Introduction to Economic Growth: Why some countries are poorer than others?

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Lecture 4: Malthusian stagnation, Transition to modern growth, and the Unified Growth Theory

Three big questions that remain unanswered by the EGT

Question 1 Why was growth absent for most of the history of the humanity? Were there no innovations or breakthrough ideas? Why such a long stagnation? Long Stagnation and then Divergence

Question 2 What can explain the transition from a long period of stagnation to a 'modern growth regime'?

Question 3 Population growth is very important: capital dilution in the Solow model, ideas creation in the EGT models... But has the relationship between population growth and income growth changed over time?

Population and incomes in transition from stagnation to growth

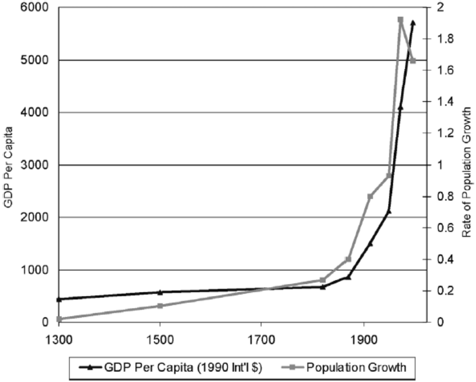

Figure 1: Population growth rates and GDP per capita levels over the last 700 years. Source: Galor (2005)

Population and incomes in transition from stagnation to growth

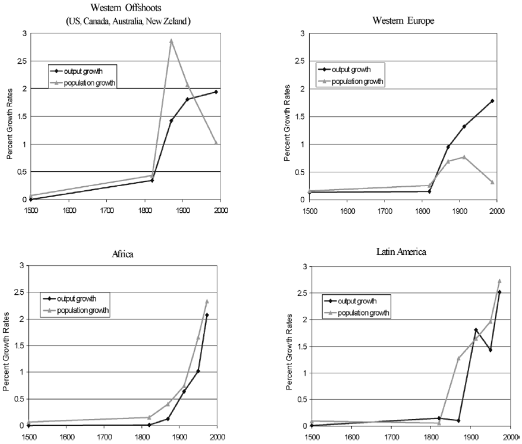

Figure 2: Population growth rates and GDP per capita growth rates across the world. Source: Galor (2005)

Today's lecture

1. The Malthusian model
   - Basic intuition behind the 'Malthusian trap'
   - Model's set up
   - Steady state and testable predictions
   - Testing the model against historical data

2. The Unified Growth Theory (UGT)
   - Basic building blocks
   - Escaping the Malthusian Trap: post-Malthusian regime
   - Entering the modern growth regime

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Thomas Malthus (1766-1834)

Figure 3: Thomas Malthus, the famous economist, and one of history's greatest pessimists. Source: Wiki

Thomas Malthus (1766-1834)

Thomas Malthus was an English cleric, scholar and influential economist in the fields of political economy and demography.

He is mostly famous for his fundamental work on population dynamics and economic growth, summarized in his 1798 book "An Essay on the Principle of Population". He wrote

"The power of population is indefinitely greater than the power in the earth to produce subsistence for man."

Malthus observed that improvements in food production in England had increased living standards, but only temporarily: population increased, and then living standards collapsed back to where they were. He believed that humanity is doomed to remain in this (how we call it now) "Malthusian trap".

Malthusian model: basic intuition

There are two key ideas behind the Malthusian model:

1. Diminishing returns to labor (because there is a constraint coming from fixed factor of production - land)
2. Positive effect of incomes per capita on population growth (people give more births when they are richer)

Because of this, any shocks to productivity (TFP) or land quality/quantity will have only temporary effects on incomes:

- higher incomes allow for a larger population
- and larger population decreases incomes per worker back to where they were
- note that in the Solow model or the EGT models, we did not have this positive effect of income on population growth (is this a bug? or a feature?)

