# 2008 Lawrence R. Klein Lecture – Comparative Economic Development: Insights from Unified Growth Theory*

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**Abstract**

This paper explores the implications of Unified Growth Theory for the origins of existing differences in income per capita across countries. The theory sheds light on three fundamental layers of comparative development. It identifies the factors that have governed the pace of the transition from stagnation to growth and have thus contributed to contemporary variation in economic development. It uncovers the forces that have sparked the emergence of multiple growth regimes and convergence clubs, and it underlines the persistent effects that variations in pre-historical biogeographical conditions have generated on the composition of human capital and economic development across the globe.

*Keywords:* Growth, Comparative Development, Globalization, Technological Progress, Demographic Transition, Diversity, Human Capital, Malthusian Stagnation

*JEL Classification Numbers:* F40, O11, O14, O15, O33, O40, J10, J13, N0

*Proposed Running Head:* UGT and Comparative Development

## 1 Introduction

The transition from an epoch of Malthusian stagnation to a state of sustained economic growth and the associated divergence in income per capita across the globe have been the subject of intensive research in the growth literature in recent years.[1] The inconsistency of exogenous and endogenous growth models with some of the most fundamental features of the growth process has led to the development of a unified theory of economic growth that captures in a single framework the epoch of Malthusian stagnation that characterized most of human history, the contemporary era of sustained economic growth, and the underlying driving forces that triggered the transition from stagnation to growth and the divergence in income per capita across regions of the world.[2]

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[1] The transition from stagnation to growth is explored by Galor and Weil (1999, 2000), Galor and Moav (2002), Lucas (2002), Hansen and Prescott (2002), Jones (2001), Doepke (2004), Fernandez-Villaverde (2001), Galor (2005), Lagerlof (2006), O'Rourke, Rahman and Taylor (2008), as well as others. The association of this transition with the divergence in income per capita across regions of the world is examined by Galor and Mountford (2006, 2008), Voigtlander and Voth (2006), Galor, Moav and Vollrath (2009), Broadberry (2007), and Ashraf and Galor (2009).

[2] Non-unified growth models have been instrumental in advancing our understanding of the role of factor accumulation and technological progress in the growth process during the modern era. Nevertheless, they are inconsistent with the qualitative aspects of the growth process over most of human existence. In particular, they are at odds with the evolution

The advancement of Unified Growth Theory was fueled by the conviction that the understanding of global variation in economic development would be fragile and incomplete unless growth theory would reflect the principal driving forces over the entire process of development and would capture the central role played by historical and pre-historical factors in the prevailing disparity in economic development across countries and regions.[3] Moreover, it was fostered by the realization that a comprehensive understanding of the hurdles faced by less developed economies in reaching a state of sustained economic growth would remain obscure unless the factors that brought about the transition of the currently developed economies into a state of sustained economic growth could be identified and modified to account for the differences in the growth structure of less developed economies in an interdependent world.

Unified Growth Theory (Galor and Weil 1999, 2000, Galor and Moav 2002 and Galor 2005) provides a fundamental framework of analysis for the evolution of economies over the entire course of human history.[4] It unveils the principal factors that have generated the remarkable escape from the Malthusian epoch and their significance for the understanding of the contemporary growth process of developed and less developed economies. Moreover, it sheds light on the forces that have triggered the great divergence in income per capita across regions of the world in the past two centuries (Figure 1).[5]

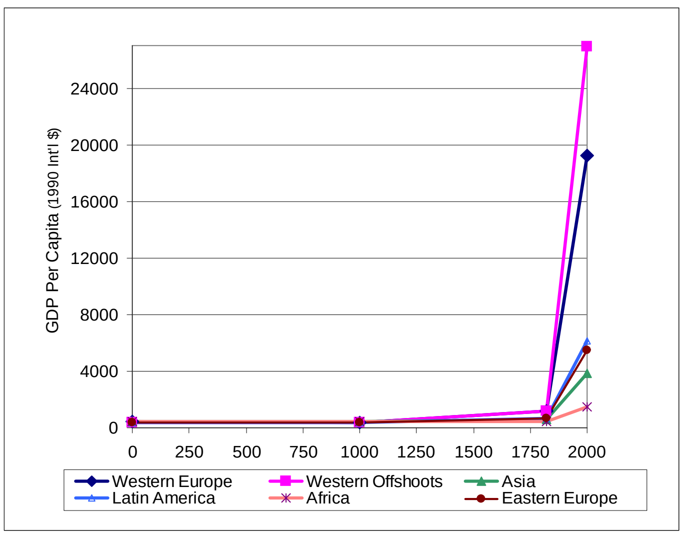


Figure 1. The Evolution of Regional Income Per Capita over the Years 1 - 2000.[6]

of economies during the Malthusian epoch, when capital accumulation and technological progress were counterbalanced almost entirely by an increase in the size of the population and had thus a negligible effect on the long-run level and growth rate of income per capita. Moreover, they fail to identify the forces that triggered the demographic transition, the take-off from stagnation to sustained economic growth, and the associated divergence in income per capita across countries – insights that are instrumental for the understanding of the growth process and comparative development.

[3] Clearly, the understanding of the contemporary world would be limited and incomplete in the absence of an historical perspective. However, the intensity of the recent exploration of the interaction between economic development and economic history could be attributed to the increasing frustration with the failure of the ahistorical branch of growth theory to capture some of the most fundamental aspects of the growth process.

[4] Moreover, it sheds light on the interaction between economic development and human evolution and the potential role of evolutionary processes in transition from stagnation to growth (Galor and Moav 2002).

[5] Some have argued that the divergence in income per capita in the past two centuries (Pritchett 1997) is accompanied by the emergence of convergence clubs (Quah 1997). Others have noted that while divergence may have taken place across countries, the recent decades were marked by convergence in income across *individuals* in the world (Sala-i-Martin 2006).

[6] The ratio of GDP per capita between the richest region and the poorest region in the world was only 1.1:1 in the year 1000, 2:1 in the year 1500, and 3:1 in the year 1820. In the course of the 'Great Divergence' the ratio of GDP per capita between the Western offshoots (United States, Canada, Australia and New Zealand) and Africa has widened considerably

The theory suggests that the inherent Malthusian interaction between the level of technology and the size and the composition of the population accelerated the pace of technological progress and ultimately raised the importance of human capital in the rapidly changing technological environment. The rise in the demand for human capital and its impact on the formation of human capital, as well as on the onset of the demographic transition, has brought about significant technological advances along with a reduction in fertility rates and population growth.[7] It has enabled economies to divert a larger share of the fruits of factor accumulation and technological progress from fueling population growth towards the advancement in income per capita and has thus paved the way for the emergence of sustained economic growth.

This paper explores the implications of Unified Growth Theory for the origins of the contemporary variation in income per capita across countries and regions. The theory sheds light on three fundamental aspects of comparative economic development. First, it identifies the factors that have governed the pace of the transition from stagnation to growth and have thus contributed to the observed worldwide differences in economic development. Second, it uncovers the forces that have sparked the emergence of multiple growth regimes and convergence clubs and unveils the characteristics that determine the association of economies with each of the clubs. Third, it underlines the persistent effects that variations in pre-historical biogeographical conditions have generated on the composition of human capital and economic development across the globe.

The theory implies that differences in the timing of the take-off from stagnation to growth across countries contributed to the divergence in income per capita across the globe. The first layer of the theory facilitates therefore the identification of pre-historical factors and their manifestation in the composition of human capital, inequality in ownership over factors of production, trade patterns, as well as institutional, demographic, and cultural factors, that have governed the pace of the transition from an epoch of Malthusian stagnation to a state of sustained economic growth and have thus contributed to the observed contemporary differences in economic development across countries.

The theory suggests that global variations in country-specific characteristics that have influenced the rate of technological progress have reinforced the differential pace of emergence of the demand for human capital, the onset of the demographic transition, and the pace of the transition to sustained economic growth, and have thus contributed to the great divergence in income per capita that was observed in the past two centuries. In particular, worldwide variation in technological progress has been triggered by cross-country differences in: (a) the level of protection of intellectual property rights, (b) the stock of knowledge and its diffusion rate across members of society, (c) the level of human diversity and the complementarity of the spectrum of human traits with the implementation and advancement of new technological paradigms, (d) the composition of religious groups and their attitude towards knowledge creation and diffusion, and (e) the propensity to trade and its effect on technological diffusion.

Moreover, the theory implies that, once the technologically-driven demand for human capital emerged in the second phase of industrialization, the prevalence of characteristics conducive for human capital formation has determined the swiftness of the process of human capital accumulation, the timing of the demographic transition, the pace of the transition from stagnation to growth, and thereby the

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from a modest 3:1 ratio in 1820, to a 5:1 ratio in 1870, a 9:1 ratio in 1913, a 15:1 ratio in 1950, and a large 18:1 ratio in 2001 (Maddison 2001).

[7] Clearly, the increased demand for human capital has not resulted necessarily in an increase in the rate of return to human capital due to institutional changes (e.g., the provision of public education) that lowered the cost of investment in human capital and facilitated a massive increase in the supply of education (Galor 2005, Section 2.3.3.).

observed distribution of income in the world economy. Thus, variation in country-specific characteristics that have contributed to human capital formation has affected differentially the pace of the transition from agriculture to industry and comparative development across the globe. In particular global variation in human capital formation has been triggered by cross-country differences in: (a) the prevalence of human-capital-promoting institutions or policies (e.g., child labor regulations and the availability, accessibility, and quality of public education), which may partly reflect the distribution of ownership over factors of production and the desirability of human capital formation for the landed aristocracy, (b) the ability of individuals to finance the cost of education as well as the foregone earnings associated with schooling, (c) the level of inequality and the degree of credit market imperfections and their impact on the extent of under-investment in education, (d) the stock of knowledge in society and its effect on the productivity of investment of human capital, (e) the propensity to trade and the existence of comparative (dis)advantage in the production of skilled intensive goods, and (f) preferences for educated offspring which may reflect: (i) cultural attributes, (ii) the composition of religious groups and their attitude towards education, and (iii) social status associated with education.

In its second layer, Unified Growth Theory advances the understanding of the forces that contributed to the existence of multiple growth regimes and the emergence of convergence clubs, attributing these phenomena to variation in the position of economies along the distinct phases of development. The theory suggests that, although the long-run equilibrium may not differ across economies, the differential timing of take-offs from stagnation to growth has segmented economies into three fundamental growth regimes: slow growing economies in the vicinity of a Malthusian steady state, fast growing countries in a sustained growth regime, and a third group of economies in the transition from one regime to another. The presence of convergence clubs may be therefore temporary, and endogenous forces would ultimately permit the members of the Malthusian club to shift their position and join the members of the sustained-growth club. In contrast to existing research that links membership in each club and the thresholds that permit economies to switch across these regimes to critical levels of income or human capital, Unified Growth Theory implies that they are in fact associated primarily with critical *rates* of technological progress, population growth and human capital formation.

Finally, in its third layer, Unified Growth Theory underlines the direct persistent effect that variations in pre-historical biogeographical conditions (e.g., biodiversity, migratory distance from the geographical origin of Homo sapiens and genetic diversity), have generated on global comparative development over the entire course of human history. Recent advances by Asharf and Galor (2009) suggests that indeed these biogeographical endowments, that were determined tens of thousands years ago, are critical for the understanding of the course of comparative economic development from the dawn of human civilization to the modern era. In particular, these pre-historical factors have a direct, long lasting effect on the existing differences in income per capita across countries that could not be captured by contemporary geographical, institutional and cultural factors.

# 2 Unified Growth Theory

## 2.1 The Mysteries of the Growth Process

The evolution of societies and their mode of production since the emergence of Homo sapiens, approximately 100,000 years ago, has been characterized by three fundamental phases: hunting and gathering, agricultural and industrial societies. As depicted in Figure 2, during nearly 90% of their existence, modern humans were associated with small nomadic tribes that were engaged in hunting and gathering. The onset of the Neolithic revolution about 10,000 years ago marked the transition of societies to sedentary agricultural communities. During this phase of development that spans about 9.8% of human existence, an increasing proportion of the human population has been engaged in agricultural production, that had gradually diffused to most societies across the globe. Finally, the emergence of the Industrial Revolution in the 18th century and the associated transition from agricultural to industrial societies initiated the recent industrial phase that has ranged over roughly 0.2% of human existence.[8]

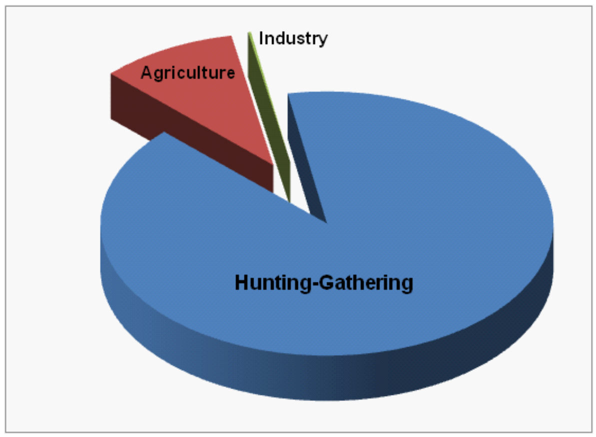


Figure 2. Phases of Development since the Emergence of Homo Sapiens.

The process of development during most of human existence was marked by Malthusian Stagnation. Technological progress was insignificant by modern standards and resources generated by technological progress and land expansion were channeled primarily towards an increase in the size of the population, with a minor long-run effect on income per capita. The positive effect of the standard of living on population growth along with diminishing labor productivity kept income per capita in the proximity of a subsistence level.[9] Variations in technology and land quality across countries were reflected primarily in differences in population density. The standard of living, in contrast, did not echo the degree of technological advancement.[10] In the past two centuries, in contrast, the pace of technological progress intensified in association with the process of industrialization. Various regions of the world departed from the Malthusian trap and experienced a considerable rise in the growth rates of income per capita as well as population. Unlike episodes of technological progress in the pre-Industrial Revolution era that failed to generate sustained economic growth, the increasing role of human capital in the production process in the second phase of industrialization ultimately prompted a demographic transition that liberated the gains in productivity from the counterbalancing effects of population growth. The decline in the growth rate of population and the associated enhancement of technological progress and human capital formation paved the way for the emergence of the modern state of sustained economic growth.[11]

[8] Non-unified growth theory is designed to capture economic development of industrial societies in the post-demographic transition era – an even smaller fraction of human existence.

[9] This subsistence level of consumption may have been well above the minimal physiological requirements that are necessary in order to sustain an active human being.

[10] Cross-country evidence is supportive of the existence of a Malthusian epoch of stagnation (Ashraf and Galor 2008).

[11] For a detailed analysis of the main stages in the process of development see Galor (2005).

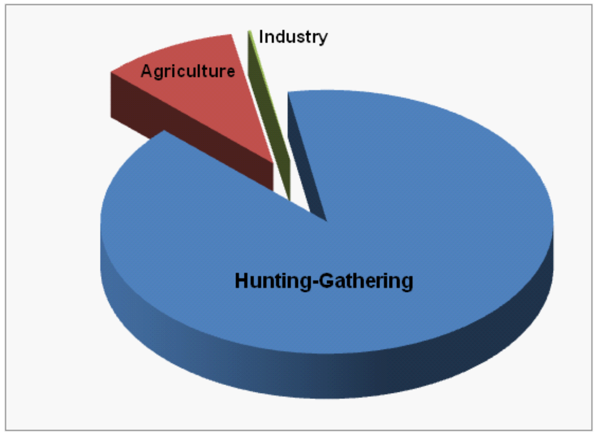


Figure 2. Modes of Production since the Emergence of Homo Sapiens.

The last two centuries have witnessed dramatic changes in the distribution of income and population across the globe. The differential timing of the take-off from stagnation to growth across countries and the corresponding variation in the timing of the demographic transition have led to a great divergence in income and to significant changes in the distribution of population over the globe. Some regions have excelled in the growth of income per capita, while other regions have been dominant in population growth. Inequality in the world economy had been insignificant until the 19th century. The ratio of GDP per capita between the richest region and the poorest region in the world was only 1.1:1 in 1000 AD, 2:1 in 1500 and 3:1 in 1820. In contrast, the past two centuries have been characterized by a 'Great Divergence' in income per capita among countries and regions. In particular, the ratio of GDP per capita between the richest and the poorest regions has widened considerably from a modest 3:1 ratio in 1820 to a large 18:1 ratio in 2001. An equally impressive transformation occurred in the distribution of world population across regions. The earlier take-off of Western European countries generated a 16% increase in the share of their population in the world economy within the time period 1820-1870. However, the early onset of the Western European demographic transition and the long delay in the demographic transition of less developed regions well into the second half of the 20th century led to a 55% decline in the share of Western European population in the world in the time period 1870-1998. In contrast, the prolongation of the Post-Malthusian period of less developed regions and the delay in their demographic transitions, generated a 84% increase in Africa's share of world population from 7% in 1913 to 12.9% in 1998, an 11% increase in Asia's share of world population from 51.7% in 1913 to 57.4% in 1998, and a four-fold increase in Latin America's share in world population from 2% in 1820 to 8.6% in 1998.

Unified growth theory explores the fundamental factors that have generated the remarkable escape from the Malthusian epoch and their significance for the understanding of the contemporary growth process of developed and less developed economies. It deciphers some of the most fundamental questions that have been shrouded in mystery: what accounts for the epoch of stagnation that characterized most of human history? why had episodes of technological progress in the pre-industrialization era failed to generate sustained economic growth? why has population growth counterbalanced the expansion of resources per capita that could have been generated by technological progress? what is the origin of the sudden spurt in growth rates of output per capita and population in the course of industrialization?

what was the source of the dramatic reversal in the positive relationship between income per capita and population that existed throughout most of human history? what triggered the demographic transition? would the transition to a state of sustained economic growth have been feasible without the demographic transition? what accounts for the transition from stagnation to growth of the currently DCs and what are the implications of these factors for the hurdles faced by LDCs in their attempt to transit into a sustained growth regime? and, what are the underlying behavioral and technological structures that can simultaneously account for these distinct phases of development and what are their implications for the contemporary growth process of developed and underdeveloped countries?

Moreover, unified growth theory sheds light on the perplexing phenomenon of the divergence in income per capita across regions of the world in the past two centuries: what accounts for the sudden take-off from stagnation to growth in some countries in the world and the persistent stagnation in others? why has the positive link between income per capita and population growth reversed its course in some economies but not in others? what governs the differential timing of the demographic transition across the globe? why have the differences in per capita incomes across regions of the world increased so markedly in the last two centuries? and has the transition to a state of sustained economic growth in advanced economies adversely affected the process of development in less-developed economies?

## 2.2 The Fundamental Challenge

The establishment of a theory of economic growth that provides a unifying framework for the process of development in its entirety has been a great intellectual challenge. It required major methodological and conceptual innovations in the construction of a unified microeconomic framework, and thus a single dynamical system, that captures the unique characteristics of each phase in the process of development, while orchestrating an endogenous transition across these distinct phases.

In light of historical evidence that the take-off from the Malthusian epoch to a state of sustained economic growth, rapid as it may appear, was a gradual process (Crafts 1985 and Crafts and Harley 1992), the development of a unified growth theory necessitated the construction of a dynamical system, in which economies take off gradually but swiftly from an absorbing (stable) Malthusian equilibrium – an apparent contradiction to the notion of an absorbing state.[12] However, the long era of Malthusian stagnation in income per capita masked a latent Malthusian dynamism (Ashraf and Galor 2008 and Voigtlander and Voth 2009) that ultimately brought about the phase transition that was associated with the take-off from the Malthusian equilibrium. In particular, although the growth of income per capita was miniscule over the Malthusian epoch, in the course of the Malthusian interaction between technology and population, technological progress intensified and world population significantly increased in size – a dynamism that was instrumental for the emergence of economies from the Malthusian epoch.

