Macroeconomic Theory I

Section 3 - Growth (II): Ideas, history, geography and institutions

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Section 3 - Growth (II): The Plan

1. Endogenous Growth Theory: key ideas.
2. EG with fixed saving rate and share of R&D.
3. Learning-by-doing: The AK model
4. The Romer (1990) model: endogenous R&D investment.
5. Fundamental determinants of growth

New growth theory: Key ideas

- Production function for innovation

$$\dot{A}(t) = f(A(t), x(t))$$

  x = some measure of R&D efforts.

- *A* is *non-rival* but potentially *excludable*

- Growth *as a result of market-based incentives* requires that innovators enjoy market power.

Determinants of innovation

1. Public support for basic research.
2. Private incentives for R&D investment
   - requires some excludability
   - rate of return on R&D.
3. Alternative opportunities for talented individuals
   - Baumol (1990); Murphy, Shleifer & Vishny (1991)
4. Learning-by-doing
   - Innovation as a side-effect of economic activity
   - AK models

EG with fixed R&D share

- 2 sectors: goods production and R&D
- No capital
- Fixed share of workforce a_L allocated to R&D
  - $a_L L(t)$ workers in R&D
  - $(1-a_L)L(t)$ workers in goods production.

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$$Y(t) = A(t)(1-a_L)L(t); \quad \dot{A}(t) = B[a_L L(t)]^\gamma A(t)^\theta; \quad \dot{L}(t) = nL(t)$$

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Model dynamics:

$$g_A = Ba_L^\gamma L(t)^\gamma A(t)^{\theta-1}$$

$$\dot{g}_A(t) = \gamma n g_A(t) + (\theta-1)[g_A(t)]^2$$

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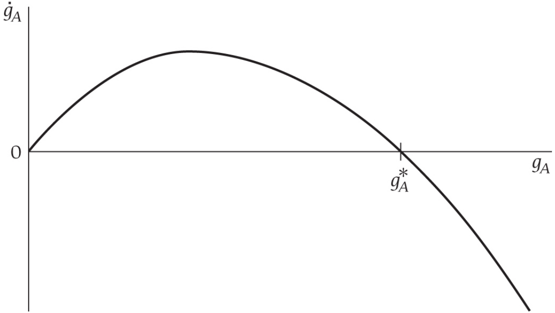
- Value of θ determines the behavior of this model.

$$\dot{g}_A(t) = \gamma n g_A(t) + (\theta - 1)[g_A(t)]^2$$

Case (1): decreasing returns to A ($\theta < 1$)



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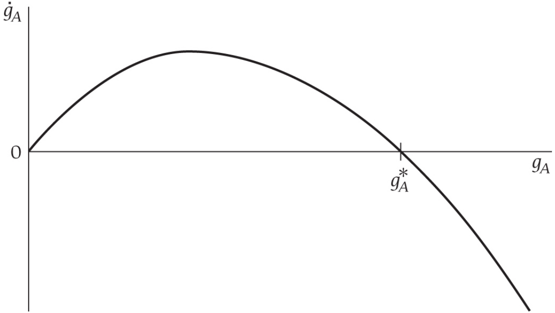

- stable equilibrium
- $g_A^* = \frac{\gamma}{1-\theta} n$;
- no growth effect of a_L and L;
- $g_{Y/L}$ depends (positively) on population growth;
- *semi-endogenous growth*.