The Malthusian mechanism: basic intuition

The basic Malthusian mechanism can be summarized as follows:

1. $A_t \uparrow \rightarrow y_t \uparrow$ (technological improvements increase incomes per worker)
2. $y_t \uparrow \rightarrow L_t \uparrow$ (higher incomes stimulate population increase)
3. $L_t \uparrow \rightarrow APL \downarrow \rightarrow y_t \downarrow$ (larger population decreases incomes per worker back)

Note that incomes per worker in the long-run are predicted to remain roughly stable.

However, every technological advance is predicted to increase population size.

The Malthusian mechanism: illustration

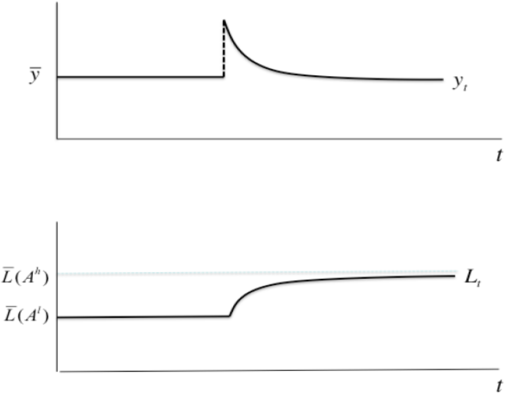

Figure 4: Dynamics of incomes per worker and population following a shock to TFP. Source: Oded Galor's lecture notes

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Malthusian model: Production

Production in the Malthusian model uses only Labor (L) and Land (X) as inputs. We assume a standard Cobb-Douglas production function:

$$Y_t = (A \cdot X)^{\alpha} \cdot L_t^{1-\alpha} \tag{1}$$

Then, output per worker is given by:

$$y_t = Y_t / L_t = (\frac{A \cdot X}{L_t})^{\alpha} \tag{2}$$

Clearly, incomes per worker are decreasing in the amount of Labor (L), and increasing in TFP (A) and Land (X)

Malthusian model: consumption and fertility behavior

In this simplified version of the model we assume:

- That people spend a fixed fraction of their incomes on consumption: $c_t = (1-\gamma) \cdot y_t$
- That the remaining income ($\gamma \cdot y_t$) is split equally between n_t children. Each child has a cost of ρ, thus:

$$n_t = \frac{\gamma}{\rho} \cdot y_t \tag{3}$$

- Note that total expenditures on children equal $n_t \cdot \rho = \gamma \cdot y_t$
- From (3) and (2), it is also clear that fertility n_t is decreasing in the amount of population (labor) L_t, because $y_t = (\frac{A \cdot X}{L_t})^\alpha$

Malthusian model: population dynamics

Each parent gives birth to n_t children. Thus, the dynamics of population is described by the following equation:

$$L_{t+1} = n_t \cdot L_t \tag{4}$$

Recall that $n_t = \frac{\gamma}{\rho} \cdot y_t$ from (3), and that $y_t = (\frac{A \cdot X}{L_t})^\alpha$ from (2).

Substituting these equations back into (4), we get that

$$L_{t+1} = \frac{\gamma}{\rho} \cdot (A \cdot X)^\alpha \cdot L_t^{1-\alpha} \tag{5}$$

This equation describes the dynamics of population in this model.

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Malthusian model: population steady state

Equation (5) describes the dynamics of population. Will population converge to a steady state?

- In the Solow model it did not (kept growing with rate n). But Malthusian dynamics has a check on reproduction: higher population decreases incomes, and lower incomes decrease reproduction rates.

Steady state requires that $\Delta L_t = L_{t+1} - L_t = 0$, i.e., there is no change in population over time. Applying this condition to (5) (same as $L_{t+1} = L_t$), we get $L^* = \frac{\gamma}{\rho} \cdot (A \cdot X)^\alpha \cdot (L^*)^{1-\alpha}$, and hence:

$$L^* = (\frac{\gamma}{\rho})^{1/\alpha} \cdot A \cdot X \tag{6}$$

Thus, steady state population is increasing in technology (A), land endowment (X), and preference for children (γ), but decreasing in costs of rasing children (ρ).