Thus, as proposed by Galor and Weil (2000), the phase transition associated with the take-off from the Malthusian epoch was orchestrated by the impact of the evolution of these latent state variables on the dynamical system. In particular, the observed rapid, yet continuous, phase transition is captured by a single dynamical system, once the evolution of latent state variables in the Malthusian epoch alters the qualitative structure of the dynamical system. The absorbing Malthusian equilibrium vanishes and

[12] Thus, the Industrial Revolution could not be plausibly viewed as an outcome of a major shock that shifted economies from the basin of attraction of the Malthusian equilibrium to that of the Modern Growth Regime. In particular, the simplest methodology for the generation of a phase transition, namely, a major shock in an environment characterized by multiple locally stable equilibria, appears inappropriate for generating the observed take-off from stagnation to growth.

the economy gravitates towards a unique and stable sustained growth steady-state equilibrium.

Galor and Weil (2000) and Galor and Moav (2002) develop a unified growth theory in which the endogenous evolution of population, technology, and income per capita is consistent with the process of development in the last thousands of years. These theories capture the fundamental regimes that have characterized the process of development as well as the fundamental driving forces that generated the transition from an epoch of Malthusian stagnation to a state of sustained economic growth. These models introduce the methodological and conceptual innovation that the evolution of latent state variables was a critical force in the observed phase transition. During the Malthusian epoch the dynamical system is characterized by a stable Malthusian equilibrium, but eventually due to a latent progression in demand for human capital (Galor and Weil 2000) or a Darwinian evolution in the propensity of individuals to invest in human capital (Galor and Moav 2002), the Malthusian steady-state equilibrium vanishes endogenously leaving the arena for the gravitational forces of the emerging sustained growth steady-state equilibrium.

## 2.3 Central Building Blocks

The theory is based upon the interaction between several building blocks: the Malthusian elements, the engines of technological progress, the origin of human capital formation, and the trigger for the demographic transition.

*The Malthusian elements.* The process of development during most of human existence was marked by Malthusian Stagnation. Resources generated by technological progress and land expansion were channeled primarily towards an increase in the size of the population, with a minor long-run effect on income per capita. The positive effect of the standard of living on population growth along with diminishing labor productivity left income per capita in the proximity of a subsistence level (Malthus 1798).

The Malthusian epoch is captured in Unified Growth Theory based on three central elements: (a) the production process is characterized by decreasing returns to labor due to the limited availability of land, (b) parents generate utility from their children and the production of children is time intensive, and, (c) individuals are subjected to a subsistence consumption constraint.[13] Thus, as long as the subsistence constraint is binding, an increase in income results in an increase in population growth. Technological progress, which brings about temporary gains in income per capita, triggers therefore an increase in the size of the population that offsets the gain in income per capita due to the existence of decreasing returns to labor.

*The engines of technological progress.* The acceleration in technological progress in the course of industrialization is a fundamental force in the transition from stagnation to growth. While the size of the population stimulates technological progress in early stages of development, human capital formation is the prime engine of technological progress in more advanced stages of development. Unified growth theory supposes that in the Malthusian era, when the technological frontier reflected the working environment of most individuals, the scale of the population affected the rate of technological progress via its effect on: (a) the supply of innovative ideas, (b) the demand for innovations, (c) the rate of technological diffusion, (d) the degree of specialization in the production process and thus the extent of 'learning by doing', and (e) the scope for inter-regional trade and thus the extent of technological

[13] Bioeconomic foundations of the Malthusian equilibrium are explored by Dalgaard and Strulik (2007).

imitation and adoption.[14] However, as advancements of the technological frontier become increasingly more complex in later stages of development, human capital is more significant in the process of technological progress (e.g., Nelson and Phelps 1966 Schultz 1975) and educated individuals are more likely to advance the technological frontier.

*The origin of human capital formation.* The rise in industrial demand for human capital in advanced stages of industrialization (Galor 2005, section 2.3.3) and its impact on human capital formation and the demographic transition is a central component of the growth process and the transition to modern economic growth. Unified growth theory postulates that changes in the economic environment that are triggered by technological progress raise the demand for, and thus the formation of, human capital, since educated individuals have a comparative advantage in adapting to the new technological environment.[15] Although technologies may be either skill-biased or skill-saving in the long-run, the introduction of new technologies increases the demand for human capital in the short-run.[16]

*The trigger for the demographic transition.* The demographic transition that marked the onset of the state of sustained economic growth is a focal development in the transition from stagnation to growth. The demographic transition brought about a reversal in the unprecedented increase in population growth that occurred during the Post-Malthusian regime. The reduction in fertility rates and population growth have enhanced the growth process via several channels. They have reduced the dilution of the stock of capital and land, enhanced investment in human capital, and altered the age distribution of the population, increasing temporarily the size of the labor force relative to the population as a whole. Thus, the demographic transition has enabled economies to convert a larger share of the fruits of factor accumulation and technological progress into growth of output per capita.

Unified Growth Theory postulates that the rise in the demand for human capital triggered the decline in fertility. Individuals generate utility from the quantity and the quality of their children as well as from their own consumption. They choose the number of children and their quality in the face of a constraint on the total amount of time that can be devoted to child-raising and labor market activities. While a rise in parental income (due to the rise in the demand for human capital) would generate conflicting income and substitution effects and would not necessarily trigger a decline in fertility,[17] the effect of the rise in the demand for human capital on the potential future earning of a child generates a pure substitution effect. It induces parents to substitute quality for quantity of children and thus operates towards a decline in fertility.[18]

[14] The positive effect of the scale of the population on technological progress in the Malthusian epoch is supported empirically (Boserup 1965 and Kremer 1993). The role of the scale of the population in the modern era is, however, controversial. As technological progress becomes human capital intensive, if the scale of the population comes on the account of population quality, it may have an ambiguous effect on technological progress.

[15] If the demand for education rises with the *level* of technology the qualitative results would not be affected. Adopting this mechanism, however, would be equivalent to assuming that changes in technology were skill-biased throughout human history, in contrast with periods in which the characteristics of new technologies could be defined as unskilled-biased, most notably, during the first phase of the Industrial Revolution.

[16] The effect of technological transition on the return to human capital is at the center of the theoretical approach of Nelson and Phelps (1966), Galor and Tsiddon (1997), Galor and Moav (2000), and Hassler and Rodriguez Mora (2000). It is supported empirically by Schultz (1975) and Foster and Rosenzweig (1996).

[17] The central building block in Becker and Lewis (1973) is the domination of the substitution effect at high levels of income. Historical evidence, however, appears inconsistent with this central supposition (Galor 2005, 227-228).

[18] The existence of a trade-off between quantity and quality of children is supported empirically (e.g., Hanushek 1992 and Rosenzweig and Wolpin 1980), and its presence in the post-industrialization, but pre-demographic transition era, when the income effect is still dominating, has been documented recently by Becker, Cinnirella and Woessmann (2009).

## 2.4 The Basic Structure of the Model

Consider an overlapping-generations economy in which activity extends over infinite discrete time. In every period the economy produces a single homogeneous good using land and efficiency units of labor as inputs. The supply of land is exogenous and fixed over time whereas the number of efficiency units of labor is determined by households' decisions in the preceding period regarding the number and level of human capital of their children.

**Production of Final Output.** Production occurs according to a constant-returns-to-scale technology that is subject to endogenous technological progress. The output produced at time $t$, $Y_t$, is

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

where $H_t$ is the aggregate quantity of efficiency units of labor employed in period $t$, $X$ is land employed in production in every period $t$, $A_t$ represents the endogenously determined technological level in period $t$, and $A_t X$ is therefore the "effective resources" employed in production in period $t$, and $\alpha \in (0,1)$.

Output per worker produced at time $t$, $y_t$, is

$$y_t = h_t^{\alpha} x_t^{1-\alpha}, \tag{2}$$

where $h_t \equiv H_t/L_t$ is the level of efficiency units of labor per worker, and $x_t \equiv (A_t X)/L_t$ is the level of effective resources per worker at time $t$.

Suppose that there are no property rights over land.[19] The return to land is therefore zero, and the wage per efficiency unit of labor is therefore equal to the output per efficiency unit of labor:

$$w_t = (x_t/h_t)^{1-\alpha}. \tag{3}$$

**Preferences and Budget Constraints.** In each period $t$, a generation that consists of $L_t$ identical individuals joins the labor force. Each individual has a single parent. Members of generation $t$ (those who join the labor force in period $t$) live for two periods. In the first period of life (childhood), $t-1$, individuals consume a fraction of their parental unit time endowment. The required time increases with children's quality. In the second period of life (parenthood), $t$, individuals are endowed with one unit of time, which they allocate between child rearing and labor force participation. They choose the optimal mixture of quantity and quality of (surviving) children and supply their remaining time in the labor market, consuming their wages.

Preferences of memebers of generation $t$ are represented by a utility function, $u_t$, defined over consumption above a subsistence level $\tilde{c} > 0$, as well as over the quantity and quality (measured by human capital) of their (surviving) children:[20]

$$u_t = {c_t}^{1-\gamma}(n_t h_{t+1})^{\gamma}, \qquad \gamma \in (0,1), \tag{4}$$

[19] Allowing for capital accumulation and property rights over land would complicate the model to the point of intractability, but would not affect the qualitative results.

[20] For simplicity parents derive utility from the expected number of surviving offspring and the parental cost of child rearing is associated only with surviving children. A more realistic cost structure would not affect the qualitative features of the theory.

where $c_t$ is the consumption of individual of generation $t$, $n_t$ is the number of (surviving) children of individual $t$, and $h_{t+1}$ is the level of human capital of each child.[21] The utility function is strictly monotonically increasing and strictly quasi-concave, satisfying the conventional boundary conditions that assure, for a sufficiently high income, the existence of an interior solution for the utility maximization problem. However, for a sufficiently low level of income the subsistence consumption constraint is binding and there is a corner solution with respect to the consumption level.

Individuals choose the number of children and their quality in the face of a constraint on the total amount of time that can be devoted to child-raising and labor market activities. Let $\tau + e_{t+1}$ be the time cost for a member $i$ of generation $t$ of raising a child with a level of education (quality) $e_{t+1}$.[22] That is, $\tau$ is the fraction of the individual's unit time endowment that is required in order to raise a child, regardless of quality, and $e_{t+1}$ is the fraction of the individual's unit time endowment that is devoted for the education of each child.[23]

Consider members of generation $t$ who are endowed with $h_t$ efficiency units of labor at time $t$. Define potential income, $z_t$, as the potential earning if the entire time endowment is devoted to labor force participation, earning the competitive market wage, $w_t$, per efficiency unit. The potential income, $z_t \equiv w_t h_t$, is divided between consumption, $c_t$, and expenditure on child rearing (quantity as well as quality), evaluated according to the value of the time cost, $w_t h_t[\tau + e_{t+1}]$, per child. Hence, in the second period of life (parenthood), the individual faces the budget constraint

$$w_t h_t n_t(\tau + e_{t+1}) + c_t \leq w_t h_t \equiv z_t. \tag{5}$$

**The Production of Human Capital.** Individuals' level of human capital is determined by their quality (education) as well as by the technological environment. Technological progress reduces the adaptability of existing human capital to the new technological environment (the 'erosion effect'). Education, however, lessens the adverse effects of technological progress. In particular, the time required for adaptation to a new technological environment diminishes with the level of education and increases with the rate of technological change.

The level of human capital of children of a member $i$ of generation $t$, $h^i_{t+1}$, is an increasing strictly concave function of their parental time investment in education, $e^i_{t+1}$, and a decreasing strictly convex function of the rate of technological progress, $g_{t+1} \equiv (A_{t+1} - A_t)/A_t$ :

$$h_{t+1} = h(e_{t+1}, g_{t+1}). \tag{6}$$

Education lessens the adverse effect of technological progress. That is, technology complements skills in the production of human capital (i.e., $h_{eg}(e^i_{t+1}, g_{t+1}) > 0$). In the absence of investment in quality,

[21] Alternatively, the utility function could have been defined over consumption above subsistence rather than over a consumption set that is truncated from below by the subsistence consumption constraint. In particular, if $u_t = (c_t - \tilde{c})^{(1-\gamma)}(n_t h_{t+1})^\gamma$, the qualitative analysis would not be affected, but the complexity of the dynamical system would be greatly enhanced. The income expansion path would be smooth, transforming continuously from being nearly vertical for low levels of potential income to asymptotically horizontal for high levels of potential income.

[22] The time required to produce a child can be purchased from other individuals. However, in the absence of heterogeneity across individuals, or increasing returns in the production of human capital these transactions will not take place. As follows from Galor and Moav (2002), the introduction of heterogeneity will not affect the qualitative analysis. Moreover, if there exists increasing returns in the production of education, or if both time and goods are required in order to produce child quality, the process would be intensified. As the economy develops and wages increase, and as the demand for human capital formation rises, the relative cost of child quality will diminish and individuals will substitute quality for quantity of children.

[23] $\tau$ is assumed to be sufficiently small so as to assure that population can have a positive growth rate. That is, $\tau < \gamma$.

each individual has a basic level of human capital that is normalized to 1 in a stationary technological environment, i.e., $h(0,0) = 1$.[24]

**Optimization.** Members of generation $t$ choose the number and quality of their (surviving) children and their own consumption so as to maximize their intertemporal utility function subject to the subsistence consumption constraint. Substituting (5)-(6) into (4), the optimization problem of a member of generation $t$ is:

$$\{n_t, e_{t+1}\} = \arg\max\{w_t h_t[1 - n_t(\tau + e_{t+1})]\}^{1-\gamma}\{n_t h(e_{t+1}, g_{t+1})\}^{\gamma} \tag{7}$$

subject to:

$$\begin{array}{l} w_t h_t[1 - n_t(\tau + e_{t+1})] \geq \tilde{c}; \\ (n_t, e_{t+1}) \geq 0. \end{array}$$

Hence, as long as potential income at time $t$ is sufficiently high so as to assure that $c_t > \tilde{c}$ (i.e., as long as $z_t \equiv w_t h_t$ is above the level of potential income at which the subsistence constraint is just binding, (i.e., $z_t > \tilde{z} \equiv \tilde{c}/(1-\gamma)$)), the fraction of time spent by a member of generation $t$ raising children is $\gamma$, while $1-\gamma$ is devoted to labor force participation. However, if $z_t \leq \tilde{z}$ , the subsistence constraint is binding, the fraction of time necessary to assure subsistence consumption, $\tilde{c}$, is larger than $1-\gamma$ and the fraction of time devoted for child rearing is therefore below $\gamma$. That is,

$$n_t[\tau + e_{t+1}] = \begin{cases} \gamma & \text{if} \quad z_t \geq \tilde{z}; \\ 1 - [\tilde{c}/w_t h_t] & \text{if} \quad z_t \leq \tilde{z}. \end{cases} \tag{8}$$

Figure 3 shows the effect of an increase in potential income $z_t$ on the individual's allocation of time between child rearing and consumption. The income expansion path is vertical as long as the subsistence consumption constraint is binding. As the wage per efficiency unit of labor increases in this income range, the individual can generate the subsistence consumption with a lower level of labor force participation and the fraction of time devoted to child rearing increases. Once the level of income is sufficiently high such that the subsistence consumption constraint is not binding, the income expansion path becomes horizontal at a level $\gamma$ in terms of time devoted to child rearing.

[24] For simplicity, investment in quality is not beneficial in a stationary technological environment, i.e., $h_e(0,0) = 0$, and in the absence of investment in education, there exists a sufficiently rapid technological progress, that due to the erosion effect renders the existing human capital obsolete (i.e., $\lim_{g\to\infty} h(0,g) = 0$). Furthermore, although the potential number of efficiency units of labor is diminished due to the transition from the existing technological state to a superior one (due to the erosion effect), each individual operates with a superior level of technology and the productivity effect is assumed to dominate, i.e., $\partial y_t/\partial g_t > 0$.

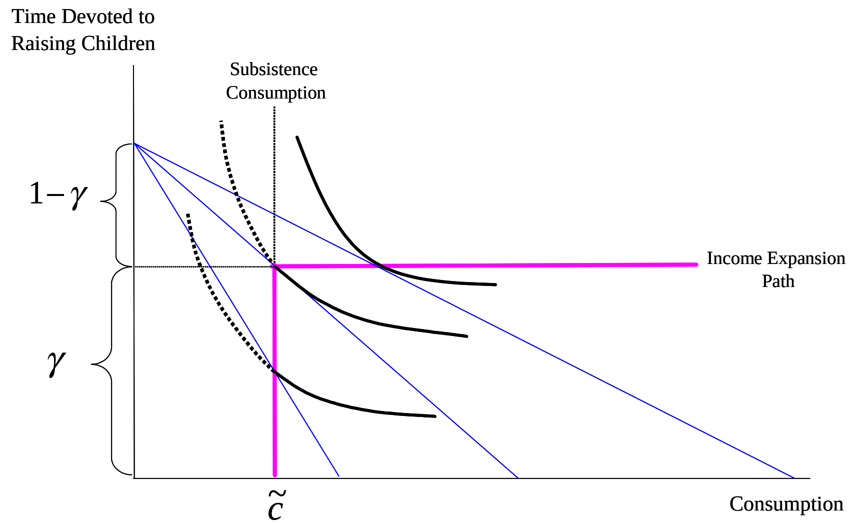


Figure 3. Preferences, Constraints, and Income Expansion Path.

Note: The figure depicts the household's indifference curves, budget constraints, as well as the subsistence consumption constraint, $c \geq \tilde{c}$. The income expansion path is vertical as long as the subsistence consumption constraint is binding and horizontal at a level $\gamma$ once the subsistence consumption constraint is not binding.

Furthermore, the optimization with respect to $e_{t+1}$ implies that the level of education chosen by members of generation $t$ for their children, $e_{t+1}$, is an increasing function of $g_{t+1}$. In particular, there exists a critical level $\hat{g}$ of the rate of technological progress such that

$$e_{t+1} = e(g_{t+1}) \quad \begin{cases} = 0 & \text{if} \quad g_{t+1} \leq \hat{g}, \\ > 0 & \text{if} \quad g_{t+1} > \hat{g}, \end{cases} \tag{9}$$

where $e'(g_{t+1}) > 0$ and $e''(g_{t+1}) < 0 \ \ \forall g_{t+1} > \hat{g} > 0$.[25]

Hence, the optimal level of investment in child quality and thus the optimal division of child-rearing time between quality and quantity is unaffected by the parental level of income, but only by the rate of technological progress via its effect on the demand for education.

Furthermore, substituting (9) into (8), it follows that $n_t$ is:

$$n_t = \begin{cases} \frac{\gamma}{\tau + e(g_{t+1})} \equiv n^b(g_{t+1}) & \text{if} \quad z_t \geq \tilde{z}, \\ \frac{1 - [\tilde{c}/z_t]}{\tau + e(g_{t+1})} \equiv n^a(g_{t+1}, z(e_t, g_t, x_t)) & \text{if} \quad z_t \leq \tilde{z}. \end{cases} \tag{10}$$

where $z_t \equiv w_t h_t = z(e_t, g_t, x_t)$ as follows from (3) and (6)

Hence, as follows from the properties of $e(g_{t+1}), n^b(g_{t+1})$, and $n^a(g_{t+1}, z_t)$:

*(a) An increase in the rate of technological progress reduces the number of children and increases their quality, i.e.,*

$$\partial n_t / \partial g_{t+1} \leq 0 \ \ \textit{and} \ \ \partial e_{t+1} / \partial g_{t+1} \geq 0.$$

[25] $e''(g_{t+1})$ depends upon the third derivatives of the production function of human capital. $e(g_{t+1})$ is assumed to be concave, which appears plausible.