Effect of a increase in a_L with $\theta < 1$

$$g_A(t) = B{a_L}^{\gamma} L(t)^{\gamma} A(t)^{\theta-1}$$

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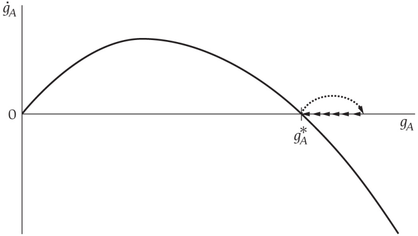

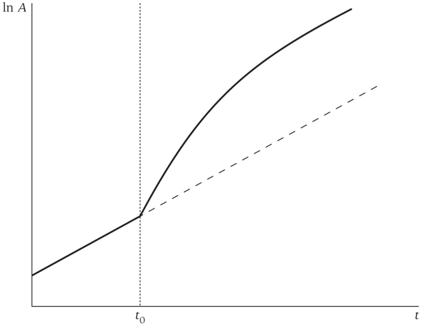

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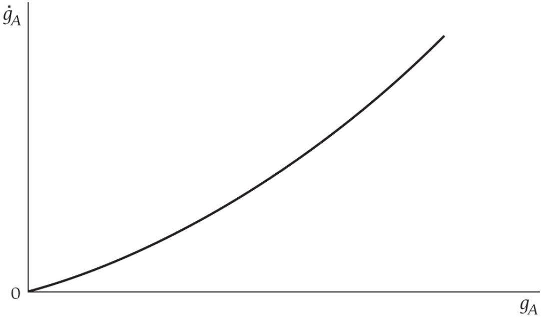
Case (2): increasing returns to A ($\theta > 1$)



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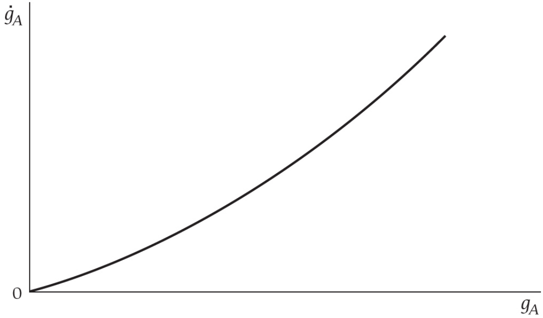

- no equilibrium;
- ever-increasing ('explosive') growth;
- intuition: every marginal addition to A results in a bigger increase in A.

Case (3): constant returns to A ($\theta = 1$)

$$g_A(t) = Ba_L^{\gamma} L(t)^{\gamma}$$
$$\dot{g}_A(t) = \gamma n g_A(t)$$

- if $n > 0$, g_A is ever-increasing ('explosive' growth);
- If $n = 0$, g_A fixed.
  - no transitions, always in equilibrium
  - fully endogenous growth: growth depends on a_L
  - example of a *linear growth model* ($\dot{A}$ linear in A)

Learning-by-doing: The AK model

Assumptions:

$$Y(t) = K(t)^{\alpha}[A(t)L(t)]^{1-\alpha}; \qquad A(t) = BK(t);$$

$$\dot{K}(t) = sY(t); \qquad L(t) = \bar{L}.$$

Kenneth Arrow

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Dynamics of the model:

$$Y(t) = bK(t) \quad \text{with } b = (B\bar{L})^{1-\alpha}$$

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$$\dot{K}(t) = sbK(t) \Rightarrow g_K = sb$$

PS: where have you seen $Y = bK$ and $g_K = sb$ before??

EGT and the *linearity* assumption

- *AK model*
  - o A=BK $\Rightarrow$ g_Y depends on s.
- *EG model with fixed R&D share and $\theta = 1$*
  - o $\dot{A} = \left[B\left(a_L L\right)^{\gamma}\right] A$ $\Rightarrow$ g_Y depends on a_L and L.
- *Romer (1990)* is also a *linear* growth model
  - o $\dot{A} = \left(D L_A\right) A$ $\Rightarrow$ g_Y depends on L.

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- *Romer (1990)* is also a *linear* growth model
  - o $\dot{A} = (DL_A)\,A$ $\Rightarrow$ g_Y depends on L.
- Linearity $\rightarrow$ stable endogenous growth.
- *The 'trick' of EGT*:
  - o if $\dot{A}$ is linear in A, it means that the other factors that multiply A in the knowledge-production function affect the rate of growth of technology (so they will affect growth).
  - o $\dot{A} = f(x)A$ $\Rightarrow$ $\frac{\dot{A}}{A} = f(x)$

The Romer model

(a simplified version)

- Output produced from intermediate inputs.
- Technical progress = increasing variety of intermediate inputs.
- Innovation arises from *R&D* investment by private actors.
- Market power: inventor has permanent patent rights.