Malthusian model: steady state illustration

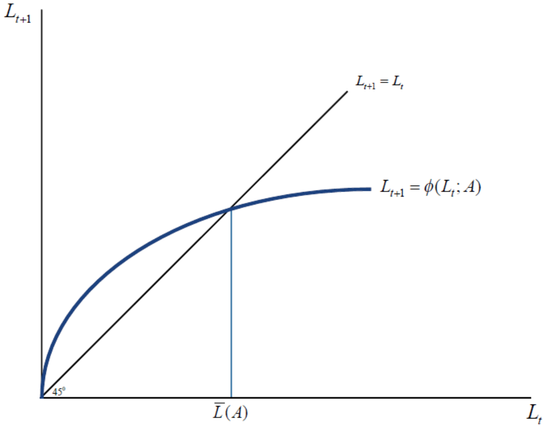

Figure 5: Illustration of the steady state population size. Source: Oded Galor's Lecture notes

Malthusian model: improvement in technology

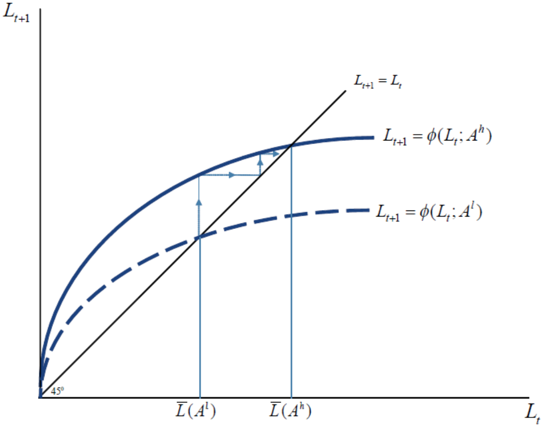

Figure 6: Illustration of how the steady state population reacts to technological advancement. Source: Oded Galor's Lecture notes

Malthusian model: incomes per capita steady state

From equation (2) we know that $y_t = (A \cdot X / L_t)^\alpha$. Thus, $y_{t+1} = (A \cdot X / L_{t+1})^\alpha$ (simply repeating this for the next period).

Thus, noting that $L_{t+1} = n_t \cdot L_t$ from (4), we get $y_{t+1} = (A \cdot X / n_t \cdot L_t)^\alpha = \frac{y_t}{n_t^\alpha}$.

And since we know from (3) that $n_t = \frac{\gamma}{\rho} \cdot y_t$, we get the following dynamics of y_t:

$$y_{t+1} = \frac{y_t}{n_t^\alpha} = \frac{y_t}{(\frac{\gamma}{\rho})^\alpha \cdot y_t^\alpha} \tag{7}$$

Or, to simplify:

$$y_{t+1} = (\frac{\rho}{\gamma})^\alpha \cdot y_t^{1-\alpha} \tag{8}$$

What is the level of income in the steady state? (as an exercise)

Malthusian model: income steady state illustration

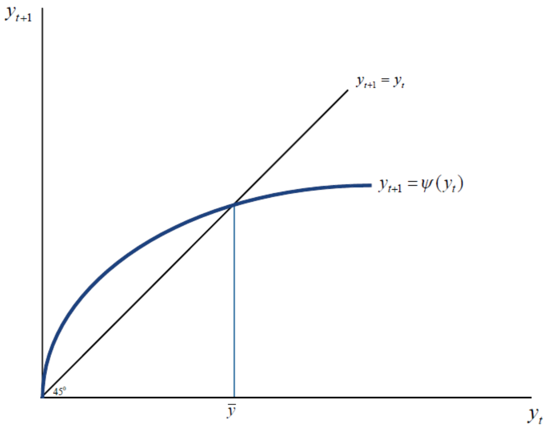

Figure 7: Illustration of the steady state incomes per capita. Source: Oded Galor's Lecture notes