*(b) If the subsistence consumption constraint is binding (i.e., if parental potential income is below $\tilde{z}$), an increase in parental potential income raises the number of children, but has no effect on their quality, i.e.,*

$$\partial n_t/\partial z_t > 0 \quad and \quad \partial e_{t+1}/\partial z_t = 0 \qquad if \quad z_t < \tilde{z}.$$

*(c) If the subsistence consumption constraint is not binding (i.e., if parental potential income is above $\tilde{z}$), an increase in parental potential income does not affect the number of children or their quality, i.e.,*

$$\partial n_t/\partial z_t = \partial e_{t+1}/\partial z_t = 0 \qquad if \quad z_t > \tilde{z}.$$

**Technological Progress.** Suppose that technological progress, $g_{t+1}$, that takes place between periods $t$ and $t+1$ depends upon the education per capita among the working generation in period $t$, $e_t$, and the population size in period $t$, $L_t$ : [26]

$$g_{t+1} \equiv \frac{A_{t+1} - A_t}{A_t} = g(e_t, L_t), \tag{11}$$

where for $e_t \geq 0$ and a sufficiently large population size, $L_t$, $g(0, L_t) > 0$, $g_i(e_t, L_t) > 0$, and $g_{ii}(e_t, L_t) < 0$, $i = e_t, L_t$.[27] Hence, for a sufficiently large population size, the rate of technological progress between time $t$ and $t+1$ is a positive, increasing, strictly concave function of the size and level of education of the working generation at time $t$. Furthermore, the rate of technological progress is positive even if labor quality is zero.

The state of technology at time $t+1$, $A_{t+1}$, is therefore

$$A_{t+1} = (1 + g_{t+1})A_t, \tag{12}$$

where the state of technology at time 0 is given at a level $A_0$.

**Population.** The size of population at time $t+1$, $L_{t+1}$, is

$$L_{t+1} = n_t L_t, \tag{13}$$

where $L_t$ is the size of population at time $t$ and $n_t$ is the number of children per person; $L_0$ is given. Hence, given (10), the evolution of population over time is

$$L_{t+1} = \begin{cases} n^b(g_{t+1})L_t & \text{if} \quad z_t \geq \tilde{z}, \\ \\ n^a(g_{t+1}, z(e_t, g_t, x_t))L_t & \text{if} \quad z_t \leq \tilde{z}. \end{cases} \tag{14}$$

[26] While the role of the scale effect in the Malthusian epoch is essential, none of the results depend on the presence or the absence of the scale effect in the modern era. The functional form of technological progress given in (11) can capture both the presence and the absence of the scale effect in the modern era. In particular, the scale effect can be removed, once investment in education is positive, assuming for instance that $\lim_{L\to\infty} g_L(e_t, L) = 0$ for $e_t > 0$.

[27] For a sufficiently small population the rate of technological progress is strictly positive only every several periods. Furthermore, the number of periods that pass between two episodes of technological improvement declines with the size of population. These assumptions assure that in early stages of development the economy is in a Malthusian steady-state with zero growth rate of output per capita, but ultimately the growth rate becomes positive and slow. If technological progress would occur in every time period at a pace that increases with the size of population, the growth rate of output per capita would be positive in every period, despite the adjustment in the size of population.

**Effective Resources.** The evolution of effective resources per worker, $x_t \equiv (A_t X)/L_t$, is determined by the evolution of population and technology. The level of effective resources per worker in period $t+1$ is

$$x_{t+1} \equiv \frac{(A_{t+1}X)}{L_{t+1}} = \frac{1+g_{t+1}}{n_t} x_t, \tag{15}$$

where $x_0 \equiv A_0 X/L_0$ is given. Furthermore, as follows from (10) and (11)

$$x_{t+1} = \begin{cases} \frac{[1+g(e_t,L_t)][\tau+e(g(e_t,L_t))]}{\gamma} x_t \equiv \phi^b(e_t,L_t)x_t & \text{if} \quad z_t \geq \tilde{z}, \\ \frac{[1+g(e_t,L_t)][\tau+e(g(e_t,L_t))]}{1-[\tilde{c}/z(e_t,g_t,x_t)]} x_t \equiv \phi^a(e_t,g_t,x_t,L_t)x_t & \text{if} \quad z_t \leq \tilde{z}. \end{cases} \tag{16}$$

## 2.5 The Dynamical System

The development of the economy is fully determined by a sequence $\{e_t, g_t, x_t, L_t\}_{t=0}^{\infty}$ that satisfies (9), (11), (14), and (16), in every period $t$ and describes the joint evolution of education, technological progress, effective resources per capita, and population over time.

The dynamical system is characterized by two regimes. In the first regime the subsistence consumption constraint is binding and the evolution of the economy is governed by a four dimensional non-linear first-order autonomous system

$$\begin{cases} x_{t+1} = \phi^a(e_t,g_t,x_t,L_t)x_t, \\ e_{t+1} = e(g(e_t,L_t)), \\ g_{t+1} = g(e_t,L_t), \\ L_{t+1} = n^a(g(e_t,L_t),\ z(e_{t,}g_t,x_t))L_t \end{cases} \quad \text{for } z_t \leq \tilde{z}, \tag{17}$$

where the initial conditions $e_0, g_0, x_0$ and $L_0$ are historically given.

In the second regime the subsistence consumption constraint is not binding and the evolution of the economy is governed by a three dimensional system

$$\begin{cases} x_{t+1} = \phi^b(e_t,x_t,L_t)x_t, \\ e_{t+1} = e(g(e_t,L_t)), \\ L_{t+1} = n^b(g(e_t,L_t))L_t \end{cases} \quad \text{for } z_t \geq \tilde{z}. \tag{18}$$

In both regimes, however, the analysis of the dynamical system is greatly simplified by the fact that the evolution of $e_t$ and $g_t$ is independent of whether the subsistence constraint is binding, and that, for a given population size $L$, the joint evolution of $e_t$ and $g_t$ is determined independently of $x_t$. The education level of workers in period $t+1$ depends only on the level of technological progress expected between period $t$ and period $t+1$, while technological progress between periods $t$ and $t+1$, for a given population size $L$, depends only on the level of education in period $t$. Thus, for a given population size $L$, the dynamics of technology and education can be analyzed independently of the evolution of resources per capita.

**A. The Dynamics of Technology and Education.** The evolution of technology and education, for a given population size $L$, is characterized by the sequence $\{g_t, e_t; L\}_{t=0}^{\infty}$ that satisfies in every period $t$

the equations:[28]

$$\begin{aligned} g_{t+1} &= g(e_t; L); \\ e_{t+1} &= e(g_{t+1}). \end{aligned} \tag{19}$$

In light of the properties of the functions $e(g_{t+1})$ and $g(e_t; L)$, this dynamical sub-system is characterized by three qualitatively different configurations, which are depicted in the top panels of Figures 4, 5 and 6. The inherent Malthusian interaction between the size of the population and the level of technology increases gradually the size of population and the rate of technological progress and generates an upward shift in the curve $g(e_t; L)$. Ultimately, the rate of technological progress exceeds the threshold level, $\hat{g}$, above which investment in the human capital is beneficial, the Malthusian steady-state vanishes and the economy is gravitated towards the modern growth regime.

In particular, for a range of small population size, depicted in the top panel of Figure 4, the dynamical system is characterized by a globally stable steady-state equilibrium, $(\bar{e}(L), \bar{g}(L)) = (0, g^l(L))$, where $g^l(L)$ increases with the size of the population while the level of education remains unchanged. For a range of moderate population size, as depicted in the top panel of Figure 5, the dynamical system is characterized by three steady-state equilibria, two locally stable steady-state equilibria: $(0, g^l(L))$ and $(e^h(L), g^h(L))$, and an interior unstable steady-state equilibrium $(e^u(L), g^u(L))$, where $(e^h(L), g^h(L))$ and $g^l(L)$ increase monotonically with the size of the population. Finally, for a range of large population size, as depicted in the top panel of Figure 6, the dynamical system is characterized by a globally stable steady-state equilibrium, $(e^h(L), g^h(L))$,where $e^h(L)$ and $g^h(L)$ increase monotonically with the size of the population.

**B. Global Dynamics.** This analysis of the evolution of the economy from the Malthusian Regime, through the Post-Malthusian Regime, to the demographic transition and Modern Growth is based on a sequence of phase diagrams that describe the evolution of the system, within each regime, for a given population size, and the transition between these regimes as population increases in the process of development. Each of the phase diagrams is a projection of the three dimensional system $\{e_t, g_t, x_t; L\}$ to the plane $(e_t, x_t; L)$.[29]

The phase diagrams, depicted in the bottom panels of Figures 4, 5 and 6, contain three elements: the Malthusian Frontier, which separates the regions in which the subsistence constraint is binding from those where it is not; the $XX$ locus, which denotes the set of all triplets $(e_t, g_t, x_t; L)$ for which effective resources per worker are constant; and the $EE$ locus, which denotes the set of all pairs $(e_t, g_t; L)$ for which the level of education per worker is constant.

**The Malthusian Frontier.**

As was established in (17) and (18) the economy exits from the subsistence consumption regime when potential income, $z_t$, exceeds the critical level $\tilde{z}$. This switch of regime changes the dimensionality of the dynamical system from three to two, for fixed $L$.

Let the *Malthusian Frontier* be the set of all triplets $(e_t, x_t, g_t; L)$ for which individuals' incomes equal $\tilde{z}$.[30] Using the definitions of $z_t$ and $\tilde{z}$, it follows from (3) and (6) that the Malthusian Frontier is

[28] Although this dynamical sub-system consists of two independent one dimensional, non-linear first-order difference equations, it is more revealing to analyze them jointly.

[29] See Galor (2007) for the analysis of discrete dynamical systems.

[30] Below the Malthusian Frontier, the effect of income on fertility will be positive, while above the frontier there will be no effect of income on fertility. Thus, the Malthusian Frontier separates the Malthusian and Post-Malthusian Regimes, on

$MM \equiv \{(e_t, x_t, g_t; L) : x_t^{1-\alpha} h(e_t, g_t)^\alpha = \tilde{c}/(1-\gamma)\}$.

Let the *Conditional Malthusian Frontier* be the set of all pairs $(e_t, x_t; L)$ for which, conditional on a given technological level $g_t$, individuals' incomes equal $\tilde{z}$. Following the definitions of $z_t$ and $\tilde{z}$, equations (3) and (6) imply that the Conditional Malthusian Frontier, $MM_{|g_t}$, is $MM_{|g_t} \equiv \{(e_t, x_t; L) : x_t^{1-\alpha} h(e_t, g_t)^\alpha = \tilde{c}/(1-\gamma) \mid g_t\}$, where $x_t$ *is* a decreasing strictly convex function of $e_t$ along the $MM_{|g_t}$ locus.

Hence, the Conditional Malthusian Frontier, as depicted in the bottom panels of Figures 4,5 and 6, is a strictly convex, downward sloping curve in the $(e_t, x_t)$ space. Furthermore, it intersects the $x_t$ axis and approaches asymptotically the $e_t$ axis as $x_t$ approaches infinity. The frontier shifts upward as $g_t$ increases in the process of development.

**The $XX$ Locus.**

Let $XX$ be the locus of all triplets $(e_t, g_t, x_t; L)$ such that the effective resources per worker, $x_t$, are in a steady-state: $XX \equiv \{(e_t, x_t, g_t; L) : \; x_{t+1} = x_t\}$.

If the subsistence consumption constraint is not binding (i.e., if $z_t \geq \tilde{z}$), it follows from (16) that there exists a unique value $0 < \hat{e}(L) < e^h(L)$, such that $x_t \in XX$ :[31]

$$x_{t+1} - x_t \begin{cases} > 0 & \text{if} \quad e_t > \hat{e}(L), \\ = 0 & \text{if} \quad e_t = \hat{e}(L), \\ < 0 & \text{if} \quad e_t < \hat{e}(L). \end{cases} \tag{20}$$

Hence, the $XX$ Locus, as depicted in Figures 4-6 is a vertical line above the Conditional Malthusian Frontier at a level $\hat{e}(L)$.

If the subsistence constraint is binding, the evolution of $x_t$ is based upon the rate of technological change, $g_t$, the effective resources per-worker, $x_t$, as well as the quality of the labor force, $e_t$. Let $XX_{|g_t}$ be the locus of all pairs $(e_t, x_t; L)$ such that $x_{t+1} = x_t$, for a given level of $g_t$. That is, $XX_{|g_t} \equiv \{(e_t, x_t; L) : \; x_{t+1} = x_t \mid g_t\}$ It follows from (16) that for $z_t \leq \tilde{z}$, and for $0 \leq e_t \leq \hat{e}(L)$, there exists a single-valued function $x_t = x(e_t)$ such that $(x(e_t), e_t) \in XX_{|g_t}$.

$$x_{t+1} - x_t \begin{cases} < 0 & \text{if} \quad (e_t, x_t) > (e_t, x(e_t)) \quad \text{for} \quad 0 \leq e_t \leq \hat{e}(L), \\ = 0 & \text{if} \quad x_t = x(e_t) \quad \text{for} \quad 0 \leq e_t \leq \hat{e}(L), \\ > 0 & \text{if} \quad [(e_t, x_t) < (e_t, x(e_t)) \quad \text{for} \quad 0 \leq e_t \leq \hat{e}(L)] \;\text{ or }\; [e_t > \hat{e}(L)]. \end{cases} \tag{21}$$

Hence, without loss of generality, the locus $XX_{|g_t}$ (i.e., the $XX$ locus below the Conditional Malthusian Frontier) is depicted in Figure 4, as an upward sloping curve in the space $(e_t, x_t)$, defined for $e_t \leq \hat{e}(L)$. $XX_{|g_t}$ is strictly below the Conditional Malthusian Frontier for values of $e_t < \hat{e}(L)$, and the two coincide at $\hat{e}(L)$. Moreover, the Conditional Malthusian Frontier, the $XX$ locus above the Conditional Malthusian Frontier, and the $XX_{|g_t}$ locus coincide at $(\hat{e}(L), \hat{x}(L))$.

**The $EE$ Locus.**

Let $EE$ be the locus of all triplets $(e_t, g_t, x_t; L)$ such that the quality of labor, $e_t$, is in a steady-state: $EE \equiv \{(e_t, x_t, g_t; L) : \; e_{t+1} = e_t\}$.

the one hand, from the Modern Growth regime, on the other. Crossing this frontier is associated with the demographic transition.

[31] In order to simplify the exposition without affecting the qualitative nature of the dynamical system, the parameters of the model are restricted so as to assure that the $XX$ locus is non-empty when $z_t \geq \tilde{z}$. That is, $\hat{g} < (\gamma/\tau) - 1 < g(e^h(L_0), L_0)$.

As follows from (9) and (11), $e_{t+1} = e(g(e_t, L))$ and thus, for a given population size, the steady-state values of $e_t$ are independent of the values of $x_t$ and $g_t$. The locus $EE$ evolves through three phases in the process of development, corresponding to the three phases that describe the evolution of education and technology, as depicted in the top panels of Figures 4-6.

In early stages of development, when population size is sufficiently small, the joint evolution of education and technology is characterized by a globally stable temporary steady-state equilibrium, $(\bar{e}(L), \bar{g}(L)) = (0, g^l(L))$, as depicted in the top panel of Figure 4. The corresponding $EE$ locus, depicted in the space $(e_t, x_t; L)$ in the bottom panel of Figure 4, is vertical at the level $e = 0$, for a range of small population sizes. Furthermore, for this range, the global dynamics of $e_t$ are given by:

$$e_{t+1} - e_t \begin{cases} = 0 & \text{if} \quad e_t = 0, \\ < 0 & \text{if} \quad e_t > 0. \end{cases} \tag{22}$$

In later stages of development, as population size increases sufficiently, the joint evolution of education and technology is characterized by multiple locally stable temporary steady-state equilibria, as depicted in the top panel of Figure 5. The corresponding $EE$ locus, depicted in the space $(e_t, x_t; L)$ in the bottom panel of Figure 5, consists of three vertical lines corresponding to the three steady-state equilibria for the value of $e_t$. That is, $e = 0$, $e = e^u(L)$, and $e = e^h(L)$. The vertical lines $e = e^u(L)$ and $e = e^h(L)$ shift leftward and rightward, respectively, as population size increases. Furthermore, the global dynamics of $e_t$ in this configuration are given by:

$$e_{t+1} - e_t \begin{cases} < 0 & \text{if} \quad 0 < e_t < e^u(L) \ \text{ or } \ e_t > e^h(L), \\ = 0 & \text{if} \quad e_t \in \{0,\ e^u(L),\ e^h(L)\}, \\ > 0 & \text{if} \quad e^u(L) < e_t < e^h(L). \end{cases} \tag{23}$$

In mature stages of development, when population size is sufficiently large, the joint evolution of education and technology is characterized by a globally stable steady-state equilibrium, $(\bar{e}(L), \bar{g}(L)) = (e^h(L), g^h(L))$, as depicted in the top panel of Figure 6. The corresponding $EE$ locus, as depicted in the bottom panel of Figure 6 in the space $(e_t, x_t; L)$, is vertical at the level $e = e^h(L)$. This vertical line shifts rightward as population size increases. Furthermore, the global dynamics of $e_t$ in this configuration are given by:

$$e_{t+1} - e_t \begin{cases} > 0 & \text{if} \quad 0 \leq e_t < e^h(L), \\ = 0 & \text{if} \quad e_t = e^h(L), \\ < 0 & \text{if} \quad e_t > e^h(L). \end{cases} \tag{24}$$

**Conditional Steady-State Equilibria.**

In early stages of development, when population size is sufficiently small, the dynamical system, as depicted in Figure 4 is characterized by a unique and globally stable conditional steady-state equilibrium.[32] It is given by the point of intersection between the $EE$ locus and the $XX$ locus. That is, conditional on a given technological level, $g_t$, the Malthusian steady-state equilibrium, $(0, \bar{x}(L))$, is

[32] Since the dynamical system is discrete, the trajectories implied by the phase diagrams do not necessarily approximate the actual dynamic path, unless the state variables evolve monotonically over time. As shown, the evolution of $e_t$ is monotonic, whereas the evolution and convergence of $x_t$ may be oscillatory. Non-monotonicity in the evolution of $x_t$ may arise only if $e < \hat{e}$ and it does not affect the qualitative description of the system. Furthermore, if $\phi_x^a(e_t, g_t, x_t)x_t > -1$ the conditional dynamical system is locally non-oscillatory. The phase diagrams in the bottom panels of Figures 4-6 are drawn under the assumptions that assure that there are no oscillations.

globally stable.[33] In later stages of development, as population size increases sufficiently, the dynamical system, as depicted in Figure 5, is characterized by two conditional steady-state equilibria. The Malthusian conditional steady-state equilibrium is locally stable, whereas the steady-state equilibrium $(e^u(L), x^u(L))$ is a saddle point.[34] For education levels above $e^u(L)$ the system, as depicted in Figure 6, converges to a stationary level of education $e^h(L)$ and possibly to a steady-state *growth rate* of $x_t$. In mature stages of development, when population size is sufficiently large, the system converges globally to an educational level $e^h(L)$ and possibly to a steady-state *growth rate* of $x_t$.

