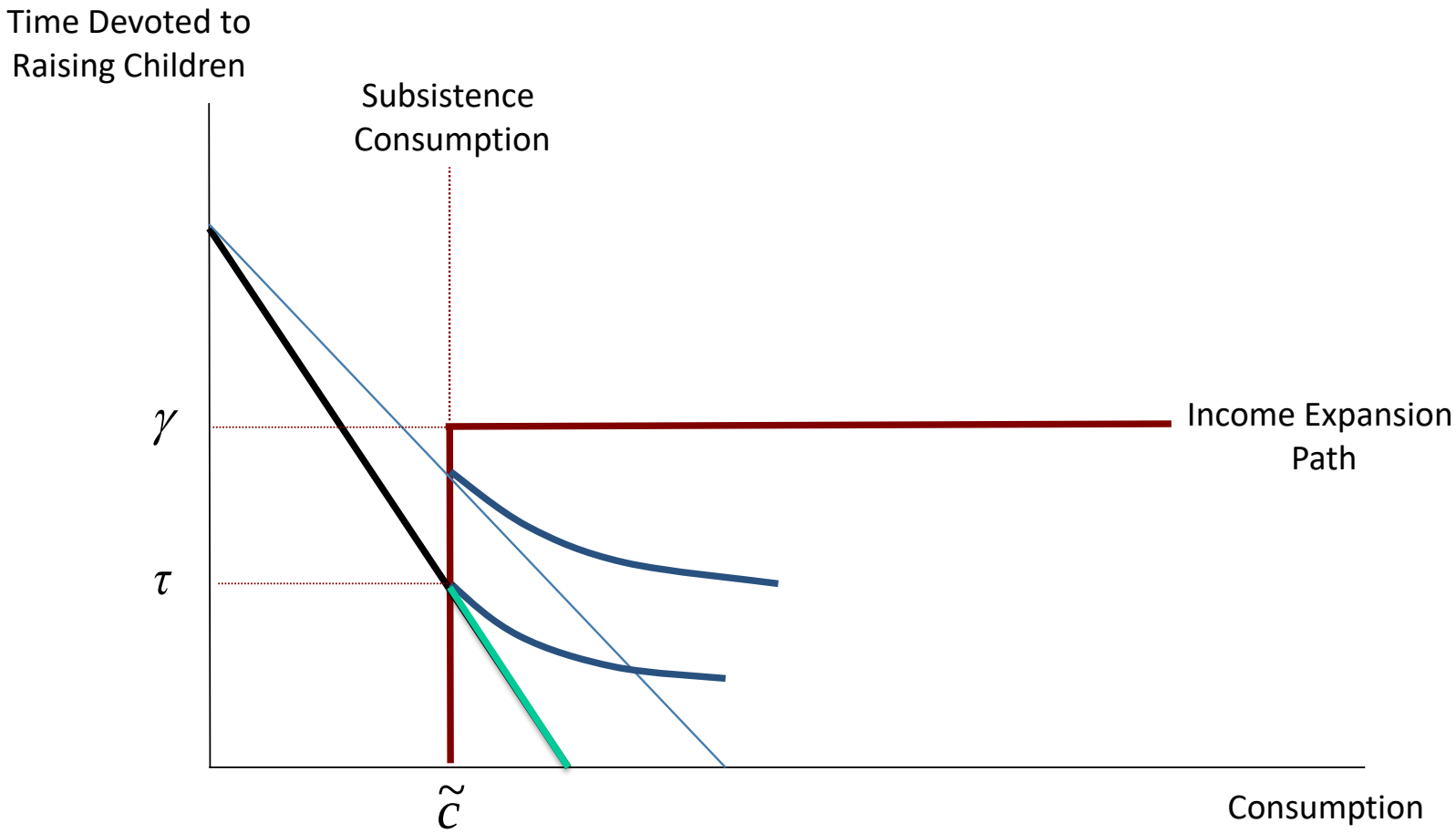
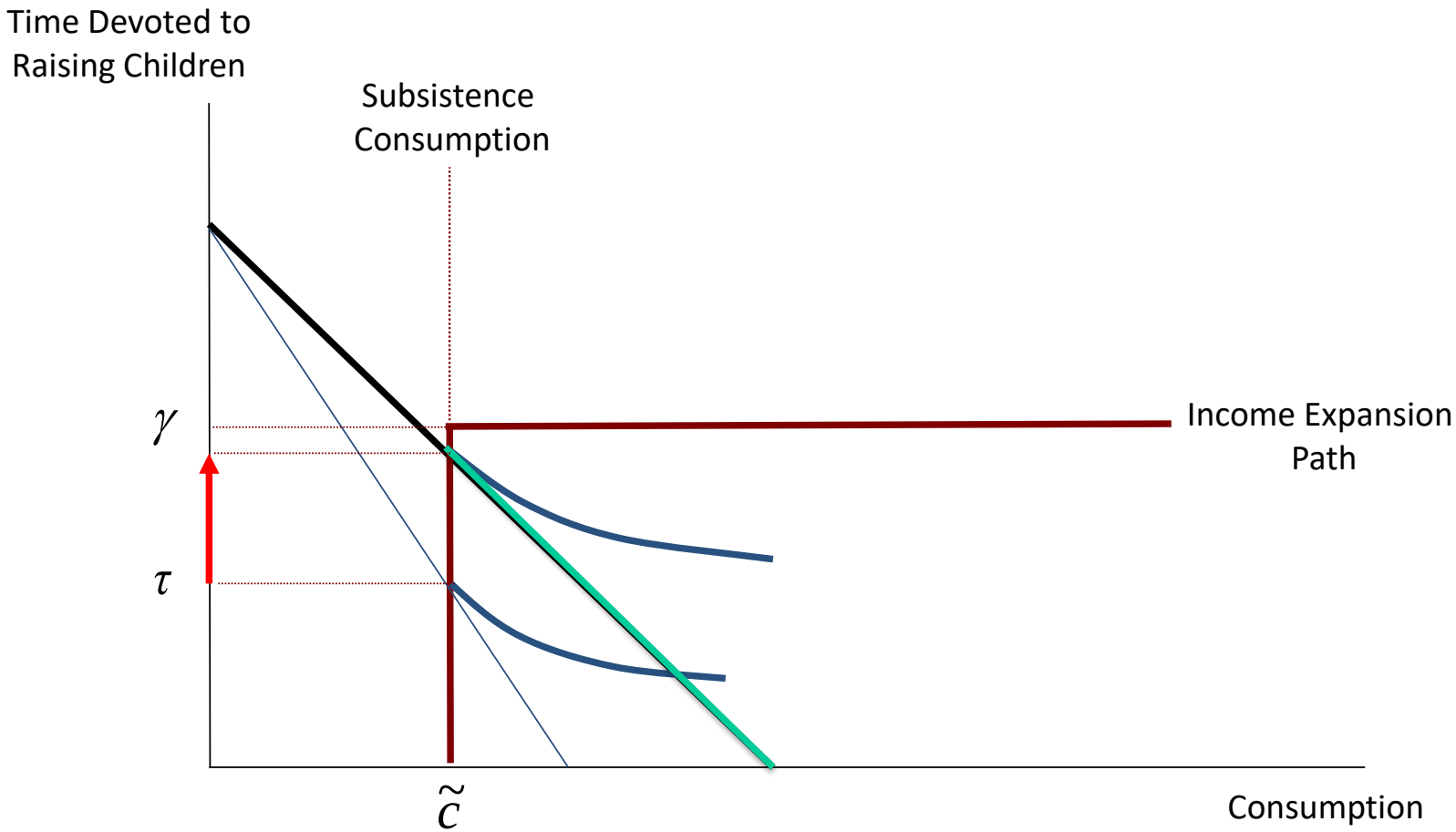
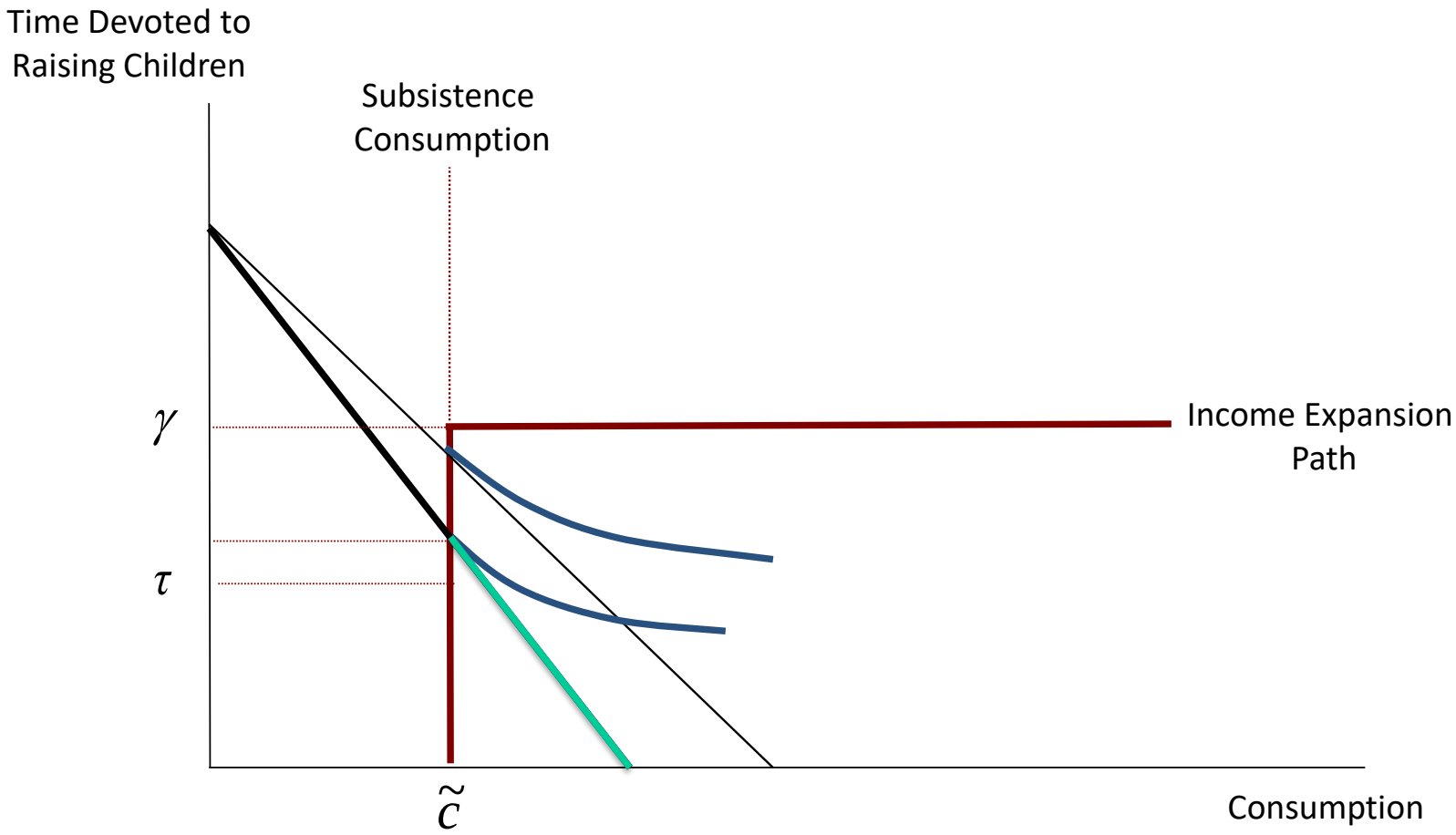