Malthusian model: improvement in technology

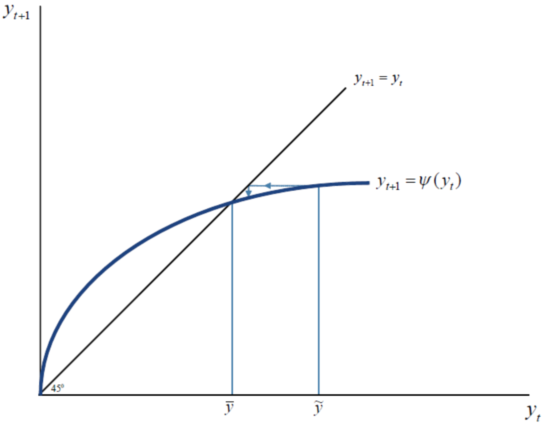

Figure 8: Illustration of how the steady state income per capita reacts to technological advancement. Source: Oded Galor's Lecture notes

Malthusian model: example

Let's solve a simple exercise for the Malthusian economy with the following production function parameters $A = 10$, $X = 10$, $\alpha = 1/2$, $\gamma = 1/2$, and $\rho = 2$. (i) derive the output per capita function; (ii) derive the dynamics of population function; (iii) find the steady state population per unit of land (population density); (iv) find the dynamics of output per capita and the steady state output per capita; (v) what happens to the steady state values of L and y if a country adds new territory, (X increases)?

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Malthusian dynamics: prominent examples

1. Irish economy (1650-1850)
   - Triggered by the cultivation of the New World crop - potato
2. Chinese economy (1500-1800)
   - Triggered by superior agricultural technology
3. English economy (1348-1700)
   - Triggered by the Black Death

Chinese case

- Superior agricultural technology (1500-1820)
  - Population increased from 103 to 381 million.
  - Share of China in the World population increased from 23% to 37%,
  - But! Income per capita was basically almost constant at around $600.
- Adoption of maize (1776-1910)
  - Explained up to 1/5 of the Chinese population growth over the period
  - No impact on income per capita

English case: the Black death

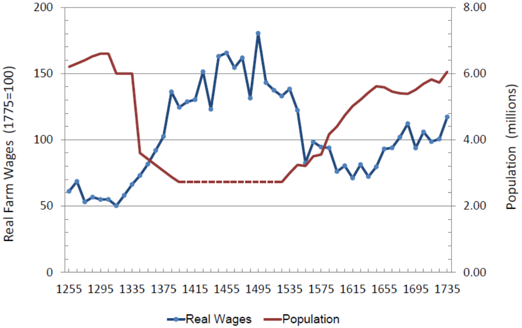
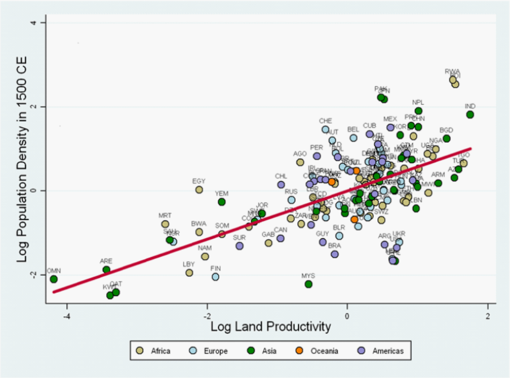


Figure 9: Malthusian dynamics following the Black Dealth in England. Source: Gregory Clark (2001, 2002)

The role of land productivity in the Malthusian period

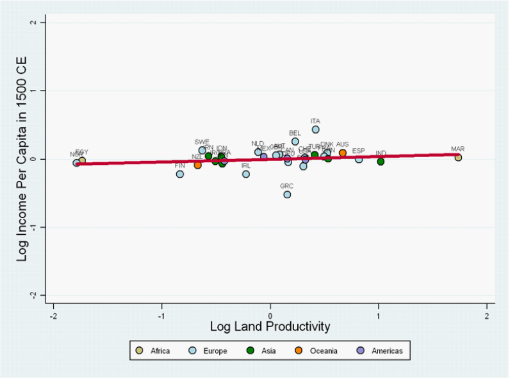


Conditional on transition timing, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2011)

Figure 10: Population density and land productivity in year 1500. Source: Ashraf and Galor (2011)

