What Was the Industrial Revolution ?

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ADEMU Lecture

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The characteristic which distinguishes the modern period in world history from all past periods is the fact of economic growth. It began in western Europe and spread first to the overseas countries settled from Europe....For the first time in human history it was possible to envisage a sustained increase in the volume of goods and services produced per unit of human effort or per unit of accessible resources.

Wherever this enlargement of the productive horizon of the ordinary man appeared it involved a distinctive transformation of the economy concerned. A predominantly agricultural, family-based system of economic organization began to give way to a predominantly industrial system in which representative unit of production was necessarily larger than the family...

- From: W.A. Cole and Phyllis Deane, 1966 Cambridge Economic History of Europe

- A compact, elegant and (I think) accurate statement of facts of IR

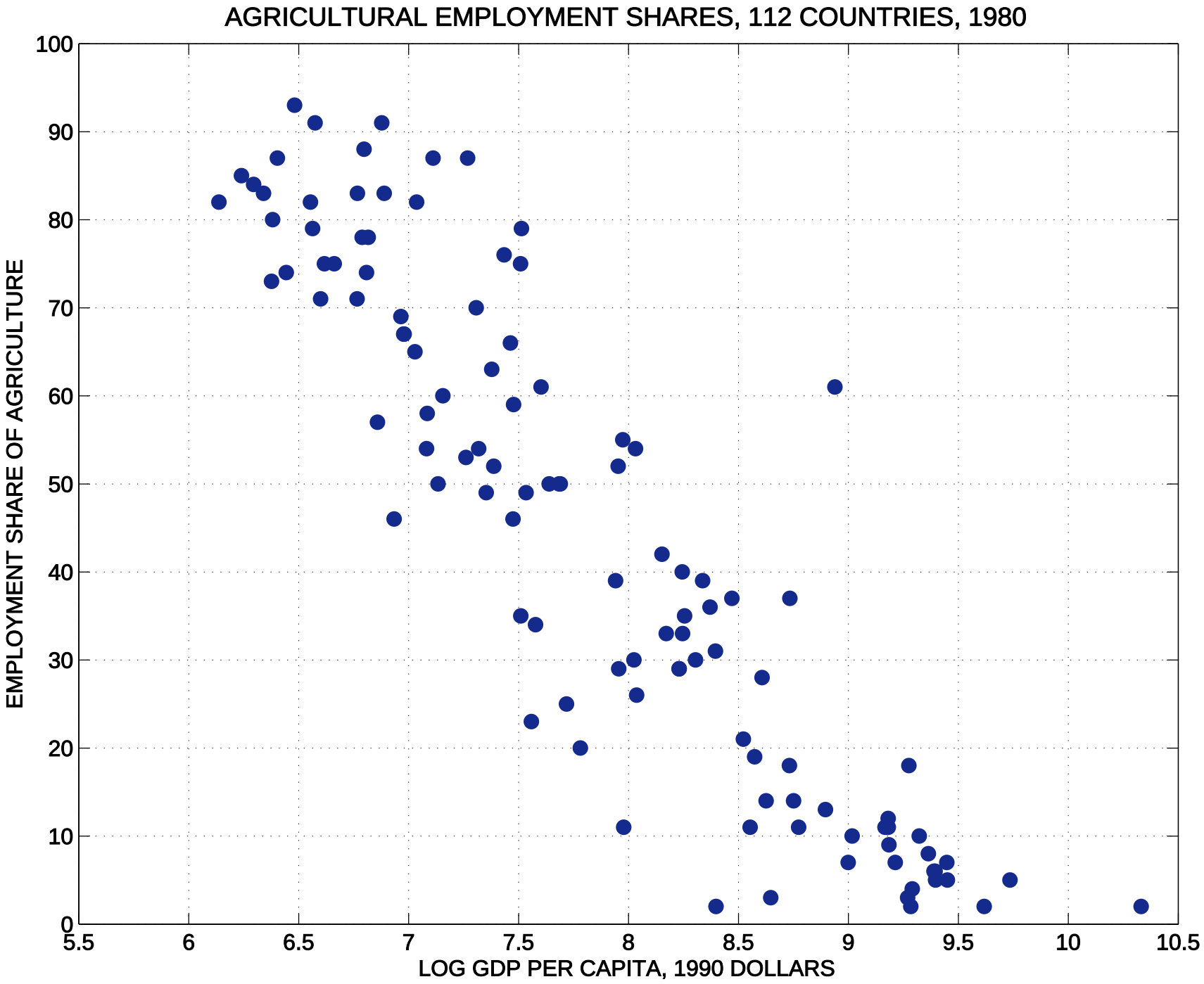
- But does not address question: How, after all those centuries of subsistence living for landless working people, did British and soon other Europeans move into regime of sustained growth?

- Useful to restate this question as one of demography (cf EA Wrigley): How and why, after all those centuries of Malthusian fertility, did British and soon other Europeans in the 19th century, choose to reduce fertility in the face of ongoing increases in incomes?

- Want to address these questions

- But first I want to put some data in front of us

- First slides illustrate the relative decline of "traditional agriculture"—agriculture of illiterate workers carried on at near subsistence levels


