Natural Selection and The Origin of Economic Growth

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"It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change."

Charles Darwin

Objective:

Unified evolutionary growth theory (the first one) that captures the co-evolution of:

- Homo Sapience

- Economies

in the long transition from an epoch of Malthusian stagnation to sustained growth.

The theory suggests that:

- The epoch of stagnation that has characterized most of human history led to a process of natural selection that transformed the characteristics of the human population and made them more complementary to the growth process

- The change in the composition of the population was a necessary condition for the take-off from an epoch of stagnation to sustained economic growth

The theory captures 2 distinct regimes that have characterized the process of economic development and the endogenous transition from one to another:

I. Malthusian Epoch: (- 1750)

II. Take-off:

(a) Early take-off (1750-1870)

(b) Demographic Transition & Sustained Growth: (1870-)

Fundamental Premise :

During the Malthusian Epoch, the composition of characteristics of the human species that are highly relevant for the understanding of the origin of economic growth has not been stationary. Hereditary human traits, physical or mental, that raised earning capacity, generated an evolutionary advantage

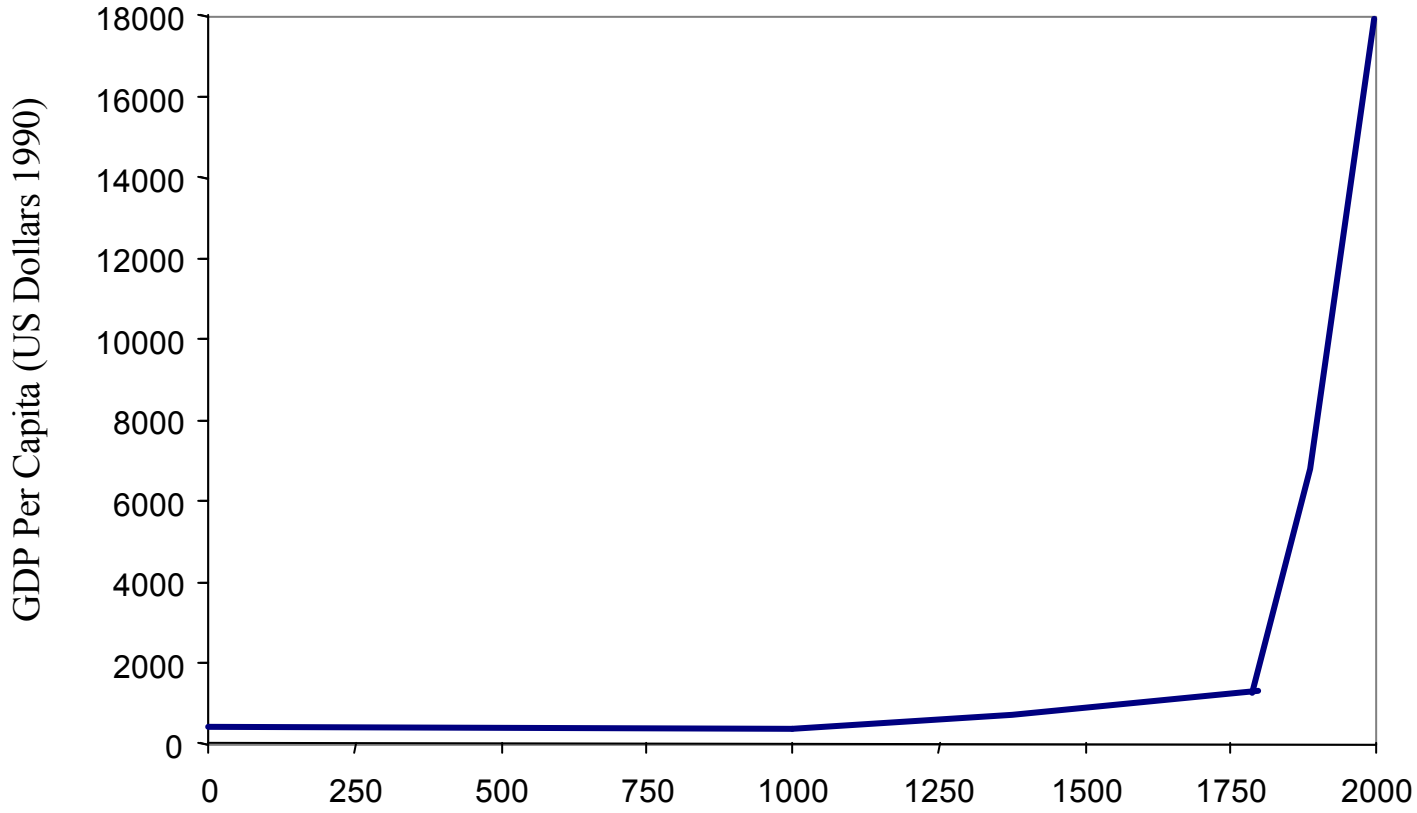
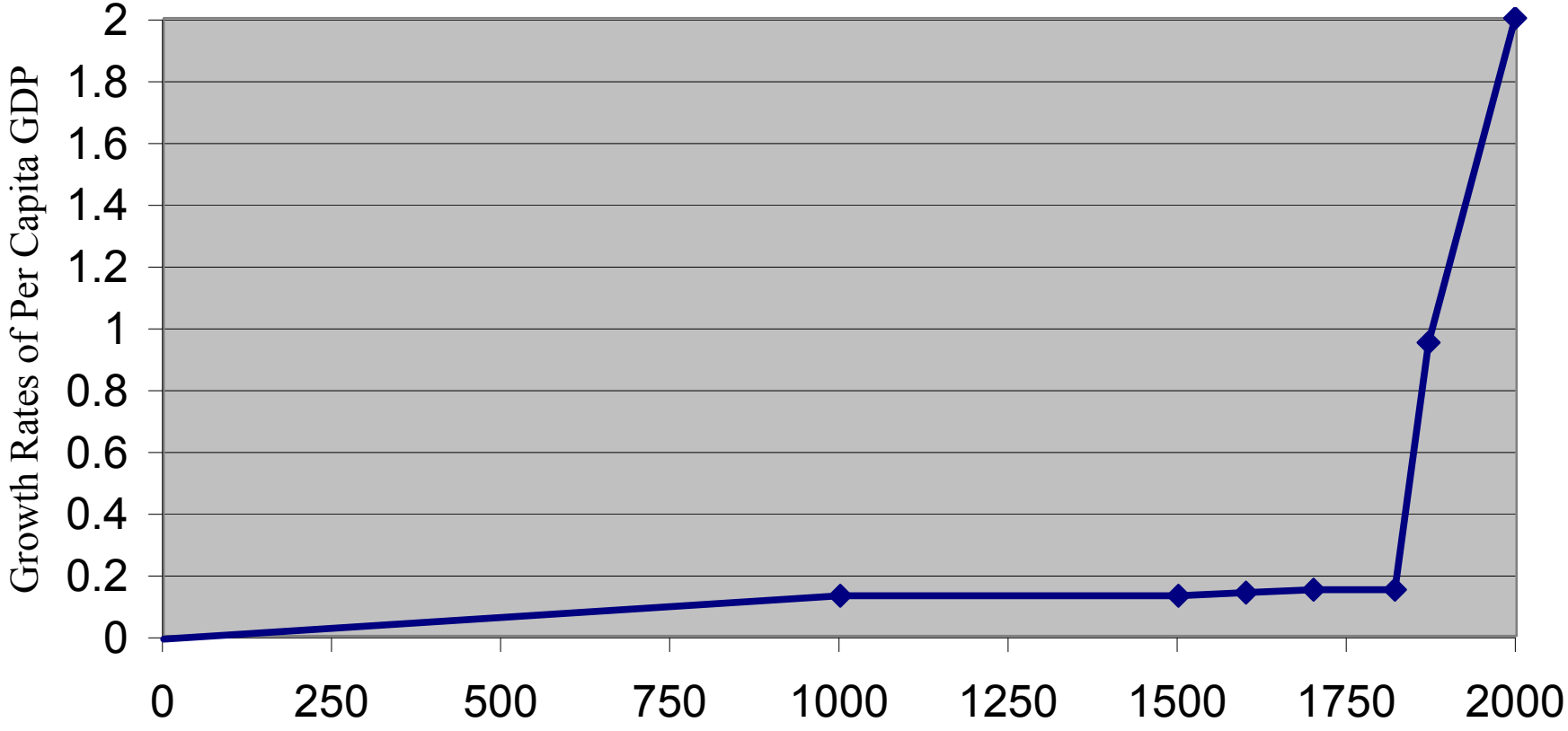


Figure I
Output Per Capita in Western Europe in the Years 0-2000

Figure 1b: Western Europe's
Growth Rates of Per Capita GDP



Data Source: Maddison 2001

I. Malthusian Stagnation: (– 1750)

In this epoch of Malthusian stagnation the world economy is in the proximity of a Malthusian equilibrium:

- Population growth is positively related to the level of income per capita.

- Technological progress exits but it is slow and it results in a proportional increase in output and population.

- Output per capita fluctuates around a subsistence level.

Evidence:

Madison (2001)

For Western Europe: 0-1750

- Growth in output per-capita: 0.0%
- The rate of population growth increases: 0.1%

Other Evidence:

Income:

- Chao (1986)
  Real wages in China were lower at the end of the 18th century than they had been at 0.

- Clark (1957)
  Income per capita in Greece in 400 BC was similar to that in Britain in 1850 or Germany and France in 1870.

- Mokyr (1990) & Lucas (1999)
  The rise in living standards above the subsistence level is only a few centuries old, even in the richest countries.

Population:

- Livi-Bacci (1997)
  0 – 1750: population growth rate in the world 0.064% per year.

Income and Population:

- Lee (1997)
  Positive income elasticity of fertility
  in pre-industrial countries.

- Wrigley and Schofield (1981)
  Strong positive correlation between real wages and marriage rates in England over the period 1551-1801.

- Livi-Bacci, (1997)
  Negative shocks to population, such as the Black Death, generated higher real wages and a lower age of marriage.