The role of land productivity in the Malthusian period

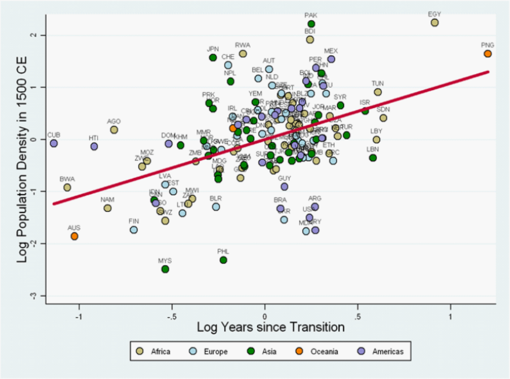


Conditional on transition timing, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2011)

Figure 11: Incomes per capita and land productivity in year 1500. Source: Ashraf and Galor (2011)

The role of technology (TFP) in the Malthusian period



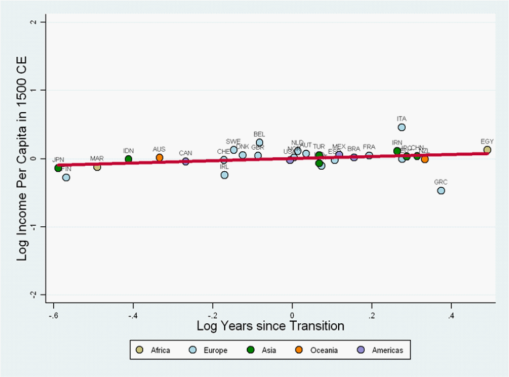
Years elapsed since the Neolithic Transition reflects the technological level in 1500.

Conditional on land productivity, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2011)

Figure 12: Population density and proxy for technological sophistication in year 1500. Source: Ashraf and Galor (2011)

The role of technology (TFP) in the Malthusian period



Years elapsed since the Neolithic Transition reflects the technological level in 1500.

Conditional on land productivity, geographical factors, and continental fixed effects.

Source: Ashraf-Galor (AER 2011)

Figure 13: Incomes per capita and proxy for technological sophistication in year 1500. Source: Ashraf and Galor (2011)

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How to escape the Malthusian stagnation?

We see that the Malthusian mechanism keeps standards of living low:

- Any increase in incomes increases fertility
- As a result, higher population pushes labor productivity and incomes back to the initial steady state.

However, population density is gradually increasing after seldom technological advances. Can we now combine several of the previous ideas?

- Malthusian positive link between incomes and fertility prevents economies from growing
- But population pressure also stimulates technological advances, and the pace of technological progress accelerates
- The UGT gives us the last piece of the puzzle: the quantity-quality trade-off in raising children.

The Unified Growth Theory: basics

A key component of the UGT is that parents choose how much they invest into human capital of their children:

- Parents spend incomes on consumption and costs (food, time) of raising children (quantity)
- Part of parental income is also spent on education, to increase children's human capital (quality)
- But why would parents invest in human capital of their children in a Malthusian world?

Here is where the model combines several of the key ideas we discussed before:

- Higher population size increases the pace of technological progress
- And faster technological progress depreciates previous knowledge base:
  - Education 'updates' human capital to keep up with the changing world

Technological progress in the UGT

Technological progress is denoted by g, and depends on the population size and on education of the labor force:

$$g_{t+1} = g(e_t, L_t) \tag{9}$$

- function g is increasing in e_t (more educated labor brings faster technological progress)
- g is increasing in L_t (higher population size brings faster technological progress: supply of researchers and demand for innovations)
- g is positive even in the Malthusian equilibrium with zero education