AGRICULTURAL EMPLOYMENT SHARES, 112 COUNTRIES, 1980
EMPLOYMENT SHARE OF AGRICULTURE
LOG GDP PER CAPITA, 1990 DOLLARS
0
10
20
30
40
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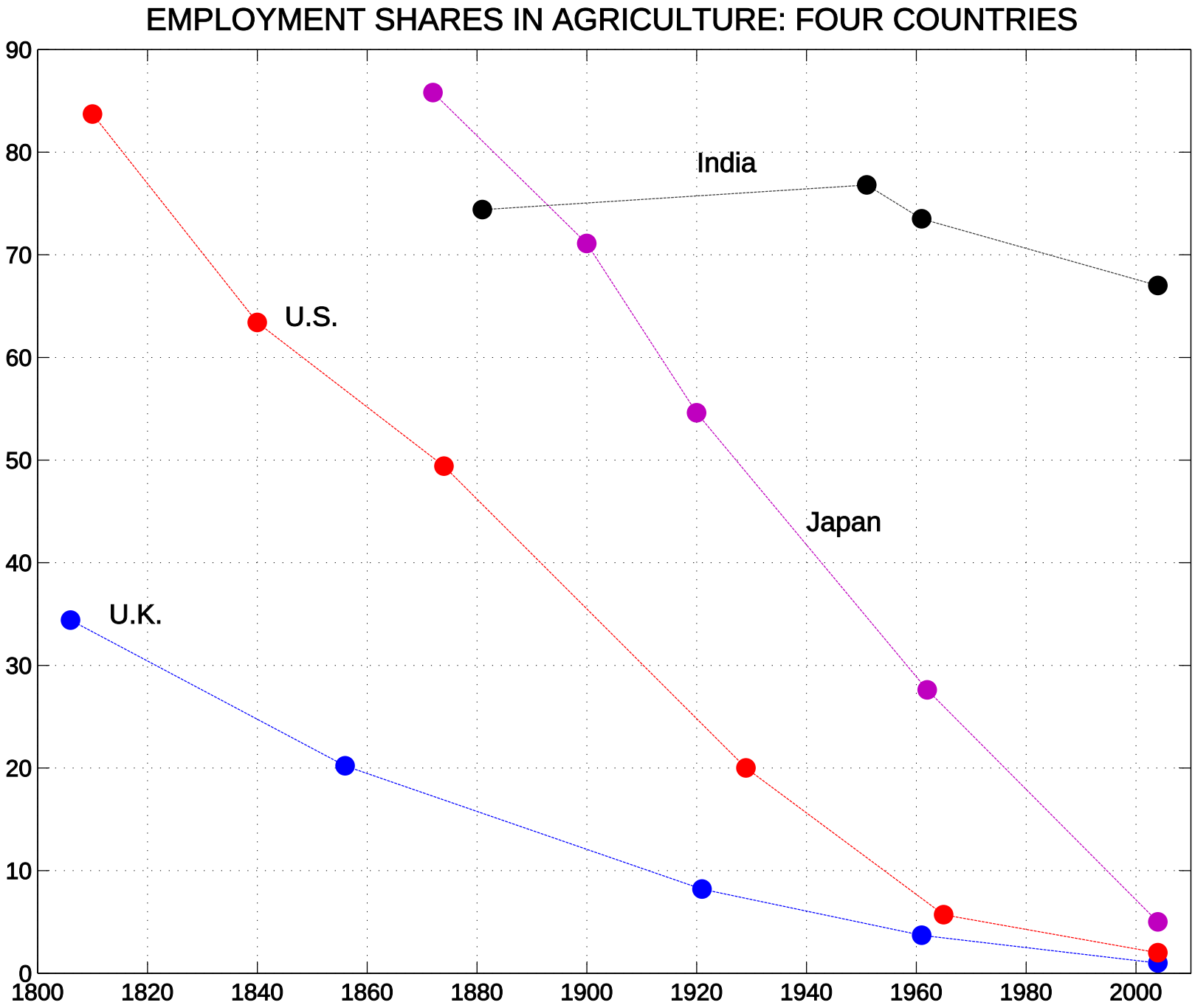
EMPLOYMENT SHARES IN AGRICULTURE: FOUR COUNTRIES
90
80
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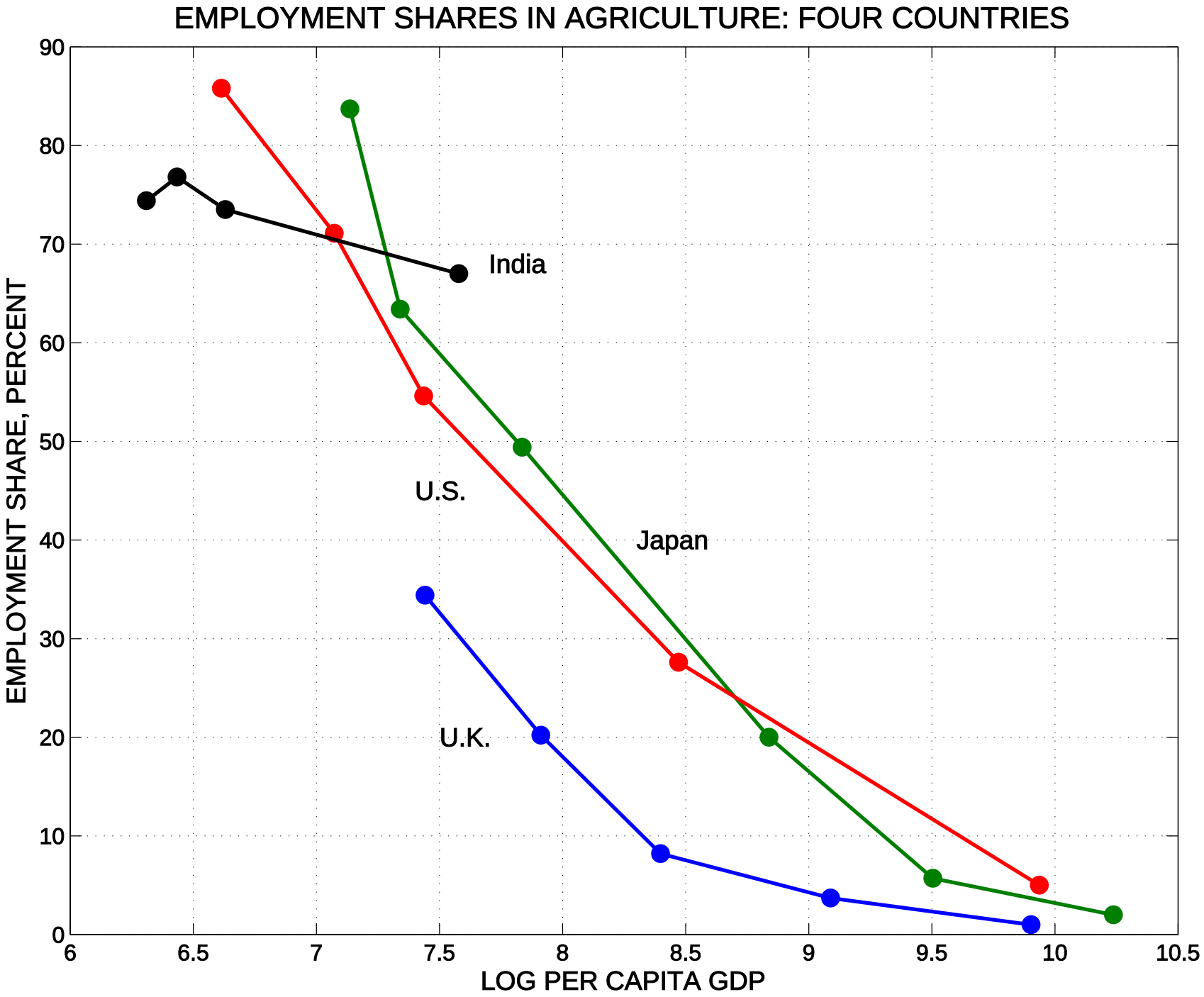
EMPLOYMENT SHARES IN AGRICULTURE: FOUR COUNTRIES
EMPLOYMENT SHARE, PERCENT
LOG PER CAPITA GDP
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India
U.S.
Japan
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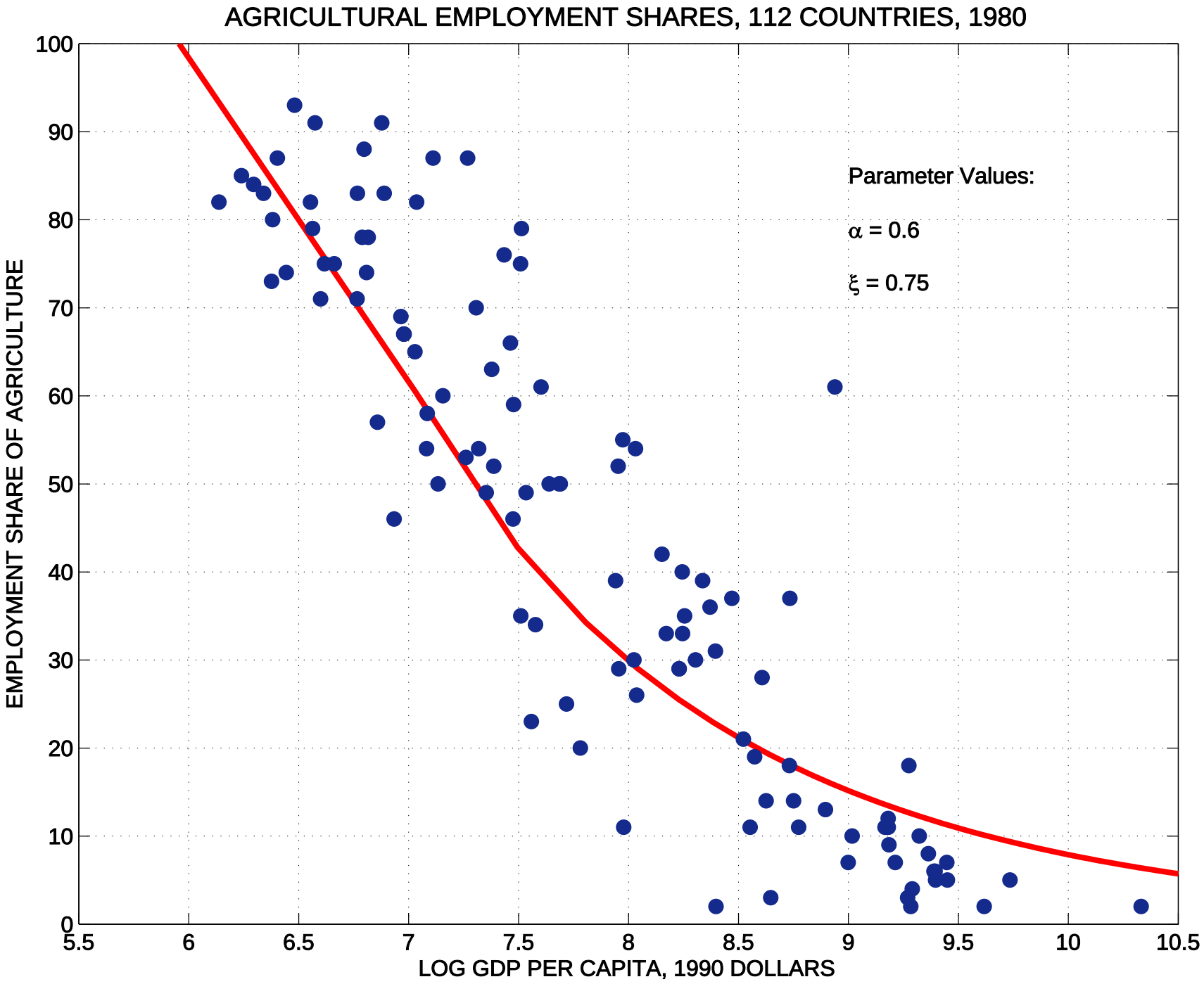
AGRICULTURAL EMPLOYMENT SHARES, 112 COUNTRIES, 1980
EMPLOYMENT SHARE OF AGRICULTURE
LOG GDP PER CAPITA, 1990 DOLLARS
Parameter Values:
α = 0.6
ξ = 0.75
100
90
80
70
60
50
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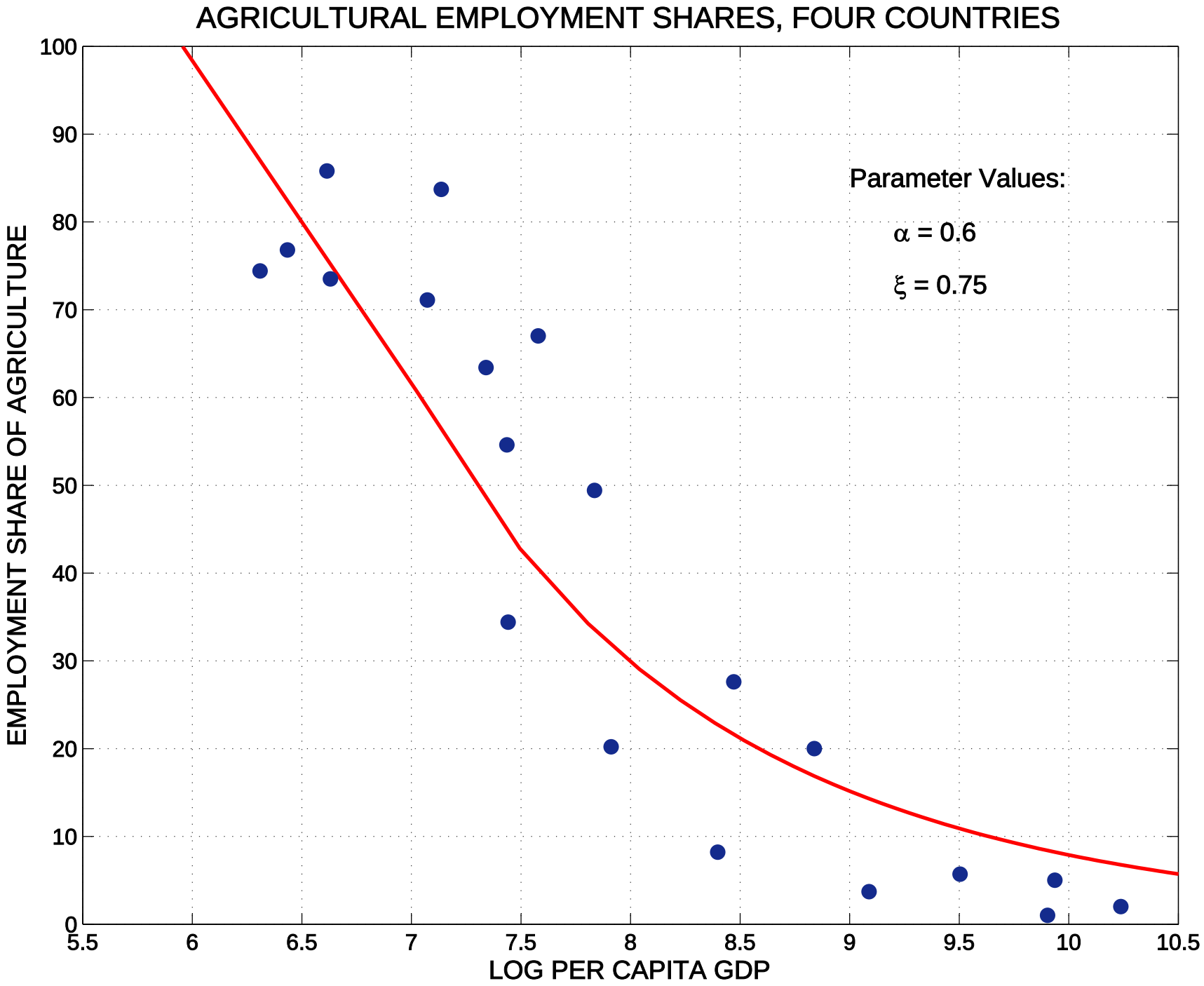
AGRICULTURAL EMPLOYMENT SHARES, FOUR COUNTRIES
EMPLOYMENT SHARE OF AGRICULTURE
LOG PER CAPITA GDP
Parameter Values:
α = 0.6
ξ = 0.75
100
90
80
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- Close connection between traditional agriculture and low income
- Also illustration of importance of "dual economy": cf Arthur Lewis, Theodore Schultz
- Note that calendar time not shown