Assumptions about production

- Production function:

$$Y = \left[\int_{i=0}^{A} L(i)^{\phi} di \right]^{1/\phi}, \quad 0 < \phi < 1$$

  - A continuum of inputs, ranging from 0 to A.
  - $L(i)$ = quantity of input i = labor employed in producing i;
  - Decreasing MP of each input i, but CRS in total inputs amount L_Y.

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- When all existing inputs are produced in equal quantities:

$$Y = \left[A \left(\frac{L_Y}{A} \right)^{\phi} \right]^{1/\phi} = A^{\frac{1-\phi}{\phi}} L_Y$$

  - L_Y= workers in inputs production = tot. amount of inputs

Demand for inputs

- Patent-holder hires workers to produce the input associated with her idea
- Inputs then sold to final output producers
- Downward-sloping demand curve for input i:

$$L(i) = \left[\frac{\lambda}{p(i)} \right]^{\frac{1}{1-\phi}}$$

$p(i)$ = price of input i.

Other key assumptions

- Full-employment and fixed labor force:

$$L_A(t) + L_Y(t) = \bar{L}$$

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- Euler equation (from log utility & budget constraint):

$$g_C = \dot{C}(t)/C(t) = r(t) - \rho$$

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- Free-entry condition in the R&D sector:

$$\int_{\tau=t}^{\infty} e^{-r(\tau-t)}\pi(i,\tau)d\tau = \frac{w(t)}{BA(t)}$$

PV of profits from an idea = production cost

The logic of the Romer model

Discount rate (ρ)

$\downarrow$

Interest rate (r)

$\searrow$

Market power of innovators $\left(\frac{1-\phi}{\phi}\right)$

$\swarrow$

Discounted returns from R&D activity (R) $\leftarrow$ **Population** $(\bar{L})$

$\searrow$ $\swarrow$

Number of workers in R&D (L_A)

$\downarrow$

growth rate of technical knowledge (g_A)

$\downarrow$

Growth rate of the economy (g_Y)

Solving the model

- $g_Y = \frac{1-\phi}{\phi} g_A + g_{L_Y} = \frac{1-\phi}{\phi} B L_A + g_{(\bar{L}-L_A)}$.
- Steady state $\rightarrow$ constant L_A.
- Use R&D free-entry condition to infer $L_A^\star$ and thus $g_Y^\star$.

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- Steps:

1. Calculate $\pi(t)$ and $g_\pi = g_\pi(g_W)$
2. Figure out r and g_W
3. Calculate PV of profits from a new idea $R(t)$ using $R(t) = \frac{\pi(t)}{r-g_\pi}$
4. Set PV of profits from idea = production cost, to obtain L_A^* & g_Y^*.

Step 1: find $\pi(t)$ and g_π

- Monopolist patent-holder sets

$$p(i,t) = \frac{\eta}{\eta - 1} w(t)$$

- From demand curve we have:

$$\eta = -\frac{\partial L(i)}{\partial p(i)} \frac{p(i)}{L(i)} = \frac{1}{\phi - 1} \quad \rightarrow \quad p(i,t) = \frac{w(t)}{\phi}$$

- Profits at each point in time:

$$\pi(t) = \frac{\bar{L} - L_A}{A(t)} \left[\frac{w(t)}{\phi} - w(t) \right] = \frac{1-\phi}{\phi} \frac{\bar{L} - L_A}{A(t)} w(t)$$