## 2.6 From Malthusian Stagnation to Sustained Growth

The economy evolves from an epoch of Malthusian stagnation through the Post-Malthusian Regime to the demographic transition and a Modern Growth Regime.[35] This pattern and the prime driving forces in this transition emerge from the phase diagrams depicted in Figures 4-6.

Consider an economy in early stages of development. Population size is relatively small and the implied slow rate of technological progress does not provide an incentive to invest in the education of children. As depicted in the top panel of Figure 4, the interaction between education, $e_t$, and the rate of technological change, $g_t$, for a constant small population, $L$, is characterized by a globally stable steady-state equilibrium $(0, g^l(L))$, where education is zero and the rate of technological progress is slow. This steady-state equilibrium corresponds to a globally stable conditional Malthusian steady-state equilibrium, depicted in the bottom panel of Figure 4. For a constant small population, $L$, and for a given rate of technological progress, effective resources per capita, as well as the level of education, are constant, and output per capita is therefore constant as well. Moreover, shocks to population or resources are resolved in a classic Malthusian fashion.

As population grows slowly in reaction to technological progress, the $g(e_t; L)$ locus, depicted in the top panel of Figure 4, gradually shifts upward and the steady-state equilibrium shifts vertically upward reflecting small increments in the rate of technological progress, while the level of education remains constant at a zero level. Similarly, the conditional Malthusian steady-state equilibrium drawn in the bottom panel of Figure 4 shifts vertically upward, as the $XX$ locus shifts upward. However, output per capita remains initially constant at the subsistence level and ultimately creeps forward at a miniscule rate.

[33] The eigenvalues of the Jacobian matrix of the conditional dynamical system evaluated at the conditional steady-state equilibrium, $(0, \overline{x}(g_t))$, are both smaller than one (in absolute value).

[34] Convergence to the saddle point takes place only if the level of education is $e^u$. That is, the saddle path is the entire vertical line that corresponds to $e_t = e^u$.

[35] The unified theory of Galor and Weil is calibrated by Lagerlof (2006). His analysis demonstrates that the theory *quantitatively* replicates the observed time paths of population, income per capita, and human capital, generating (a) a Malthusian epoch, (b) an endogenous take-off from Malthusian stagnation that is associated with an acceleration in technological progress and is accompanied initially by a rapid increase in population growth, and (c) a rise in the demand for human capital, followed by a demographic transition and sustained economic growth.

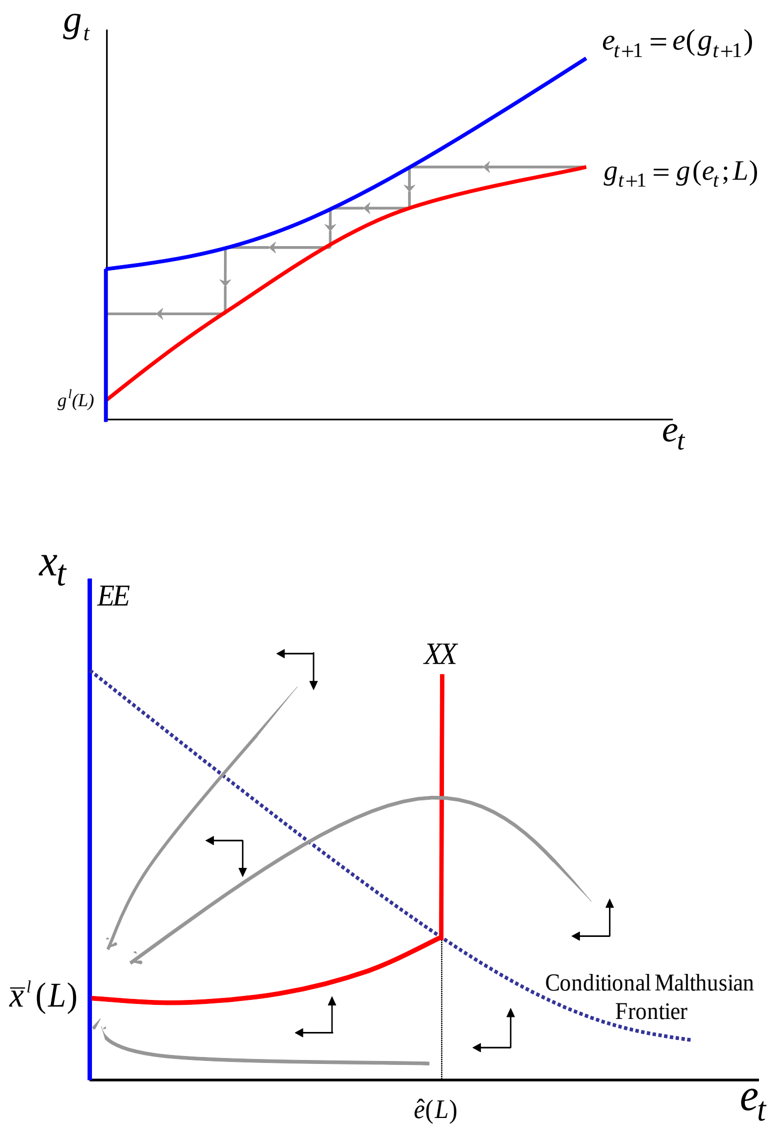


Figure 4. The Evolution of Technology, $g_t$, Education, $e_t$, and Effective Resources, $x_t$ :
Small Population.

Notes: The top panel describes the evolution of education $e_t$ and the rate of technological change $g_t$ for a constant small population $L$. The curve labeled $g_{t+1} = g(e_t; L)$ shows the effect of education on the growth rate of technology. The curve labeled $e_{t+1} = e(g_{t+1})$ shows the effect of expected technological change on optimal education choices. The point of intersection between the two curves is the globally stable steady-state equilibrium $(0, g^l(L))$. In early stages of development, the economy is in the vicinity of this steady-state equilibrium where education is zero and the rate of technological progress is slow.
The bottom panel describes the evolution of education $e_t$ and effective resources per worker $x_t$ for a constant small population, $L$. The $EE$ locus is the set of all pairs $(e_t, x_t; L)$, for which education is constant over time. The $XX$ locus is the set of all pairs $(e_t, x_t; L)$, given $g_t$, for which effective resources per worker are constant over time. The point of intersection between the two curves is a unique globally stable steady-state equilibrium. In early stages of development, the system is in the vicinity of this conditional Malthusian steady-state equilibrium. The Conditional Malthusian Frontier is the set of all pairs $(e_t, x_t; L)$, given $g_t$, below which the subsistence constraint is binding.

Over time, the slow growth in population that takes place in the Malthusian Regime raises the rate of technological progress and shifts the $g(e_t; L)$ locus in Figure 4 sufficiently upward, generating a qualitative change in the dynamical system, as depicted in Figure 5.

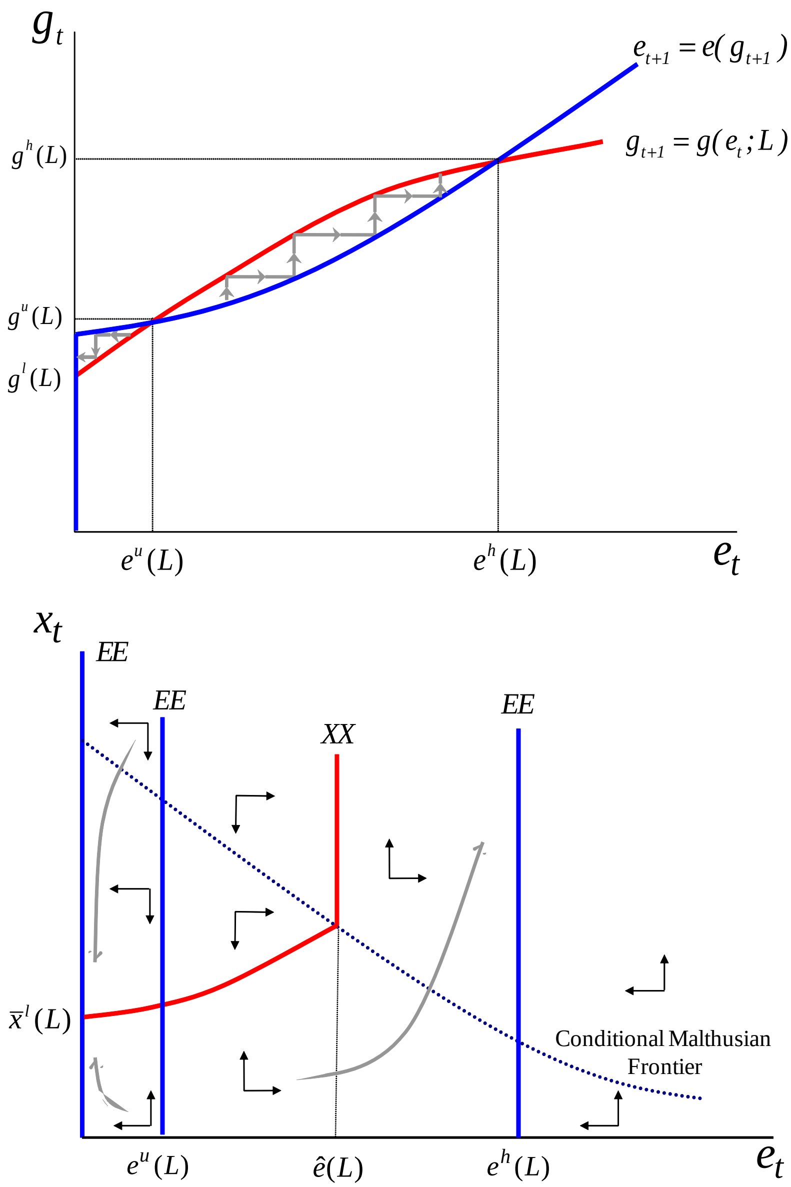


Figure 5. The Evolution of Technology, $g_t$, Education, $e_t$, and Effective Resources, $x_t$ : Moderate Population.

Notes: The top panel describes the evolution of education $e_t$ and the rate of technological change $g_t$, once the size of the population has grown to reach a moderate size, $L$. The system is characterized by multiple steady-state equilibria. The steady-state equilibria $(0, g^l(L))$ and $(e^h(L), g^h(L))$ are locally stable, whereas $(e^u(L), g^u(L))$ is unstable. Given the initial conditions, in the absence of large shocks the economy remains in the vicinity of the low steady-state equilibrium $(0, g^l(L))$, where education is still zero but the rate of technological progress is moderate.
The bottom panel describes the evolution of education $e_t$ and effective resourcess per worker $x_t$ for a constant small population, $L$.

The dynamical system of education and technology, for a moderate population, is characterized by multiple, history-dependent, stable steady-state equilibria: The steady-state equilibria $(0, g^l(L))$ and $(e^h(L), g^h(L))$ are locally stable, whereas $(e^u(L), g^u(L))$ is unstable. Given the initial conditions, in the absence of large shocks the economy remains in the vicinity of the low steady-state equilibrium $(0, g^l(L))$, where education is still zero but the rate of technological progress is moderate. These steady-state equilibria correspond to multiple locally stable conditional Malthusian steady-state equilibria, depicted in Figure 5: a Malthusian steady state, characterized by constant resources per capita, slow technological progress, and no education, and a modern growth steady state, characterized by a high level of education, rapid technological progress, growing income per capita, and moderate population growth. However, since the economy starts in the vicinity of the Malthusian steady state, it remains there.[36]

As the rate of technological progress continues to rise in reaction to the increasing population size, the $g(e_t; L)$ locus shifts upward further and ultimately, as depicted in Figure 6, the dynamical system experiences another qualitative change. The Malthusian steady-state equilibrium vanishes, and the conditional dynamical system is characterized by a unique globally stable modern steady-state equilibrium $(e^h(L), g^h(L))$ with high levels of education and technological progress. The increase in the pace of technological progress has two opposing effects on the evolution of population. On the one hand, it eases households' budget constraints, allowing the allocation of more resources for raising children. On the other hand, it induces a reallocation of these additional resources toward child quality. In the Post-Malthusian Regime, due to the limited demand for human capital, the first effect dominates and the rise in real income permits households to increase their family size as well the quality of each child.[37] The interaction between investment in human capital and technological progress generates a virtuous circle: human capital formation prompts faster technological progress, further raising the demand for human capital, inducing further investment in child quality, and ultimately, as the economy crosses the Malthusian frontier, triggering a demographic transition. The offsetting effect of population growth on the growth rate of income per capita is eliminated and the interaction between human capital

[36] Large shocks to education or technological progress would permit the economy to jump to the Modern Growth steady state, but this possibility appears inconsistent with the evidence.

[37] Literally, income per capita does not change during the Post-Malthusian Regime. It remains fixed at the subsistence level. This is an artifact of the assumption that the only input into child (quality and quantity) is parental time, and that this time input does not produce measured output. If child rearing, especially the production of quality, requires goods or if the time required to raise children can be purchased in the market (e.g., schooling), then the shift towards higher child quality that takes place during the post-Malthusian Regime would be reflected in higher market expenditures (as opposed to parental time expenditures) and rising measured income.

accumulation and technological progress permits a transition to a state of sustained economic growth.

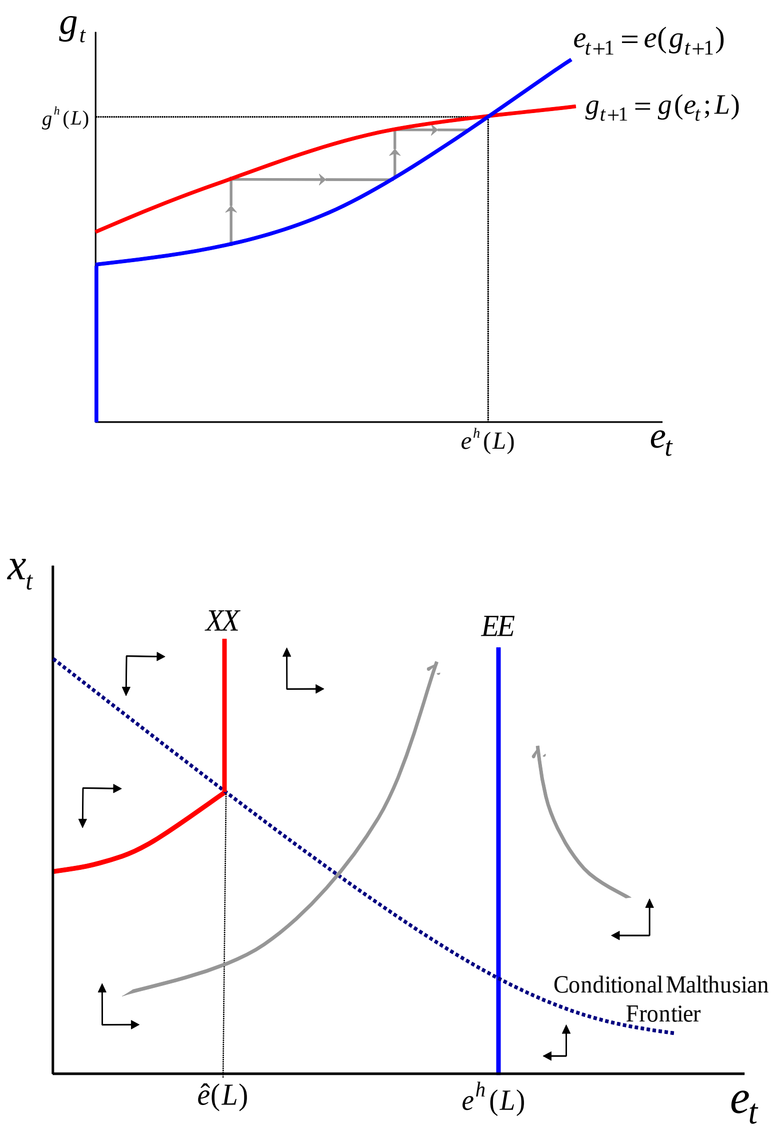


Figure 6. The Evolution of Technology, $g_t$, Education, $e_t$, and Effective Resources, $x_t$ : Large Population.

Notes: The top panel describes the evolution of education $e_t$ and the rate of technological change $g_t$ once the size of the population grows to a high level, $L$. The system is characterized by a unique globally stable steady-state equilibrium $(e^h(L), g^h(L))$. In mature stages of development, the economy converges monotonically to this steady state with high levels of education and technological progress.
The bottom panel describes the evolution of education $e_t$ and the rate of technological change $x_t$, once the size of the population has reached a high level, $L$. The dynamical system changes qualitatively and the conditional Malthusian steady state vanishes. The economy evolves through a Post-Malthusian Regime until it crosses the Conditional Malthusian Frontier, converging to the Modern Growth regime.

In the Modern Growth Regime, resources per capita rise, as technological progress outpaces population growth. Provided that population size converges to a constant level, the levels of education and technological progress and the growth rates of resources per capita and thus output per capita are constant in the modern growth steady-state equilibrium.

## 2.7 Complementary Mechanisms

The emergence of human capital formation and its impact on the demographic transition and the technological frontier is a central force in the transition from the Post-Malthusian Regime to the state of sustained economic growth in unified theories of economic growth in which population, technology and income per capita are endogenously determined.

Various complementary mechanisms that generate or reinforce the acceleration in technological progress, the rise in human capital formation, and the onset of the demographic transition have been proposed and examined quantitatively. They have demonstrated that Unified Growth Theory can be augmented and fortified by additional characteristics of the transition from stagnation to growth without altering the fundamental hypothesis regarding the central role played by technological acceleration, the emergence of human capital formation, and the demographic transition in this process.

**Sources of the Rise in the Demand for and the Formation of Human Capital.** The rise in the demand for human capital, and thus the formation of human capital, is attributed by Galor and Weil (2000) and Galor and Moav (2002) to the acceleration in technological progress, underlying the role of educated individuals in coping with a rapidly changing technological environment. However, the link between industrial development and the demand for human capital could have been generated by various complementary mechanisms without altering the fundamental insights. In particular, the rise in the demand for human capital could be reinforced by: (a) capital accumulation in a technological environment characterized by capital-skill complementarity (Goldin and Katz 1998, Fernandez-Villaverde 2001 and Galor and Moav 2004, 2006), (b) the rise in the *level* of a skilled-intensive industrial technology (Doepke 2004), or (c) increased specialization in the production of skilled-intensive goods due to international trade (Galor and Mountford 2008).

Moreover, while according to Unified Growth Theory human capital formation is induced directly by the rise in the demand for human capital, this mechanism could be reinforced by: (a) the rising incentives of capitalists to support the provision of public education for the masses (Galor and Moav 2006, Galor, Moav and Vollrath 2009) and to establish child labor laws (Hazan and Berdugo 2002 and Doepke and Zilibotti 2005), (b) an improvement in the health infrastructure and its effect on individuals' capacity to produce and benefit from human capital (Galor and Weil 1999, Boucekkine, de la Croix and Licandro 2003, Cervellati and Sunde 2005, Soares 2005, Tamura 2006, Hazan and Zoabi 2006, Lorentzen, McMillan and Wacziarg 2008), (c) the evolution of preferences for offspring quality (Galor and Moav 2002),[38] or (d) the reduction in the cost of education due to increased population density (Boucekkine, de la Croix and Peeters 2007).