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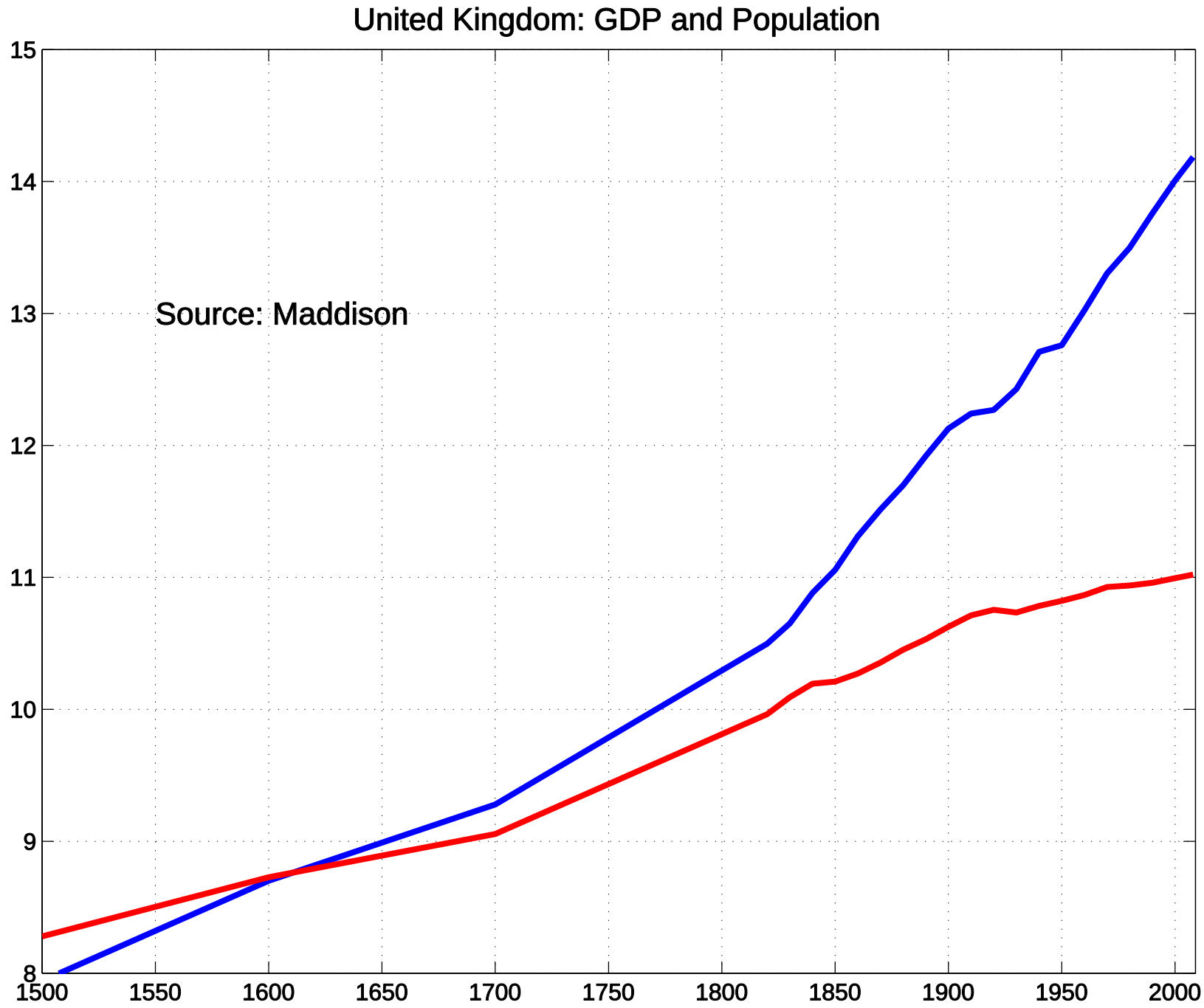
- Next slides illustrate demographic transition—the fact that the demography of Malthus and Ricardo ceased to hold as incomes rose