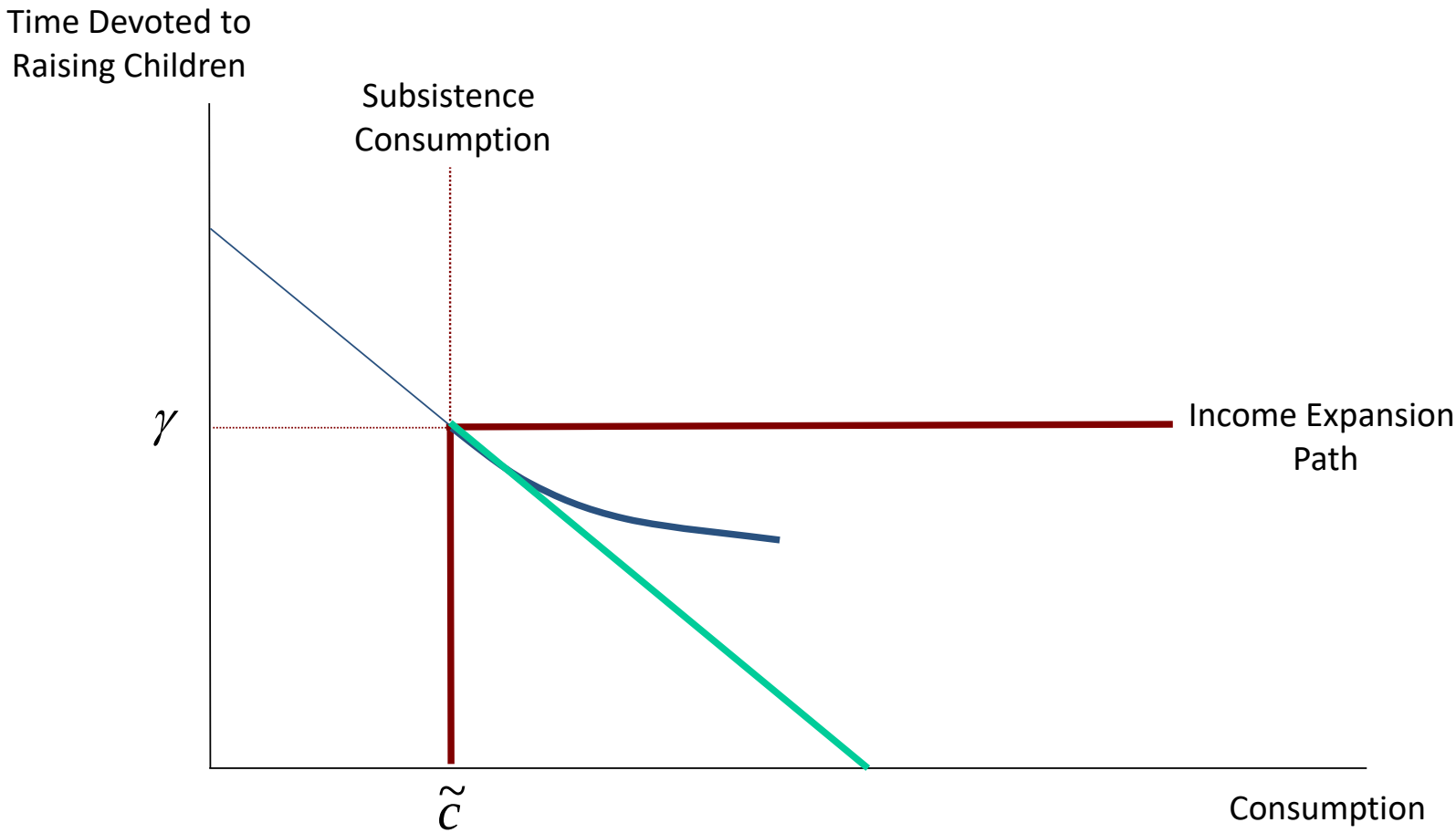
Optimization - Additional Tech Progress in the Malthusian Epoch (SR)



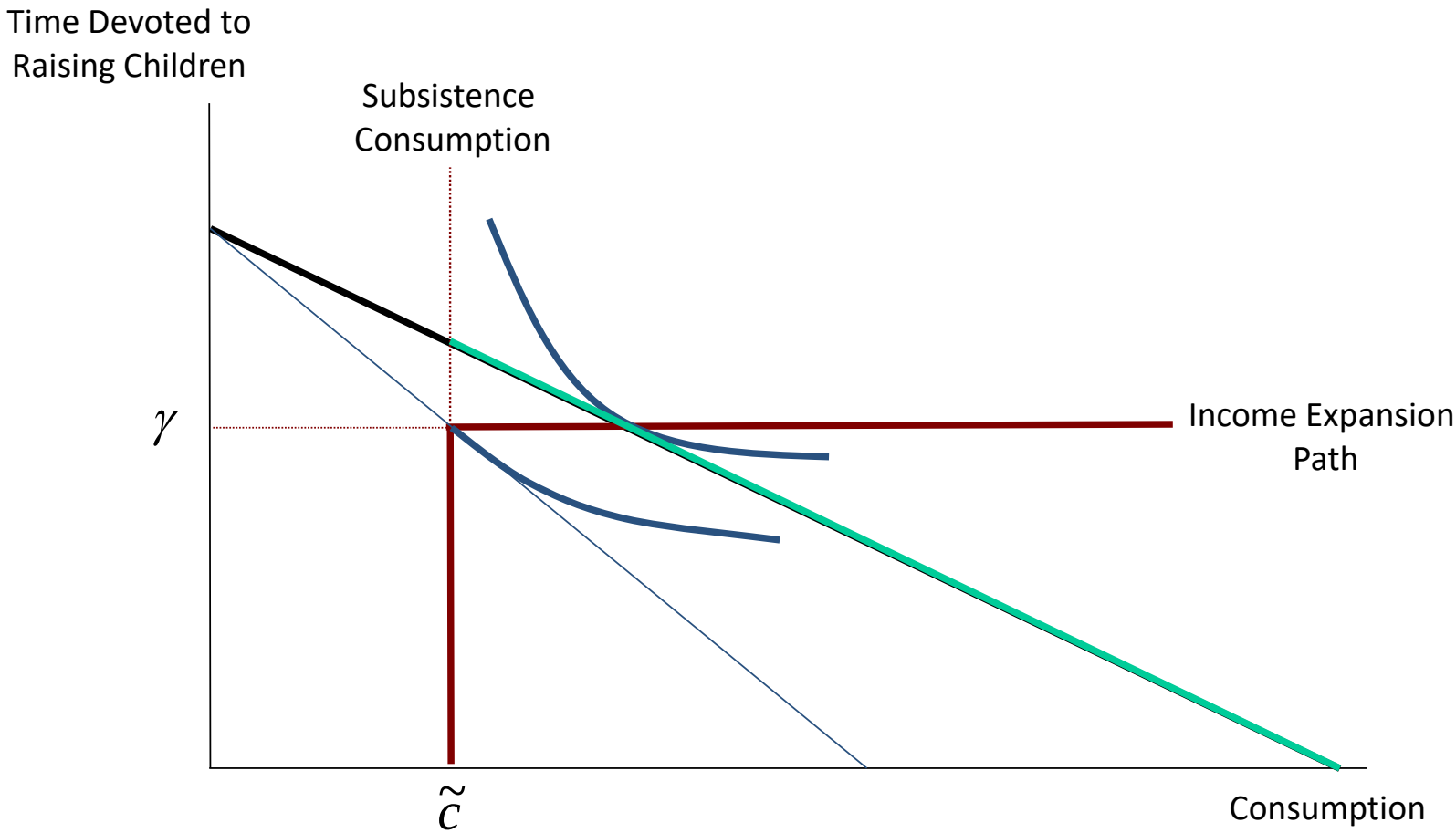
Optimization - Additional Tech Progress in the Malthusian Epoch (LR)



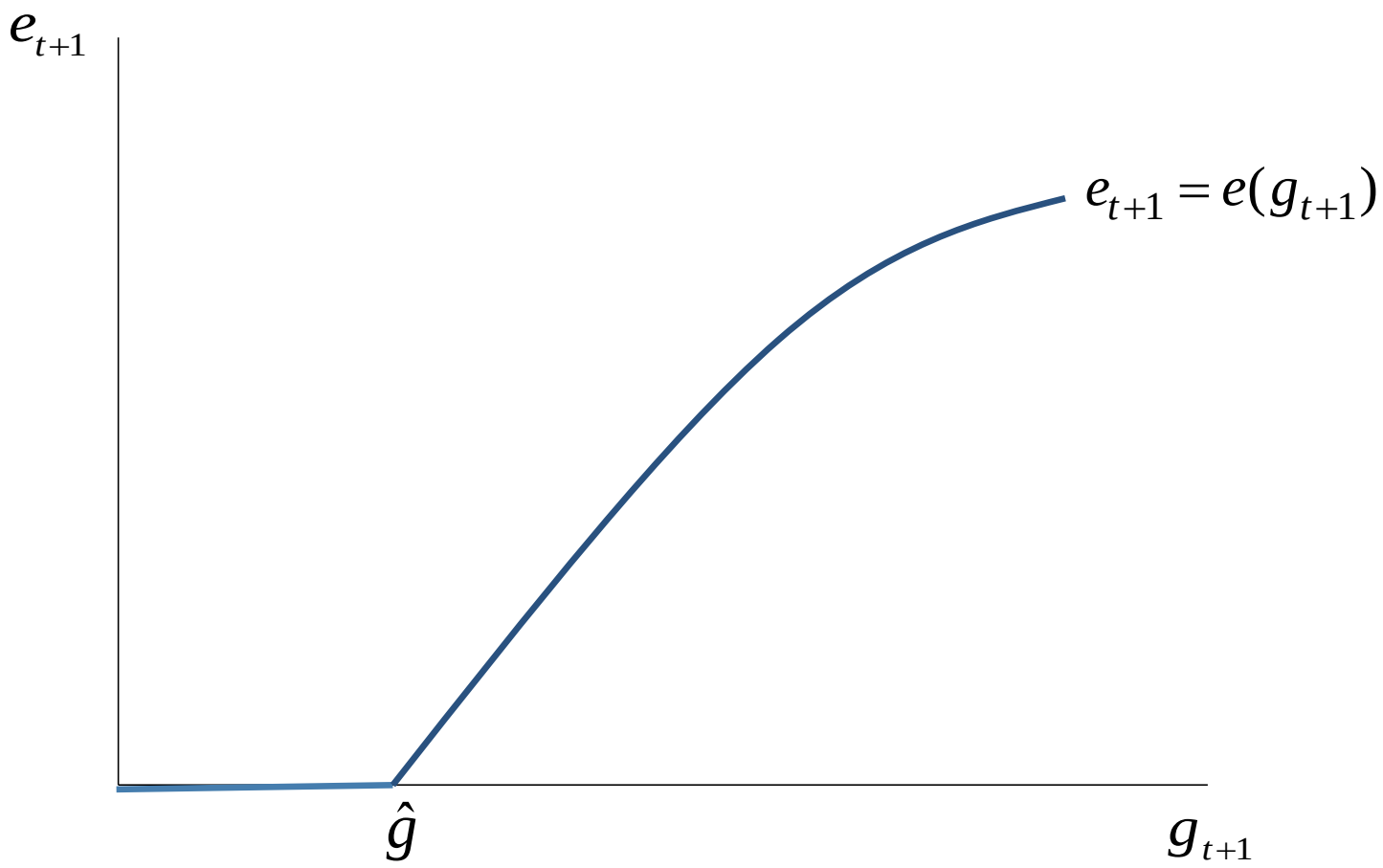
Optimization - Impact of Technological Progress (Eve of the Take-off)