Technological progress in the UGT

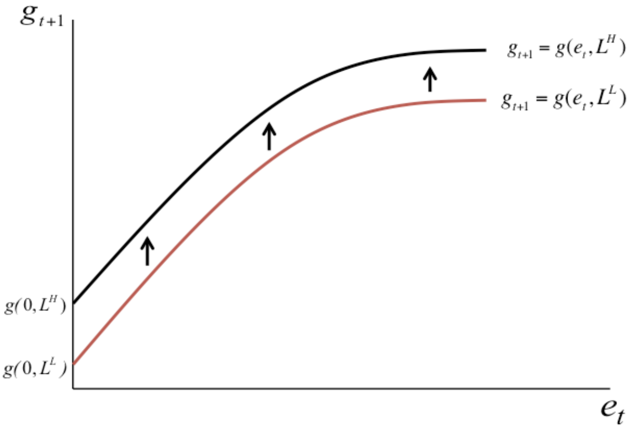

Figure 14: Technological progress, education, and increase in population size.
Source: Oded Galor's Lecture notes

Human capital formation in the UGT

Why did parents invest into education of their children in a world with little change and little employment outside of agriculture?

- Well, for most of the human history, the answer is: they did not!
- But once the pace of technological improvements accelerates, it becomes reasonable
- Parents educate their children because returns to this investment increases
- Namely, education pays off more in a rapidly changing world, with 'skill-biased' technological change

Human capital formation in the UGT

Human capital is denoted by h, and depends on parental investment in education, and on the pace of technological change:

$$h_{t+1} = h(e_{t+1}, g_{t+1}) \tag{10}$$

where

- h is increasing in e_{t+1} (more education increases the stock of human capital one possesses)
- h is increasing in g_{t+1} (faster technological progress makes pre-existing human capital less useful)
- h is positive even in the Malthusian equilibrium with zero education

Human capital formation in the UGT

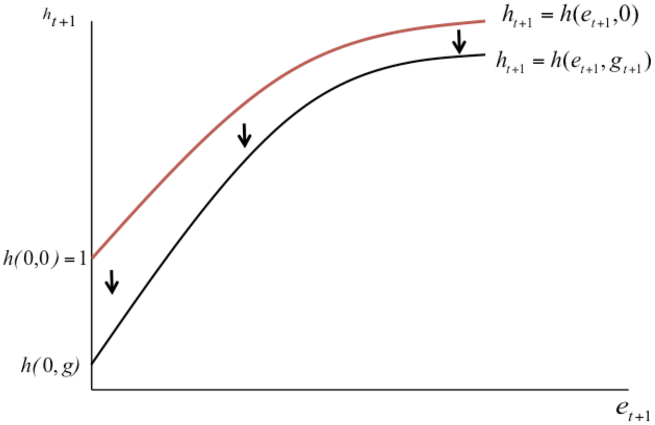

Figure 15: Human capital, education, and increase in the pace of technological progress. Source: Oded Galor's Lecture notes

Demographic transition in the UGT

The rise in demand for human capital incentivizes parents to substitute quantity of children for their quality.

- As technological progress accelerates, there are two main effects:
  - Income effect: parental incomes increase, so they can have more quantity and more quality of children
  - Substitution effect: return to educating children increases, so parents substitute quantity for quality
- Income effect dominates at the earlier stages of development: population growth rates increase
- Substitution effect dominates later on: population growth rates decline, and human capital formation intensifies

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The UGT: transition from Malthusian stagnation to the Post-Malthusian regime

1. In the Malthusian epoch, incomes are stagnant, and population slowly increases due to rare improvements in technology

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2. As population slowly increases, technological advances become more regular, so population increases faster (incomes are still subject to the Malthusian trap)
3. At a certain point, due to higher population counts, technological advances become so frequent that incomes per worker don't have time to revert back to their Malthusian steady state
4. Income is still mostly spent on children's quantity, not education, so see an increase in both population and incomes per capita, with little increase in education

Post-Malthusian population and income growth

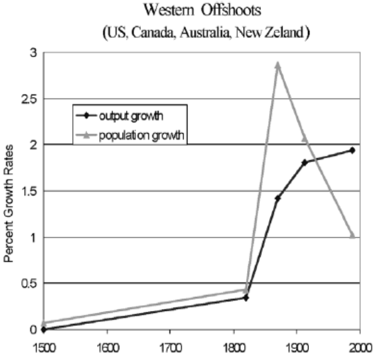

Figure 16: Population growth rates and GDP per capita growth rates in developed economies. Source: Galor (2005)