United Kingdom: GDP and Population
Source: Maddison
15
14
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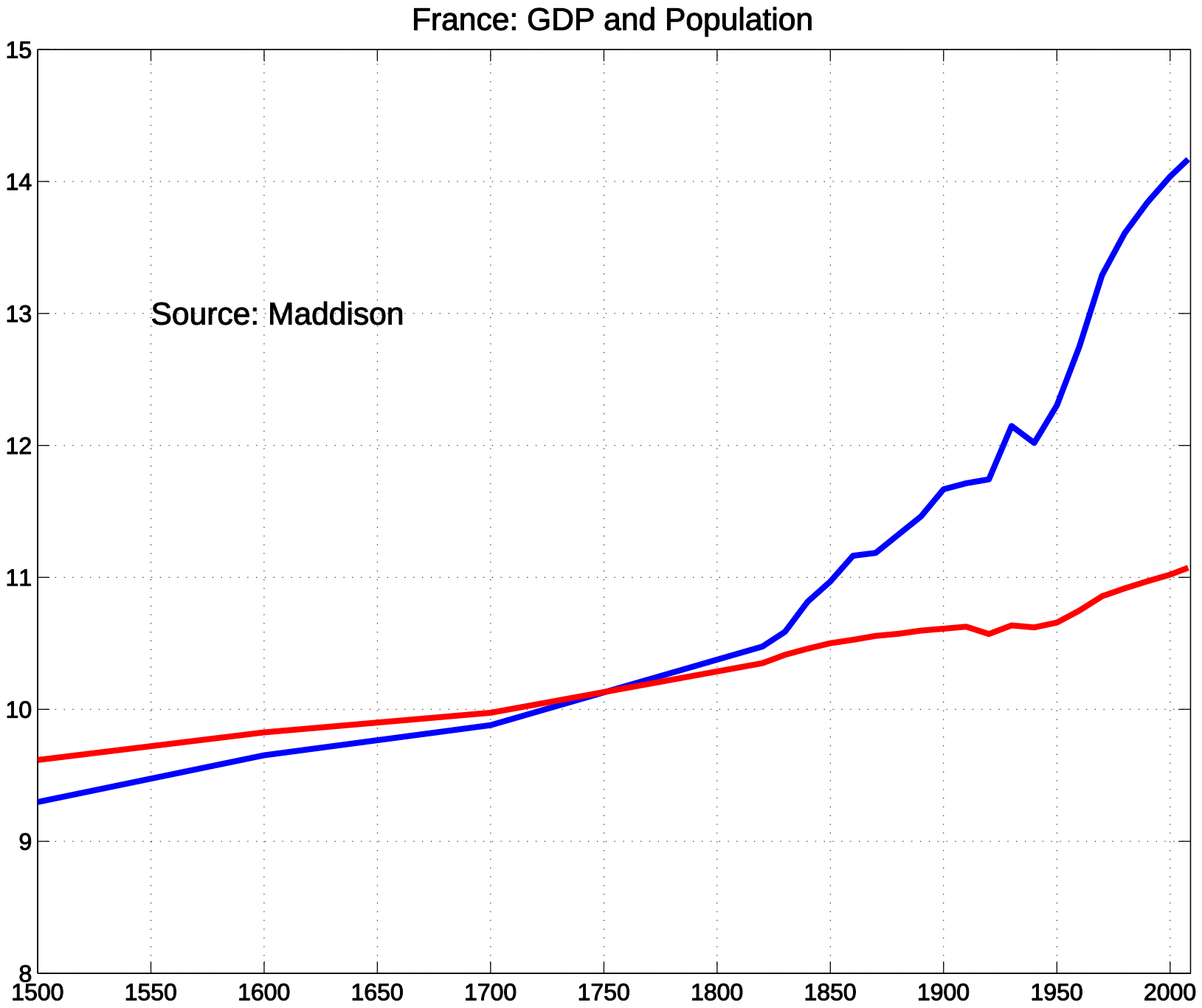
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000


