Convergence, divergence, convergence clubs

Mayer-Foulkes (2002): 5 clusters of countries forming convergence clubs

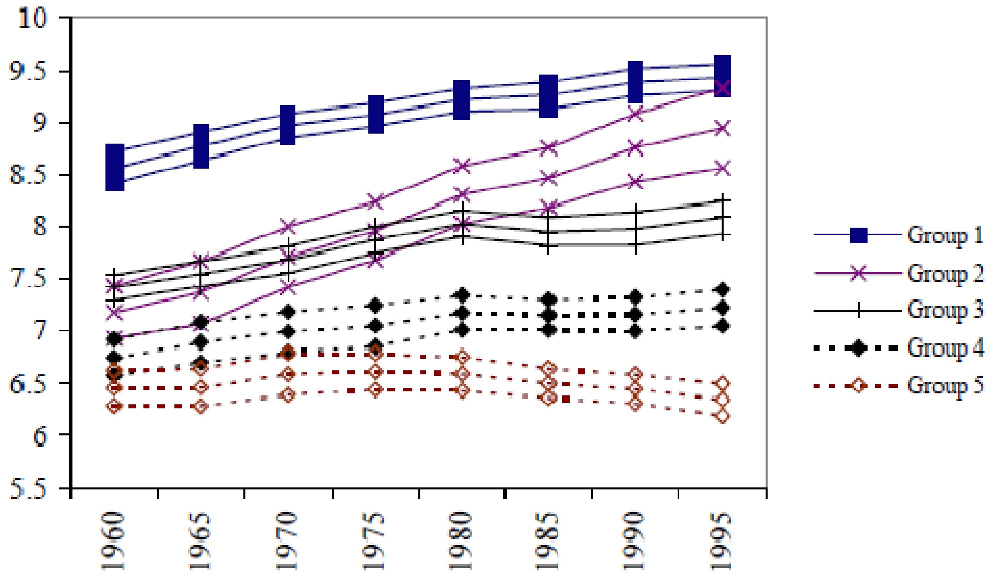
period: 1960 - 1997

Group	West Europe and North America	East Asia Pacific	Latin America and Caribbean	Middle East, North Africa and Turkey	South Asia	Sub-Saharan Africa	Total
1	19	3	7	1	0	0	30
2	3	7	2	0	0	2	14
3	0	3	15	5	1	3	27
4	0	2	4	3	5	13	27
5	0	0	1	0	1	26	28
Total	22	15	29	9	7	44	126

Table I. The five clusters of countries by continents.

Five convergence clubs in set of 'non-mainly-oil exporting countries': 1960-1997
Mayer-Foulkes (2002)