Optimization - Escape from the Malthusian Trap



Optimization - Investment in Child Quality



The Dynamical System

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

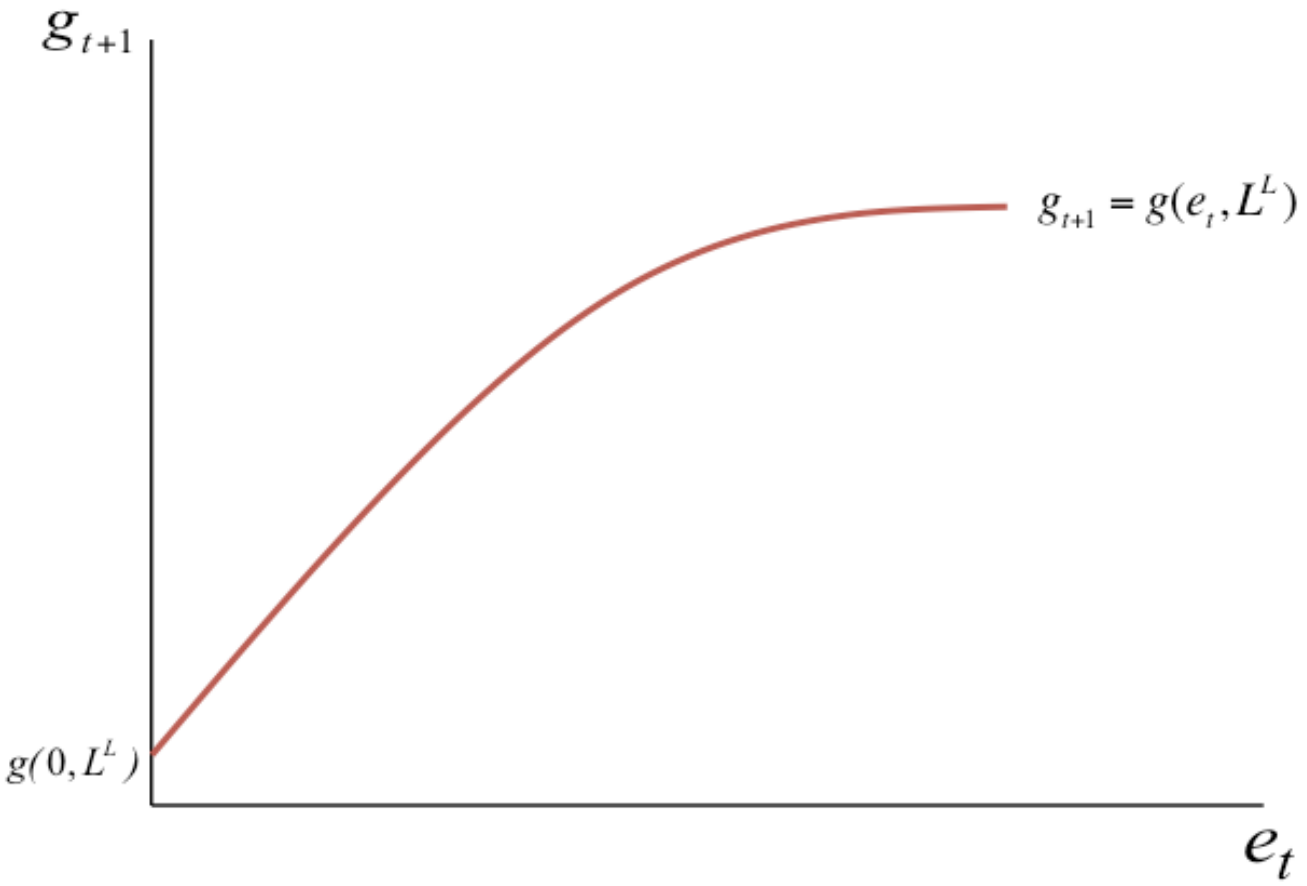
$$\begin{cases} g_{t+1} = g(e_t, L_t) \\ e_{t+1} = e(g_{t+1}) = e(g(e_t, L_t)) \\ L_{t+1} = n_t L_t = n(e_t, g_t, x_t, L_t) \\ x_{t+1} = \frac{A_{t+1} X}{L_{t+1}} = \phi(e_t, g_t, x_t, L_t) \end{cases}$$

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



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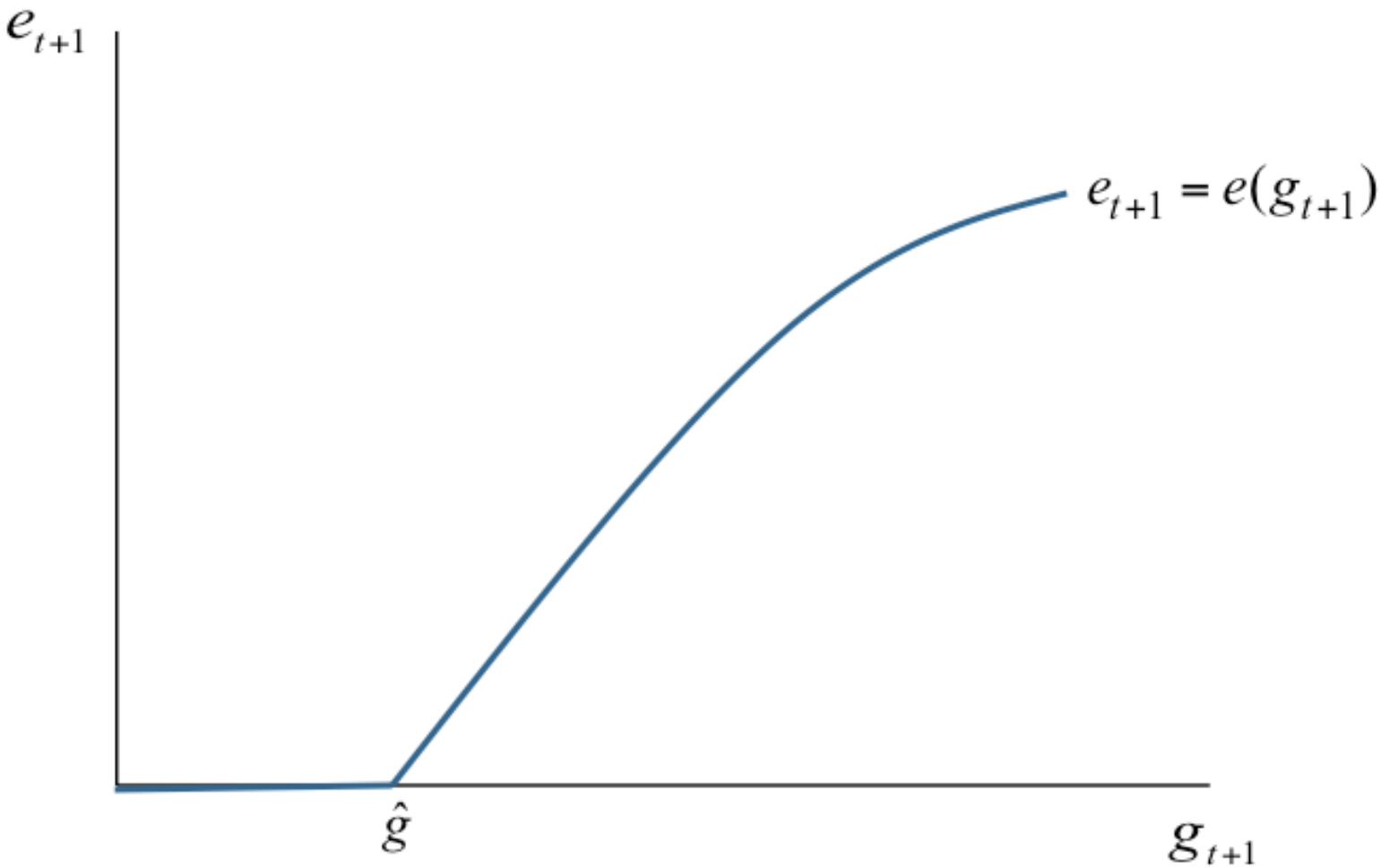
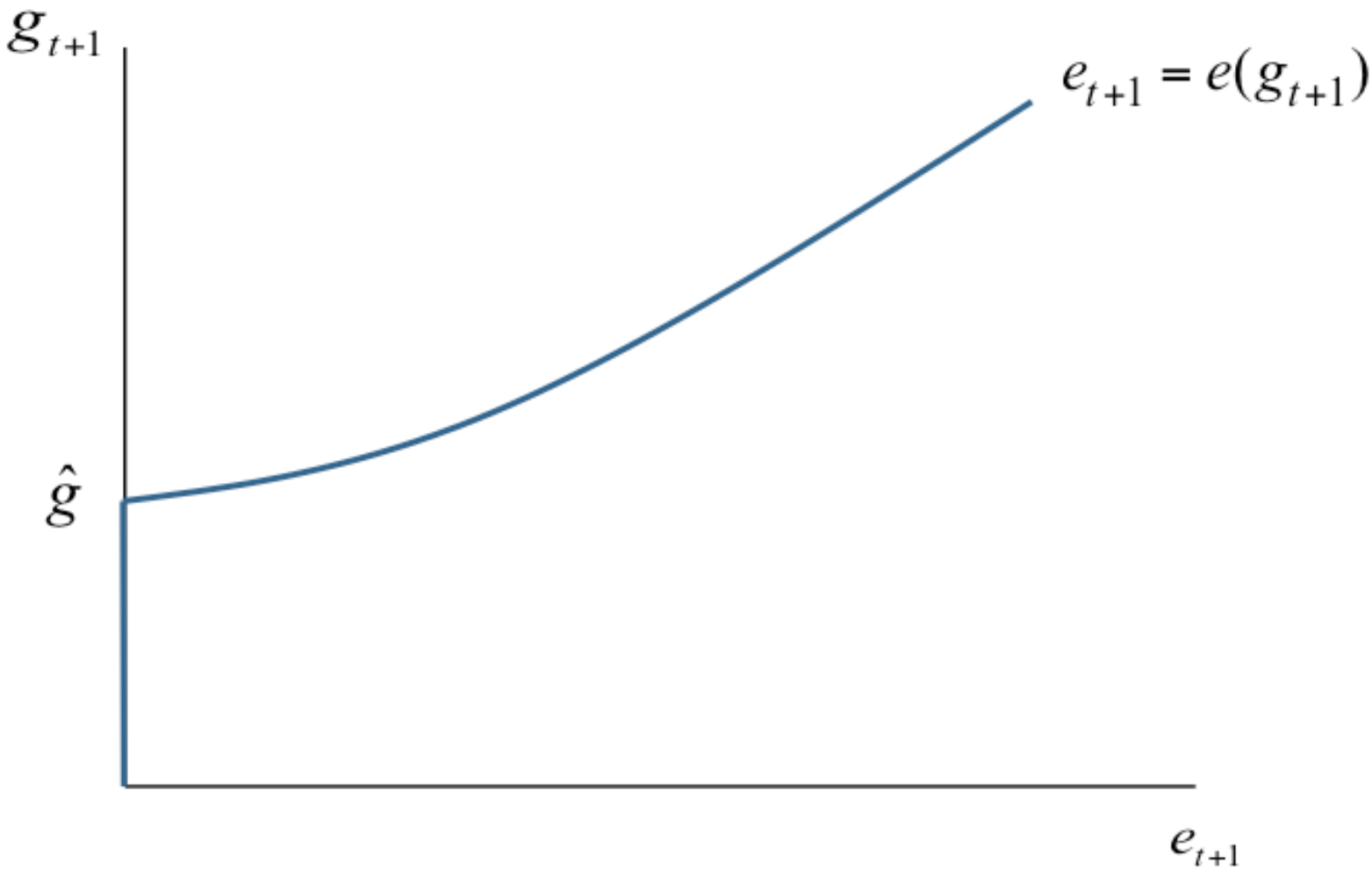
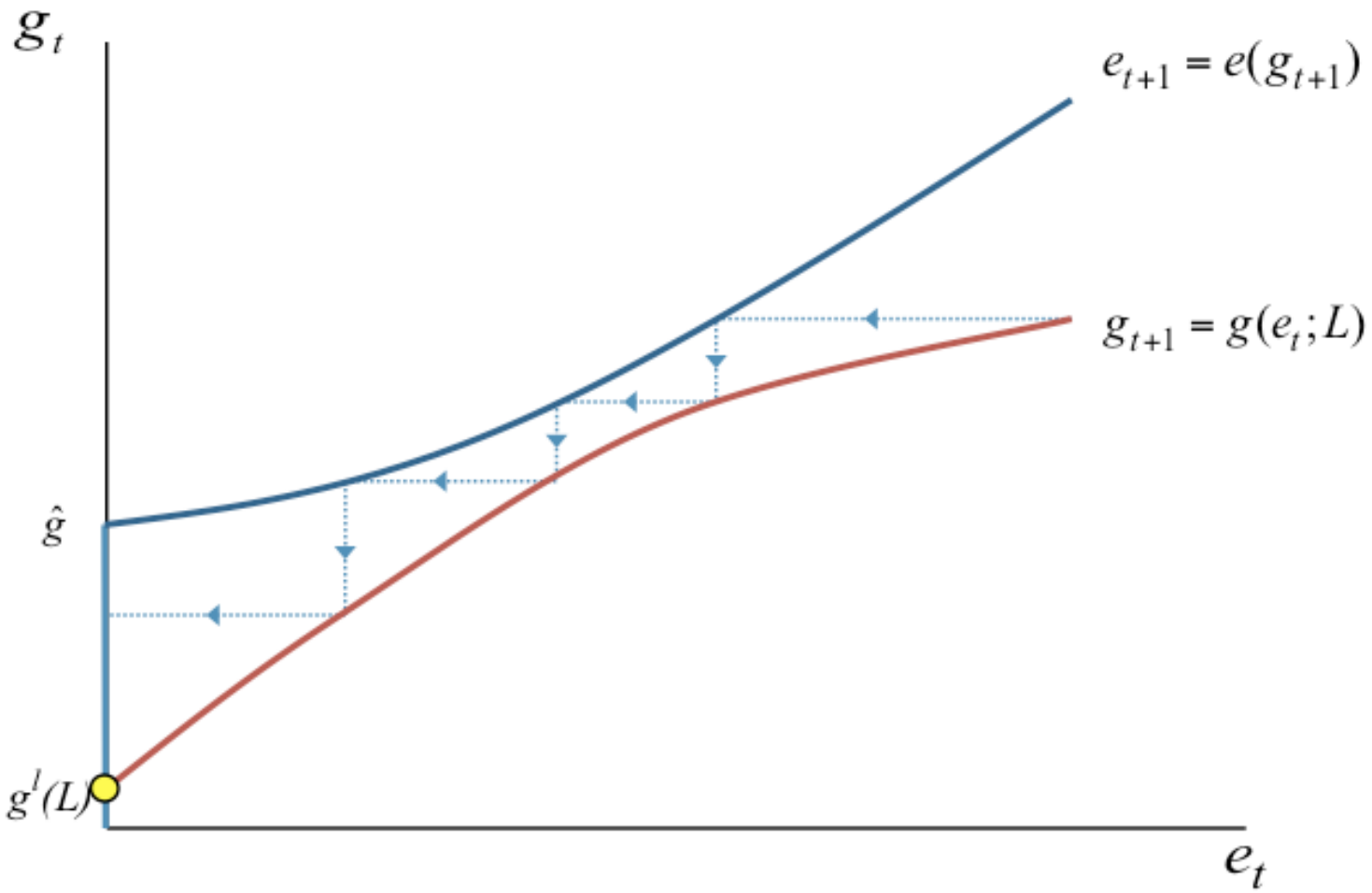