France: GDP and Population
Source: Maddison
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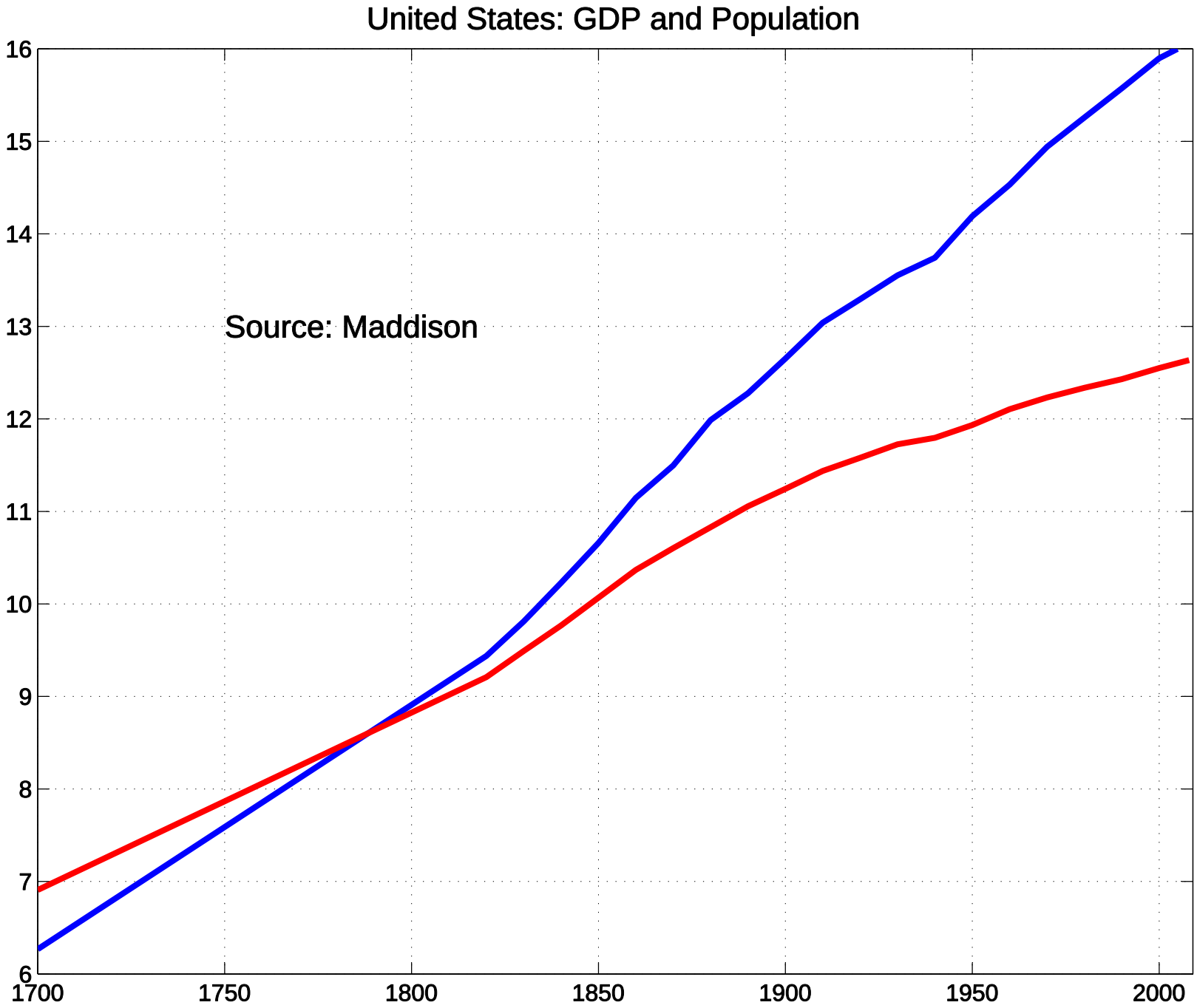
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000


United States: GDP and Population
Source: Maddison
16
15
14
13
12
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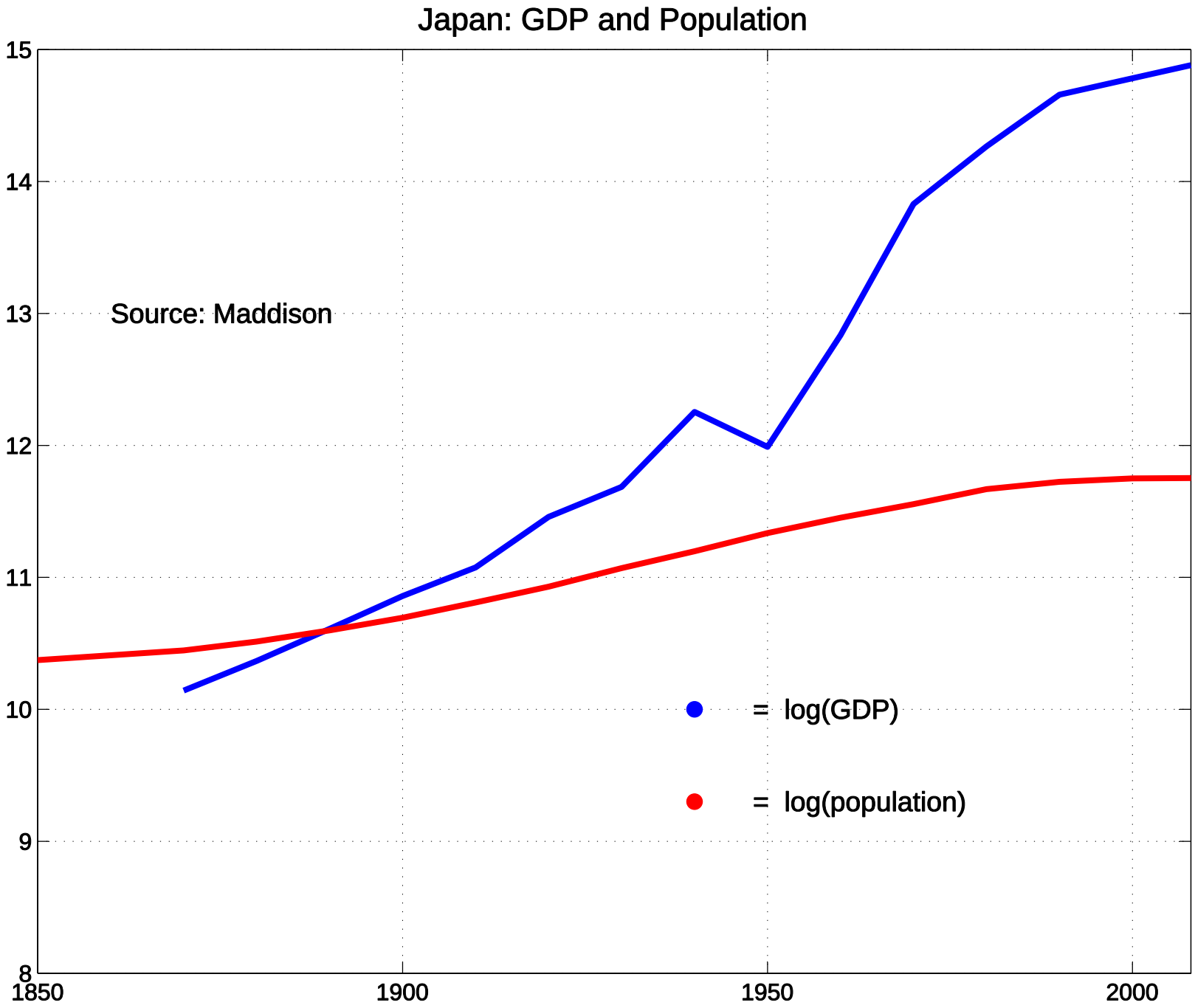
6
1700
1750
1800
1850
1900
1950
2000