- Stone (1977) and Haines (1997)
  Settlers from North-West Europe who came to the American colonies, where land was abundant, married early and bred prolifically.

II. Early Take-off (1750-1870)

In these intermediate stages of development the world economy takes-off from Malthusian stagnation:

- Population growth is still positively related to the level of income per capita.

- The growth rates of technology and total output increase.

- Technological change causes a larger increase in output than in population, but population growth absorbs most of the growth of output.

- Income per capita *rises* slowly.

Evidence:

Madison (1982, 1995)

For Western Europe

- Growth in output per-capita increases:

1700 – 1820	0.2%
1820 – 1870	1.0%

- The rate of population growth increases:

1700 – 1820	0.4%
1820 – 1870	0.7%

III. Demographic Transition & Sustained Growth (1870 -)

In these mature stages of development economies experience demographic transitions - a decline in population growth accompanied by an increase in output growth

- The positive relationship between income per capita and population growth is *reversed*.
- The growth rates of technology and total output intensify.
- Population growth declines
- Income per capita rises rapidly and steadily.

Evidence:

Madison (1995)

For Western Europe

- Growth in output per-capita increases:

1870 - 1929	1.2%
1929 - 1990	2.2%

- The rate of population growth *decreases*:

1870 – 1929	0.64%
1929 – 1990	0.57%

Malthusian Epoch vs. Sustained Growth

Output Growth

- **In recent centuries:**

Output per-capita grows at positive and sustainable rate.

- **In the Malthusian Epoch**

Output per-capita fluctuates around a constant level.

Population growth and Income:

- **In the recent century**:

Negative relationship between population growth and income per capita

- **Through most of history**

Positive relationship between population growth and income per capita

Fundamental Questions:

- How does one account for the sudden spurt in growth rates of output?

- Why had waves of rapid technological progress not generated sustained economic growth in the Pre-Industrial Revolution era?

- Is there a *unified* theory that account for the intricate evolution of economic growth and mankind since the origin of the human species?

Fundamental Premise:

- In light of the Darwinian theory, it appears that the long Malthusian stagnation generated an evolutionary pressure on the human species that gave an evolutionary advantage to the fittest. During the Malthusian Epoch, the composition of characteristics of the human species that are highly relevant for the understanding of the origin of economic growth has not been stationary. Hereditary human traits, physical or mental, that raised earning capacity, generated an evolutionary advantage

- The evolution of the human brain in the transition to Homo Sapience and the complementarity between brain capacity and the reward for human capital has increased the evolutionary optimal investment in offspring's quality.

The Main Hypothesis

- The epoch of stagnation that has characterized most of human history led to a process of natural selection that transformed the characteristics of the human population and made them more complementary to the growth process.

- This evolutionary change is the trigger of the take-off from an epoch of stagnation to sustained economic growth

- Most of this evolutionary change occurred in the transition from the Neolithic Revolution to the Industrial Revolution (i.e. over about 10,000 years)

Evidence for Rapid Evolutionary Changes

Other Species:

1. The color change that *peppered moths* underwent during the 19th century.

   Duration: 300-500 generations
   (Kettlewell, 1973).

2. Major evolutionary changes in Darwin's *Finches*

   Duration: 1 generation.
   (Grant and Grant, 1989).

3. Dramatic Changes in color patterns of *Guppies*:

   Duration: within 15 generations.
   (Endler (1986)).

English Peppered Moths

The color change that English peppered moths underwent during the 1800s is a classic example of the speed of natural selection. Before the Industrial Revolution took place in England in the late 1700s, light-colored English peppered moths that blended with the lichen-covered bark of trees were far more prevalent than dark-colored English peppered moths. However, pollution from the Industrial Revolution killed the lichen on trees, leaving their dark bark exposed, and the contrasting light-colored moths became easy prey for birds. The dark English peppered moths, camouflaged on the dark bark, soon became far more common than the lighter varieties in polluted areas.

Human Species:

4. Lactose Tolerance

Developed among European and Near Easterners since the domestication of dairy animals in the Neolithic revolution. In regions that were exposed to dairy animals in later stages the population does not retain the ability to digest lactose into adulthood.

Duration: within 10,000 years.

5. Gluten Tolerance

The ability to tolerate a protein present in wheat, rye, barley, and some oats, first domesticated in the course of the agricultural revolution.

Duration: within 10,000 years.

6. Sickle Cell Trait

Genetic immunity to malaria provided by the sickle cell trait developed among Africans engaged in slash-and-burn agriculture - a method that generated an ideal breeding ground for mosquitoes and thereby high incidence of malaria. Absent in nearby populations that have not made the transition to agriculture.

Duration: within 10,000 years.

The Basic Structure of the Model

- Overlapping-generations economy
- Single homogeneous good.
- 2 factors of production:
  - Efficiency units of labor,
  - Land

Factor Supply:

The supply of land is fixed over time.

The number of efficiency units of labor is determined by the evolution in the composition of the population and households' decisions in the preceding period regarding the number and level of human capital of their children.

Individuals

Heterogeneous individuals

Individuals live for 2 period

- 1st Period: (Childhood)

Consume a fraction of their parental unit-time endowment. The required time increases with children's quality.

- 2nd Period (Parenthood)

Individuals allocate their time between childrearing and labor force participation. They choose the optimal mixture of quantity and quality of children and supply their remaining efficiency units of labor in the labor market. They earn the competitive market wage per each efficiency unit of labor and consume.

Central Elements:

• The Malthusian Elements:

The first element incorporates the main ingredients of a Malthusian world.

- Subsistence consumption constraint

For low level of income, the subsistence consumption constraint imposes a binding physiological constraint on the size of a family.

- **Fixed factor – land**

Decreasing return to other factors

- **Positive effect of income per capita on population growth**

If technological progress is slow, the increase in wages induces an increase in population, the land-labor ratio declines and wages and output per capita return to their Malthusian constant levels.

If technological progress is rapid, then population adjusts, but wages and output per capita grow despite the decline in the Land-Labor ratio.

Production of Final Output

The output produced at time t, Y_t, is

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

H_t - efficiency units of labor

X - land

A_t - technological level

Output per efficiency unit of labor is

$$y_t = x_t^{\alpha};$$

$x_t \equiv A_t X/H_t$ - effective resources per efficiency unit of labor

• The Darwinian Elements

The second element incorporates the main ingredients of the Darwinian world (i.e., variety, natural selection, and evolution) in a changing economic environment originated in a Malthusian stagnation.

Preferences

- Preferences reflect the implicit Darwinian survival strategy. Although individuals do not operate consciously so as to assure the evolutionary advantage of their type (i.e., their variant within the species), the existence of variety of types enables nature to select those who fit the economic environment (assuring the survival of the human species).

Preferences are defined over:

- consumption above a subsistence level

- quality and the quantity of their children.

These preferences are the manifestation of the Darwinian survival strategy and represents the most fundamental trade-off that exist in nature:

- Trade-off between resources allocated to the parent and offspring

- Trade-off between the number of offspring and resources allocated to each offspring.

Evidence: Rosenzweig and Wolpin (1980) and Hanushek (1992).

Preferences

Preferences are defined over consumption above a subsistence level $\tilde{c} > 0$, as well as over the quality of their children (measured by their potential income) and the quantity of their children

$$u_t^i = (1-\gamma)\ln c_t^i + \gamma[\ln n_t^i + \beta^i \ln h_{t+1}^i]$$

c_t^i - household consumption

n_t^i - number of children

h_{t+1}^i - level of human capital of each child

β^i - weight given to quality

The quality-parameter, β^i, is transmitted from generation to generation within a dynasty and remains stationary across time.

As is established in evolutionary biology (Lack, 1954), the allocation of resources between child caring and child bearing is subjected to evolutionary changes.

- Subsistence consumption constraint:
  assures the survival of the parent and hence the survival of the lineage (dynasty).

- Consumption <u>beyond</u> subsistence:

  - **Positive Effect** on:

    Parental fitness & the survival of the lineage

    via increase in:

    - Parental resistance to adverse shocks (e.g., famine, disease, and variability in output),

    - labor productivity (via improved nourishment)

- **Negative Effect on:**

  the survival of the lineage.

  (due to reduction in resources to offspring)

- Trade-off between child quantity & quality reflect the implicit Darwinian survival strategy

  a quantity-biased preference has

  - Positive effect on:

  Fertility rates (evolutionary advantage)

  - Negative effect on

  Quality of offspring & their income (fitness)
  In the pre-demographic transition era, when fertility rates are positively associated with income levels, this effect generates an evolutionary disadvantage.

The Composition of preferences

The economy consists of a variety of types distinguished by the weight given to child quality in their preference.

- Individuals choose the number of children and their quality in the face of a constraint on the total amount of resources that can be devoted to child-raising and labor market activities.

- Preferences are hereditary and hence the distribution of types evolves over time due to the effect of natural selection.

Kohler et. al. (1999), and Rodgers et. al (2001), Rodgers and Doughty (2000) find that 25-30% of the variance in fertility is attributable to genetic influence.

Lack (1954) demonstrates that clutch sizes, among owls and other predatory vole-eating birds, for instance, are positively related to food abundance. He argues that the clutch size is selected such that under any feeding conditions fertility rates ensure the maximal reproductive success.

- The economic environment determines the type with the evolutionary advantage (i.e., the type characterized by higher fertility rates).

Main Result:

In the pre-demographic transition era, when fertility rates are positively associated with income levels, the Malthusian pressure generates an evolutionary advantage to individuals whose preferences are biased towards child quality increasing their representation in the population.

“The smallest grain in the balance, in the long run, must tell on which death shall fall and which shall survive"

“`What a trifling difference must often determine which shall survive and which perish!"

Charles Darwin

• Endogenous Technological progress

The third element links the evolution of the human species to the process of economic growth.

Human capital is assumed to have a positive effect on technological progress and therefore on economic growth

Educated individuals have a comparative advantage in implementing new technologies (e.g., Nelson-Phelps (1966), Easterlin (1981), and Doms, Dunne, Troske (1997)).