**Triggers of the Demographic Transition.** The demographic transition is attributed by Galor and Weil (2000) and Galor and Moav (2002) to the rise in the demand for human capital and the inducement that it prodived to substitute quality for quantity of children. However, the link between industrial development, technological progress, human capital formation and the demographic transition could be generated by various complementary mechanisms without altering the fundamental insights. In

[38] For the effect of institutions on the evolution of preferences see Bowles (1998).

particular, the demographic transition could be generated by: (a) female-biased technical change that increases the opportunity cost of children rearing more than household's income (Galor and Weil 1996), (b) the decline in benefits from child labor (Hazan and Berdugo 2002, Doepke 2004, Doepke and Zilibotti 2005), (c) the decline in mortality rates and the improvement in health infrastructure (Galor and Weil 1999, Kalemli-Ozcan 2002, Lagerlof 2003, Tamura 2006, Hazan and Zoabi 2006, Birchenall 2007, Bar and Leukhina 2010), (d) globalization and its effect on the demand for human capital (McDermott 2002, and Galor and Mountford 2006, 2008), (e) the evolution of preferences for offspring quality (Galor and Moav 2002), and (e) the transition from agriculture to industry (Strulik and Weisdorf 2008).[39]

**Engines of technological progress.** The rise in the pace of technological progress in early stages of development is attributed to the inherent Malthusian interaction between population and technology, whereas its intensification in later stages of development is linked to the rise in human capital formation. Alternatively, the acceleration can be generated by a gradual movement from a slow growing agricultural technology to rapidly evolving industrial technology (Hansen and Prescott 2002), the evolution of markets (Desmet and Parente 2009), institutions conducive for R&D (Mokyr 2002, Acemoglu et al. 2005, and Aghion and Howitt 2009), globalization (O'Rourke and Williamson 2005, and Galor and Mountford 2006, 2008), or a selection of educated, entrepreneurial individuals in the process of development (Galor and Moav 2002, and Galor and Michalopolous 2006).

**The Transition from Agricultural to Industrial Economy.** The structure of the aggregate production function and its interaction with technological progress in the unified theories of Galor and Weil (2000) and Galor and Moav (2002) reflects implicitly a transition from an agricultural to an industrial economy that accompanied the transition from stagnation to growth. In early stages of development, the economy is agricultural (i.e., the fixed amount of land is a binding constraint on the expansion of the economy). Population growth reduces labor productivity since the rate of technological progress is not sufficiently high to compensate for the land constraint. However, as the rate of technological progress intensifies in the process of development, the economy becomes industrial. Technological progress counterbalances the land constraint, the role of land gradually diminishes, and "effective resources" are expanding at a rate that permits sustained economic growth.

An explicit modeling of the transition from agriculture to industry (e.g., Hansen and Prescott 2002, Hazan and Berdugo 2002, Doepke 2004, Galor and Mountford 2008, Galor, Moav and Vollrath 2009, and Mourmouras and Rangazas 2009) does not alter the fundamental insight from the framework of Galor and Weil. Namely, the acceleration in technological progress and its impact on the demand for human capital and thus on the decline of population growth is a critical force in the transition from stagnation to growth.[40] As discussed in the next section, a two-sector framework is instrumental in the exploration of the effect of international trade on the differential timing of the transition from

[39] The quantitative examination of Doepke (2004), Fernandez-Villaverde (2001), and Lagerlof (2006) confirms the significance of these channels in originating the demographic transition and the shift from stagnation to growth.

[40] Although the reduced form analysis of the transition from stagnation to growth in Hansen and Prescott (2002) appears not to rely on human capital formation, it is merely an artifact of the lack of micro-foundations for the critical factors behind the transition. Unlike Galor and Weil (2000) in which the time paths of technological progress, population growth, and human capital formation are endogenously determined on the basis of explicit micro-foundations, in Hansen and Prescott (2002) technological progress is exogenous and population growth is assumed to follow the hump-shaped pattern that is observed over human history. However, a constant rate of technological progress in the industrial sector (as is assumed by Hansen and Prescott) is unlikely to be sustainable without human capital formation, and their (assumed) decline in population growth (as income rises sufficiently) is plausibly linked to the rise in the demand for human capital.

stagnation to growth and the associated phenomenon of the great divergence (Galor and Mountford 2008). Moreover, it would be necessary in order to examine the incentives of land owners to block education reforms and the development of the industrial sector (Galor, Moav and Vollrath 2009).

## 2.8 Main Hypotheses

The theory generates several hypotheses about the evolution of population, human capital and income per capita in the process of development, underlining the role of the inherent interaction between population and technology in the Malthusian epoch, as well as the formation of human capital and the associated demographic transition, in the emergence of a state of sustained economic growth.

Unified growth theory proposes that in early stages of development economies were in the proximity of a stable Malthusian equilibrium. Technology advanced rather slowly and generated proportional increases in output and population. The inherent positive interaction between technology and the size and the composition of the population in this epoch gradually increased the pace of technological progress. However, due to the adjustment of population, output per capita advanced at a miniscule rate.[41] The slow pace of technological progress in the Malthusian epoch provided a limited scope for human capital in the production process and parents, therefore, had limited economic incentives to reallocate resources towards the formation of human capital of their offspring.

The epoch of positive Malthusian feedback between the level of technology and the size and the composition of the population accelerated the pace of technological progress and permitted ultimately a gradual take-off to the Post-Malthusian Regime. Although the expansion of resources was still partially counterbalanced by the enlargement of population, the delayed adjustment of population permitted the economy to experience rapid growth rates of income per capita as well as population. The acceleration in technological progress inevitably raised the demand for human capital in the production process, in order to cope with the rapidly changing economic environment. The rise in the demand for human capital in the second phase of industrialization induced the formation of human capital. It generated two opposing effects on population growth. On the one hand, it eased households' budget constraints, allowing the allocation of more resources for raising children. On the other hand, it induced a reallocation of resources toward child quality. In the Post-Malthusian Regime, due to the modest demand for human capital, the first effect dominated and the rise in real income permitted households to increase the number as well the quality of their children.

The interaction between investment in human capital and technological progress generated a virtuous circle: human capital generated faster technological progress, which in turn further raised the demand for human capital, inducing further investment in child quality, that ultimately triggered a decline in fertility rates and population growth.[42] The onset of the demographic transition reduced the dilution of the stock of capital and land, enhanced the investment in the human capital of the population, and altered the age distribution of the population, increasing temporarily the size of the

[41] See the evidence in Galor (2005) and Ashraf and Galor (2008).

[42] Quantitative analysis of unified growth theories by Doepke (2004), Fernandez-Villaverde (2001), Lagerlof (2006), indeed suggests that the rise in the demand for human capital was a significant force behind the demographic transition and the emergence of a state of sustained economic growth. Recent empirical evidence confirms the importance of the rise in the demand for human capital in the second phase of industrialization in the emergence of human capital formation (Galor 2005). Moreover, recent evidence suggests that human capital formation prior to the process of industrialization played an important role in technological progress and in the industiral take-off (Baten and Zanden 2008 and Boucekkine, de la Croix and Peeters 2007), in triggering the decline in fertility in general (Murtin 2009) and via a substitution of quality for quantity of children in particular (Becker, Cinnirella and Woessmann 2009).

labor force relative to the population as a whole. Thus, it enabled economies to convert a larger share of the fruits of factor accumulation and technological progress into growth of income per capita and paved the way for the emergence of sustained economic growth.[43]

# 3 UGT and Comparative Development

Existing theories of comparative development highlight a variety of proximate and ultimate factors underlying some of the vast inequities in living standards across the globe. The importance of geographical, cultural and institutional factors, human capital formation, ethnic, linguistic, and religious fractionalization, colonialism and globalization has been at the center of a debate regarding the origins of the differential timing of transitions from stagnation to growth and the remarkable transformation of the world income distribution in the last two centuries.[44] While theoretical and empirical research has typically focused on the contemporaneous effects of such factors or their influence in giving rise to and sustaining the disparity in income per capita across the globe, attention has recently been drawn towards pre-historical factors that have been argued to affect the course of comparative economic development from the dawn of human civilization to the modern era.

Unified Growth Theory sheds light on three aspects of comparative economic development. First, it generates direct hypotheses about the factors that govern the pace of the transition from Malthusian stagnation to a state of sustained economic growth and thus the emergence of significant differences in economic development across countries and regions. Second, it suggests that initial biogeographical conditions that were determined tens of thousands years ago, via their effect on the composition of the human population had a persistent effect on comparative economic development across the globe. Third, it advances the understanding of the origins of multiple growth regimes and convergence clubs that are often found in cross-country analysis of economic growth.

Unified Growth Theory suggests that the development process is fueled by the interaction between the rate of technological progress and the size and the level of human capital of the population. In particular, the rate of technological progress is governed by the size and the level of human capital of the population (i.e., $g_{t+1} = g(e_t; L)$), whereas the level of human capital formation is affected by the rate of technological progress (i.e., $e_{t+1} = e(g_{t+1})$).

For given initial conditions, $(e_0, g_0)$, this vital interaction between the rate of technological progress and the size and the level of human capital of the population is affected differentially by a large number of country-specific characteristics (e.g., biogeographical, cultural, and institutional factors, as well as public policy and trade). These characteristics affect the intensity of the positive

[43] Similarly, unified evolutionary growth theory suggests that the transition from stagnation to growth is an inevitable outcome of the effect of the process of development in the Malthusian epoch on the selection of traits that are complementary to the growth process, such as higher valuation for child quality (Galor and Moav 2002) and longer life expectancy (Galor and Moav 2008). Hence, the transition is brought about by a gradual change in the composition of the population and its effect on technological progress and human capital formation. It is interesting to note that the non-evolutionary perspective suggests that the adverse effect of limited resources on population growth in the Malthusian era delays the process of development, while the evolutionary theory suggests that the Malthusian constraint generates the necessary evolutionary pressure for the ultimate take-off.

[44] The influence of geographical factors has been stressed by Jones (1981), Diamond (1997) and Pomeranz (2000), Gallup et al. (1998), and Olsson and Hibbs (2005). Institutional factors have been advanced by North (1981), Engerman and Sokoloff (2000), Hall and Jones (1999), Acemoglu et al. (2005), Mokyr (2002), Rodrik et al. (2004), Levine (2005), and Greif (2006). The effect of ethno-linguistic fractionalization is advocated by Easterly and Levine (1997) and Alesina et al. (2003). The impact of sociocultural factors has been highlighted by Weber (1905) and Landes (1998), Barro and McCleary (2003), Guiso et al. (2006) and Tabellini (2008). Finally, the importance of human capital formation has been underlined in Unified Growth Theory and has been demonstrated empirically by Glaeser et al. (2004).

feedback between population and technology in the Malthusian epoch, the strength of the effect of human capital on technological progress in the post-Malthusian era, and the significance of the impact of the rise in the demand for human capital (in a rapidly changing technological environment) on the pace of human capital formation and fertility decline. These country-specific elements generate, therefore, variation in the pace of the transition from stagnation to growth across countries as well as differences in the steady-state levels of income per capita across the globe.

As the two theoretical black boxes of Unified Growth Theory (i.e., the effect of the size and the level of human capital of the population on the rate of technological progress ($g_{t+1} = g(e_t; L)$), and the effect of the rate of technological progress on human capital formation ($e_{t+1} = e(g_{t+1})$) are opened and filled with additional characteristics that affect the incentives for and the constraints on technological innovations and human capital formation, variation in these characteristics across countries would generate variations in economic development across the globe. Thus, Unified Growth Theory provides a fundamental framework that encompasses various forces that have generated variations in the performance across countries (e.g., the earlier European take-off and overtaking in the growth process) and sustained differences in income per-capita across the globe. In particular, contemporary differences in income per capita across the globe can be attributed to the effect of country-specific biogeographical, cultural, and institutional characteristics, as well as public policy and trade, on the pace of the transition from stagnation to growth, the distribution of economies along the development path from stagnation to growth, and variation in the steady-state levels of income per capita.

Suppose that, as postulated in the basic model, technological progress that takes place between periods $t$ and $t+1$ in country $i$, $g^i_{t+1}$, depends upon the level of education per capita among the working generation in period $t$, $e^i_t$, and the population size in period $t$, $L^i_t$, as well as on country-specific factors, $\Omega^i_t$, that affect technological progress such as the protection of intellectual property rights, the stock of knowledge and its rate of diffusion, religious composition, cultural and genetic diversity, and propensity to trade:

$$g^i_{t+1} = g(e^i_t, L^i_t, \Omega^i_t), \tag{25}$$

where for a sufficiently large population size $g(0, L^i_t, \Omega^i_t) > 0$, $g_j(e^i_t, L^i_t, \Omega^i_t) > 0$, and $g_{jj}(e^i_t, L^i_t, \Omega^i_t) < 0$, $j = e^i_t, L^i_t, \Omega^i_t$. Hence, for a sufficiently large population size, the rate of technological progress between time $t$ and $t+1$ is a positive (even in the absence of investment in human capital), increasing, strictly concave function of the size and level of education of the working generation at time $t$, as well as country-specific factors that are conducive for technological progress.

For given levels of population and human capital, $(e^i_t, L^i_t)$, the rate of technological progress is governed by a number of country-specific characteristics. (a) The level of protection of intellectual property rights may have an ambiguous effect on technological progress, reflecting the trade-off between the positive effect of intellectual property rights on the incentive to innovate and its adverse effect on the proliferation of existing knowledge across firms.[45] (b) The stock of knowledge within a society, and its rate of creation and diffusion may create a platform upon which faster technological innovations may emerge (Mokyr 2002). (c) The composition of religious groups within a society and their attitude towards knowledge creation and diffusion may affect the incentive of individuals to innovate and the rate of proliferation of innovations. (d) The composition of interest groups in society and their incentive

[45] The optimal level of protection of intellectual property rights may be altered in the process of development, and thus, countries in different stages of development may benefit from different policies.

to block or promote technological innovation.[46] (e) The level of diversity within a society, as reflected by the composition of human capital, may provide a wider spectrum of traits that are complementary to the implementation of advanced technological paradigms, but may reduce cooperation and thus the efficiency of the production process (Ashraf and Galor 2009). (f) The propensity of a country to trade, reflecting its geographical characteristics, as well as its trade policy, may foster technological diffusion across nations.

Suppose that, as underlined in the basic model, the level of human capital, $h^i_{t+1}$, of children of a member of generation $t$, is an increasing strictly concave function of their parental time investment in education, $e^i_{t+1}$, and a decreasing strictly convex function of the rate of technological progress, $g^i_{t+1}$. Suppose further that it is affected by country-specific characteristics, $\phi^i_t$, that may affect the cost of education, its availability for different segments of society, and the efficiency of human capital formation:

$$h^i_{t+1} = h(e^i_{t+1}, g^i_{t+1}, \phi^i_t), \tag{26}$$

where $\phi^i_t$ is a vector of country-specific characteristics that affect human capital formation such as the availability and accessibility of public education, credit markets imperfections, the stock of knowledge in society, religious composition, the degree of inequality in society, and the distribution of ownership over factors of production.

Suppose that, as postulated in the basic model, individuals' preferences in country $i$ are represented by a utility function, $u^i_t$, defined over consumption above a subsistence level $\tilde{c} > 0$, as well as over the quantity and quality of their (surviving) children. Suppose further that there are variations in the degree of preference for child quality across countries, as captured by the preference parameter, $\mu^i_t \in (0,1)$.

$$u^i_t = (c^i_t)^{1-\gamma}[(n^i_t)^{1-\mu^i_t}(h^i_{t+1})^{\mu^i_t}]^{\gamma}, \qquad \gamma \in (0,1), \tag{27}$$

where $c^i_t$ is the consumption of individual of generation $t$, $n^i_t$ is the number of (surviving) children of individual of generation $t$, and $h^i_{t+1}$ is the level of human capital of each child. As follows from (7), (9), (26) and (27), investment in education would depend upon the rate of technological progress, $g^i_{t+1}$, as well as on a number of country-specific characteristics captured by the vector $\Psi^i_t \equiv [\phi^i_t, \mu^i_t]$, i.e.,

$$e^i_{t+1} = e(g^i_{t+1}; \Psi^i_t) \begin{cases} = 0 & \text{if} \quad g^i_{t+1} \leq \hat{g}(\Psi^i_t), \\ > 0 & \text{if} \quad g^i_{t+1} > \hat{g}(\Psi^i_t), \end{cases} \tag{28}$$

where $e_g(g^i_{t+1}; \Psi^i_t) > 0$ and $e_{gg}(g^i_{t+1}; \Psi^i_t) < 0 \;\; \forall g^i_{t+1} > \hat{g}(\Psi^i_t)$.

Hence, human capital formation would depend upon a number of country-specific factors. (a) The ability of individuals to finance the cost of education and the forgone earnings associated with schooling influence their capability to implement the desirable level of investment in education. (b) The availability, accessibility, and quality of public education determine the extent of human capital formation. (c) The degree of credit markets imperfection and inequality in society affect the extent of under-investment in education, in the absence of subsidized public education and in the presence of sizable opportunity cost of education.[47] (c) The stock of knowledge in society contributes to the

[46] Interest groups (e.g., landed aristocracy and monopolies) may block the introduction of new technologies in order to protect their political power and thus maintain their rent extraction (Olson 1982, Krusell and Rios-Rull 1996, Parente and Prescott 2000, and Acemoglu et al. 2005).

[47] See Galor and Zeira (1993).

productivity of acquisition of human capital. (d) The propensity of a country to trade and its inherent comparative advantage (reflecting its geographical characteristics, as well as its trade policy) affect the skill-intensity in production and thus human capital formation. (e) The degree of investment in human capital, particularly in societies in which the market reward for human capital is limited in the short-run, would be influenced by individual's preferences with respect to educated offspring which may reflect: (i) cultural attributes, (ii) the composition of religious groups within a society and their attitude towards education, and (iii) the social status associated with education.

The evolution of technology and education in country $i$, for a given population size, $L^i$, and country specific characteristics, $\Omega^i$ and $\Psi^i$, is characterized by the sequence $\{g_t^i, e_t^i; L^i, \Omega^i, \Psi^i\}_{t=0}^{\infty}$ that satisfies in every period $t$ the equations:

$$\begin{aligned} g_{t+1}^i &= g(e_t^i; L^i, \Omega^i); \\ e_{t+1}^i &= e(g_{t+1}^i; \Psi^i). \end{aligned} \tag{29}$$

In light of the properties of the functions $e(g_{t+1}^i; \Psi^i)$ and $g(e_t^i; L^i, \Omega^i)$, this dynamical system is characterized by two qualitatively different configurations, as depicted in Figure 7. For a range of small population size, depicted in the upper panel of Figure 7, the dynamical system is characterized by a globally stable (conditional) steady-state equilibrium, $(\bar{e}(L^i, \Omega^i, \Psi^i), \bar{g}(L^i, \Omega^i, \Psi^i)) = (0, g^l(L^i, \Omega^i))$, where $g^l(L^i, \Omega^i)$ increases with the size of the population and with country-specific characteristics that are conducive for technological progress, while the level of education remains unchanged.

The inherent Malthusian interaction between the size of the population and the level of technology increases gradually the size of population and the rate of technological progress and generates an upward shift in the curve $g(e_t^i; L^i, \Omega^i)$. Ultimately, the rise in the rate of technological progress (and thus in the demand for human capital) increases sufficiently and $g(e_t^i; L^i, \Omega^i)$ crosses the threshold level, $\hat{g}(\Psi_t^i)$, above which parental investment in the human capital of their offspring is beneficial. The Malthusian steady-state equilibrium vanishes and the economy takes off to a state of sustained economic growth, as depicted in the bottom panel of Figure 8. The economy converges to a globally stable (conditional) steady-state equilibrium, $(e^h(L^i, \Omega^i, \Psi^i), g^h(L^i, \Omega^i, \Psi^i))$, where $e^h(L^i, \Omega^i, \Psi^i)$ and $g^h(L^i, \Omega^i, \Psi^i)$ increase monotonically with the size of the population and with country-specific characteristics that are conducive for technological progress and human capital formation.