Post-Malthusian fertility and mortality

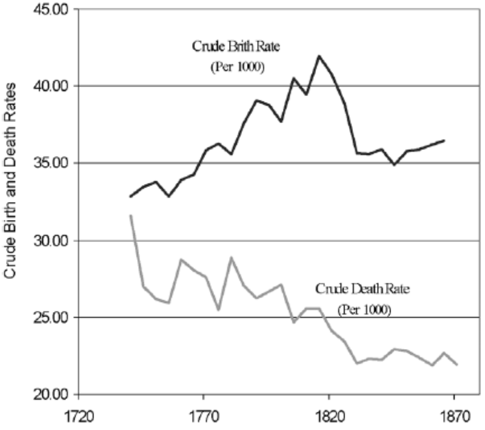

Figure 17: Fertility and Mortality in England, 1730-1871. Source: Galor (2005)

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The UGT: transition from the Post-Malthusian regime to the Modern Growth regime

1. In the post-Malthusian regime, growth in incomes per capita is constrained by fast population growth

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1. In the post-Malthusian regime, growth in incomes per capita is constrained by fast population growth
2. However, fast population growth also means that technological advances are becoming more and more frequent
3. Gradually, substitution effect becomes a dominant factor, and parents invest more and more in education of children, cutting on the quantity of children
4. Thus, population growth slows down, leading to faster growth of incomes per capita
5. Eventually, the main driver of sustained growth in the modern growth regime is technological progress and human capital investment
   - population growth has no big role to play in innovations and TFP growth (as we saw in Module 3) in the modern growth regime

Timing of the demographic transition

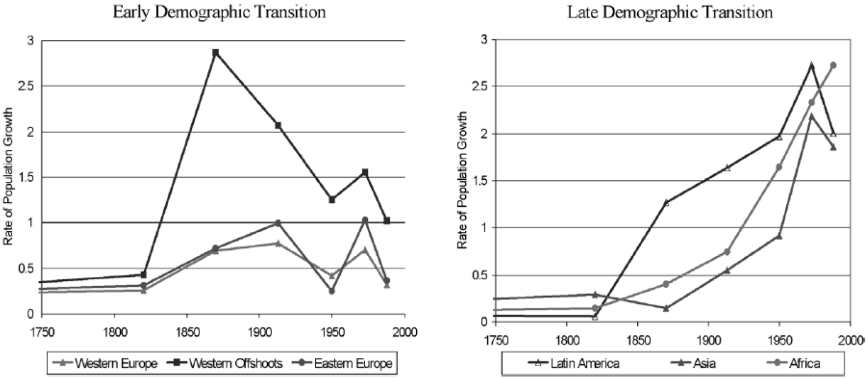


Figure 18: Demographic transition: changes in population growth rates. Source: Galor (2005)

Timing of mass education

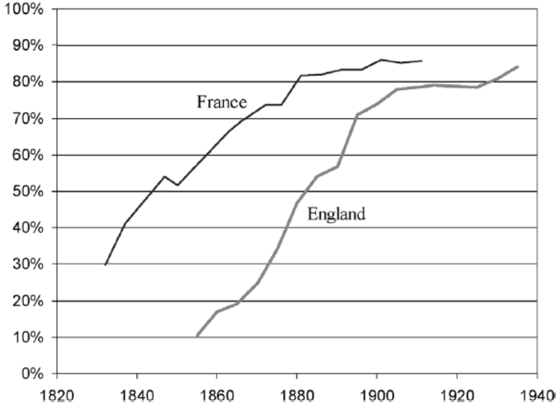


Figure 19: The fraction of children age 5–14 in public primary schools, 1820–1940. Source: Galor (2005)