- Growth rate of profits:

$$g_\pi = g_W - g_A$$

Step 2: find r and g_W

- All output is consumed and we are assuming constant L_A, so

$$g_C = g_Y = \frac{1-\phi}{\phi} B L_A$$

- Having g_C, we can derive interest rate $r(t)$ from Euler equation:

$$r(t) = \rho + \frac{\dot{C}(t)}{C(t)} = \rho + \frac{1-\phi}{\phi} B L_A$$

- Constant monopoly mark-up implies constant wage share, so

$$g_W = g_Y = \frac{1-\phi}{\phi} B L_A \quad \rightarrow \quad g_\pi = g_W - g_A = \frac{1-\phi}{\phi} B L_A - B L_A$$

Step 3 - Figure out the PV of profits from a new idea

- PV of profits from a new idea:

$$R(t) = \frac{\pi(t)}{r - g_\pi}$$

- From previous steps:

$$\pi(t) = \frac{1-\phi}{\phi}\frac{\bar{L} - L_A}{A(t)} w(t); \quad r = \rho + \frac{1-\phi}{\phi} BL_A; \quad g_\pi = \frac{1-\phi}{\phi} BL_A - BL$$

- Plugging-in:

$$R(t) = \frac{\pi(t)}{r - g_\pi} = \frac{\frac{1-\phi}{\phi}\frac{\bar{L}-L_A}{A(t)} w(t)}{\rho + BL_A} = \frac{1-\phi}{\phi}\frac{\bar{L} - L_A}{\rho + BL_A}\frac{w(t)}{A(t)}$$

Step 4 - Set R(t) = production cost and infer L_A^*

$$\frac{1-\phi}{\phi}\,\frac{\bar{L}-L_A}{\rho+BL_A}\,\frac{w(t)}{A(t)}=\frac{w(t)}{BA(t)} \quad \rightarrow \quad L_A^{\star}=(1-\phi)\bar{L}-\frac{\phi\rho}{B}$$

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$$\Downarrow$$

$$L_A^*=\max\{(1-\phi)\bar{L}-\frac{\phi\rho}{B},0\}$$

$$\Downarrow$$

$$g_Y^*=\max\{\frac{(1-\phi)^2}{\phi}B\bar{L}-(1-\phi)\rho,0\}$$

(note: economy always on equilibrium path–no transition dynamics)

(A second look at) The logic of the model

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Welfare: optimal vs. actual growth

1. *Write PV of lifetime utility as a function of L_A*

$$U = \int_{t=0}^{\infty} e^{-\rho t} \ln C(t) dt \quad \Rightarrow \quad U = \int_{t=0}^{\infty} e^{-\rho t} ln\left[C(0) e^{g_C t}\right] dt$$

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$$C(t) = Y(t)/\bar{L}; \qquad C(0) = \frac{\bar{L} - L_A}{\bar{L}} A(0)^{\frac{1-\phi}{\phi}}; \qquad g_c = g_y = \frac{1-\phi}{\phi} B L_A$$

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$$U = \frac{1}{\rho}\left(ln \frac{\bar{L} - L_A}{\bar{L}} + \frac{1-\phi}{\phi} ln A(0) + \frac{1-\phi}{\phi} \frac{B L_A}{\rho} \right)$$

Welfare: optimal vs. actual growth

2. *Maximize PV lifetime utility w.r.t. L_A*

$$\max_{L_A} U = \frac{1}{\rho}\left(ln\frac{\bar{L}-L_A}{\bar{L}} + \frac{1-\phi}{\phi} lnA(0) + \frac{1-\phi}{\phi}\frac{BL_A}{\rho}\right)$$

$$\downarrow$$

$$L_A^{OPT} = \max\{\bar{L} - \frac{\phi}{1-\phi}\frac{\rho}{B}, 0\}$$

3. *Compare L_A^{OPT} with $L_A^\star$*

$$L_A^\star = (1-\phi)L_A^{OPT}$$

Takeaways:

- Too little R&D ($L_A^* < L_A^{OPT}$);
- more market power for innovators (lower input substitutability ϕ) would increase welfare.