Thus, variations in country-specific characteristics and their effect of the interaction between the rate of technological progress and human capital formation generate a differential pace of transition from stagnation to growth across countries and determine the timing of the take-off (i.e., the time period in which the rate of technological progress in country $i$, $g^l(L^i, \Omega^i)$ exceeds the threshold level of technological progress, $\hat{g}(\Psi^i)$, above which investment in human capital is profitable) and the variation in (conditional) long-run steady-state equilibrium (i.e., $(e^h(L^i, \Omega^i, \Psi^i), g^h(L^i, \Omega^i, \Psi^i))$).

The examination of the effect of country-specific characteristics on comparative economic development within the context of Unified Growth Theory is advanced in the next sections, using several specific mechanisms that link comparative economic development to country-specific factors that affected variation in the pace of the transition from stagnation to growth and the long-run steady-state equilibria across the globe.

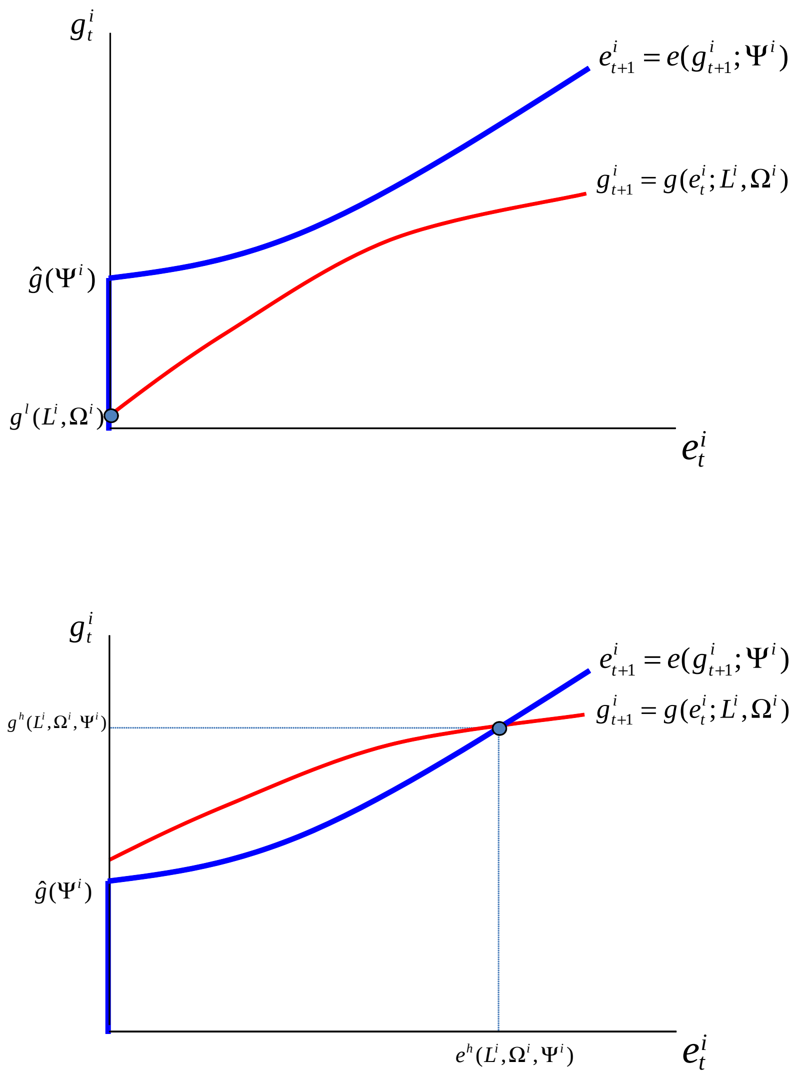


Figure 7. The Evolution of Technology, $g_t^i$, and Education, $e_t^i$, in the Development Process of Country $i$.

Notes: Top panel: In early stages of development, population size is relatively low and the economy is in a stable (conditional) Malthusian steady-state equilibrium characterized by low level of technological progress, $g^l(L^i, \Omega^i)$, and no investment in education.

Bottom panel: As population and the rate of technological progress increase in the course of the positive Malthusian feedback between population and technology, the curve $g_{t+1}^i = g(e_t^i; L^i, \Omega^i)$ shifts gradually upward and ultimately its vertical intercept crosses the threshold level of technological progress, $\hat{g}(\Psi^i)$, above which investment in human capital is profitable. The Malthusian steady-state equilibrium vanishes and the economy takes off to a (conditional) sustained-growth steady-state equilibrium, $(e^h(L^i, \Omega^i, \Psi^i), g^h(L^i, \Omega^i, \Psi^i))$.

## 3.1 Variations in Technological Progress

Unified Growth Theory establishes theoretically and quantitatively that the intensification of technological progress in the process of development and its effect on human capital formation and the onset of the demographic transition have been the prime forces in the transition from stagnation to growth and thus in the divergence in income per capita across regions of the world in the past two centuries. Thus, country-specific characteristics that have affected the rate of technological progress, such as the level of protection of intellectual property rights, the stock of knowledge, the composition of religious and interest groups, the level of diversity, and the propensity to trade, contributed to the differential pace of the transition from stagnation to growth and comparative economic development across the globe.

Consider two economies, $A$ and $B$, that are identical in all respects, except for country-specific characteristics that contribute to technological progress. In particular, suppose that the countries are identical in the characteristics that are conducive for human capital formation (i.e., $\Psi^A = \Psi^B \equiv \Psi$) and thus, as follows from (28), for any given level of technological progress, $g_{t+1}$, human capital formation is equal in the two economies. Namely, as depicted in Figure 8,

$$e^A_{t+1} = e^B_{t+1} = e(g_{t+1}; \Psi), \tag{30}$$

and the threshold level of the rate of technological progress above which parental investment in human capital is beneficial, $\hat{g}(\Psi)$, is equal in the two countries.

Suppose further that country-specific characteristics that are conducive for technological progress, $\Omega^i$, $i = A, B$, are more prevalent in country $B$. Hence, as depicted in Figure 8, for any given level of population, $L$, and human capital, $e_t$, the rate of technological progress is higher in country $B$, i.e.,

$$g^B_{t+1} = g(e_t; L, \Omega^B) > g^A_{t+1} = g(e_t; L, \Omega^A). \tag{31}$$

In the Malthusian regime, as depicted in the upper panel of Figure 8, while income per capita in the two economies may be equal, for a given level of population, the rate of technological progress is higher in country $B$. The steady-state equilibrium level of education and technology in county $B$ is $(0, g^l(L, \Omega^B)$, whereas the level in country $A$ is $(0, g^l(L, \Omega^A)$. The inherent Malthusian interaction between the size of the population and the level of technology in each of the countries increases gradually the size of population and the rate of technological progress and generates an upward shift in the curves $g(e^A_t; L, \Omega^A)$ and $g(e^B_t; L, \Omega^B)$. Ultimately, the rate of technological progress in country $B$ increases sufficiently, and as depicted in the bottom panel of Figure 8, it crosses the threshold level of the rate of technological progress, $\hat{g}(\Psi)$, above which parental investment in human capital is beneficial. The (conditional) Malthusian steady-state equilibrium vanishes in country $B$, and the economy takes off to a (conditional) sustained-growth steady-state equilibrium $(e^h(L, \Omega^B, \Psi), g^h(L, \Omega^B, \Psi))$. Country $A$, in contrast, experiences a later take-off. Moreover, if the country-specific characteristics of the two economies do not converge in the long-run, country $B$ will be have a superior steady-state equilibrium.

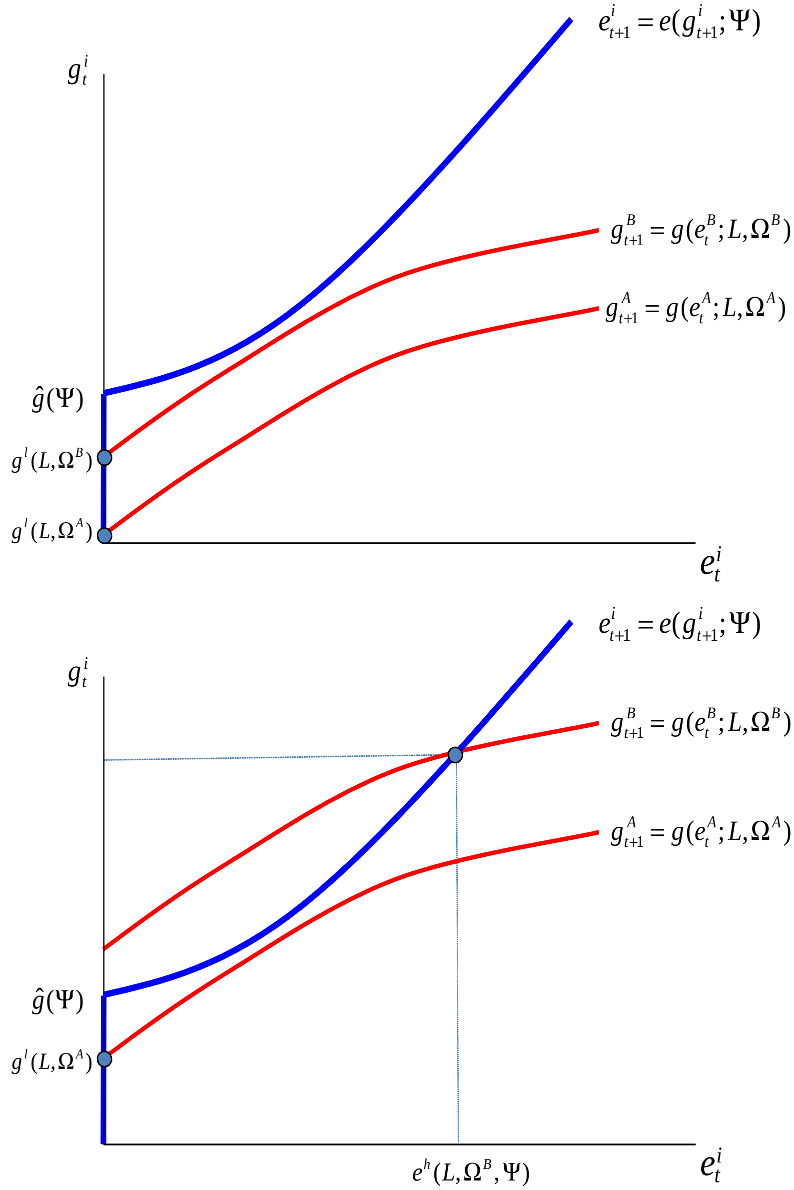


Figure 8. Variations in Country-Specific Characteristics that Contribute to Technological Progress and Comparative Development.

Notes: Top Panel: In early stages of development, prior to the emergence of demand for human capital, the two economies are in a (conditional) Malthusian steady-state equilibrium. Country $B$'s characteristics, $\Omega^B$, are more conducive for technological progress than those in country $A$, $\Omega^A$, and, for a given population size, its rate of technological progress, $g^l(L, \Omega^B)$, is higher than that in country A, $g^l(L, \Omega^A)$.

Bottom Panel: As population and the rate of technological progress increase in the course of the positive Malthusian feedback between population and technology, the curves $g^B_{t+1} = g(e^B_t; L, \Omega^B)$ and $g^A_{t+1} = g(e^A_t; L, \Omega^A)$ shift gradually upward and ultimately the vertical intercept of $g^B_{t+1} = g(e^B_t; L, \Omega^B)$ crosses the threshold level of technological progress, $\hat{g}(\Psi)$, above which investment in human capital is profitable, while the vertical intercept of the curve $g^A_{t+1} = g(e^A_t; L, \Omega^A)$ remains below this threshold. The Malthusian steady-state equilibrium vanishes in country B and the economy converges to a sustained-growth steady-state equilibrium, $(e^h(L, \Omega^B, \Psi), g^h(L, \Omega^B, \Psi))$, whereas country $A$ still remains in the (conditional) Malthusian steady-state equilibrium, $(0, g^l(L, \Omega^A))$.

### 3.2 Variations in Human Capital Formation

Unified Growth Theory establishes theoretically and quantitatively that the increase in the pace of technological progress and its effect on human capital formation and the onset of the demographic transition have been the focal forces in the transition from stagnation to growth and thus in the divergence in income per capita across regions of the world in the past two centuries. Once the technologically-driven demand for human capital emerged, the prevalence of characteristics conducive for human capital formation influenced the swiftness of the process of human capital accumulation, the timing of the demographic transition, the pace of the transition from stagnation to growth, and thereby the observed distribution of income in the world economy.[48] Thus, country-specific characteristics that affect human capital formation, such as the availability and accessibility of public education, credit market imperfections, the stock of knowledge in society, religious composition, the degree of inequality in society, the distribution of ownership over factors of production, and the economy's comparative advantage, contributed to the differential pace of the transition from agriculture to industry and comparative economic development across the globe.

Consider two economies, $A$ and $B$, that are identical in all respects, except for specific characteristics that contribute to human capital formation. In particular, suppose that the two economies are identical in their country-specific characteristics that are conducive for technological progress (i.e., $\Omega^A = \Omega^B \equiv \Omega$) and thus, as follows from (25), for any given level of population, $L$, and human capital, $e_t$, the rates of technological progress in countries $A$ and $B$, as depicted in Figure 9, are equal as well. Namely, for every $(e_t; L)$,

$$g^A_{t+1} = g^B_{t+1} \equiv g(e_t; L, \Omega). \tag{32}$$

Suppose further that country-specific characteristics that are conducive for human capital formation, $\Psi^i$, $i = A, B$, are more prevalent in country $B$, and thus, as follows from (28), and depicted in Figure 9, for any given level of technological progress, $g_{t+1}$, human capital formation is at least as high in country $B$ as it is in country $A$. Namely,

$$e^A_{t+1} = e(g_{t+1}; \Psi^A) \leq e^B_{t+1} = e(g_{t+1}; \Psi^B), \tag{33}$$

and the threshold level of the rate of technological progress above which parental investment in human capital is beneficial is lower in country $B$, i.e.,

$$\hat{g}(\Psi^B) < \hat{g}(\Psi^A). \tag{34}$$

In particular,

$$e^A_{t+1} = e(g_{t+1}; \Psi^A) \begin{cases} = e^B_{t+1} = 0 & \text{if} \quad g_{t+1} \leq \hat{g}(\Psi^B), \\ < e^B_{t+1} = e(g_{t+1}; \Psi^B) & \text{if} \quad g_{t+1} > \hat{g}(\Psi^B). \end{cases} \tag{35}$$

As depicted in the upper panel of Figure 9, prior to the emergence of demand for human capital the two economies are in the same (conditional) steady-state equilibrium, $(0, g^l(L, \Omega))$, but country

[48] Consistent with empirical evidence, the increased demand for human capital has not resulted necessarily in an increase in the equilibrium rate of return to human capital due to a massive supply response generated by (a) the increase in the incentive for investment in education, and (b) institutional changes (e.g., the provision of public education) that lowered the cost of investment in human capital.

$B$ faces a lower threshold for a take-off $\hat{g}(\Psi^B) < \hat{g}(\Psi^A)$. The positive Malthusian interaction between the size of the population and the level of technology in each of the countries increases gradually the size of population and the rate of technological progress and generates an upward shift in the curve $g^i_{t+1} = g(e^i_t; L, \Omega)$. In particular, as depicted in the bottom panel of Figure 9, once the rate of technological progress increases sufficiently and crosses the threshold level of the rate of technological progress, $\hat{g}(\Psi^B)$, above which parental investment in human capital is profitable in country $B$, while it remains below the corresponding threshold for country $A$, $\hat{g}(\Psi^A)$, the Malthusian steady-state equilibrium vanishes in country $B$, and the economy takes off to a (conditional) sustained-growth steady-state equilibrium, $(e^h(L^B, \Omega, \Psi^B), g^h(L^B, \Omega, \Psi^B))$. In contrast, in country $A$ the rise in the demand for human capital is still insufficient to generate a take-off and the economy remains temporarily in a (conditional) Malthusian steady-state equilibrium, $(0, g^l(L, \Omega))$. Moreover, if the country-specific characteristics of the two economies do not converge in the long-run, country $B$ will be have a superior steady-state equilibrium.

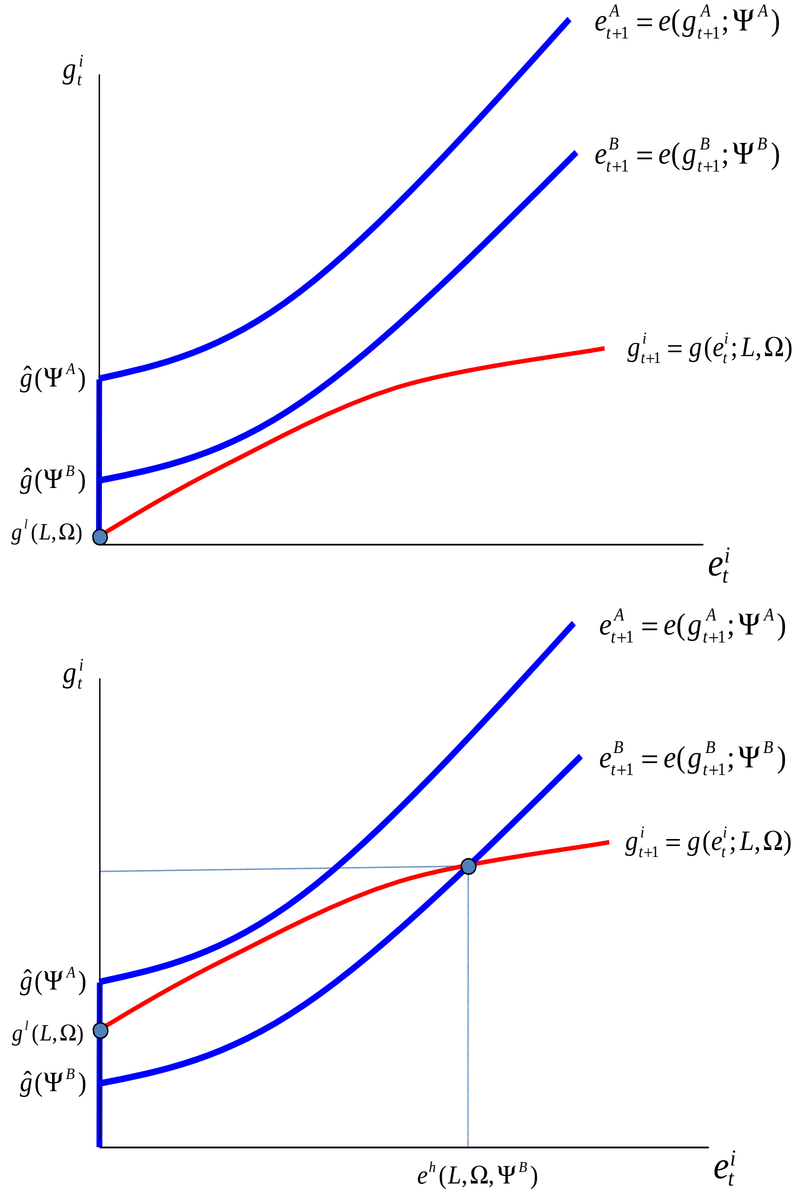


Figure 9. Variations in Country-Specific Characteristics that Contribute to Human Capital Formation and Comparative Development.