Hence, the Malthusian pressure, which increases the representation of individuals whose preferences are biased towards child quality, has a positive effect on the average quality of the population and therefore on the rate of technological progress.

Technological Progress

Technological progress depends on the average quality (education) among the working generation in period t, e_t.

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

$\psi'(e_t) > 0$

$\psi''(e_t) < 0$

$\psi(0) = 0$

- **Technological transition raises the return to human capital**

The fourth element links the rise in the rate of technological progress to the demographic transition and sustained economic growth.

The introduction of new technologies is skill-biased in the short-run, although technologies may be skill-biased or skill- saving in the long run.

Consistent with:

Schultz (1964)

Comparative advantage for educated individuals to cope with technological change.

- Goldin and Katz (1998)

Technology-skill complementarity

- Foster-Rosensweig (AER 1996).

Technological change during the Green Revolution in India raised the return to schooling.

- Bartel and Sicherman (JPE 2000)

Reward to human capital is higher in the presence of technological progress.

The Production of Human Capital

Individuals' level of human capital is determined by their quality (education) as well as by the technological environment.

The level of human capital is

$$h^i_{t+1} = h(e^i_{t+1}, g_{t+1})$$

e^i_{t+1} - individual's quality

$g_{t+1} \equiv (A_{t+1} - A_t)/A_t$ - technological progress

$h_e(e^i_{t+1}, g_{t+1}) > 0$

$h_{eg}(e^i_{t+1}, g_{t+1}) > 0$

Hence, technological progress increases the return to education.

- **An increase in the return to human capital induces parents to substitute quality for quantity of children.**

The fifth element links fertility choices to the return to human capital.

In Initial stages:
Quantity and quality increase
In later stages:
Quantity declines and quality increases

Evidence:

Fertility rates increased in most of Western Europe until the second half of the nineteenth century.
Dyson and Murphy (1985), and Coale and Treadway (1986)

The reduction in fertility in England

1871-80	153.6 (births per 1000)
1901-10	109.0

Wrigley (1969)

The average years of schooling in England and Wales

1801 - 1805	2 years
1852 - 1856	5 years
1897 - 1901	9 years

Budget Constraints

$$w_t h_t^i n_t^i (\tau + e_{t+1}^i) + c_t^i \leq w_t h_t^i \equiv z_t^i.$$

τ - Time required in order to raise a child, regardless of quality

e_{t+1}^i - Time required for rasing a child of quality e_{t+1}^i.

$\tau + e_{t+1}^i$ - Time cost for of raising a child with a level of education (quality) e_{t+1}^i

Potential income is divided between expenditure on child rearing and consumption, c_t^i.

$w_t h_t^i [\tau + e_{t+1}^i]$ - opportunity cost per child

$z_t^i \equiv w_t h_t^i = x_t^\alpha h_t^i$ - potential income

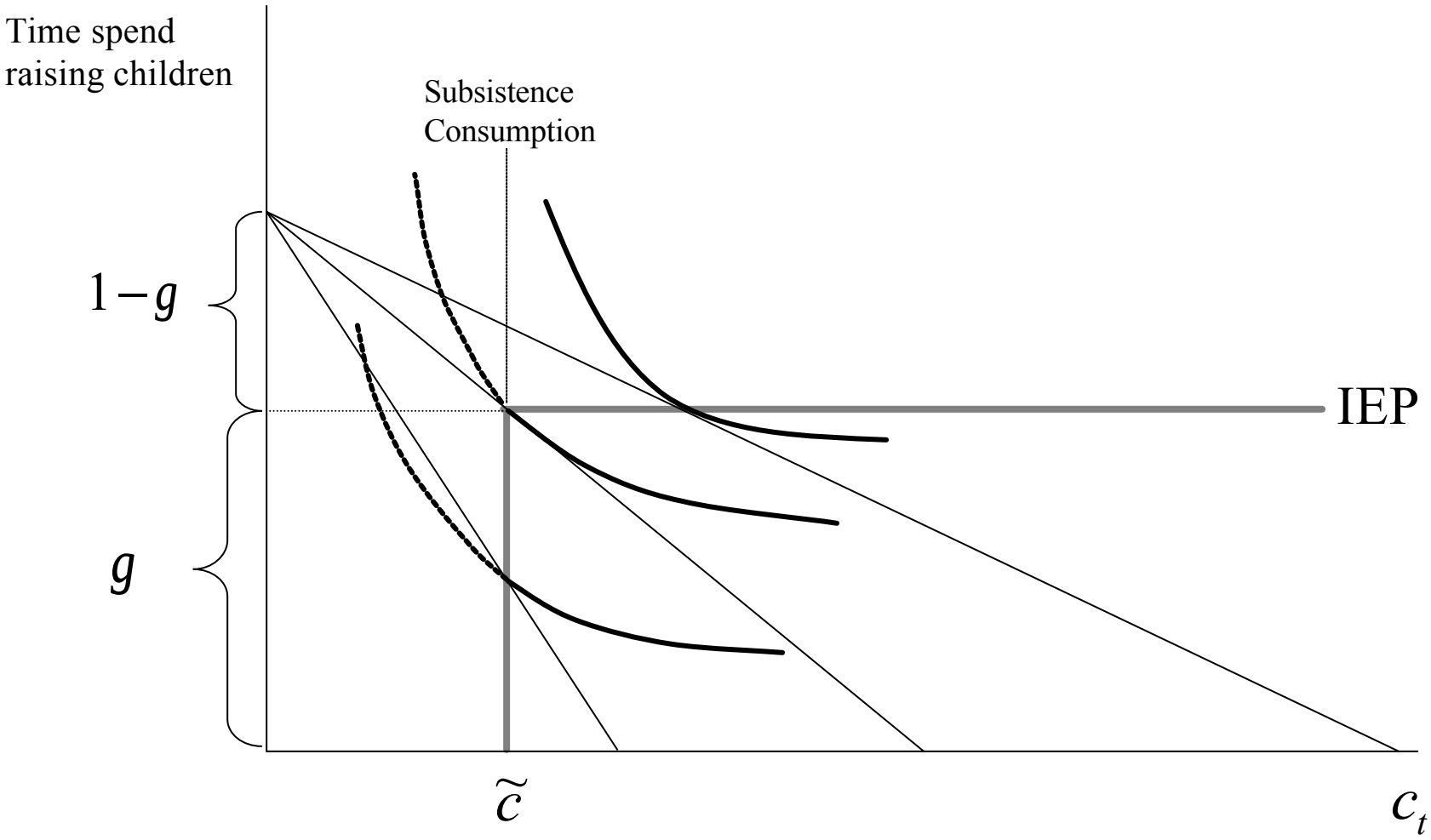


Figure II

Preferences, Constraints and Income Expansion Path

Optimization

The quality of children, e^i_{t+1}, chosen by a member i of generation t is an increasing function of g_{t+1} and β^i,

$$e^i_{t+1} = \varepsilon(g_{t+1};\beta^i) \equiv e^i(g_{t+1})$$

$$\begin{cases} = 0 & if \quad g_{t+1} \leq \underline{g}(\beta^i) \\ > 0 & if \quad g_{t+1} > \underline{g}(\beta^i) \end{cases}$$

where for all $g_{t+1} > \underline{g}(\beta^i)$:

- $\varepsilon_g(g_{t+1};\beta^i) > 0$
- $\varepsilon_\beta(g_{t+1};\beta^i) > 0 \quad \forall g_{t+1} > \underline{g}(\beta^i)$