Extensions

- Introducing fixed capital K
  - K produces Y but not $\dot{A}$ –> s has level effect [Romer 1990]
  - but if K produces $\dot{A}$, s can have growth effects.
- Decreasing returns to A in the production of $\dot{A}$
  - –> semi-endogenous growth [Jones 1995]
  - long-run growth depends only on n, while forces affecting L_A have only level effects.
- Quality-ladder models
  - innovation = improvement of existing inputs [Grossman & Helpman 1991; Aghion & Howitt 1992]
  - Similar conclusions.

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- Solow predicts too much convergence...

  ...but Romer predicts too much *divergence!*

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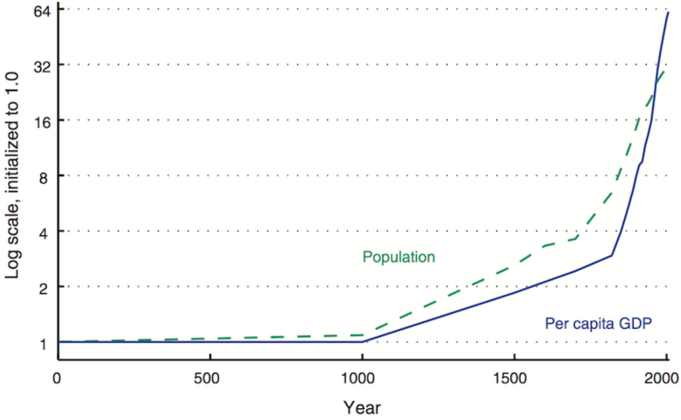
- EGT ignores technological imitation across countries
- L_A & $\bar{L}$ increasing in most countries, but no 'exploding' growth
- P.Krugman: *"too much of [EGT] involves making assumptions about how unmeasurable things affect other unmeasurable things."*
- BUT: EGT might explain growth at a worldwide scale in the very long-run.

GDP per capita & population in US + Europe



(from Paul Romer "The deep structure of economic growth")

"The factors we have listed (innovation, economies of scale, education, capital accumulation, etc.) are not causes of growth: they *are* growth"

(North and Thomas, 1973, p.2)

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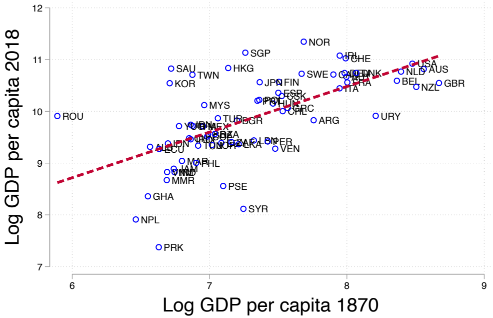
Persistence in GDP per capita

- most countries that are rich today were rich in 1870.
- hard to explain based on the growth models we studied.
- are there deeper fundamental forces that exhibit persistence and explain both past and current productivity?



Fundamental causes: the main candidates

Should be very persistent, vary substantially across countries, and plausibly affect productivity.

- Historical events at critical junctures
- Geography
- Culture
- Institutions
- Their historical interactions.

Institutions

"Institutions are the rules of the game in a society (...) the humanly devised constraints that shape human interaction" [North 1990]

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Laws, organizations, social norms, conventions.

- determine the organization of production, the distribution of wealth & power, and the structure of incentives for investment
- 'old-school' Marxian view: institutions=relations of production
- today's standard view: property rights and contracting institutions
- both too narrow!

Institutions

Game-theoretical definition:

- Institutions determine payoff-matrix & strategy set in a game
- but at the same time are equilibrium outcomes of a prior game.

How do we know if institutions matter?

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How do we know if institutions matter?

- Institutions are endogenous and evolve slowly
- randomized experiments are usually impossible
- evidence from *natural experiments*
  - Accidents of history/policy that create arbitrary differences in institutions.
  - A few examples...