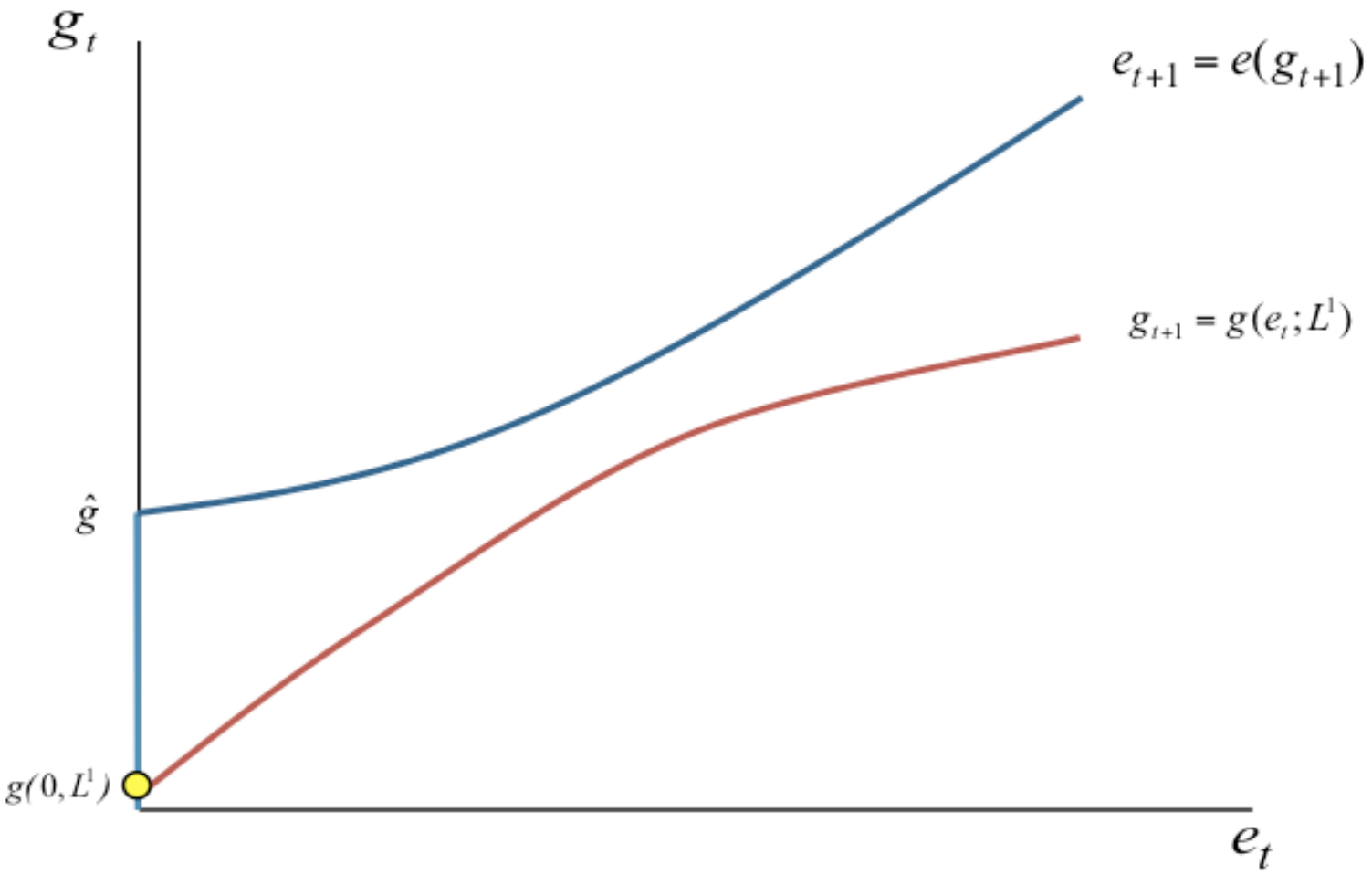
The Effect of Technology on Education: Flipped Axis



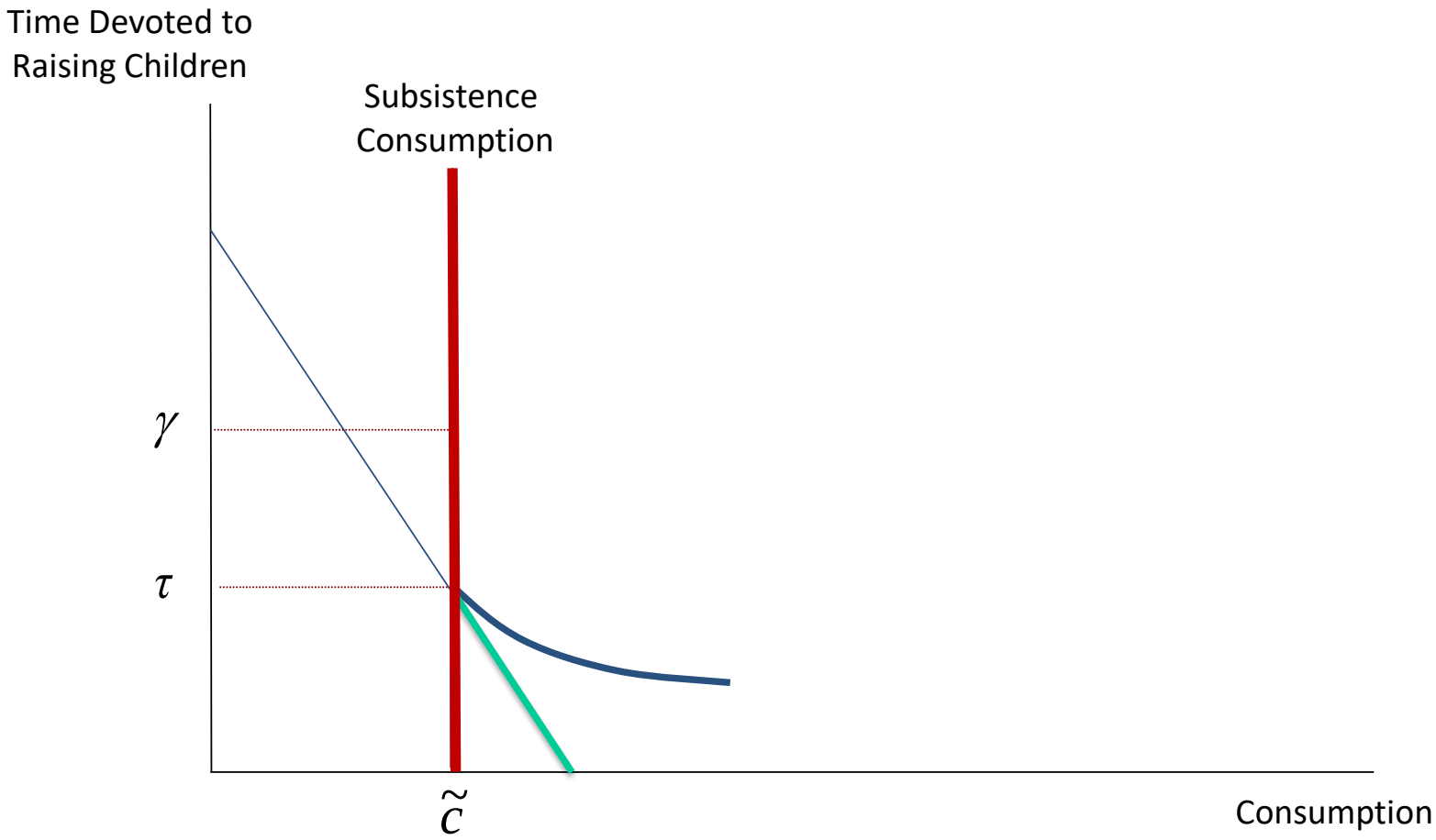
The Evolution of Education and Technology: For a Given L



The Evolution of Education and Technology (Initial Population $L = L^1$)



Optimization - Malthusian Steady-State Equilibrium (Population $L = L^1$)