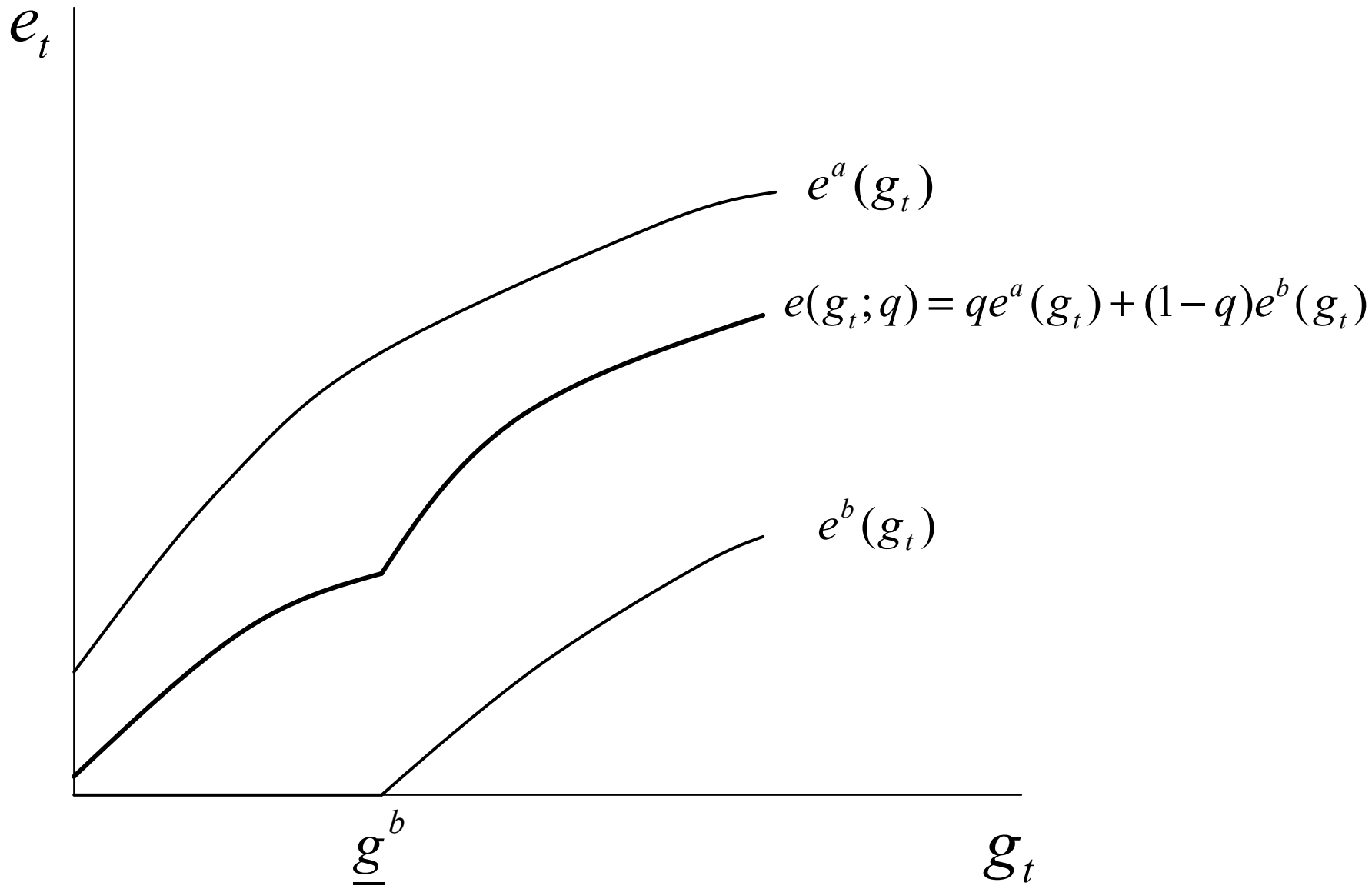


Figure III

Investment in Quality as a Function of the Rate of Technological Progress

The Dynamical System

$\{x_t, g_t, e_t, q_t\}_{t=0}^{\infty}$

such that for all t

$$\begin{cases} x_{t+1} = x(g_t, x_t, q_t); \\ q_{t+1} = q(g_t, x_t, q_t); \\ g_{t+1} = \psi(e_t); \\ e_t = e(g_t, q_t). \end{cases}$$

x_t - effective resources per efficiency unit of labor

g_t - the rate of technological progress

q_t - fraction of individuals of the quality type in the adult population

e_t - average quality (education) among the working generation

The Conditional Dynamical System

$\{g_t, e_t; q\}_{t=0}^{\infty}$

such that for all t

$$\begin{cases} e_t = e(g_t; q) \\ \\ g_{t+1} = \psi(e_t). \end{cases}$$

The Fundamental Mechanism

The Malthusian Epoch:

Suppose that in the early era of mankind, the population of the world consisted of homogeneous individuals of the "quantity type".

The economy is in a locally stable Malthusian steady-state equilibrium.

- Technology is stationary

- Parents have no incentive to raise quality children

- Human capital and effective resources are constant

- Output per capita and population are constant

Deviations from this steady-sate equilibrium, due to some exogenous shocks to population or resources are undone in a classic Malthusian fashion.

They will induce temporary changes in the real wage and fertility, which will in turn drive income per capita back to its stationary equilibrium level.

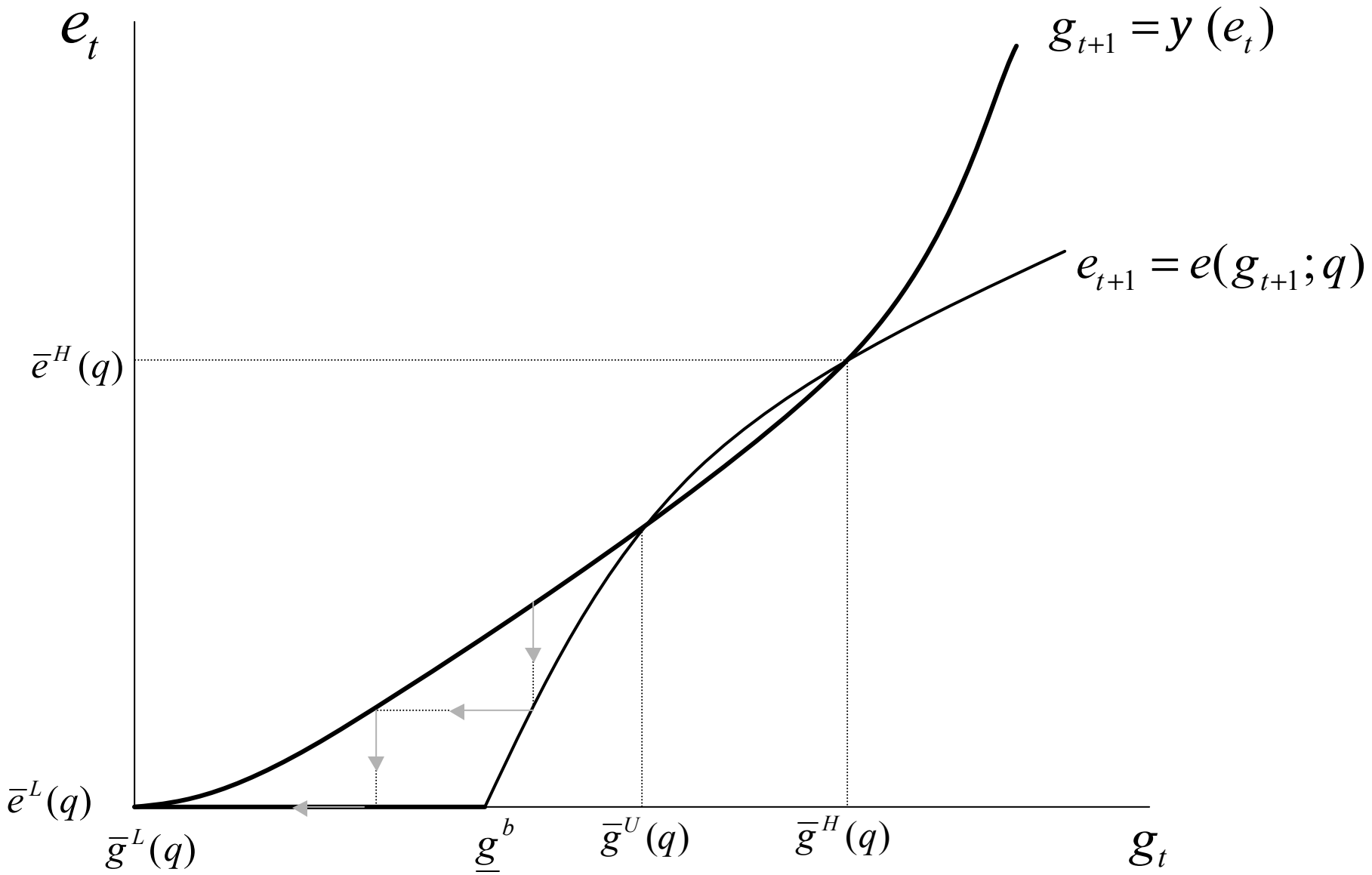


Figure V(a)

The Evolution of Education and Technological Progress in the Absence of Individuals of the Quality Type in the Population

q=0

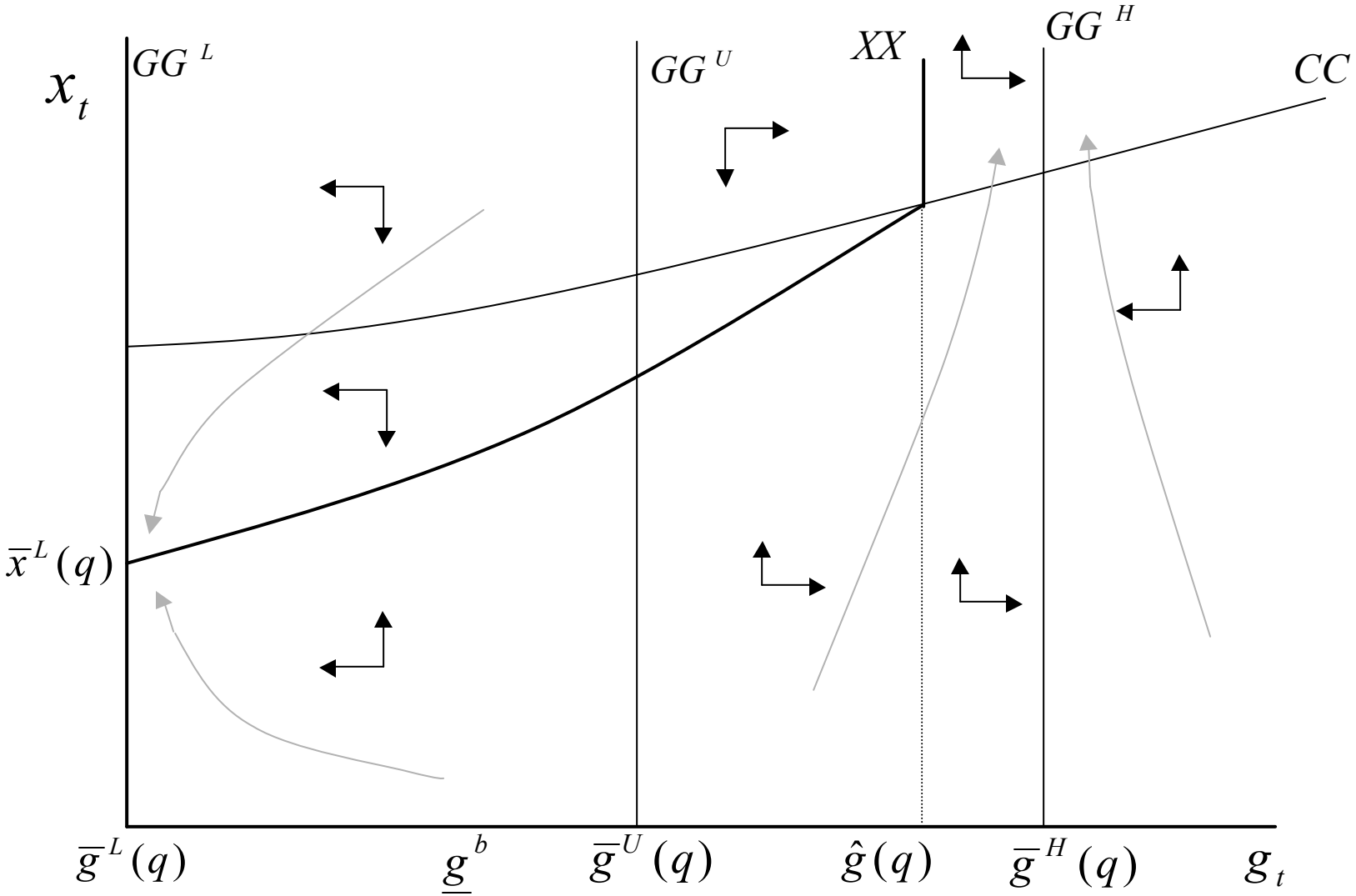


Figure VI(a)

The Evolution of Technological Progress and Effective Resources in the Absence of Individuals of the Quality Type in the Population

$$q = 0$$

Mutation

Mutation introduces a very small number of individuals of “the quality type” - who places higher weight on the quality of their children.