The Korean War as a natural experiment

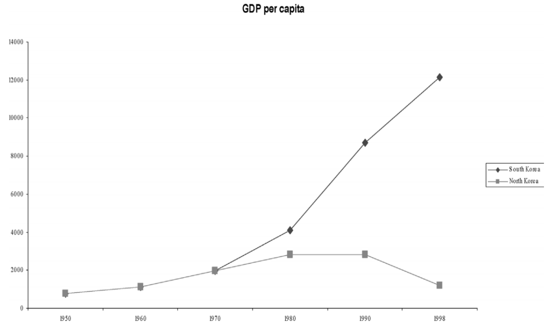
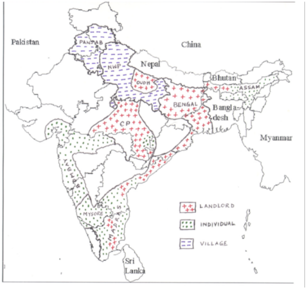


Figure 3. GDP per capita in North and South Korea, 1950–98.

- Similar economy, same culture and common government until 1948/1950
- Then North ‘treated’ with authoritarian communist central planning and South with export-oriented capitalism.

Development legacy of colonialism in India

- 1750-1860: British colonization of India.
- *Zamindari system*: local elite given right to extract taxes from farmers; they then pass a share to British.
- *Ryotwari system*: individual peasants fully own their land and pay taxes directly to the British.

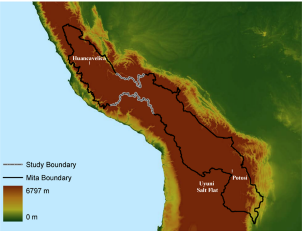


Development legacy of colonialism in India

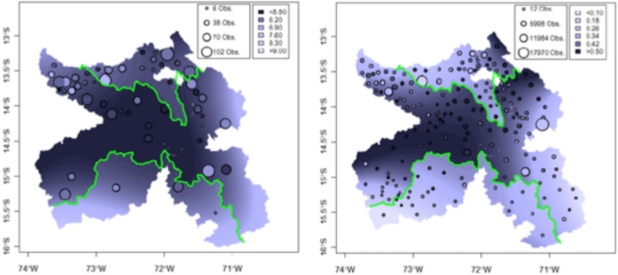
- *Zamindari system* ⇒ worse agricultural productivity, health and education that still persist today
- Main channel seem to be investment in agricultural improvements and public goods.
  - Not having secure property rights on their land, farmers did not invest.
  - After independence, former Zamindari districts display higher inequality and economically-disruptive social conflict.
  - Farmers & local elites cannot form an alliance to get infrastructures built.
- Zamindari system led to more *extractive* institutions.
- Banerjee and Iyer (2004)

Colonialism and forced labor in Peru

- 1573-1812 *Mita* system
  - forced labor in Potosi silver/mercury mines
- *Mita* area delineated by Spanish in 1573
- Melissa Dell (2010) compared villages on different sides of the Mita border.



Effect of the *Mita* institution in Peru



(a) Consumption (2001) (b) Stunting (2005)

Today households inside the Mita have ≈ 25% lower consumption, worse health outcomes, participate less in markets

What accounts for the Mita effects?

Dell (2010) proposed explanation:

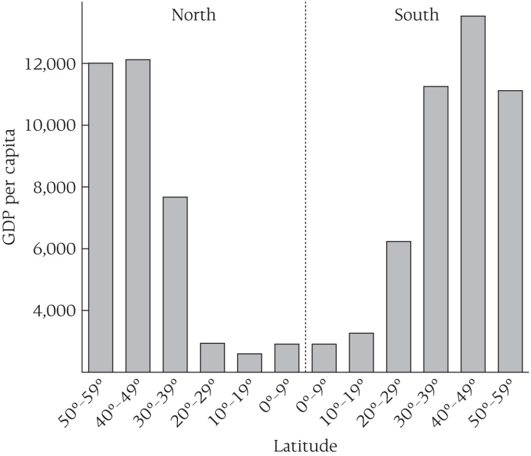
- To minimize competition in exploiting labor, the Spanish restricted the formation of haciendas in Mita districts
- Subsistence farming with little formal markets and no well-defined property rights over land for long time
- Outside the Mita, many powerful haciendas formed a lobby that was able to get roads built, improving market access
- Areas inside the Mita have inherited fewer infrastructures, and worse access to road networks

...OK, but what causes institutions?