Murtin (2012): education as a main driver of decline in fertility

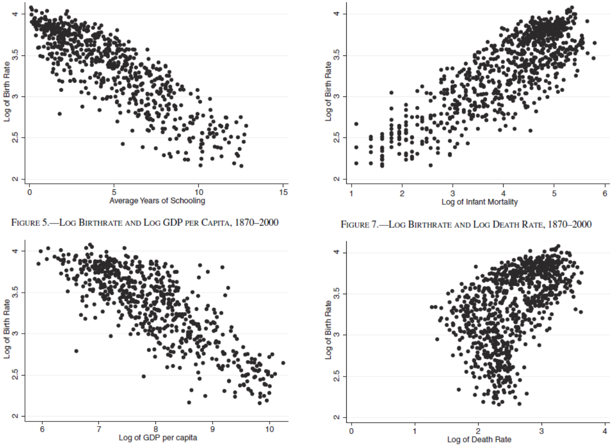
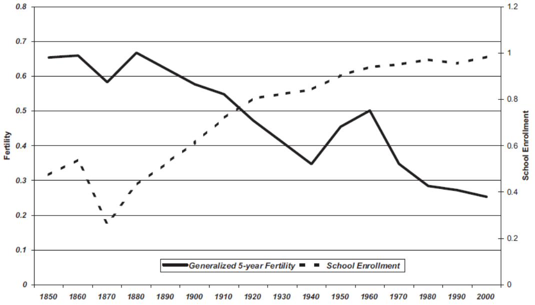


Figure 20: Correlations between Birth rates and potential explanatory factors. Source: Murtin (2012)

Bleakley and Lange (2009): returns to education lower fertility



Notes: This figure plots averages by Census year of the indicated variables. The base sample consists of natives living in the southern United States in the IPUMS data, 1850–2000. The fertility measure is the number of own children in the household for females aged 15–49. The school enrollment data are computed for children aged 8–16.

Figure 21: Fertility and Schooling in the US. Source: Bleakley and Lange (2009)

The authors show that the hookworm eradication campaign at around 1910 has increased children's return from schooling (because hookworm stunts learning), and thus has led to a decrease in fertility.

Long stagnation and subsequent divergence in incomes

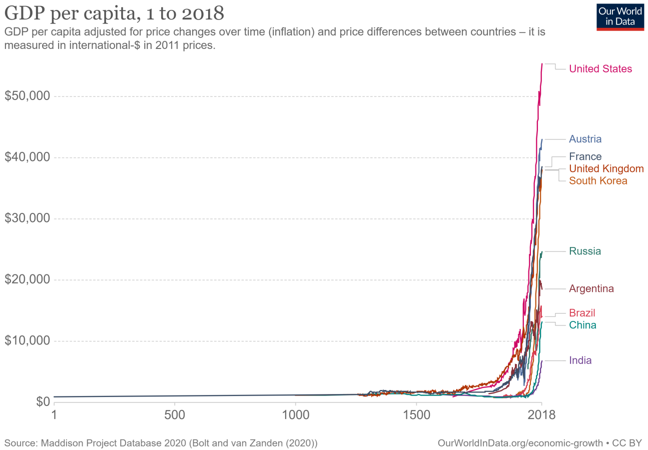


Figure 22: Long stagnation and then divergence. Source: ourworldindata.org

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Relative length of the three periods of development

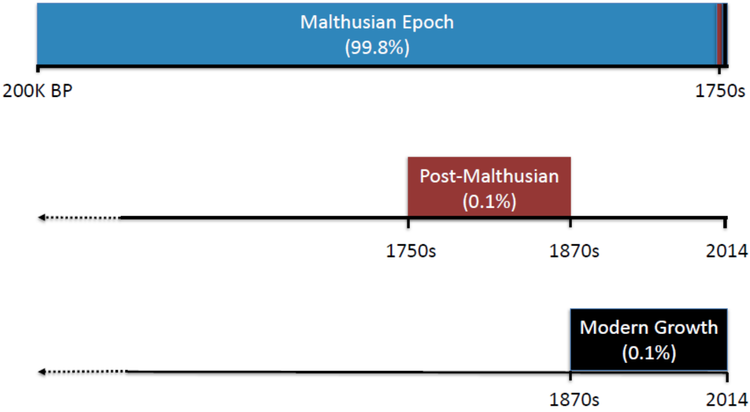

Figure 23: Three periods of development. Source: Oded Galor's Lecture Notes

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