Japan: GDP and Population
Source: Maddison
= log(GDP)
= log(population)
15
14
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1850
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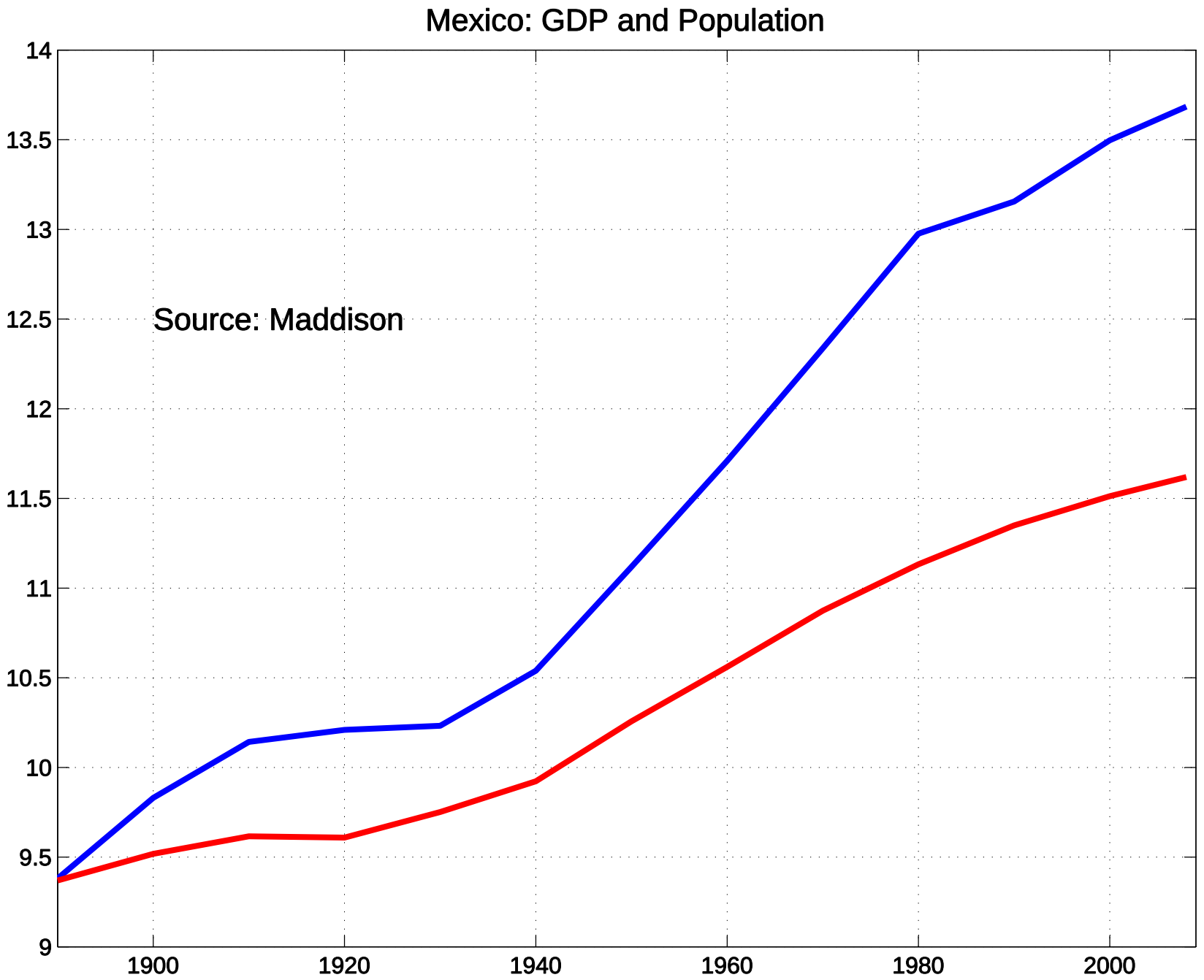
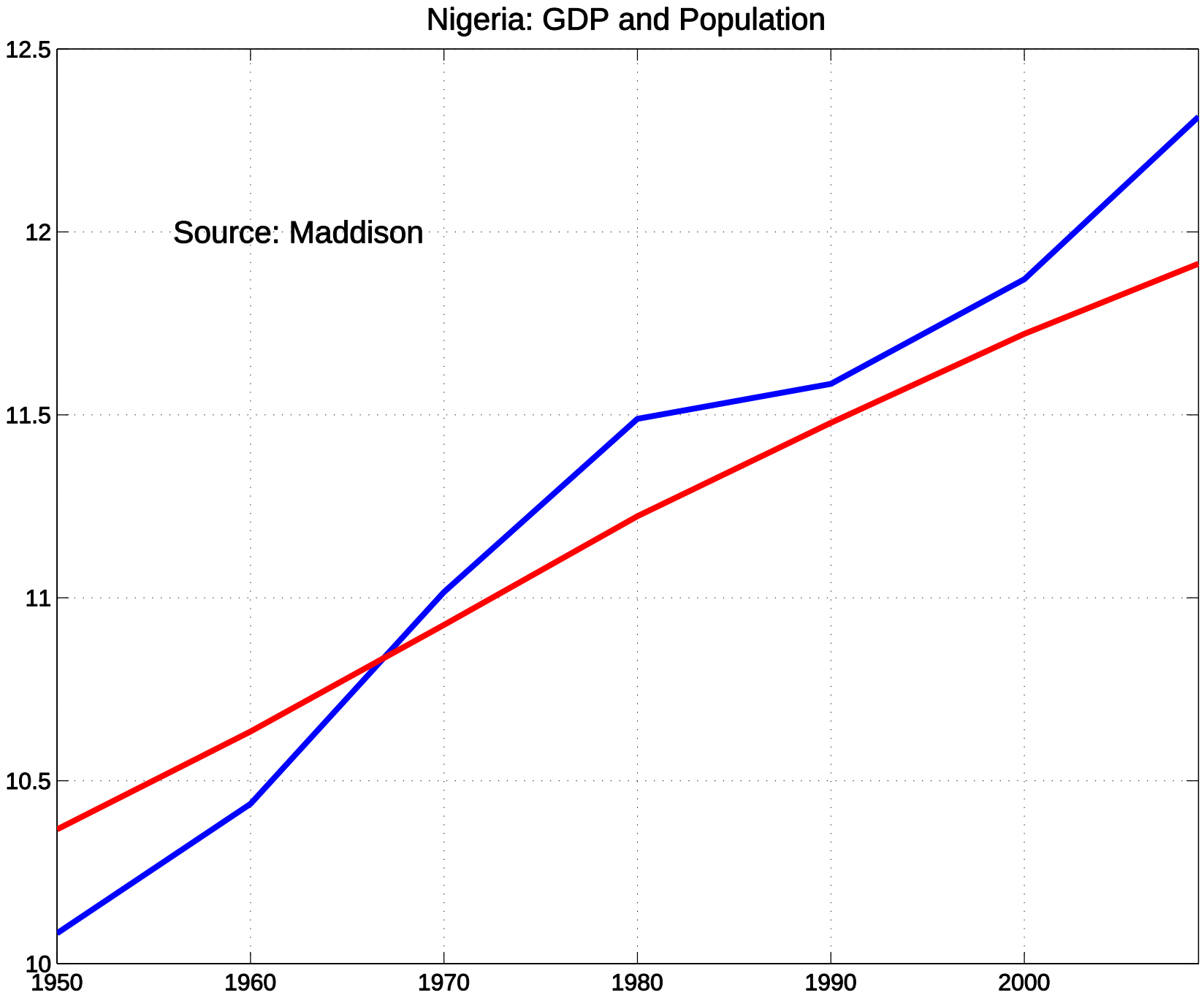
2000


Mexico: GDP and Population
Source: Maddison
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
1900
1920
1940
1960
1980
2000


Nigeria: GDP and Population
Source: Maddison
12.5
12
11.5
11
10.5
10
1950
1960
1970
1980
1990
2000

- As incomes rose, beginning in 18th century in Europe, populations rose dramatically: a Malthusian response

- But as incomes continued to grow, population growth slowed down, even contracted

- What fertility choices were people making during these demographic transitions?

- Becker (1960) saw (initially in completely different context) that parents' desire for children needed to involve two dimensions—one for the number of children, a "good", and another for the legacy left for each child, also a "good": a "quantity/quality" tradeoff

- In later developments, in joint work with Barro (1988),(1989), and Murphy and Tamura (1990), Becker applied the quantity/quality trade-off directly on growth and the demographic transition

- Related papers by Hansen and Prescott (1998), Doepke (2000), Galor and Weil (2000), Lucas (2002)

- This paper follows these in attempting to understand the problems people face in deciding on family size and child raising and why these decisions changed so radically during the industrial revolution

- What follows next is

  1. Model of Malthusian society of traditional farm workers
  2. Stand-alone model based on human capital, potential for sustained growth
  3. Migration - 1
  4. Migration - 2
  5. Conclusion

1. A Land-Based Economy

- Smith, Ricardo, Malthus
- Fertility, population central to production, incomes
- Becker, Barro (1988)

- Bellman equation

$$v(x) = \max_{c,n} W(c, n, v\left(x/n\right))$$

- Specialize to log preferences

$$v(x) = \max_{c,n} c^{1-\beta} n^{\eta} v\left(x/n\right)^{\beta}$$

- One unit of labor, x units of land $\Longrightarrow Ax^{\alpha}$ units of consumption good

- Divided between adults and children

$$c + kn \leq Ax^{\alpha}$$

- Land divided equally: x/n units of land per child

- Solve BE, conclude that number of children is

$$n = \frac{\eta - \alpha\beta}{1 - \beta + \eta} \frac{Ax^{\alpha}}{k}$$

  provided that $\eta > \alpha\beta$.