"While we have good reason to believe that economic institutions matter for economic growth, we lack the crucial comparative static results which will allow us to explain why equilibrium economic institutions differ." (Acemoglu, 2005, p.389)

- Why Europe (and not Africa or America) first developed the complex capitalist institutions that led to the industrial revolution?
- Can geography help answer these questions?

Latitude and income



- suggests that geography must somehow *be part* of the story
- *directly*: land, labor productivity, natural resources... [Bloom & Sachs, 1998]
- *indirectly*: influence on the historical evolution of institutions [J. Diamond, 1997]

Diamond (1997): Guns, Germs and Steel

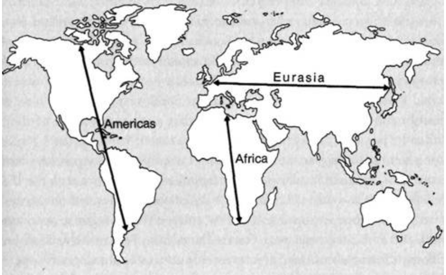
- Why was it Europeans that colonised the rest of the world and first experienced economic growth?

- Eurasia had a head start (1000s of years) in agriculture
  - Agriculture arose independently only in 9 small regions around the world.
  - Fertile Crescent by far the earliest ($> 10,000$ years ago)
  - Outside Eurasia food production arose only thousands of years later (2,500 BC in today's eastern USA)

- Agriculture → Sedentary societies w/ storable food surpluses → complex States & markets → technology and military power

Diamond (1997): Guns, Germs and Steel

- Why Eurasia?
- Eurasia was better endowed with wild plants and animals suitable for domestication...
- ..and its east/west axis facilitated the spread of these domesticates throughout the continent.



The Fertile Crescent

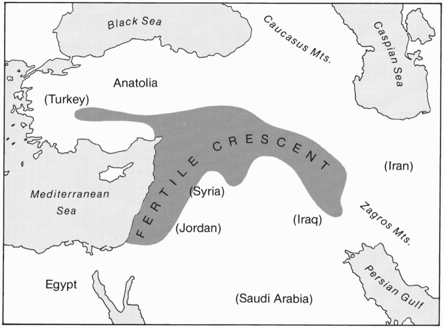


Figure 8.1. The Fertile Crescent, encompassing sites of food production before 7000 B.C.

- The earliest ‘cradle of civilization’
- Other cradles of civilization in the rest of the world?
- Yes, but: much later, with less productive species available, and with less margin for east-west spread.

A formalization of the J.Diamond hypothesis

- Olsson & Hibbes (2005)

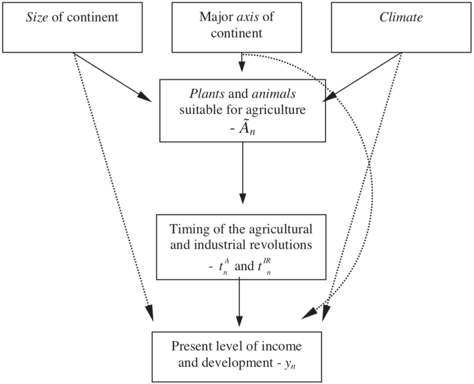


Fig. 1. Biography and long-run economic development.

Geography & Institutions

- Both 'fundamental causes' of growth
- But only geography is exogenous
- The most important determinant of institutions might be 'length of exposure to sedentary agriculture'
- Historical exposure to agriculture → historical evolution of institutions → institutions today
- Of course, institutions also differ for reasons unrelated to geography.
- Geography does not seem to explain why the industrial revolution happened in Britain rather than some other part of Eurasia.