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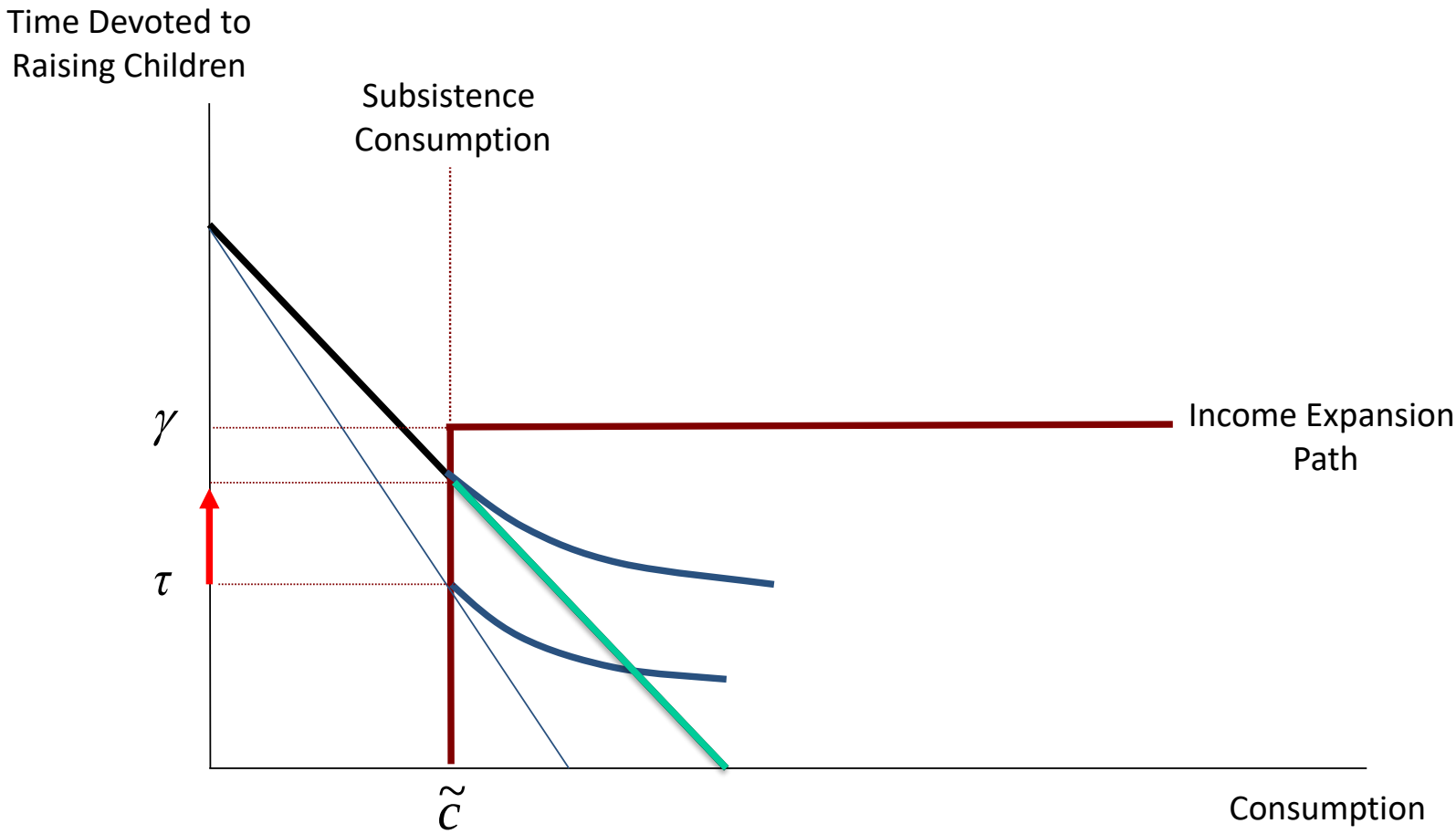
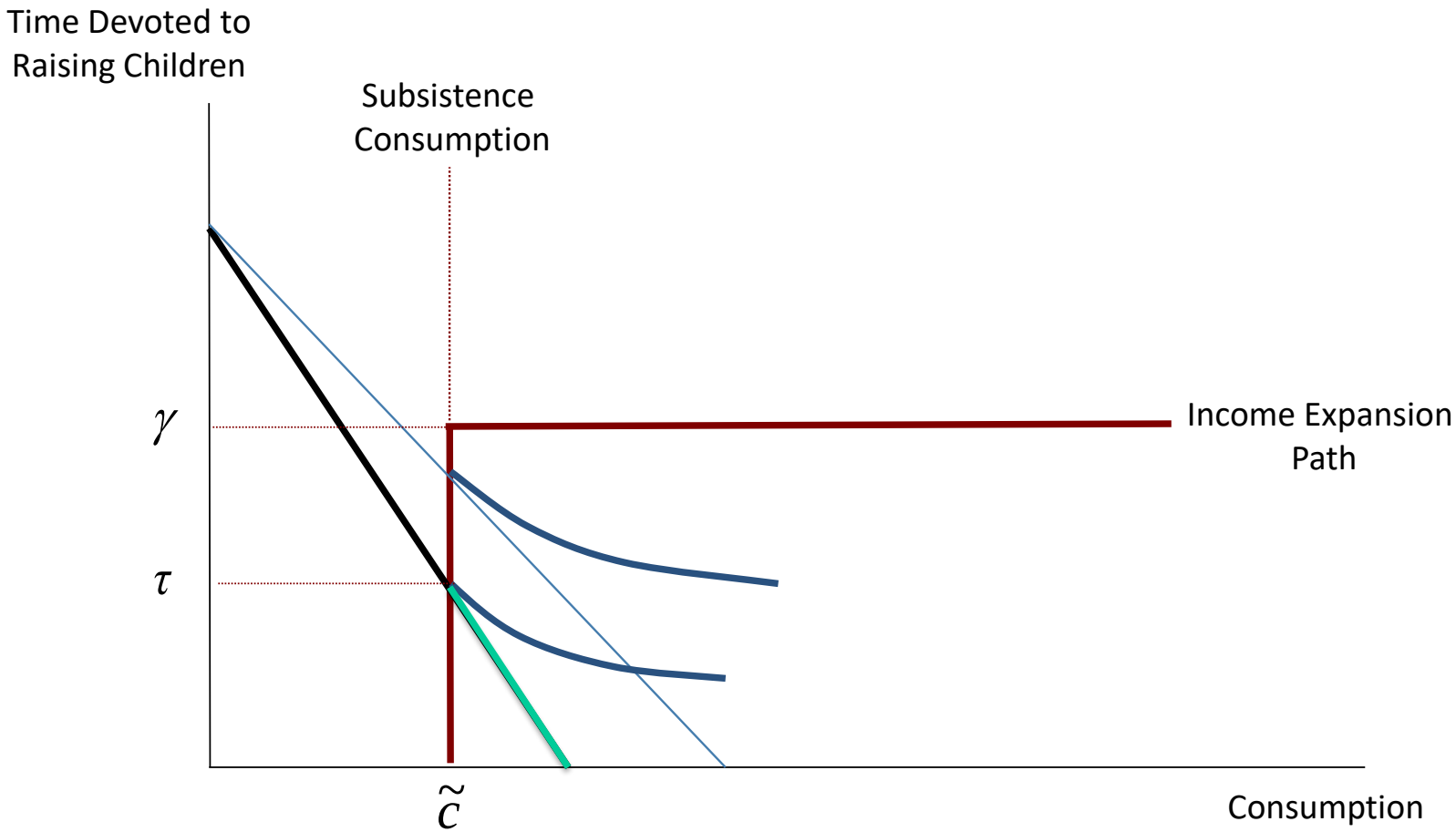
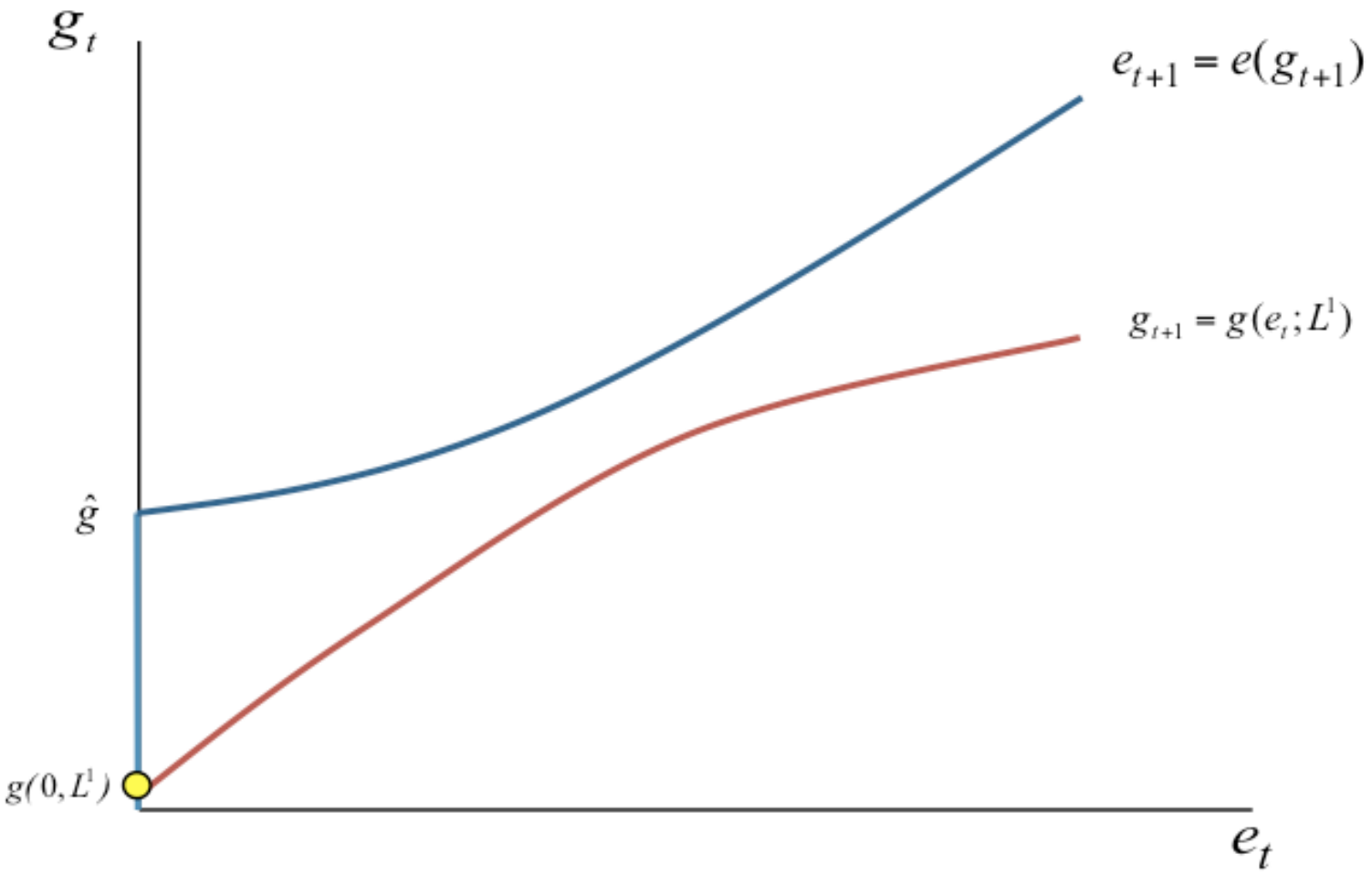


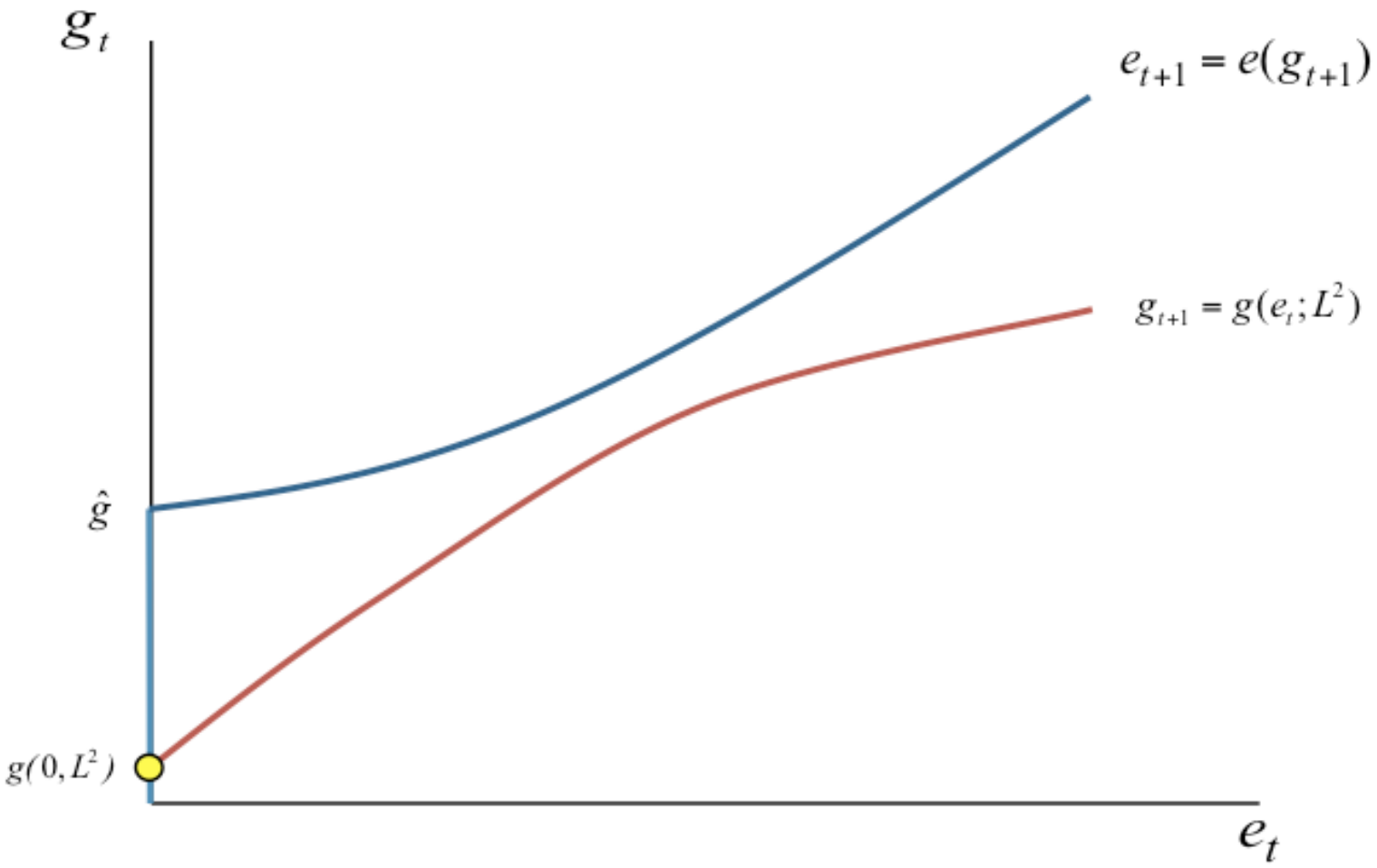
Optimization - Impact of Tech Progress in the Malthusian Epoch (LR)