Notes: Top Panel: Prior to the emergence of demand for human capital the two economies are in the same (conditional) steady-state equilibrium, $(0, g^l(L, \Omega))$, but since country $B$'s characteristics, $\Psi^B$, are more conducive for human capital formation than those in country $A$, $\Psi^A$, country $B$ faces a lower threshold for a take-off (i.e., $\hat{g}(\Psi^B) < \hat{g}(\Psi^A)$).

Bottom Panel: As population and the rate of technological progress increase in the course of the positive Malthusian feedback between population and technology, the curve $g^i_{t+1} = g(e^i_t; L, \Omega)$, $i = A, B$, shifts gradually upward and ultimately its vertical intercept crosses the threshold level of technological progress, $\hat{g}(\Psi^B)$, above which investment in human capital in country $B$ is profitable, while it remains below the corresponding threshold for country $A$, $\hat{g}(\Psi^A)$. The Malthusian steady-state equilibrium vanishes in country B and the economy takes off to a (conditional) sustained-growth steady-state equilibrium, $(e^h(L, \Omega, \Psi^B), g^h(L, \Omega, \Psi^B))$, while country A remains temporarily in a (conditional) Malthusian steady-state equilibrium, $(0, g^l(L, \Omega))$.

**The Emergence of Human Capital Promoting Institutions.** While the process of industrialization raised the importance of human capital in the production process, reflecting its complementarity with technology in a rapidly changing technological environment, human capital accumulation has not benefited all sectors of the economy. Inequality in the ownership of factors of production has generated an incentive for better endowed agents to block the implementation of institutional changes and policies that promote human capital formation, resulting in a suboptimal level of investment in human capital from a growth perspective.

As argued by Galor, Moav and Vollrath (2009), the transition from an agricultural to an industrial economy changed the nature of the main economic conflict in society. Unlike the agrarian economy, which was characterized by a conflict of interests between the landed aristocracy and the masses, the process of industrialization has brought about an additional conflict between the entrenched landed elite and the emerging capitalist elite. In light of a lower degree of complementarity between human capital and land, education has increased the productivity of labor in industrial production more than in agricultural production, inducing rural-urban migration and thus a decline in the rental rate. Thus, while industrialists have had a direct economic incentive to support education policies that would foster human capital formation (Galor and Moav 2006), landowners, whose interests lay in the reduction of the mobility of the rural labor force, have favored policies that deprived the masses from education, as long as their stake in the productivity of the industrial sector was insufficient.[49]

The adverse effect of the implementation of public education on landowners' income from agricultural production is magnified by the concentration of land ownership, and thus, as long as landowners affected the political process and thereby the implementation of growth-enhancing education policies, inequality in the distribution of land ownership has been a hurdle for human capital accumulation, slowing the process of industrialization and the transition to modern growth. Economies in which land has been more equally distributed have implemented earlier public education campaigns and have benefited from the emergence of a skilled-intensive industrial sector and a rapid process of development. In contrast, among economies marked by a more unequal distribution of land ownership, land abundance that was a source of richness in early stages of development has led in later stages to under-investment in human capital, an unskilled-intensive industrial sector, and a slower growth process. Thus, variations in the distribution of land ownership across countries, which could potentially be mapped into differences in geographical conditions across the globe, have contributed to disparity in the industrial composition of the economy, and thereby to divergent development patterns across the globe.[50]

This hypothesis is consistent with evidence by Galor, Moav and Vollrath (2009) that suggests that indeed the distribution of land ownership has affected the nature of the transition from an agrarian to an industrial economy and has been significant in the emergence of sustained differences in human capital

[49] Landowners may benefit from the economic development of other segments of the economy due to capital ownership, labor supply to the industrial sector, the provision of public goods, and demand spillovers from economic development of the urban sector.

[50] Sokoloff and Engerman (2002) and Acemoglu et al. (2005) underline the role of the conflict between the elite and the masses in the delay in the implementation of growth enhancing educational policies. In contrast to this conflict-based political mechanism, Galor and Moav (2006) and Galor, Moav and Vollrath (2009) emphasize a direct economic mechanism (i.e., the adverse effect of education reforms on the land rental rate) that governs the relationship between inequality and the process of development. Unlike the analysis Engerman and Sokolof and Acemoglu et al. that implies the perpetual desirability of extractive institutions for the ruling elite, Galor, Moav and Vollrath demonstrate that, even if the political structure in the economy remains unchanged, economic development and a gradual diversification of the assets held by the landed aristocracy will ultimately trigger the implementation of growth-promoting education policies, once the stake of the landed aristocracy in the efficient operation of the industrial sector dominates their overall economic interest.

formation and growth patterns across countries. Moreover, the adverse effect of the concentration of land ownership on education expenditure is confirmed empirically by Galor, Moav and Vollrath based on variation in the concentration of land ownership and public expenditure on education across states in the USA during the period 1990-1940.

This theory can be integrated into the framework of Unified Growth Theory. Consider two economies, $A$ and $B$, that are identical in all respects, except for concentration in landownership. Suppose further that the concentration in land ownership is larger in country $A$, and thus, the concentration of land ownership in country $B$ is more conducive for human capital formation. As depicted in Figure 9, for any given level of technological progress, $g_{t+1}$, human capital formation is at least as high in country $B$ (i.e., $e^A_{t+1} = e(g_{t+1}; \Psi^A) \leq e^B_{t+1} = e(g_{t+1}; \Psi^B)$) as it is in country $A$, and the threshold level of the rate of technological progress above which parental investment in human capital is beneficial is lower in country $B$ (i.e., $\hat{g}(\Psi^B) < \hat{g}(\Psi^A)$). The process of development and the inherent Malthusian interaction between the size of the population and the level of technology in particular increase gradually the rate of technological progress and generate an upward shift in the curve $g(e^i_t; L, \Omega)$. In particular, since $\hat{g}(\Psi^B) < \hat{g}(\Psi^B)$, country $B$ experiences an earlier process of human capital formation and a faster transition to a state of sustained economic growth. However, if the effect of the concentration of land ownership on human capital formation dissipates, as the share of the agricultural sector declines, the two economies would converge to the same long-run steady-state equilibrium.

**Globalization and Divergence.** The dramatic transformation in the distribution of income and population across the globe in the past two centuries is one of the most significant mysteries in the growth process. Some regions have excelled in the growth of income per capita while other regions have been dominant in population growth.[51] This striking contrast between the development paths of large subsets of the world economy gives rise to fundamental questions about the determinants of economic growth in an interdependent world. Notably, has the pace of transition to sustained economic growth in advanced economies adversely affected the process of development in less developed economies? and have the forces of international trade contributed to the divergence in the timing of the demographic transition and the emergence of sustained economic growth across countries?

Galor and Mountford (2006, 2008) suggest that international trade has played a significant role in the differential timing of demographic transitions across countries and has been a major determinant of the distribution of world population and the divergence in income per capita across countries in the last two centuries.[52] The research suggests that international trade has an asymmetrical effect on the evolution of industrial and non-industrial economies. While in the industrial nations the gains from trade have been directed primarily towards investment in education and growth in output per capita, a greater portion of the gains from trade in non-industrial nations has been channeled towards population growth. In contrast to the existing literature on the dynamics of comparative advantage,[53] the theory suggests that even if trade equalizes the growth of total output in the trading countries (due to the terms of trade effect), income *per capita* of developed and less developed economies will diverge, since

[51] In the time period 1820-1998, the ratio between income per capita in Western Europe and Asia grew nearly three fold, whereas the ratio between the Asian population and the Western European population grew nearly two fold (Maddison 2001).

[52] See also Krugman and Venables (1995), Baldwin et al. (2001), and O'Rourke and Williamson (2005).

[53] See Findlay and Kierzkowsky (1983), Grossman and Helpman (1991), Stokey (1991), Young (1991), Matsuyama (1992), among others.

in developed economies the growth of total output will be generated primarily by an increase in output per capita, whereas in less developed economies the contribution of population growth to the growth of total output will be more significant.

The expansion of international trade enhanced the specialization of industrial economies in the production of industrial, skilled intensive, goods. The associated rise in the demand for skilled labor has induced a gradual investment in the quality of the population, expediting a demographic transition, stimulating technological progress and further enhancing the comparative advantage of these industrial economies in the production of skilled intensive goods. In non-industrial economies, in contrast, international trade has generated an incentive to specialize in the production of unskilled intensive, non-industrial, goods. The absence of significant demand for human capital has provided limited incentives to invest in the quality of the population and a larger share of their gains from trade has been utilized for a further increase in the size of the population, rather than the income of the existing population.[54] The demographic transition in these non-industrial economies has been significantly delayed, increasing further their relative abundance of unskilled labor, enhancing their comparative disadvantage in the production of skilled intensive goods, and delaying their process of development.

Empirical evidence provided by Galor and Mountford (2008) suggests that indeed international trade has reinforced the initial patterns of comparative advantage, has generated a persistent effect on the distribution of population in the world economy and has contributed to the divergence in income per capita across countries and regions.[55] In particular, cross-country regression analysis supports the hypothesis that international trade generates opposing effects on fertility rates and education in developed and less developed economies. International trade has a positive effect on fertility and a negative effect on human capital formation in non-OECD economies, whereas in OECD economies trade triggers a decline in fertility and an increase in human capital accumulation.

The theory can be incorporated into the basic framework of Unified Growth Theory. Consider two economies, India (country $A$) and Britain (country $B$), in the midst of their process of industrialization. Suppose that the countries are identical in the characteristics that are conducive for human capital formation (i.e., $\Psi^A = \Psi^B \equiv \Psi$) and thus for any given level of technological progress, $g_{t+1}$, human capital formation is equal in the two countries. Hence, as depicted in the top panel of Figure 10, for a given rate of technological progress, $g_{t+1}$, $e^A_{t+1} = e^B_{t+1} = e(g_{t+1};\Psi)$, and the threshold level of the rate of technological progress above which parental investment in human capital is beneficial, $\hat{g}(\Psi)$, is also equal in the two countries. Suppose further that the two economies are identical in all other respects, except for country-specific factors, $\Omega^i$, $i = A, B$, that contribute to a faster technological progress in Britain. Hence, for any given level of human capital, $e_t$, and population size, $L$, the rate of technological progress in country $B$ is larger than that in country $A$ (i.e., $g^B_{t+1} = g(e_t; L, \Omega^B) > g^A_{t+1} = g(e_t; L, \Omega^A)$). Moreover, as depicted in Figure 10, the rate of technological progress in the two economies is assumed

[54] Evidence suggests that the returns to human capital may have been higher in LDCs. One can therefore mistakenly suppose that incentive to invest in child quality is higher in LDCs. However, these higher rates of return are not applicable to most individuals. They reflect a suboptimal investment in human capital in an environment characterized by credit market imperfections and limited access to schooling. International trade, therefore, reduces further the modest demand for human capital and reduces further the incentive to substitute child quality for quantity.

[55] The adverse effect of international trade on industrialization and thus on the timing of the demographic transition could have been mitigated by the positive effect of trade on technological diffusion across countries. Nevertheless, since the rate of technological diffusion depends upon the appropriateness of factor endowments in the receiving country, the adverse effect of trade on the factor endowment of less developed economies would slow down the rate of technological diffusion.

to be above the threshold that justifies investment in human capital, but a decline in fertility has not yet occurred in the two economies.[56]

Suppose that international trade is established between India and Britain. Trade induces the technologically advanced economy, Britain, to specialize in the production of industrial skilled intensive goods, increasing the demand and thus the return to human capital, whereas India specializes in the production of unskilled intensive, primary goods, decreasing the return to investment in human capital. International trade generates, therefore, an asymmetric effect on demand for human capital in the two countries as captured by the parameters $\Psi^i, i = A, B$. For any given level of technological progress, $g_{t+1}$, and human capital, $e_t$, investment in child quality increases (relative to autarky) in Britain (i.e., $e^B_{t+1} = e(g_{t+1}; \Psi^B) > e(g_{t+1}; \Psi))$ and decreases in India (i.e., $e^A_{t+1} = e(g_{t+1}; \Psi^A) < e(g_{t+1}; \Psi))$. As depicted in the bottom panel of Figure 10, the curve $e^A_{t+1} = e(g_{t+1}; \Psi^A)$ represents therefore an leftward shift relative to the autarkic position, $e(g_{t+1}; \Psi)$, whereas the curve $e^B_{t+1} = e(g_{t+1}; \Psi^B))$ represents a rightward shift relative to the autarkic position, $e(g_{t+1}; \Psi)$. Thus, international trade intensifies human capital formation in Britain, leading to an earlier demographic transition and an earlier transition to a state of sustained economic growth. In contrast, international trade decelerates human capital formation in India, delaying its demographic transition and its transition to a state of sustained economic growth. Furthermore, if the asymmetric effects of international trade on human capital formation in the two economies persist, India will experience an inferior long-run equilibrium relative to Britain.

[56] As elaborated in section 2, initially the income effect with respect to fertility dominates and population size as well as quality jointly increase.

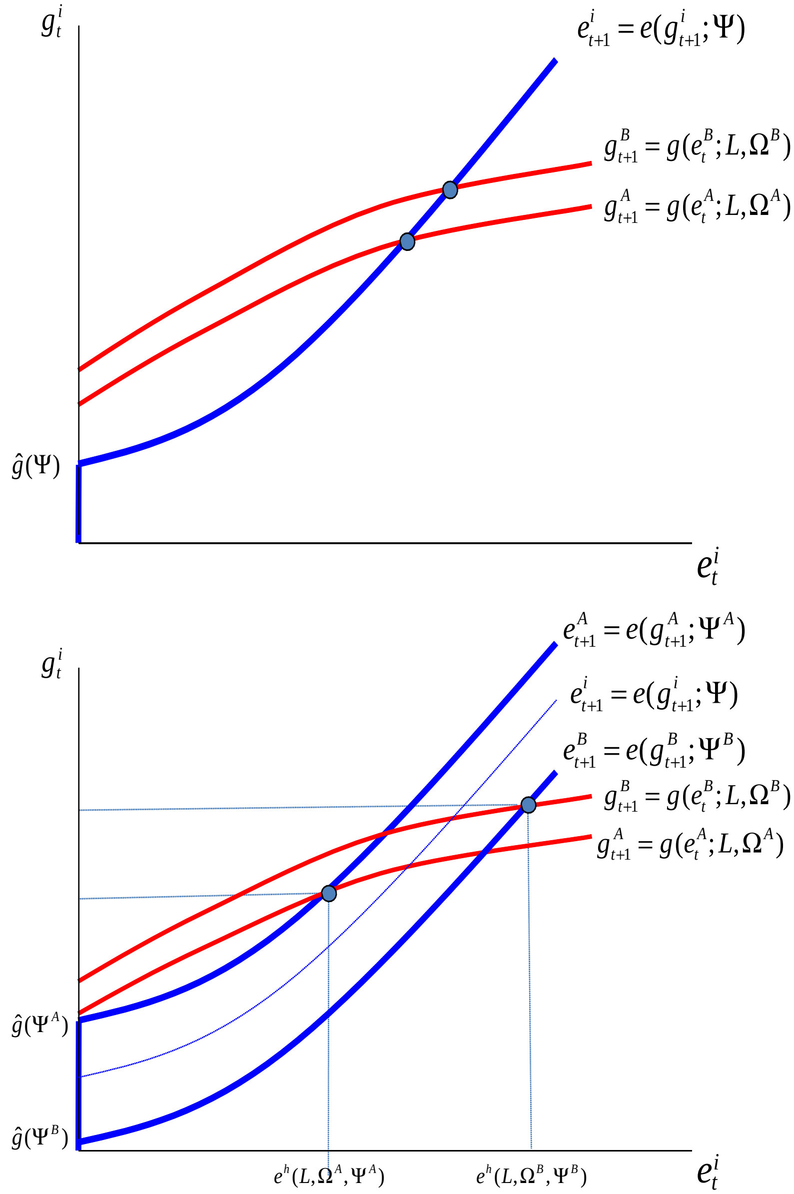


Figure 10. Asymmetric Effects of International Trade on Human Capital Formation and the Growth Process.

Notes: Top Panel: Prior to the emergence of international trade, the rate of technological progress in the two economies is above the threshold that justifies investment in human capital, but a decline in fertility has not yet occurred in either of the two. Country $B$'s characteristics, $\Omega^B$, are more conducive for technological progress than those in country $A$, $\Omega^A$, and thus, for any given level of population size, $L$, and human capital, $e_t$, the rate of technological progress in country $B$, $g_{t+1}^B = g(e_t; L, \Omega^B)$, is higher than that in country $A$, $g_{t+1}^A = g(e_t; L, \Omega^A)$. However, the countries are identical in the characteristics that are conducive for human capital formation (i.e., $\Psi^A = \Psi^B \equiv \Psi$) and for any given level of technological progress, $g_{t+1}$, human capital formation, $e_{t+1}^i = e(g_{t+1}; \Psi)$, is equal in the two countries.

Bottom Panel: International trade generates asymmetric effects, $\Psi^i, i = A, B$, on demand for human capital and hence on the incentive to invest in human capital in the two countries. It induces the technologically advanced economy, $B$, to specialize in the production of industrial skilled intensive goods, increasing its demand for human capital, while inducing country $A$ to specialize in the production of unskilled intensive goods, decreasing its demand for human capital. For any given level of technological progress, $g_{t+1}$, and investment in child quality, $e_t$, the curve $e^A_{t+1} = e(g_{t+1}; \Psi^A)$ represents therefore an leftward shift with respect to $e^i_{t+1} = e(g_{t+1}; \Psi)$, whereas the curve $e^B_{t+1} = e(g_{t+1}; \Psi^B)$ represents a rightward shift with respect to $e^i_{t+1} = e(g_{t+1}; \Psi)$. International trade intensifies human capital formation in country $B$, leading to an earlier demographic transition and an earlier transition to a state of sustained economic growth. In contrast, international trade decelerates human capital formation in country $A$ delaying its demographic transition and its transition to a state of sustained economic growth. If the asymmetric effects of international trade on human capital formation in the two economies persist, country $A$ will experience an inferior (conditional) long-run equilibrium relative to Britain (i.e., $(e^h(L, \Omega^A, \Psi^A), g^h(L, \Omega^A, \Psi^A)) < (e^h(L, \Omega^B, \Psi^B), g^h(L, \Omega^B, \Psi^B)))$, even if the variation in the factors that contribute to technological progress dissipates.

## 3.3 Persistence of Deeply Rooted Biogeographical Factors

The development of Unified Growth Theory was fueled by the conviction that the understanding of the contemporary growth process would be fragile and incomplete unless growth theory would reflect the principal driving forces over the entire growth process and thus would capture the central role of deeply rooted, historical, and pre-historical factors in contemporary comparative development.

**The Out of Africa Hypothesis and Comparative Development.** Recent advances in the spirit of Unified Growth Theory suggest that variation in deeply rooted biogeographical factors is critical for the understanding of the course of comparative economic development from the dawn of human civilization to the modern era. Ashraf and Galor (2009) demonstrate that biogeographical factors, determined tens of thousands of years ago, have generated a significant effect on the course of economic development across countries and regions of the world. In particular, they advance and empirically test the hypothesis that migratory distance from the geographical origin of Homo sapiens in East Africa has generated a persistent effect on the global patterns of economic development.