The economy consists of two types of individuals:
the “quality type”
the “quantity type”

The economy remains in the vicinity of a temporary locally stable Malthusian steady-state equilibrium.

Since the fraction of individuals of the quality type is small, the rate of technological progress is slow, inducing little investment in quality, and resulting in proportional increases in output and population.

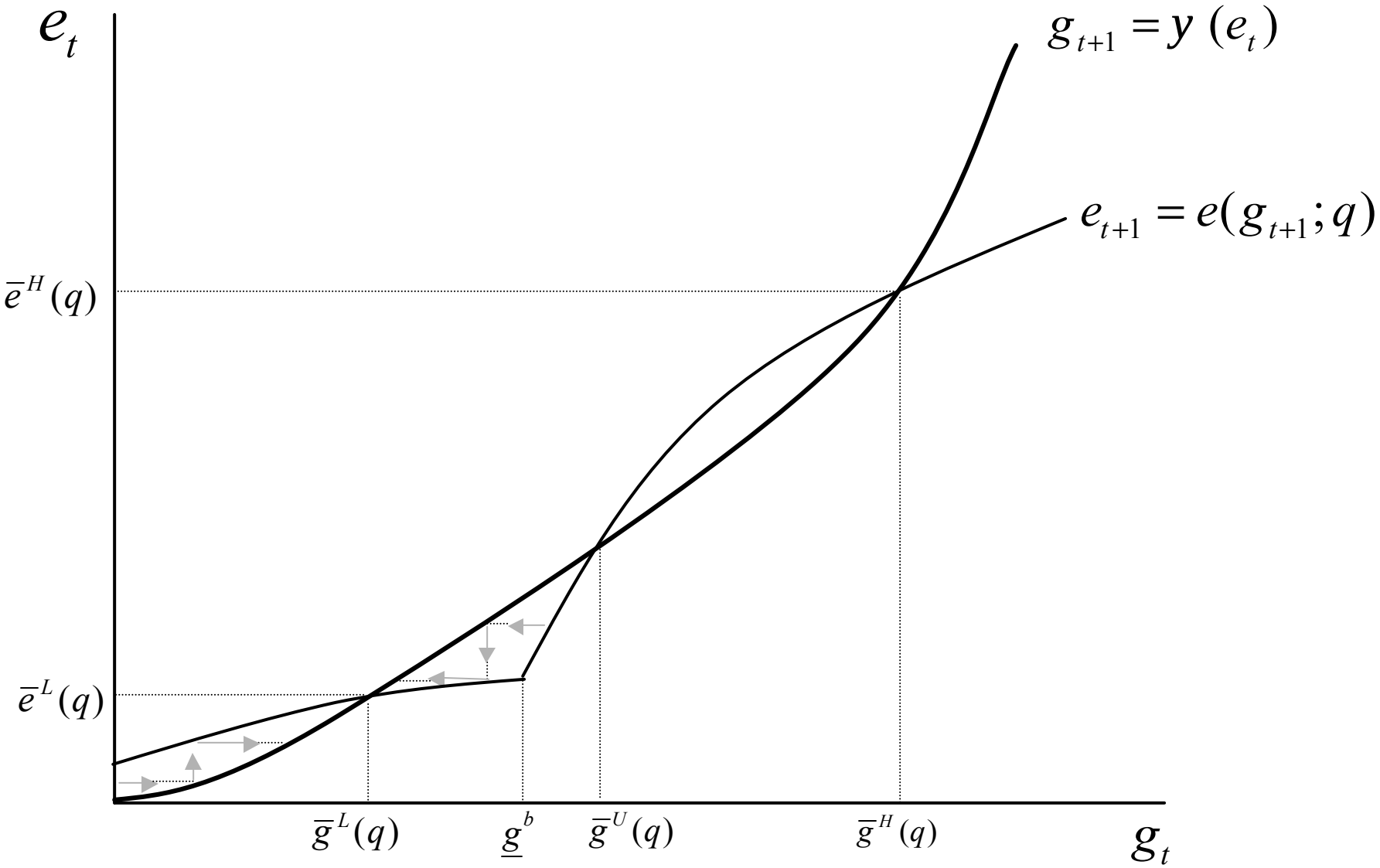


Figure V(b)

The Evolution of Education and Technological Progress for a Small Fraction of Individuals of the Quality Type $q \in (0, \hat{q})$

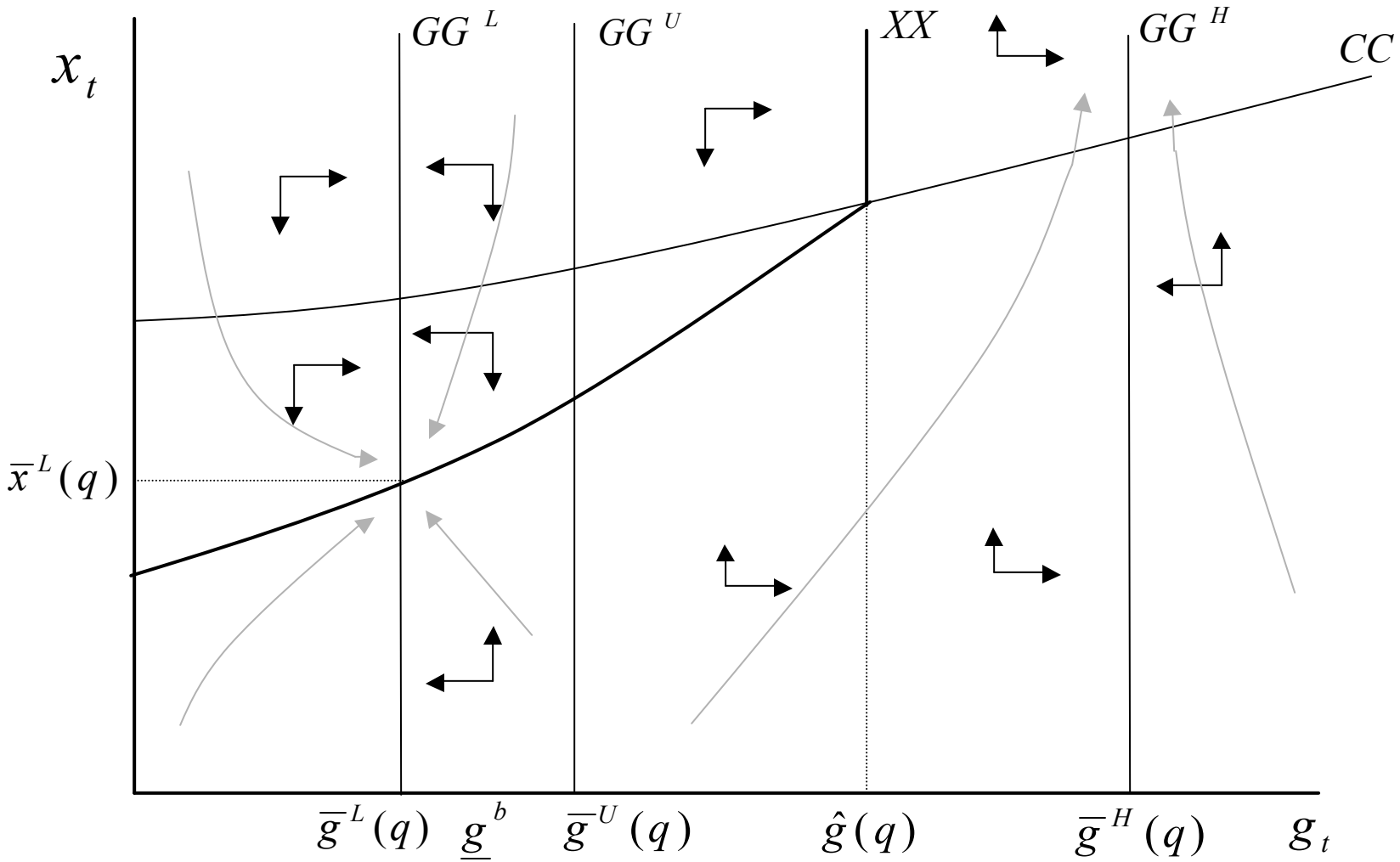


Figure VI(b)

The Evolution of Technological Progress and Effective Resources for a Small Fraction of Individuals of the Quality Type

$$q \in (0, \hat{q})$$

Evolutionary Advantage for the Quality-Type

Individuals with a preference bias towards quality of offspring have an evolutionary advantage over individuals of the quantity type. (That is, the fraction of individuals of quality type rises in the population, despite their preference bias against the quantity of their offspring).

Individuals of the quantity type:
- income near subsistence
- fertility rates near replacement level.

Individuals of the quality type
- higher income
- higher fertility rates (of higher quality offspring).