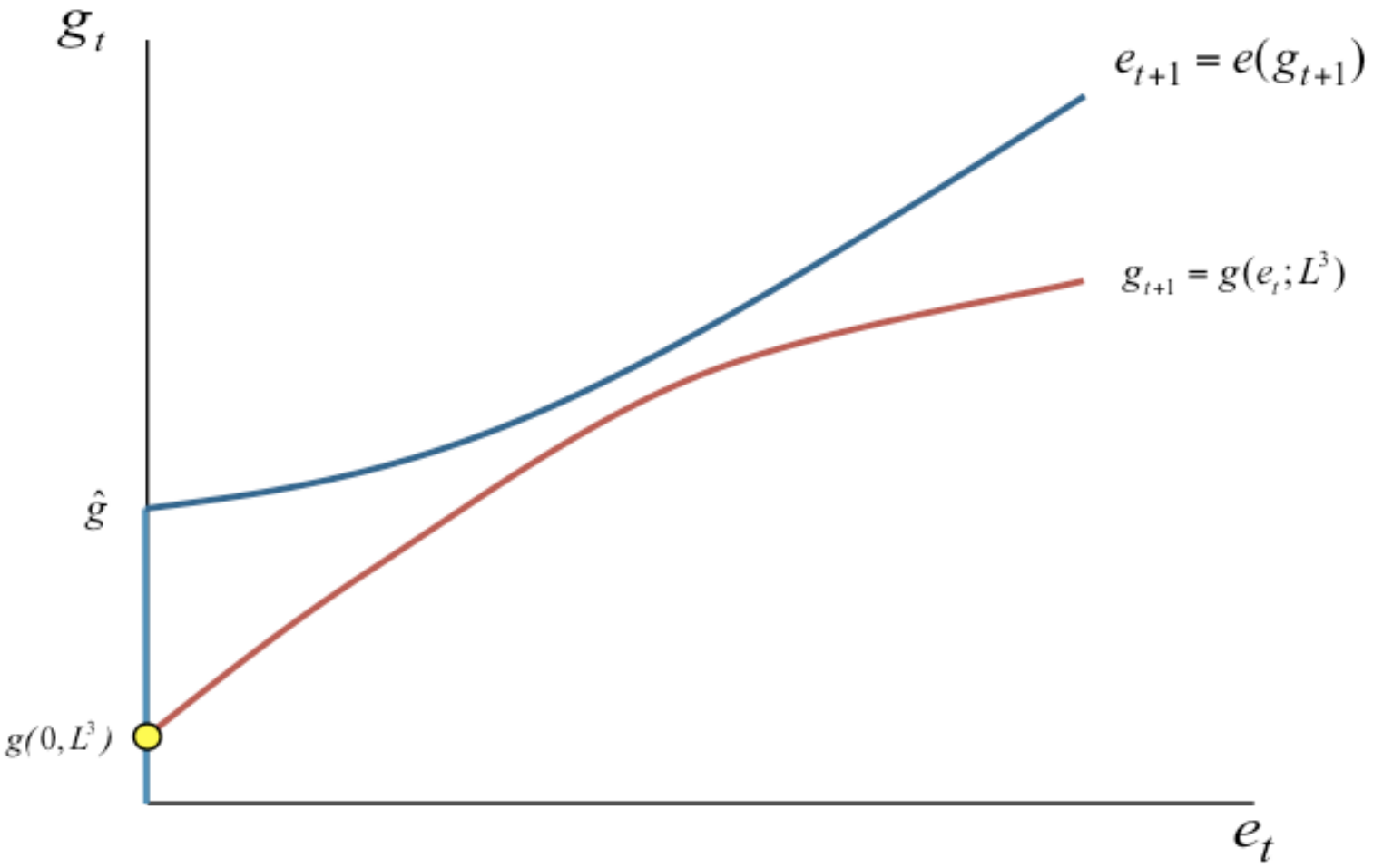
The Evolution of Education and Technology (Initial Population $L = L^1$)



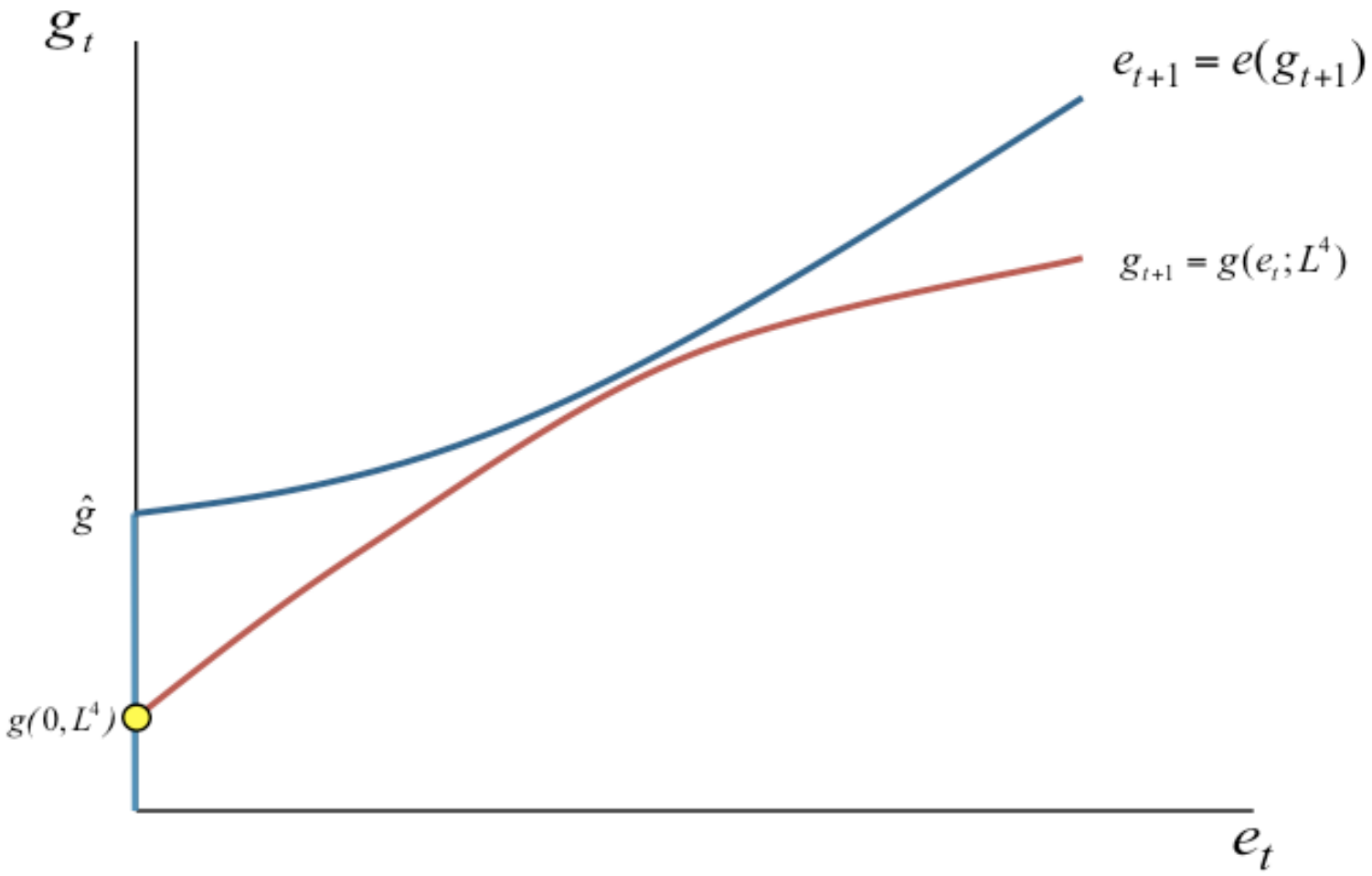
The Evolution of Education and Technology ($L = L^2$)



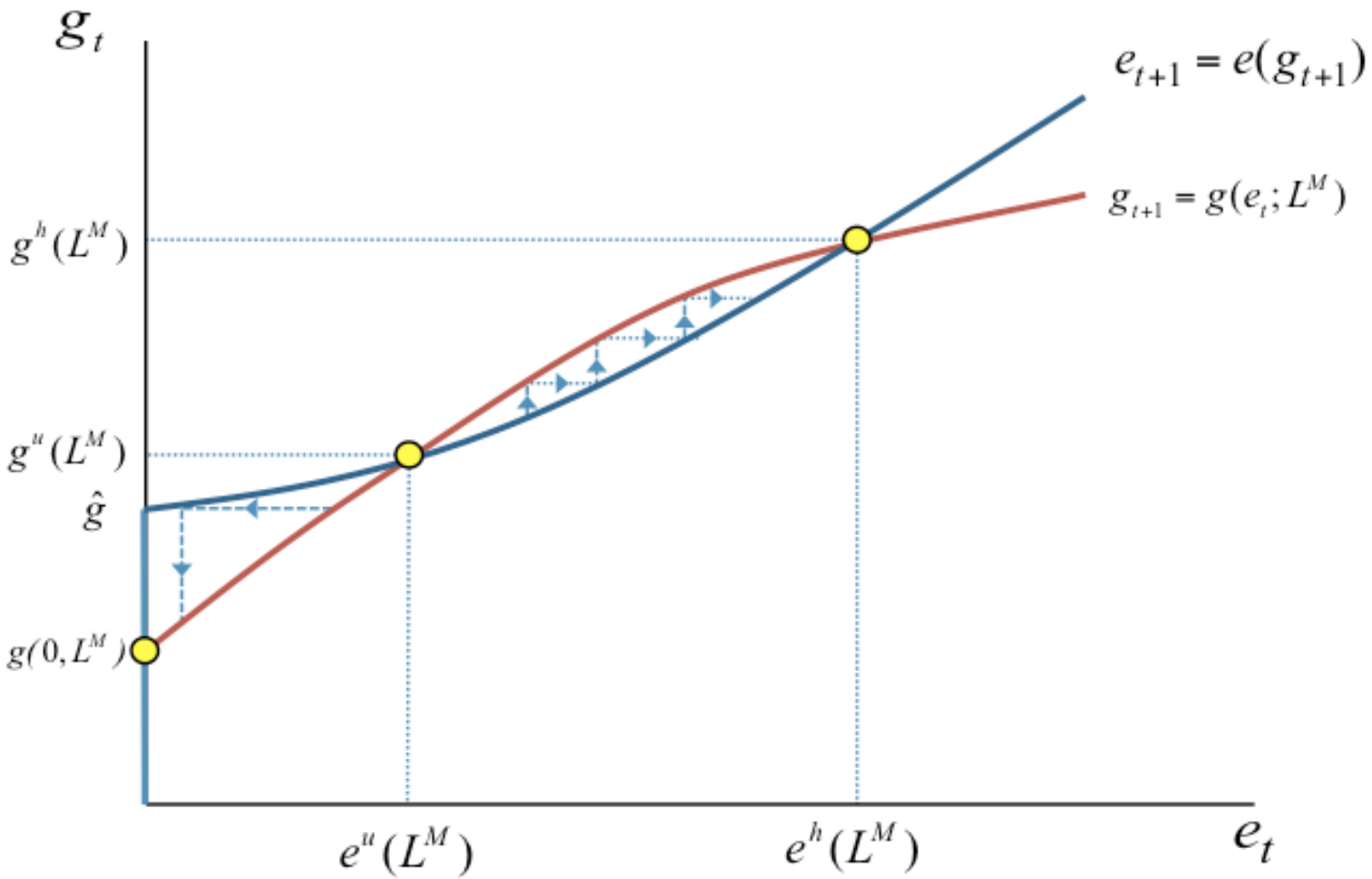
The Evolution of Education and Technology ($L = L^3$)