The theory suggests that in the course of the exodus of humans out of Africa variation in migratory distance generated heterogeneity in the degree of genetic diversity across societies, which had a long-lasting effect on the pattern of comparative development. The hypothesis rests on the interplay between two conflicting effects of diversity on the development process. On the one hand, diversity may disrupt the socioeconomic order. It increases the likelihood of miscoordination and distrust between economic agents, and reduces the cooperation among them. Thus diversity operates towards a reduction in total factor productivity, inhibiting the ability of society to operate efficiently with respect to its production possibility frontier. On the other hand, a wider spectrum of traits is more likely to contain the ones that are more complementary to the development and successful implementation of advanced technological paradigms. Greater heterogeneity therefore fosters the ability of a society to incorporate more sophisticated and efficient modes of production, expanding the society's production possibility frontier and conferring the social benefit of increased total factor productivity.

Thus, if the beneficial productivity effects of diversity dominate at lower levels of diversity and the detrimental effects dominate at higher levels (i.e., if the marginal benefits of diversity as well as homogeneity are diminishing), there exists an inverted U relationship between diversity and development outcomes. Furthermore, the optimal level of diversity increases in the process of industrialization, as the beneficial forces associated with greater diversity intensify in an environment characterized by a more rapid technological progress.[57]

Ashraf and Galor (2009) find that indeed genetic diversity has a non-monotonic effect on development outcomes, reflecting the economic trade-off associated with diversity within a society. While the intermediate level of genetic diversity prevalent among the Asian and European populations has been conducive for development, the high degree of diversity among African populations and the low degree of diversity among native American populations have been a detrimental force in the development of these regions.

The theory can be embedded in the framework of Unified Growth Theory. Consider two economies, $A$ and $B$, that are identical in all respects, except for the diversity of the human capital of their populations. In particular, suppose that the countries are identical in the characteristics that are conducive for human capital formation (i.e., $\Psi^A = \Psi^B \equiv \Psi$), and, as established in (28), and depicted in Figure 11, for any given level of the rate of technological progress, $g_{t+1}$, human capital formation is equal in the two countries (i.e., $e^A_{t+1} = e^B_{t+1} = e(g_{t+1}; \Psi)$). Moreover, the threshold level of the rate of technological progress above which parental investment in human capital is beneficial, $\hat{g}(\Psi)$, is also equal in the two countries.

Suppose that, in light of the trade-off associated with diversity, there exists an optimal level of diversity, $\Omega^*_t = \Omega(g_t)$, in each period $t$. Furthermore, since the benefits associated with diversity increase in an environment characterized by a more rapid technological progress, the optimal level of diversity is an increasing function of the rate of technological progress, i.e., $\Omega'(g_t) > 0$. Suppose further that, as long as the rate of technological progress in country $B$ is below a critical level, $\tilde{g}$ (where $\tilde{g} < \hat{g}(\Psi)$), the level of diversity in country $B$, $\Omega^B$, exceeds the optimal level (i.e., $\Omega^B > \Omega(g_t)$ for all $g_t < \tilde{g}$), and the lower level of diversity present in country $A$, $\Omega^A$, is more conducive for technological progress. However, once the rate of technological progress in country $B$ exceeds the critical level, $\tilde{g}$, the level of diversity in country $B$ is more conducive for technological progress than that in country $A$.

Hence, as depicted in Figure 11, for any given level of population, $L$, and human capital, $e_t$,

$$g^B_{t+1} = g(e_t; L, \Omega^B) \begin{cases} < g^A_{t+1} = g(e_t; L, \Omega^A) & \text{if} \quad g^l(L, \Omega^B) < \tilde{g}, \\ > g^A_{t+1} = g(e_t; L, \Omega^A) & \text{if} \quad g^l(L, \Omega^B) > \tilde{g}. \end{cases} \tag{36}$$

In the Malthusian regime, as depicted in the upper panel of Figure 11, while incomes per capita in the two economies may be equal, the rate of technological progress is higher in country $A$. In particular, for a given level of population, the steady-state equilibrium levels of education and technology in county $B$ are $(0, g^l(L, \Omega^B))$, while the levels in country $A$ are $(0, g^l(L, \Omega^A))$, where $g^l(L, \Omega^A) > g^l(L, \Omega^B)$.

The inherent Malthusian interaction between the size of the population and the level of technology in each of the countries increases gradually the size of population and the rate of technological progress and generates and upward shift in the curves $g(e_t; L, \Omega^B)$ and $g(e_t; L, \Omega^A)$. Inevitably, the rate of technological progress in country $B$ increases sufficiently and crosses threshold level of the rate of technological progress, $\tilde{g}$, above which the level of diversity in country $B$ is more conducive for technological progress than the level of diversity in country $A$. Technological progress accelerates in country $B$, due to the scale effect, as well as the diversity effect, and, for a given population size, the rate of technological progress in country $B$ is higher than that of country $A$. Ultimately each of the two economies, in its own pace, crosses the critical level of technological progress, $\hat{g}(\Psi)$, above which parental investment in human

[57] As established by Ashraf and Galor (2007) cultural rather than genetic diversity may generate a similar pattern.

capital is beneficial. The Malthusian steady-state equilibrium vanishes in the two economies and they take off to a state of sustained economic growth. During this development process, country $B$, because of its more efficient level of diversity, overtakes country $A$ and converges to a superior (conditional) steady-state equilibrium $(e^h(L, \Omega^B, \Psi), g^h(L, \Omega^B, \Psi)) > (e^h(L, \Omega^A, \Psi), g^h(L, \Omega^A, \Psi))$.

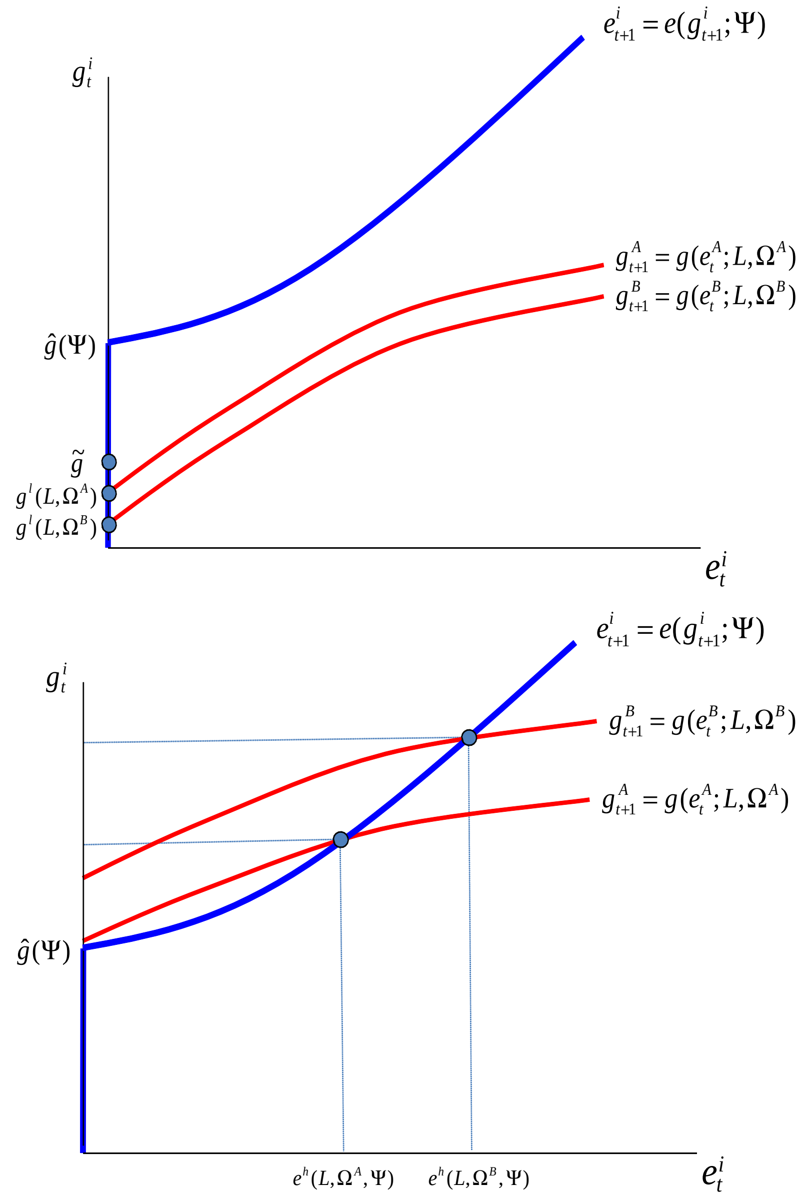


Figure 11. Diversity and Comparative Development.

Notes: Top Panel: In early stages of development, prior to the emergence of demand for human capital, the two economies are in a (conditional) Malthusian steady-state equilibrium. Country $B$'s level of diversity, $\Omega^B$, is less conducive for technological progress than that in country $A$, $\Omega^A$, and for a given population size, $L$, its rate of technological progress, $g^l(L, \Omega^B)$, is lower than that in country $A$, $g^l(L, \Omega^A)$.

Bottom Panel: As population and the rate of technological progress increase in the course of the positive Malthusian feedback between population and technology, the curves $g^B_{t+1} = g(e^B_t; L, \Omega^B)$ and $g^A_{t+1} = g(e^A_t; L, \Omega^A)$ gradually shift upward and ultimately the vertical intercept of $g^B_{t+1} = g(e^B_t; L, \Omega^B)$ crosses the threshold level of technological progress, $\tilde{g}$, above which the level of diversity in country $B$ is more conducive for technological progress than that in country $A$. Technological progress accelerates in country $B$, shifting further upward the curve $g^B_{t+1} = g(e^B_t; L, \Omega^B)$. Ultimately the vertical intercept of $g^B_{t+1} = g(e^B_t; L, \Omega^B)$ crosses the threshold level above which investment in human capital is profitable. The Malthusian steady-state equilibrium vanishes in country $B$, as well as in country $A$, and the economies take off to a state of sustained economic growth. During this development process country $B$ overtakes country $A$ and converges to a superior (conditional) steady-state equilibrium, $(e^h(L, \Omega^B, \Psi), g^h(L, \Omega^B, \Psi)) > (e^h(L, \Omega^A, \Psi), g^h(L, \Omega^A, \Psi))$.

**The Neolithic Revolution and Comparative Development.** The influential thesis of Diamond (1997) suggests that contemporary differences in economic development could be traced to biogeographical factors that led to regional variation in the timing of the Neolithic Revolution. He argues that the Neolithic Revolution conferred a developmental head-start to societies that experienced an earlier transition from primitive hunting and gathering techniques to the more technologically advanced agricultural mode of production. Favorable biogeographic endowments that contributed to the emergence of agriculture gave some societies the early advantage of operating a superior production technology and generating resource surpluses and permitted the establishment of a non-food-producing class whose members were crucial for the development of written language and science, and for the formation of cities, technology-based military powers, and nation states. The early dominance of these societies subsequently persisted throughout history, being further sustained by geopolitical and historical processes such as colonization.

Recent empirical evidence suggests that the Neolithic Revolution has a significant effect on economic development in the pre-industrial world (Ashraf and Galor 2008), and through its impact on technological, institutional, and cultural factors, on contemporary economic development (Olsson and Hibbs 2005, Putterman (2008) and Ashraf and Galor 2009). Moreover, Galor and Moav (2008) find that socioeconomic changes that were associated with the Neolithic Revolution – the transition from hunter-gatherer tribes to sedentary agricultural communities – triggered an evolutionary process that had a significant impact on contemporary mortality from infectious diseases and human longevity. Exploiting an exogenous source of variation in the time elapsed since the ancestors of the population of each country today experienced the Neolithic Revolution, every 1000 years of earlier Neolithic transition are estimated to contribute about two years to contemporary life expectancy, accounting for geographical characteristics, as well as for income, education and health expenditure per capita. Hence, once the demand for human capital emerged in the process of industrialization, variation in the timing of the Neolithic Revolution across regions of the world could have contributed to existing variation in human capital formation and economic development across the globe.

This theory can be integrated into the framework of Unified Growth Theory. Consider two economies, $A$ and $B$, that are identical in all respects, except for the time period in which the ancestors of their current population experienced the Neolithic Revolution, $\Psi^i$, $i = A, B$. Suppose that the Neolithic Revolution occurred earlier in country $B$, and thus, as follows from (28), and depicted in Figure 9, for any given level of technological progress, $g_{t+1}$, human capital formation is at least as high in country $B$ as it is in country $A$ (i.e., $e^A_{t+1} = e(g_{t+1}; \Psi^A) \leq e^B_{t+1} = e(g_{t+1}; \Psi^B)$), and the threshold level of the rate of technological progress above which parental investment in human capital is beneficial is lower in country $B$ (i.e., $\hat{g}(\Psi^B) < \hat{g}(\Psi^A)$). Suppose further that an earlier onset of the Neolithic Revolution is conducive for technological progress and thus $\Omega^B > \Omega^A$. Hence, as follows from (25) and depicted in Figure 8, for any given level of population, $L$, and human capital, $e_t$, the rate of technological progress is higher in country $B$ (i.e., $g^B_{t+1} = g(e_t; L, \Omega^B) > g^A_{t+1} = g(e_t; L, \Omega^A)$).

In the Malthusian regime, while income per capita in the two economies may be equal, the rate of technological progress is higher in country $B$. As depicted in Figure 8, for a given level of population, the (conditional) steady-state equilibrium level of education and technology in country $B$ is $(0, g^l(L, \Omega^B))$, whereas the level in country $A$ is $(0, g^l(L, \Omega^A)$. The inherent Malthusian interaction between the size of the population and the level of technology in each of the countries, increases gradually the size of population and the rate of technological progress and generates an upward shift in the curves $g(e_t; L, \Omega^B)$ and $g(e_t; L, \Omega^A)$. Inevitably, the rate of technological progress in country $B$ increases sufficiently and it crosses threshold level of the rate of technological progress, $\hat{g}(\Psi^B)$, above which parental investment in human capital is beneficial. The Malthusian steady-state equilibrium vanishes in country $B$ and the economy takes off to a state of sustained economic growth. In contrast, in country $A$ the pace of technological progress is slower and it is still insufficient to exceed that higher threshold, $\hat{g}(\Psi^A)$, that would generate a take-off. Moreover, as long as the effect of the Neolithic Revolution on technological progress and human capital formation persists, country $B$ will have a superior long-run equilibrium.

## 3.4 Multiple Growth Regimes and Convergence Clubs

The quest for an empirical determination of the forces that have contributed to the existence of multiple growth regimes and the emergence of convergence clubs, although central for the understating of the process of development, has not been universally shared by researchers in the field of economic growth.[58] Contributors to the empirical literature on multiple growth regimes have faced an increasing challenge of motivating their findings in the context of growth models that are widely perceived as plausible. The dominating tendency to rationalize and interpret these empirical explorations in the context of growth models characterized by multiple long-run equilibria, and thus, convergence clubs, based on initial conditions has been confronted by skepticism that has undermined this important endeavor and has deprived it from a central place in the growth literature.[59] If indeed there exists a threshold level of development that poor economies ought to surpass in order to join the club of the rich, and if this threshold is insurmountable in the absence of an exogenous shock, then how did the rich economies in today's world surpass this threshold in the distant past when their level of development was similar to the one experienced by those countries that are in poverty traps today?

Unified Growth Theory provides a fundamental framework of analysis that uncovers the forces that contributed to the existence of multiple growth regimes and the emergence of convergence clubs. Furthermore, it sheds light on the characteristics that determine the association of economies with each of the clubs. The theory suggests that, although the long-run equilibrium may not differ across economies, differential timing of take-offs from stagnation to growth would segment economies into three fundamental regimes that differ in their growth structure: slow growing economies in the vicinity of a Malthusian regime, fast growing countries in a sustained growth regime, and a third group of economies

[58] Growth non-linearities and convergence clubs were explored theoretically by Galor and Ryder (1999), Azariadis and Drazen (1990), Galor (1992), and Galor (1996), and empirically by Durlauf and Johnson (1995), Quah (1997), Durlauf and Quah (1999), Bloom, Canning and Silva (2003), Fiaschi and Lavezzi (2003), Feyrer (2008), among others.

[59] A notable exception is Durlauf and Johnson (1995) who provide a broader interpretation that includes, in addition to multiple long-run equilbria, a world characterized by a unique long-run equilibrium, but different stages of development.

in the transition from one regime to another. Convergence clubs, therefore, may be temporary, and endogenous forces would permit economies to shift from the Malthusian Regime into the sustained growth regime. Consistently with contemporary evidence about the existence of multiple growth regimes and non-linearities in the evolution of growth rates, the differential pace of transition from stagnation to sustained economic growth across countries suggests that in any time period in which the transition has not been completed across the globe, there exists variation in the position of economies along the distinct phases of development. Economies would be segmented into three fundamental groups. Two convergence clubs of rich and poor economies and a third group of countries in the transition from one club to another.[60] Importantly, this segmentation does not reflect the long-run steady state of these economies, as would be implied by models characterized by multiple steady-state equilibria. Rather, it is a representation of variation in the timing of the escape from a Malthusian trap and thus in the position of countries along the growth trajectory from Malthusian epoch to sustained economic growth.

In contrast to existing research that links membership in each of the clubs and the thresholds that permit economies to switch from one club to another, to critical *levels* of income and human capital, Unified Growth Theory suggests that they are in fact associated primarily with critical *rates* of technological progress, population growth and human capital formation. The theory suggests that two major transformations in the growth process determine the thresholds between the club of the slow growing economies, countries in a transition from one club to another, and the club of the fast growing economies. The first threshold is associated with a rapid increase in the rates of technological progress and population growth, and the second with a significant rise in human capital formation along with a rapid decline in population growth. Variations in the levels of income, human capital, and population growth across countries, in contrast, would not be indicative of these thresholds, and would only reflect the country-specific characteristics (e.g., geographical factors and historical accidents and their manifestation in the diversity of institutional, demographic, and cultural factors, as well as in trade patterns, colonial status, and public policy) rather than the actual stage of development.[61]

# 4 Concluding Remarks

Unified Growth Theory suggests that the inherent Malthusian interaction between the level of technology and the size and the composition of the population accelerated the pace of technological progress and ultimately raised the importance of human capital in the rapidly changing technological environment. The rise in the demand for human capital and its impact on the formation of human capital, as well as on the onset of the demographic transition, have brought about significant technological advances along with a reduction in fertility rates and population growth. It has enabled economies to divert

[60] Technological leaders largely experience a monotonic increase in the growth rates of their per capita incomes along the process of development. Their growth is slow in early stages of development, it increases rapidly during the take-off from the Malthusian epoch, and it continues to rise, often stabilizing at higher levels in the sustained growth regime. In contrast, technological followers that made the transition to sustained economic growth more recently experience a non-monotonic increase in the growth rates of their per capita incomes. Their growth rate is slow in early stages of development and it increases rapidly during their take-off from the Malthusian epoch, boosted by the adoption of technologies from the existing technological frontier. However, once these economies reach the technological frontier, their growth rates drop to the level of the technological leaders.

[61] For instance, although during the 18th century education levels were significantly lower in England than in continental Europe, England was the first to industrialize and to take off towards a state of sustained economic growth. Similarly, the demographic transition that marked a regime switch to a state of sustained economic growth occurred in the same decade across Western European countries that differed significantly in their income per capita.

a larger share of the fruits of factor accumulation and technological progress from fueling population growth towards the advancement in income per capita, and has thus paved the way for the emergence of sustained economic growth.

Unified Growth Theory sheds light on three fundamental aspects of comparative economic development. First, it identifies the factors that have governed the pace of the transition from stagnation to growth and have thus contributed to the observed worldwide differences in economic development. Second, it uncovers the forces that have sparked the emergence of multiple growth regimes and convergence clubs, and third, it underlines the persistent effects that variations in pre-historical biogeographical conditions have generated on the global composition of human capital and economic development.

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