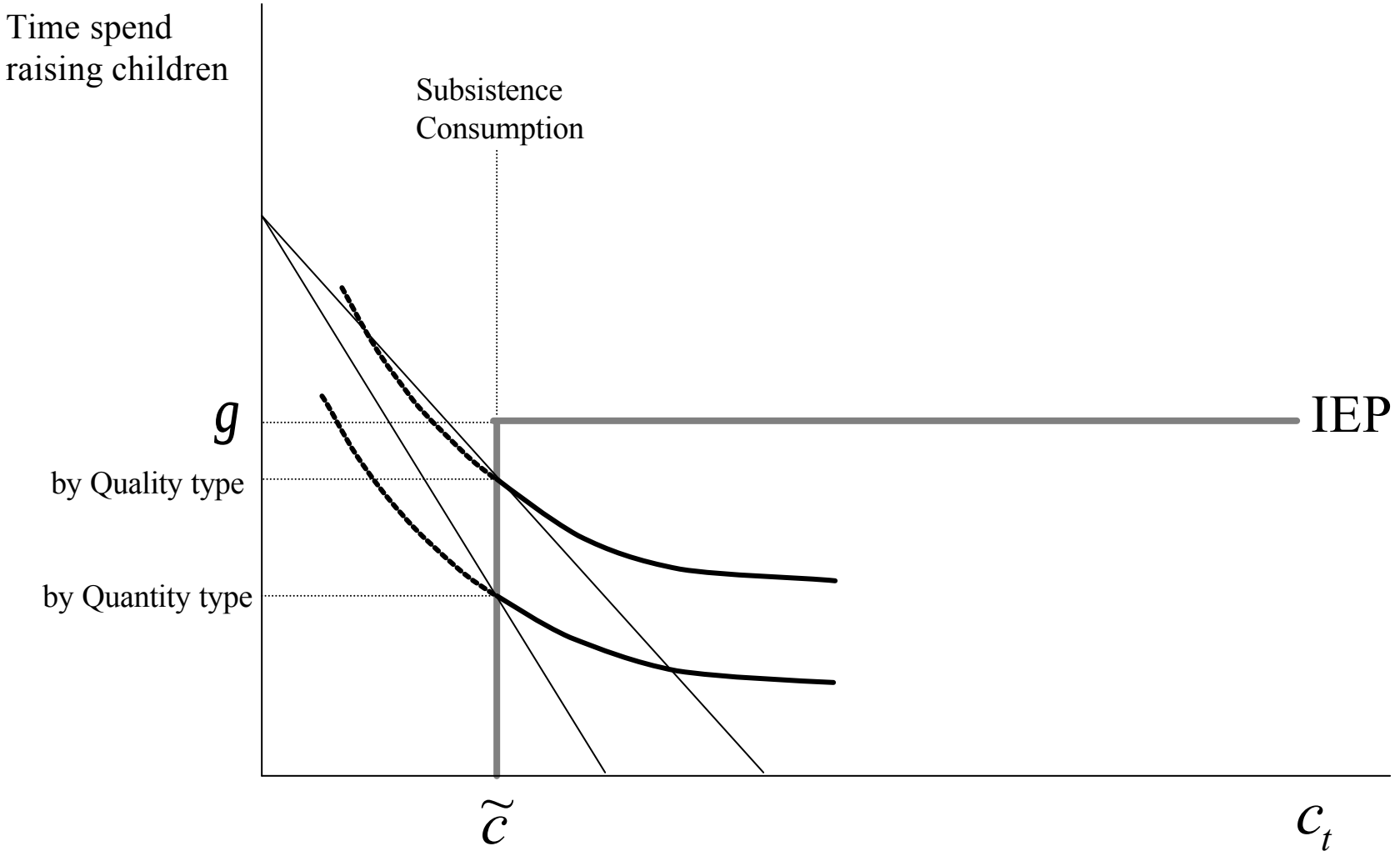
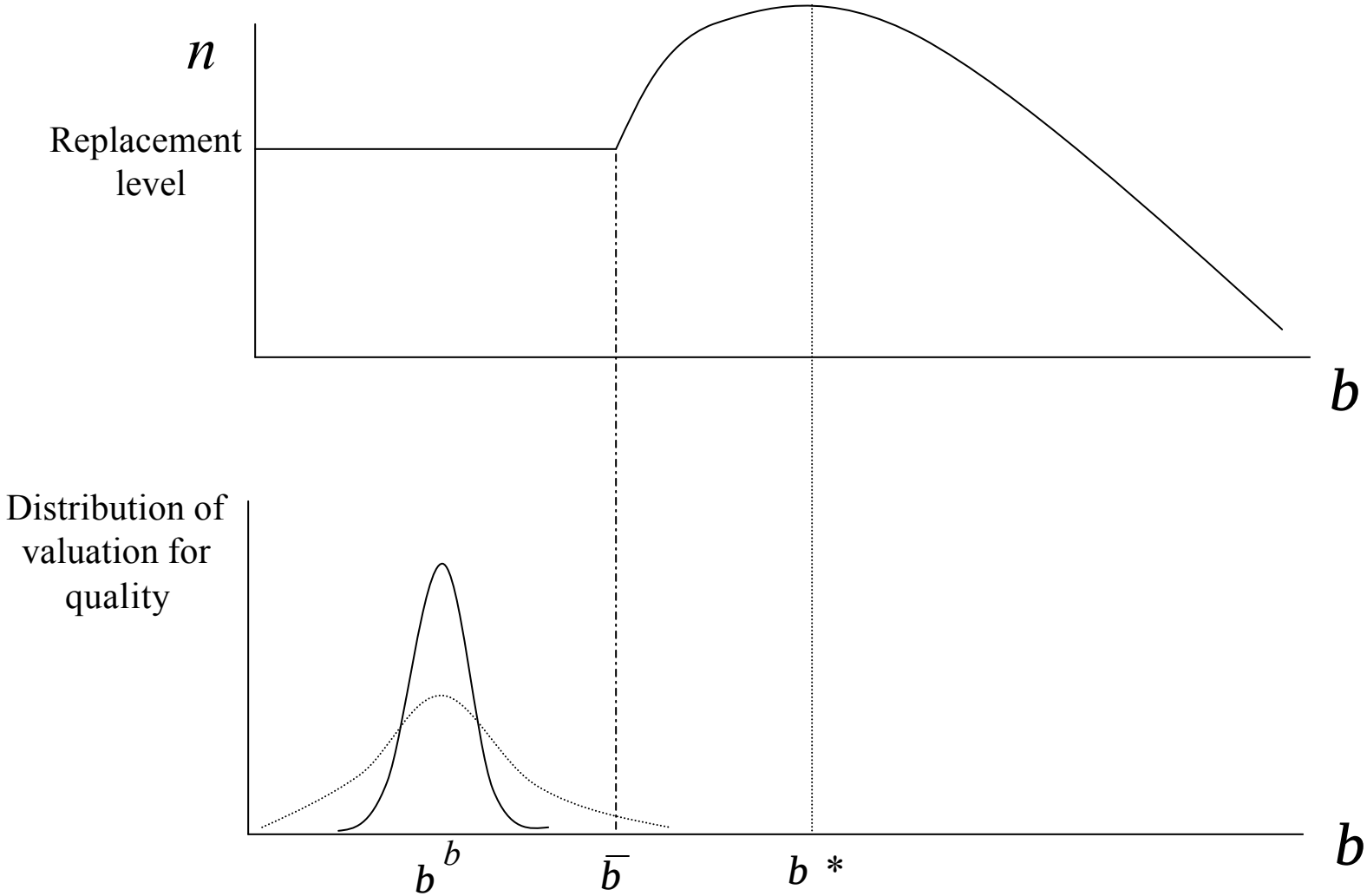


Figure VII

The Evolutionary Advantage of Individuals of the Quality Type in the Malthusian Epoch



1. For the initial valuation for quality, β^b, fertility is at replacement level.
2. Due to the evolution of the human brain, the valuation for quality lags behind the evolutionary optimal level $\beta*$.
3. One a sequence of mutations increases the valuation for quality above the threshold, $\bar{b}$ high valuation for quality generates an evolutionary advantage

Early Take-off

Technological progress becomes more rapid due to the increase in the fraction of individuals of the quality type. The incentive to invest in quality increases, investment in quality becomes universal, and the economy takes-off from the Malthusian regime since *more* individuals invest in quality.

The dynamical system changes qualitatively, the Malthusian temporary steady state vanishes endogenously and the economy takes-off from the Malthusian trap.

The positive feedback between the rate of technological progress and the level of education reinforces the growth process, setting the stage for an Industrial Revolution.