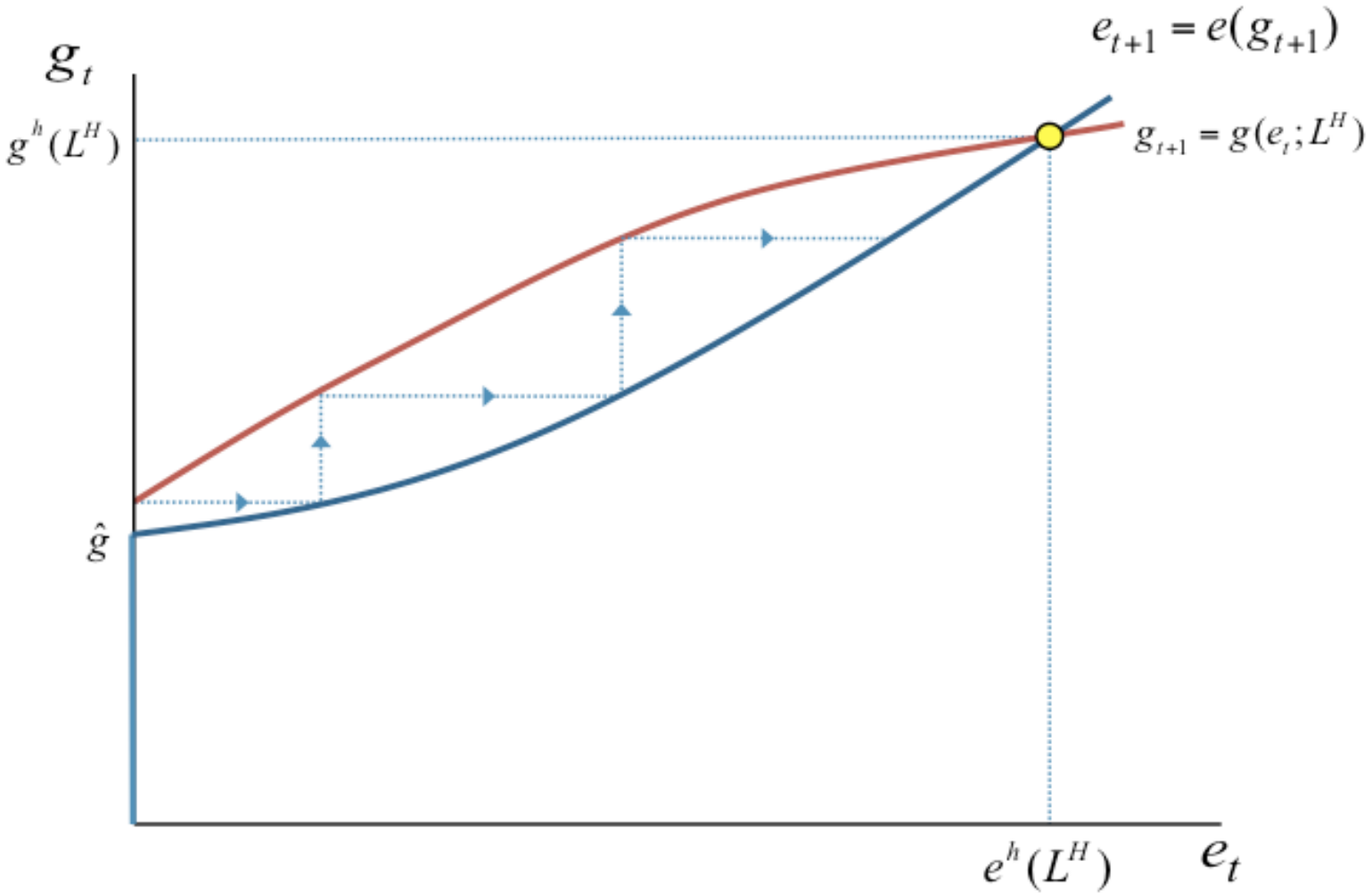
The Evolution of Education and Technology ($L = L^4$)



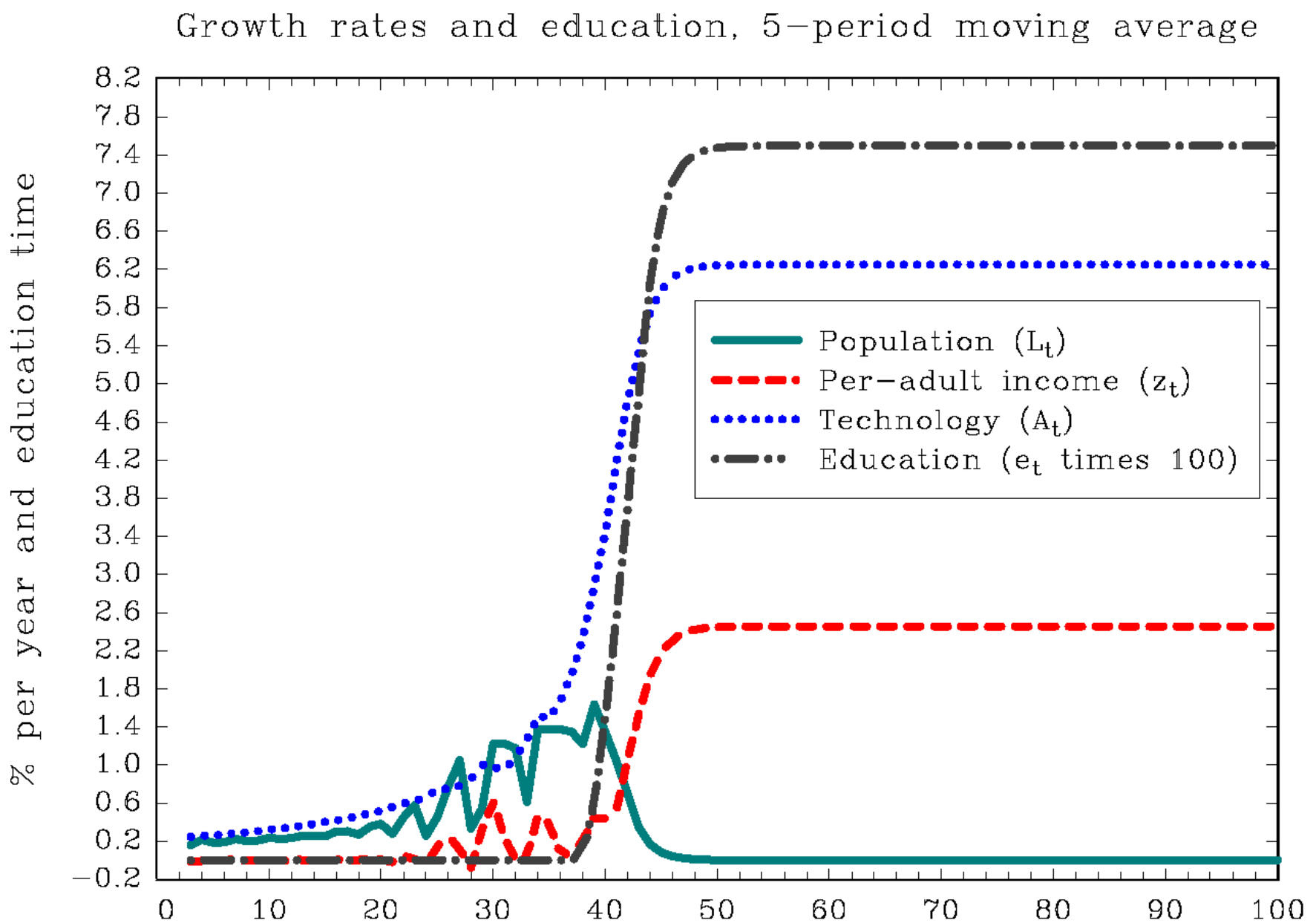
The Evolution of Education and Technology ($L = L^M$)



The Evolution of Education and Technology ($L = L^H$)



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

Country-Specific Characteristics Conducive for Technological Progress

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

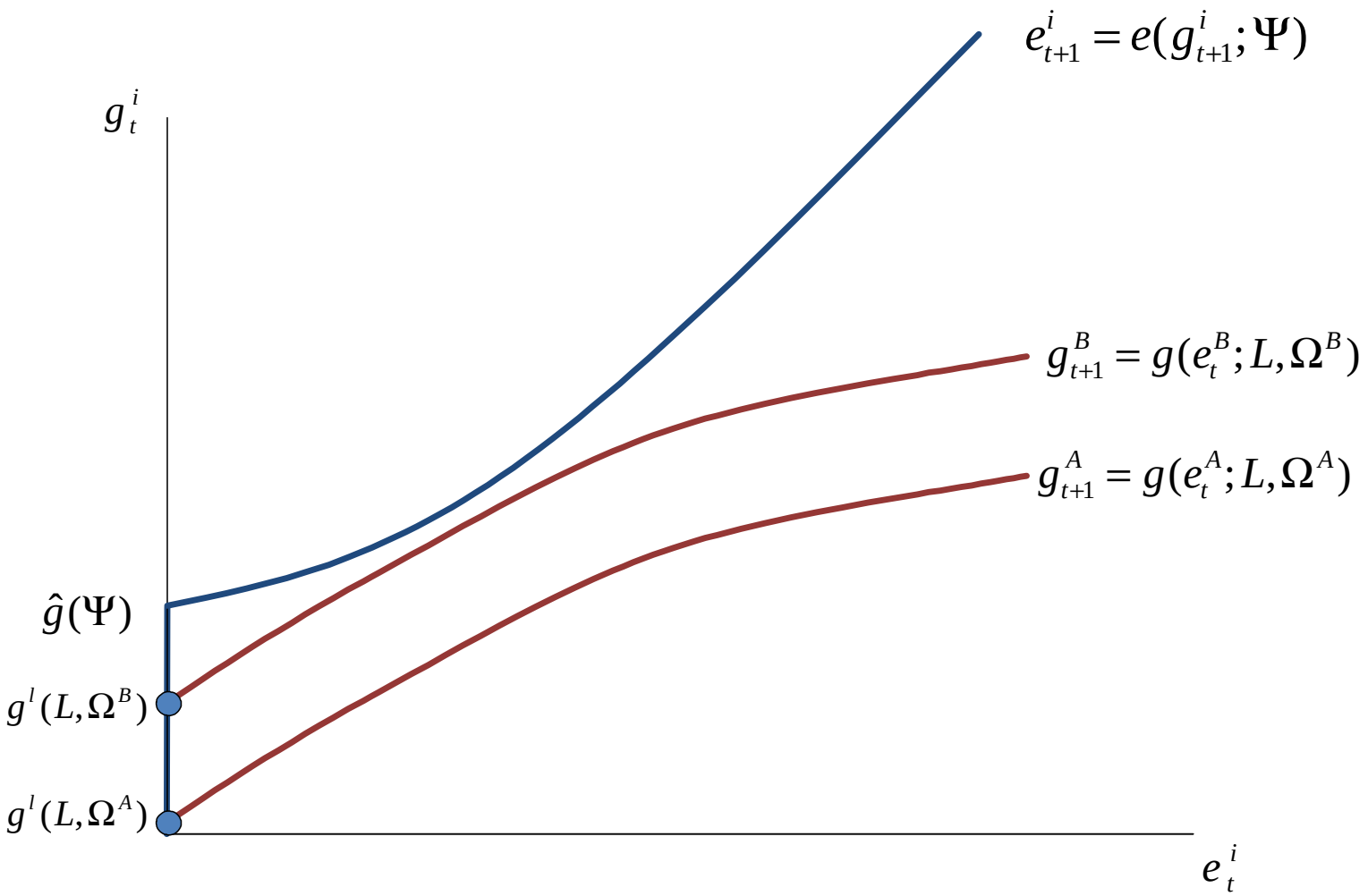
$\Omega_t^i \equiv$ characteristics affecting tech progress in country i:

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

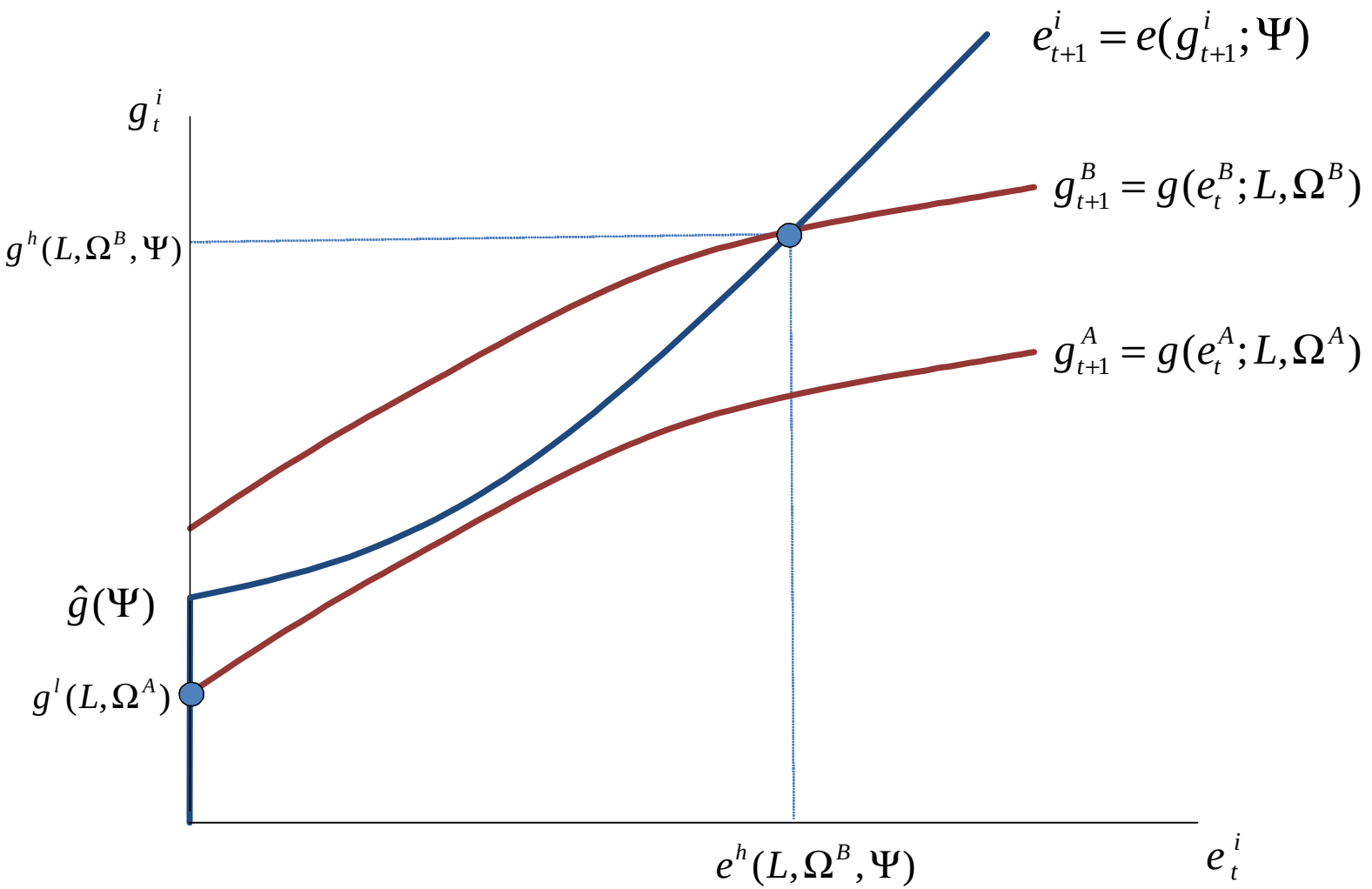
Country-Specific Characteristics Conducive for Technological Progress

- 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 innovation (e.g., Luddites; landowners)
- Cultural diversity
  - Cultural fluidity fosters the adoption of new technologies
- Abundance of natural resources
  - Complementary for industrialization (e.g., Coal & Steam engine)

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

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

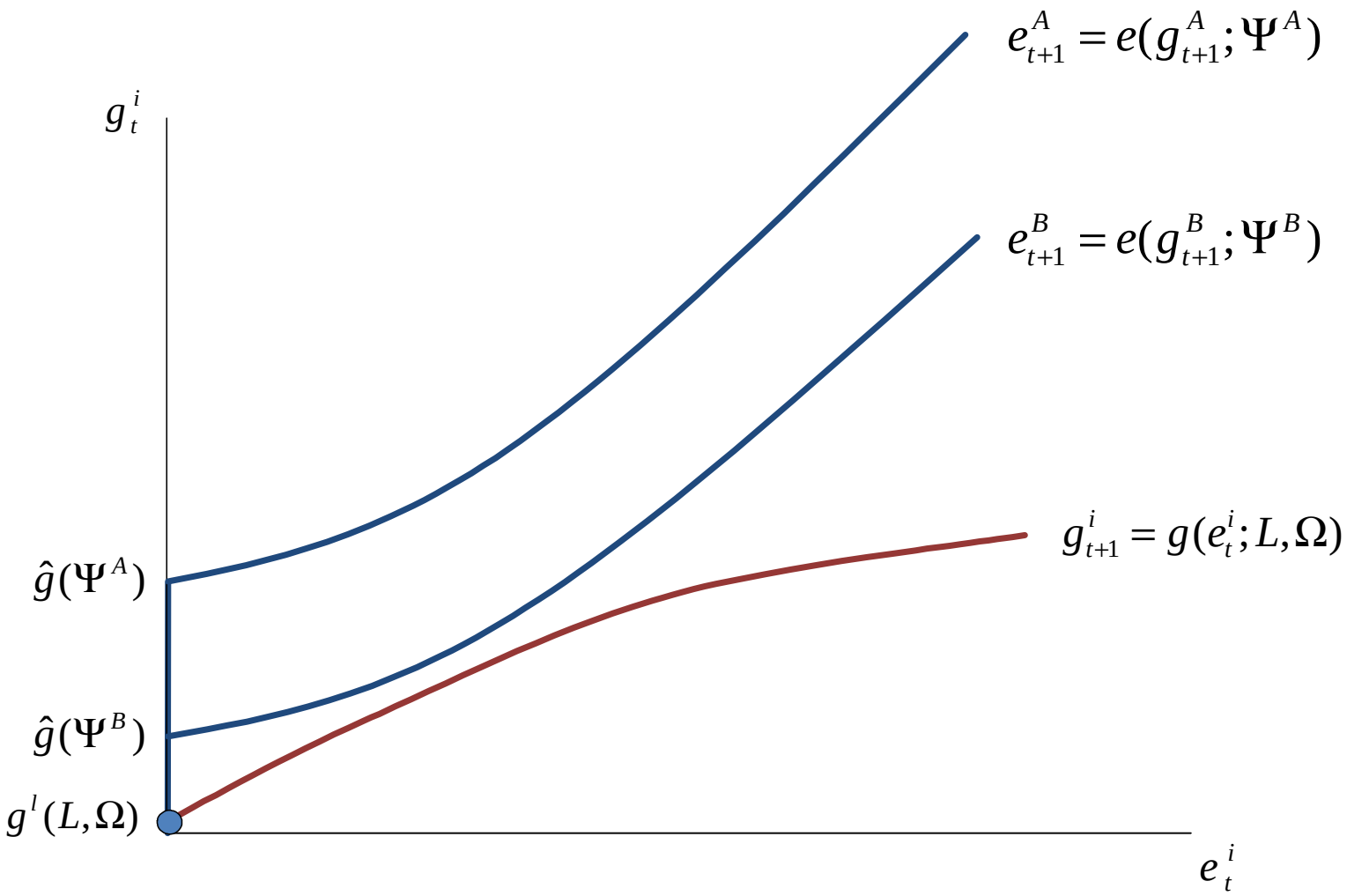
Variation in Characteristics Conducive for Human Capital Formation

- 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
  - Extent of human capital formation
- Cultural and religious composition of society
  - Attitude towards education
- The stock of knowledge in society
  - Productivity of human capital formation

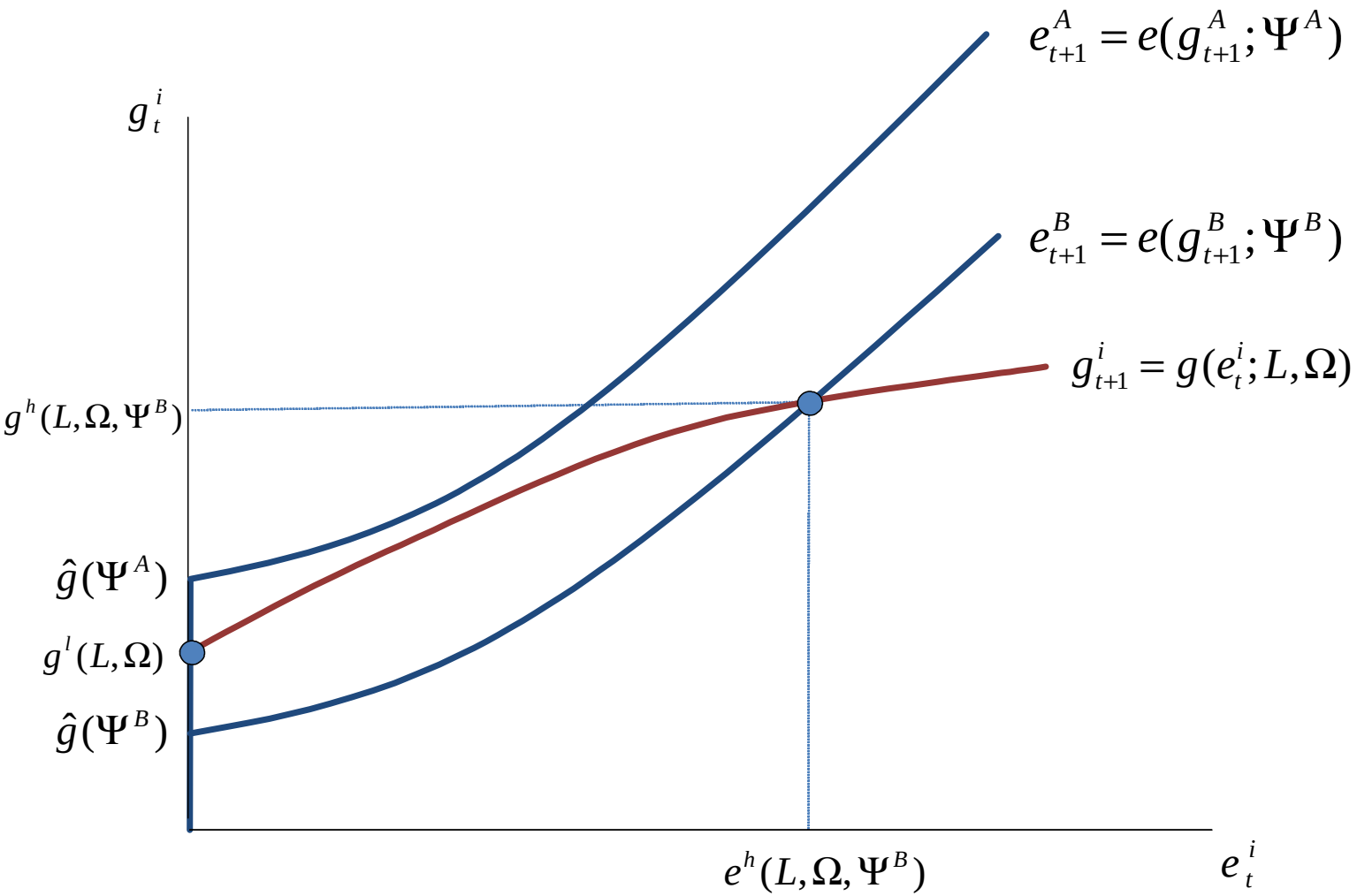
Variation in Characteristics Conducive for Human Capital Formation

- The propensity of a country to trade
  - Skill-intensity in production and its effect on the demand for HC
- 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