- Situation of individual family with x units of land

- Landless farm worker?

$$n = \frac{\eta}{1 - \beta + \eta} \frac{(1 - \alpha) Ax^{\alpha}}{k}$$

- Now consider economy as a whole

- L total land, N_t population at t

- Families alike $\Longrightarrow x_t = L/N_t$, $N_t n_t = N_{t+1}$.

- Population dynamics

$$N_{t+1} = N_t n_t = N_t^{1-\alpha} \frac{\eta - \alpha\beta}{1 - \beta + \eta} \frac{A}{k} L^{\alpha}$$

- Steady-state population N_{ss} with $n = 1$

$$N_{ss} = \left(\frac{\eta - \alpha\beta}{1 - \beta + \eta} \frac{A}{k} \right)^{1/\alpha} L$$

- Classic Malthusian model

- Population settling down to sustainable steady state

- Determined by available resources and standards of child care

- Malthusian theory is not a model of species breeding itself into starvation or extinction

- Describes a population settling down to a sustainable steady state, determined by available resources and standards of child care

- Model applies to traditional human societies, routinely applied to animal populations

- An empirical success over the centuries prior to IR: explains why pre-industrial societies in the Edens of Java or South China had similar living standards as those on fringes of Sahara or Arctic

2. A Human Capital Economy

- Have set the stage for the question: What was the industrial revolution?
- Try to avoid mere labelling: "an increase in the rate of technological change"
- Ask what individual decisions, actions brought these events about
- Focus here on educated, literate people. Urban. Landless.
- Who are these people?

- Scientists? Important sub-group but much too narrow
- Think of terms like bourgeoisie, intelligentsia, traders, merchants, middlemen.
- People we read about in work of Landes, Mokyr, Greif, Botticini and Eckstein, others
- Where did this class come from? Need to go back to pre-history
- How did it create an ongoing revolution? Let's see

- Let S be years of schooling: only "asset"

- Productivity over career is

$$v(S) = B\alpha(S)^{\theta} e^{-rS}$$

reflecting productive benefit of schooling $B\alpha(S)^{\theta}$ and cost of postponing earnings e^{-rS}.

- Bellman equation is

$$v(S) = \max_{c,n,z} c^{1-\beta} n^{\eta} \left[e^{\gamma} v\left(z\right)\right]^{\beta}$$

subject to

$$c \leq v(S)\left(1 - \delta n z\right)$$

- Re-state the problem as

$$\max_{n,z} \left([1 - \delta n z]^{1-\beta} n^{\eta} \left[e^{\gamma} v(z) \right]^{\beta} \right)$$

- Here δ is a given constant and $\delta n z$ is the **fraction** of earnings devoted to quantity n and quality z of children (cf Becker, Murphy, Tamura (1990))

- Note that sustained growth built into this equation by factor e^{γ} : $\gamma > 0$ is the growth rate of productivity per generation

- First order conditions are

$$n = \frac{\eta}{\delta z \left(1 - \beta + \eta\right)}$$

and, since $v(S) = B\alpha(S)^{\theta} e^{-rS}$,

$$\eta = \beta \frac{z v'(z)}{v(z)} = \beta z \left[\frac{\alpha'(z)}{\alpha(z)} - \frac{r}{\theta}\right]$$

- Along a balanced growth equilibrium $z = S$, a constant

- Follows that fertility n is constant as well: both $n > 1$ and $n < 1$ are possibilities

- [Digression: In this talk the growth factor γ is taken as given. Will be maintained below.

- But of course there are many well-developed models that rationalize sustained growth.

- My favorites emphasize the learning we get thoughout our careers from the people around us (Lucas (2009), Staley (2011), Luttmer (2014), Lucas and Moll (2014), Perla and Tonetti (2014), Caicedo, Lucas and Rossi-Hansberg (forthcoming))

- These models, given a cohort structure, can lead to balanced growth paths of the form

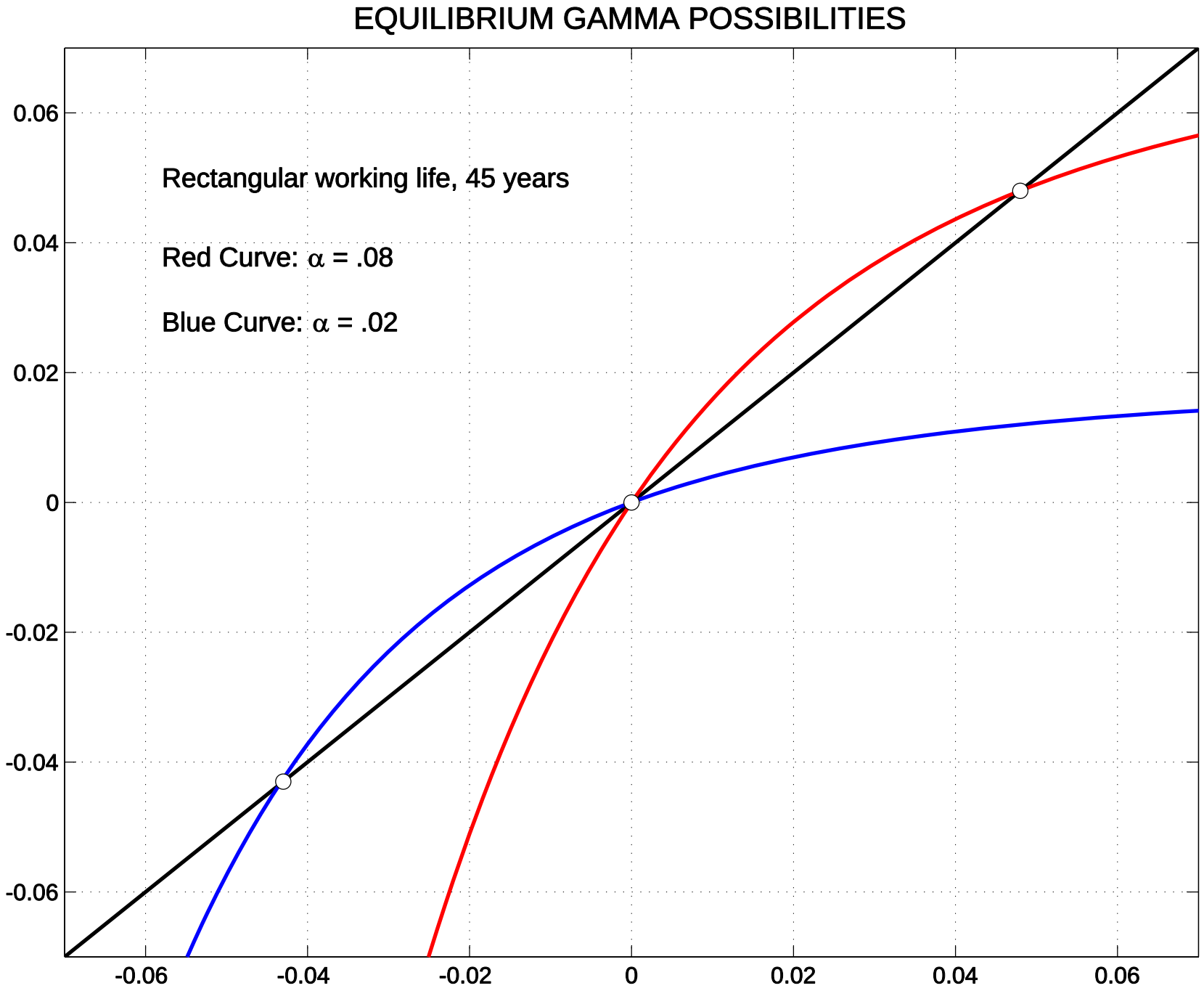
$$\frac{\gamma}{\theta} = \alpha(S) \int_0^\infty \left(1 - e^{-(\gamma/\theta)s}\right) \pi(s) ds.$$

  where $\pi(s)$ is the fraction of agents of age s, $\alpha(S)$ is the rate of Poisson arrivals of new ideas, θ is the thickness of an assumed Pareto tail.