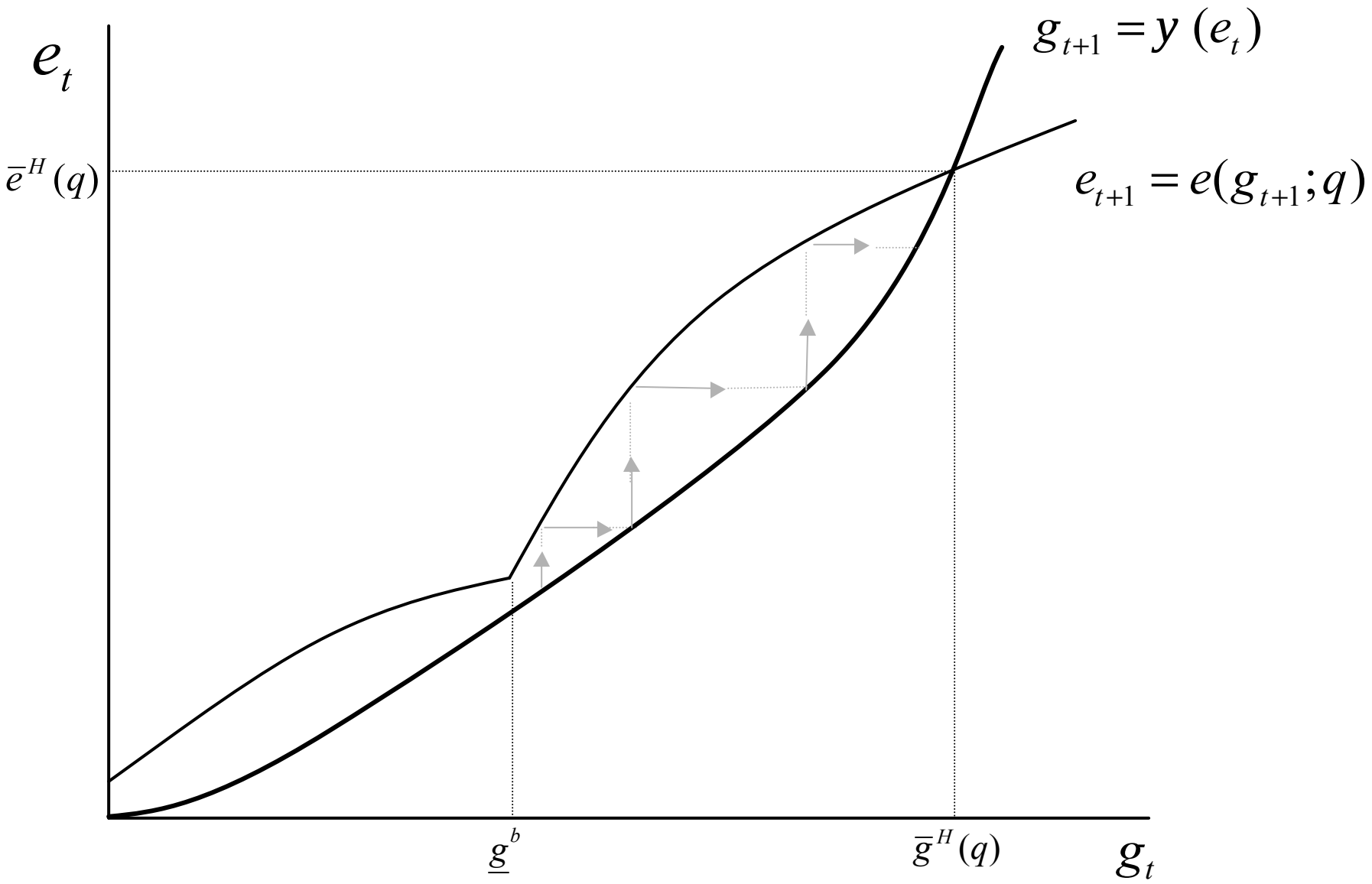


Figure V(c)

The Evolution of Education and Technological Progress for a Large Fraction of Individuals of the Quality Type

$q > \hat{q}$

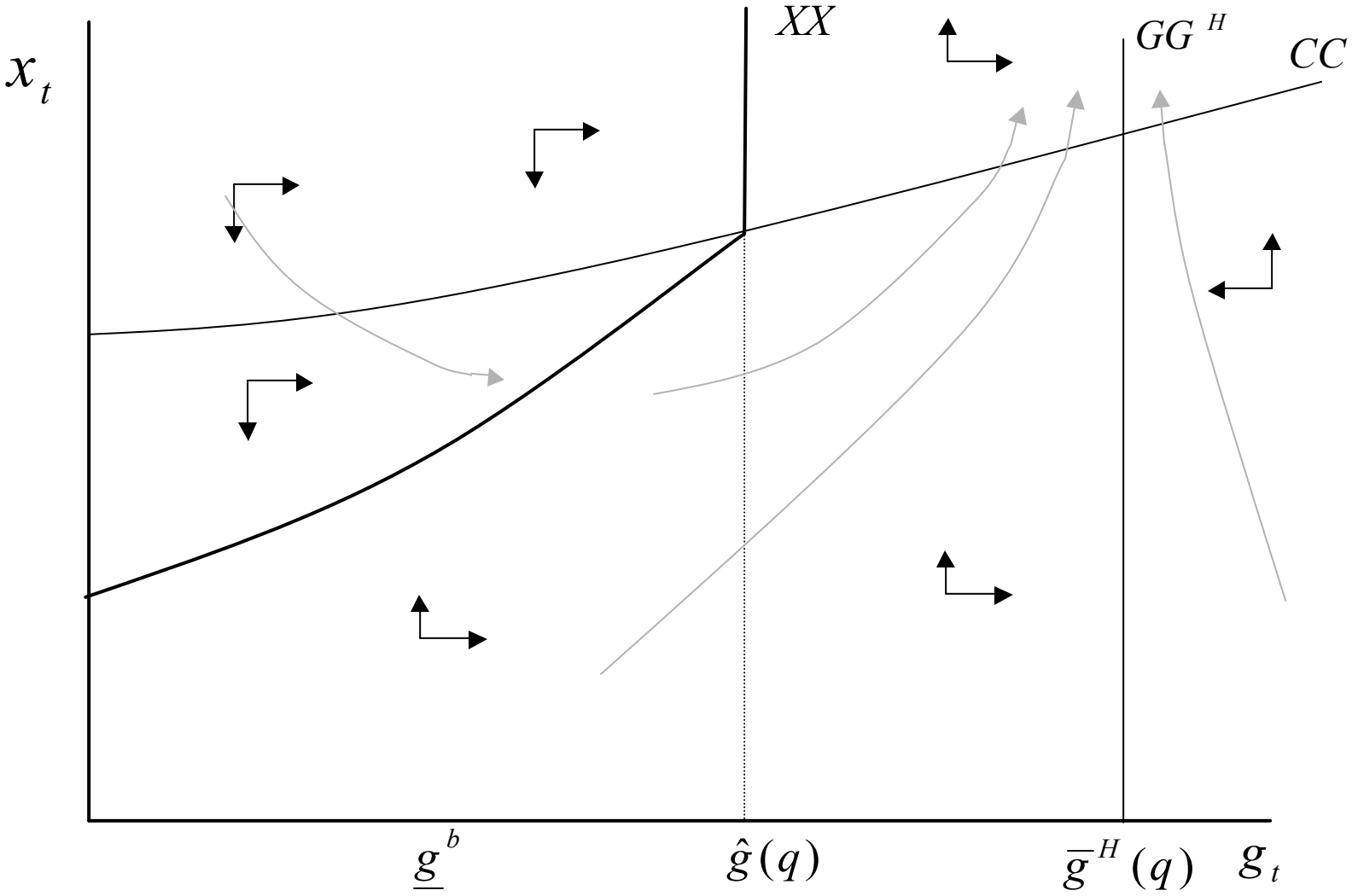


Figure VI(c)

The Evolution of Technological Progress and Effective Resources for a Large Fraction of Individuals of the Quality Type

$q > \hat{q}$

The pace of technological progress induces parents to substitute quality for quantity of children.

Technological progress has 2 effects on population growth:

1. Income Effect
More resources for raising children

2. Substitution Effect
Reallocation of resources towards child quality.

The income effect dominates:
both population quantity and quality increases.

Output per capita increases along with an increase in the rate of population growth.

Demographic Transition & Growth

Technological progress intensifies due to the gradual increase in the level of human capital

The return to human capital increases further.

Parents are induced to further substitute child quality for quantity

The substitution effect dominates generating a demographic transition:

> the rate of population growth declines along with an increase in quality.

The economy converges to a steady-state equilibrium with sustained output growth.

Reversal in the Evolutionary pattern:

During the transition from the Malthusian stagnation to the Modern growth regime, once the economic environment improves sufficiently the evolutionary pressure weakens and the significance of quality for survival (fertility) declines.

The inherent advantage of the quantity type in reproduction gradually dominates (as time rather than income becomes the binding constraint for child rearing) and fertility rates of the quantity type ultimately overtake those of the quality type.

The fraction of individuals of the quality type starts declining and the quantity type dominates the long run equilibrium.

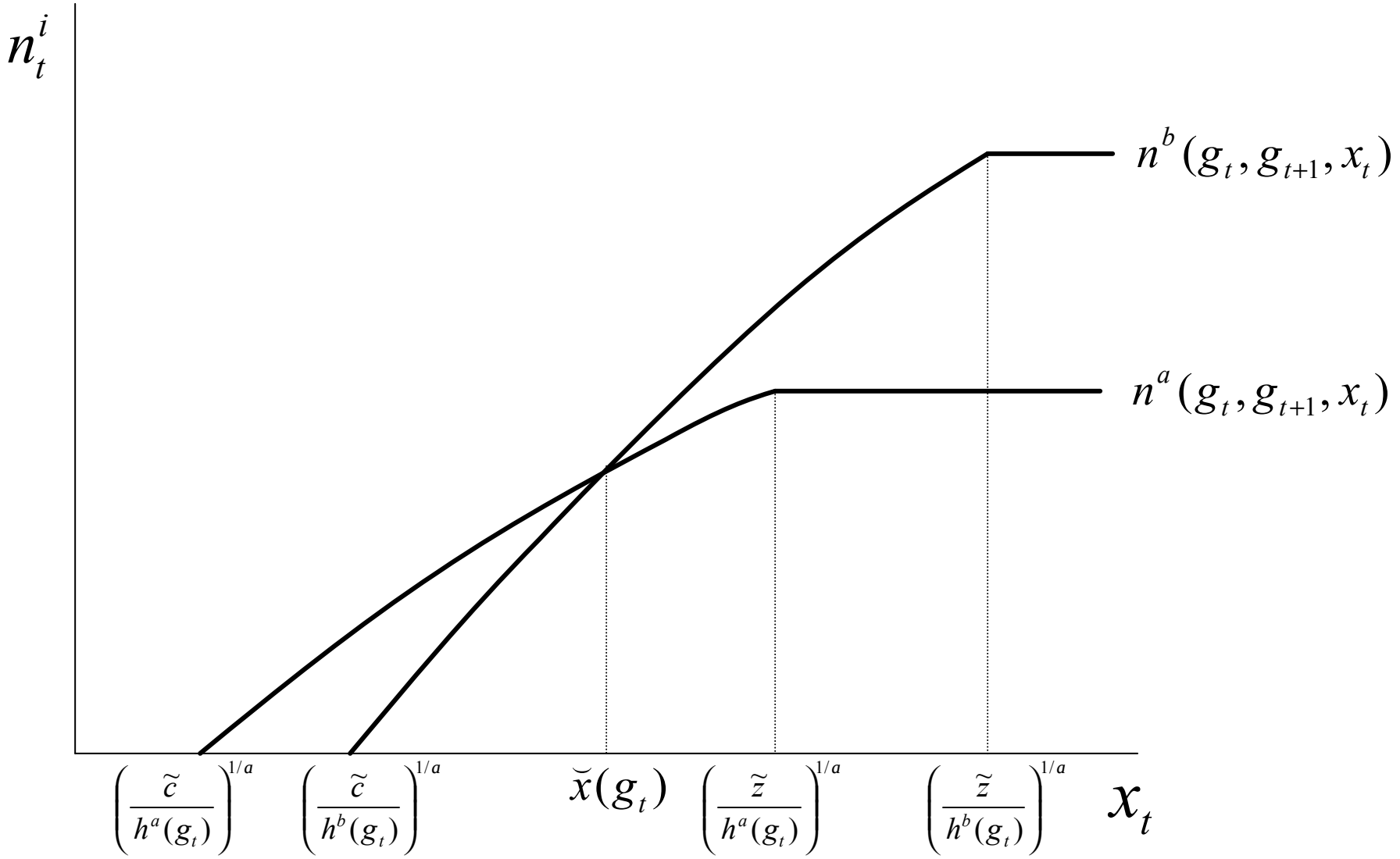


Figure IV

Differential Fertility Rates Across Types in the Process of Development

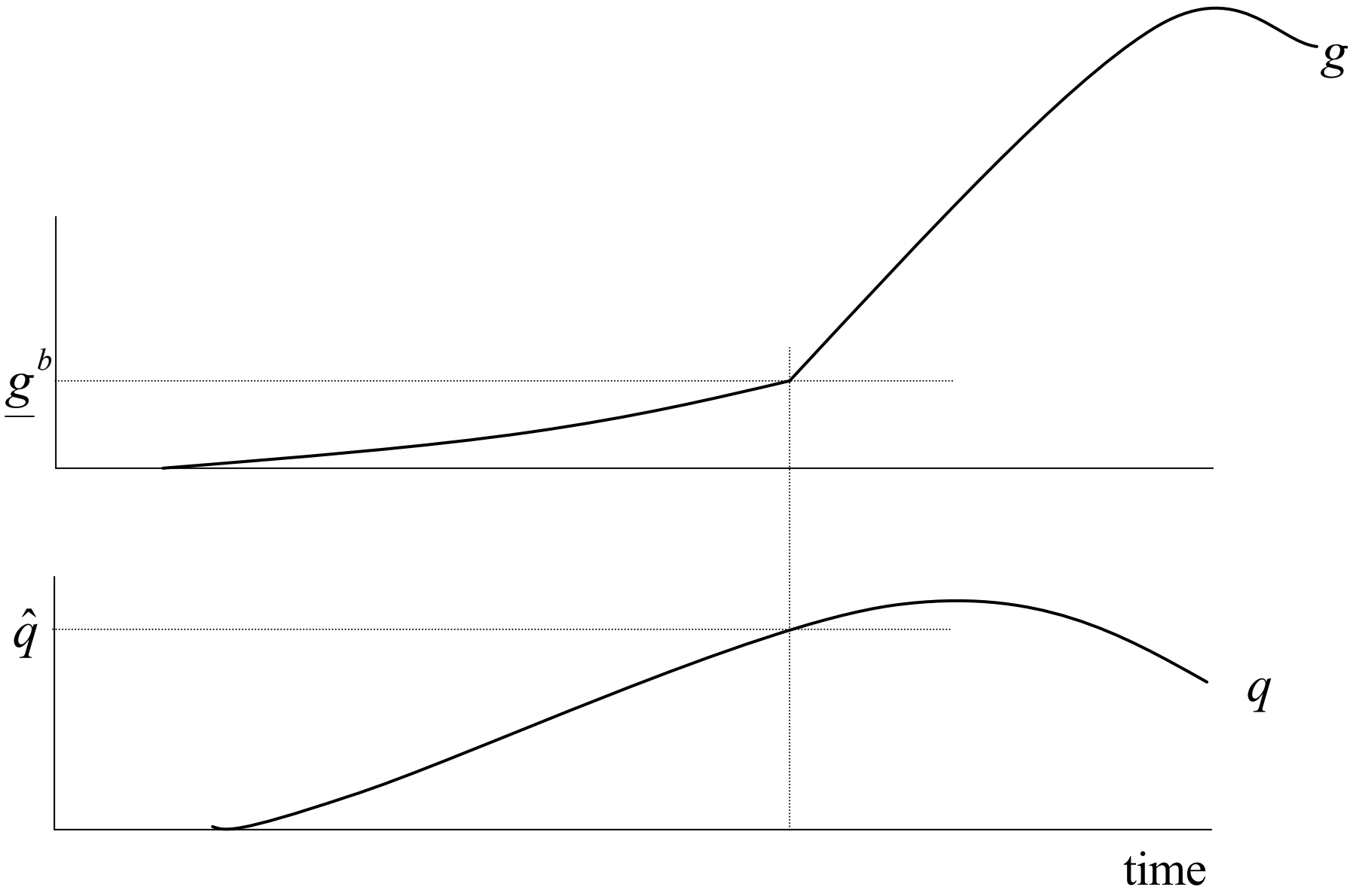


Figure VIII
The Dynamics of the Fraction of Individuals of the Quality Type and the Rate of technological progress

Alternative Evolutionary Mechanisms

Evolution of Intelligence

Complementarity between intelligence and investment in quality

Evolution of Life Expectancy

Complementarity between Life Expectancy and investment in quality

Have these traits completed most of their evolutionary change tens of thousands of years before the take-off?

- Intelligence has not evolved significantly since the emergence of Homo Sapience

  Intelligence may have reached (temporary) evolutionary optimum that reflects the trade-off between the benefits and energy cost associated with lager brain).

- Quality-bias has not reached a complete domination very early in the evolution of mankind.

Reasons for valuation for Quality being below optimum:

Evolution of the human brain in the transition to Homo Sapience &

Complementarity between brain capacity and reward for human capital

→ Increase in the evolutionary optimal investment in offspring's quality.

Sources of Delay:

In the Hunter-Gather state (prior to 10,000BC) people live in a state of **"Primitive Communism"**

Latent attribute of preferences for quality could not generate a disproportionate access to sexual mates and resources that could affect fertility rates and investment in offspring's quality, delaying the evolutionary advantage of quality-bias.

Observable attributes (strength and intelligence) could and they complete their evolutionary process much earlier

Nuclear family

Fostered intergenerational links, & enhanced the evolutionary advantage of quality-bias.

Alternative Explanation for the delay:

An alternative explanation for the delay in the evolutionary process of the quality bias relative to the evolution of intelligence is based on the notion of punctuated equilibria [Gould 1977]. A sequence of mutations, which result in a gradual increase in the variance in the distribution of the (latent) quality bias trait, had not affected investment in offspring's quality for a long period due to the low rate of return to human capital. Ultimately, however, mutations increased the variance sufficiently so as to induce investment in offspring's quality, despite the low return, and brought about an evolutionary advantage for the quality type. In contrast, a gradual increase in the variance of non-latent variables, such as intelligence, would have an immediate effect on the evolutionary process. (See the earlier figure on the evolution of beta.)

Empirical Implications:

For Economics:

- Waves of rapid technological progress in the Pre-Industrial Revolution era (e.g., during the Greco-Roman period) had not generated a sustained economic growth due to the shortage of individuals of the quality type in the population.

Although the return to quality increases temporarily, the level of human capital that is generated by the response of the existing population is not sufficient to support sustained technological progress and economic growth.

In contrast, an era of sustained economic growth in the aftermath of the Industrial Revolution era may be attributed to the presence of a sufficiently large fraction of quality type individuals in the population whose vigorous response to the rise in the return to human capital supports sustained technological progress and economic growth.

- Fertility differential across income groups evolves non-monotonically in the process of development.

- In any period within the Malthusian Regime fertility rates among richer individuals are predicted to be higher than among poorer individuals.

- In any period within the Sustained Growth Regime fertility rates among richer individuals are predicted to be lower than among poorer individuals.

  Consistent with evidence for the existence of a hump shaped cross-section relationship between fertility and income per-capita (e.g., Lee (1997), Boyer (1989), Livi-Bacci (1997)).

- Investment in human capital has increased gradually in the pre-industrial revolution era

(due to the higher representation of individuals who have higher valuation for offspring's quality.)

Consistent with:

The dramatic increase in the number of universities in Europe since the 11th century (that appear unjustified by the return, prior to the scientific revolution.

(For instance universities in Italy were founded at Padua (1222), Siena (1241), Piacenza (1248), Rome (1303), Perugia (1308), Pisa (1343), Florence (1349), Pavia (1361), and Turin (1405), etc.; in France at Paris (1150), Montpellier (1220), Toulouse (1229), Orleans (1306), Aix-en-Provence (1409), Poitiers (1431), and Caen (1432), and Strasbourg (1621), etc.; in Germany at Heidelberg (1386), Leipzig (1409), Freiburg (1457), Tobingen (1477), Trier (1450), Mainz (1476), and Wittenberg (1502), Halle (1694), Gottinger (1737), and Berlin (1809) etc.)

- In conventional Malthusian models, the adverse effect of limited resources on population growth delays the process of development, in the proposed theory the Malthusian constraint generates the necessary evolutionary pressure for the ultimate take-off.

For Evolutionary Biology:

- Genetic traits that favor investment in investment in child quality (rather than child quantity) were selected during the last 10,000 years. (i.e., The human population in the eve of the agricultural revolution has a lower valuation for child quality than the human population in the eve of the demographic transition that have started in the last two centuries).

- The human population would have a lower valuation for quality in few thousand years from now (although due to high return to quality and social factors, it would not have significant effect on investment in education).

- Selection of individuals who are, from a physiological viewpoint, moderately fertile (e.g. individuals with a moderate sperm count) and hence, can potentially invest more in the quality of their offspring would be consistent with the main thesis that traits that induce investment in quality (and are thus complementary to the growth process) were selected during the Malthusian epoch.