- With these as given fundamentals, the growth rate γ can be derived

- Higher schooling levels can induce higher growth rates

- Both stagnation and sustained growth are equilibrium possibilities: a much needed tipping point!


EQUILIBRIUM GAMMA POSSIBILITIES
Rectangular working life, 45 years
Red Curve: α = .08
Blue Curve: α = .02
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.06
-0.04
-0.02
0
0.02
0.04
0.06

- End digression]

3 . Migration dynamics - 1

- Have set out descriptions of two distinct economies
  - Land-based Malthusian economy, landless people at subsistence levels
  - Human capital-based economy, sustained productivity growth at constant rate
- Now view these types—N_{ct} the urban population at t, and N_{ft} the unskilled rural population—as co-existing in the same economy
- Dynamics involve migration from rural to urban **and** fertility choices of each type

- Assume to begin with that $N_{ct} = N_c$ (a constant, with $n = 1$ and no new entry) and that productivity in the urban sector grows as in the last section

$$v_t(S) = v_0(S)e^{\beta\gamma t}$$

- Now we modify the utility function of urban people to include a demand for low-skilled services and let rural people migrate to the city

- Retaining the log utility used above, this demand function for low-skilled services will take the form

$$e^{\beta\gamma t}v_0(S) \max_{a,n,z} \left([1 - \delta nz - wa]^{1-\beta} n^{\eta} a^{\xi} v\,(z)^{\beta} \right)$$

- The first order condition for a_t is

$$a_t w_t = e^{\beta\gamma t} v_0(S) \frac{\xi}{1-\beta+\eta+\xi} = C e^{\beta\gamma t}$$

  where C is a constant, a_t is hours of service and w_t the wage rate

- Low-skilled N_{ft} now have two sources of employment: services N_{at} and farm work $N_{ft} - N_{at}$

- Markets clear when

$$w_t = \alpha L^{1-\alpha} \left(N_{ft} - N_{at} \right)^{\alpha-1}$$

  and

$$a_t = \frac{N_{at}}{N_c}.$$

- These are three equations in a_t, w_t and N_{at}, given populations N_c and N_{ft}

- Solve for

$$\frac{N_{at}}{\left(N_{ft} - N_{at}\right)^{1-\alpha}} = De^{\beta\gamma t}$$

- Follows that $N_{at} \to N_{ft}$ (unskilled labor becomes increasingly urban) as $t \to \infty$

- Also that $w_t \to \infty$ and $a_t \to N_{ft}/N_c$ as $t \to \infty$

- This is all we need to get the emptying-out of traditional agriculture

- But landless farmers are still Malthusians, even after moving to city
- They still have nothing to pass on to their children
- Their fertility choice is still

$$n_t = \frac{1}{k} \frac{\eta w_t}{1 - \beta + \eta}$$

just as in Section 1

- Implied evolution of N_{ft} is just

$$N_{f,t+1} = n_t N_{ft}$$

- Since $w_t \to \infty$ it follows that

$$\lim_{t \to \infty} \frac{N_{f,t+1}}{N_{ft}} \to \infty$$

- A proletariat blindly multiplying itself toward subsistence income levels!

- Impossible? Well, yes.

4 . Migration dynamics - 2

- Now we go to an opposite extreme, drop the possibility of unskilled urban jobs, admit people to cities only if they match up to city standards

- What is that?

- Consider an unskilled parent, earning wage w_t.

- If he chooses to raise n unskilled children he solves

$$\max_n \left[w_t - kn\right]^{1-\beta} n^{\eta} {w_{t+1}}^{\beta}$$

- He has no control of their wage next period, but he is pleased if his children do well

- The optimal number of children is

$$n = \frac{\eta w_t}{(1 - \beta + \eta)\, k}$$

- The parent's utility (including altruism) is

$$\left(\frac{1-\beta}{1-\beta+\eta}\right)^{1-\beta} \left(\frac{\eta}{1-\beta+\eta}\right)^{\eta} k^{-\eta} {w_{t+1}}^{\beta} w_t^{1-\beta+\eta}$$

- Alternatively, an unskilled parent can decide to put his children through school

- If so, he must meet the school costs $v_t(S) = e^{\gamma t} B \alpha(S)^{\theta} e^{-rS}$

  ... and ensure that each child attains $z = S$ years of school

- Only choice left is n so he solves

$$\max_{n} \left[w_t - v_t(S) \delta n S \right]^{1-\beta} n^{\eta} e^{\beta \gamma} v_t \left(S \right)^{\beta}$$

- The first order condition is

$$v_t(S)\delta n S = \frac{\eta w_t}{1-\beta+\eta}$$

- Implied utility is

$$\left(\frac{1-\beta}{1-\beta+\eta}\right)^{1-\beta}\left(\frac{\eta}{1-\beta+\eta}\right)^{\eta}\left(\frac{1}{v_t(S)\delta S}\right)^{\eta} e^{\beta\gamma} v_t\left(S\right)^{\beta} x_t^{1-\beta+\eta}$$

- Everyone has both options so equality must hold:

$$w_{t+1} = \left(\frac{k}{\delta S}\right)^{\eta/\beta} e^{\gamma} v_t\left(S\right)^{1-\eta/\beta}$$

- Now w_t is just the marginal value of unskilled labor:

$$w_t = \alpha L^{1-\alpha} N_{ft}^{\alpha-1}$$

so we have

$$\alpha L^{1-\alpha} N_{f,t+1}^{\alpha-1} = \left(\frac{k}{\delta S}\right)^{\eta/\beta} e^{\gamma} v_t \left(S\right)^{1-\eta/\beta}$$

which reduces to

$$N_{ft} = G e^{-\gamma[(1-\eta/\beta)/(1-\alpha)]t}$$

where G is a constant

- Need $\beta > \eta$ (quality $>$ quantity) for $N_{ft} \to 0$

- In fact, both these migration models—based on employment opportunities for the unskilled or on the possibility of educating children—can operate at the same time, even in the same family

- Many combinations can be seen in different countries

- Have focused on parental role on schooling, and parental support very important

- But external effects are large and successful governments generally support schooling for all

5. Conclusion

- So what was the industrial revolution? Coal and steel and sweatshops? Still going strong in some places

- But increasingly the main consequences are the ongoing movement of people out of traditional agriculture and the steadily increasing fraction of people who are well educated, the problem-solvers who spend their working hours thinking, talking, arguing, otherwise communicating with other like-minded people

- In contrast with traditional agricultural workers, these educated people have much autonomy at work and in their personal lives, conditions that workers in the 18th century would not even have imagined

- Now everyone in the world knows that some people—and not just Europeans—enjoy these lucrative and interesting conditions, even though they themselves do not

- They know, too, that traditional agriculture is a dead end and those who can do so are escaping to the cities

- Countries that respond to these migrants with good schools, schools that open doors to challenging jobs, will be rewarded just as the U.S. was in the last century or South Korea and Taiwan in this one