Figure 3.1 Income per Capita



1 = West Europe, North Amer. **2 = East Asia, Pacific** 3 = Lat. Amer. Carabbian

4 = Middle East, North Africa, Turkey **5 = Sub Sahara Africa**

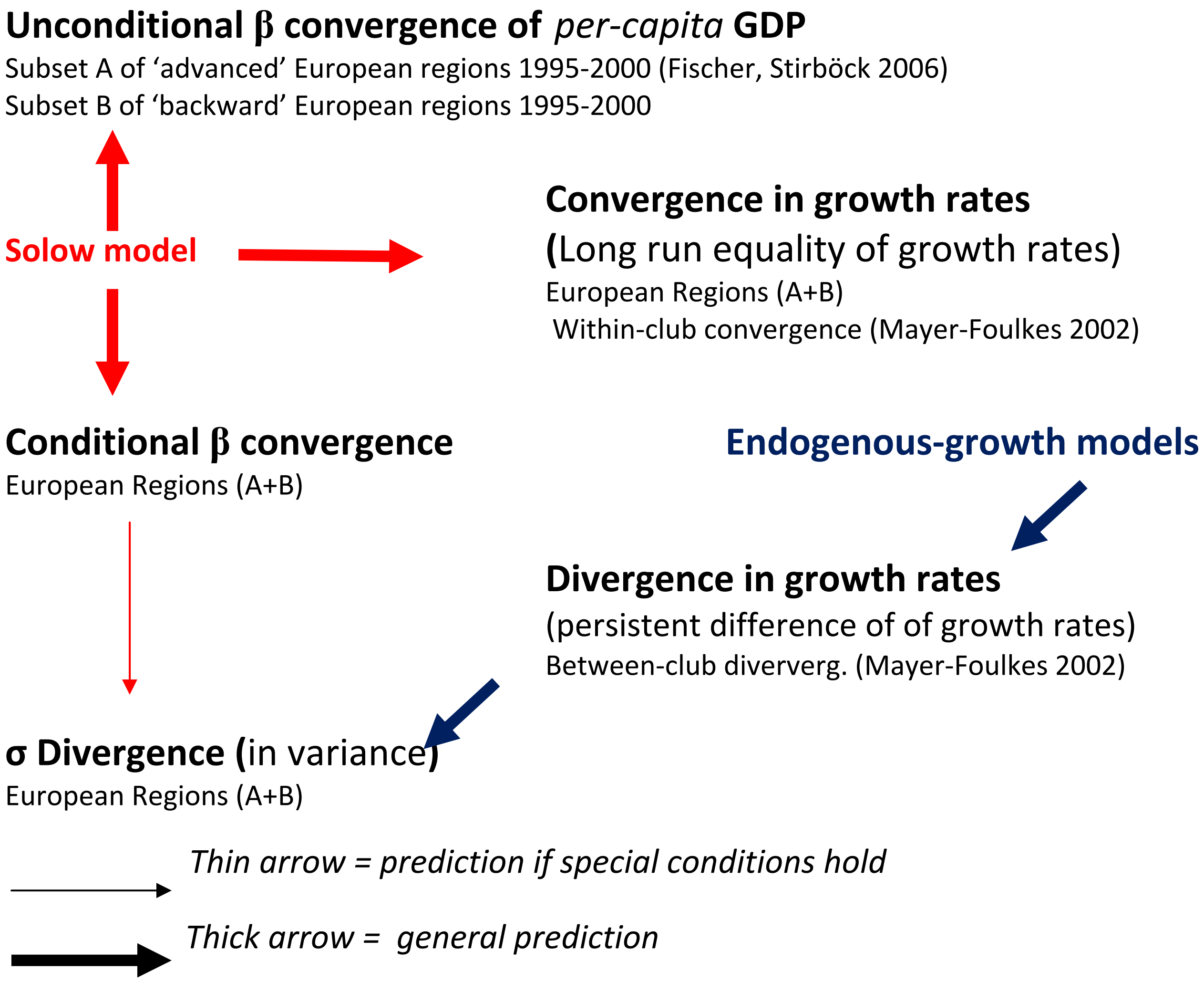
Mayer-Foulkes (2002) data show a variety of growth trajectories:

1. Selected evidence of unconditional convergence of GDP per capita (mainly **within** groups, but also **between** ‘some’ groups)

2. Evidence of convergence in growth rates **within** groups

3. Convergence in growth rates **between** ‘some’ groups

4. Divergence in growth rates **between** some other groups


Unconditional β convergence of per-capita GDP
Subset A of 'advanced' European regions 1995-2000 (Fischer, Stirböck 2006)
Subset B of 'backward' European regions 1995-2000
Solow model
Convergence in growth rates
(Long run equality of growth rates)
European Regions (A+B)
Within-club convergence (Mayer-Foulkes 2002)
Conditional β convergence
European Regions (A+B)
Endogenous-growth models
Divergence in growth rates
(persistent difference of of growth rates)
Between-club diververg. (Mayer-Foulkes 2002)
σ Divergence (in variance)
European Regions (A+B)
Thin arrow = prediction if special conditions hold
Thick arrow = general prediction

Explaining convergence and divergence in growth rates

a. Theories of convergence:	neoclassical factor accumulation costless technology transfer (knowledge spillovers)
b. Theories of divergence:	endogenous growth
c. Theories of convergence and divergence	endogenous technology growth + costly technology transfer

Assume:

1. **Knowledge spillovers within each sector**
2. **Capability of exploiting knowledge spillovers requires up-to-date 'innovation experience', that is, it requires that the firm is currently engaged in R&D activity.**
3. **developing domestic applications of foreign technology (technology adoption) is not much different from R&D. Foreign technologies need successful adaptation to the local conditions of production.**
4. **successful adaptation of foreign technology is produced by a successful R&D investment: a successful innovation.**
5. **A successful innovation in sector i will then:**
   - **Fill gap between domestic and world-frontier technology in i**
   - **Contribute to the advancement of frontier technology in i**

Implications:

6. **No matter how backward was sector *i* in country h before time t, after one innovation arrives at time t, the sector is poised on the knowledge-frontier till one innovation arrives in some country, other than h.**
7. **The average time interval sector *i* of country h will spend on the frontier depends on the frequency of innovation arrival in country h, relative to the rest of the world.**
8. **The expected distance of country h from the world frontier, will depend on the same circumstances affecting the relative innovation probability, hence on the R&D effort of country h relative to the rest of the world.**
9. **If the country in question does not innovate at all, the expected distance to the frontier will grow to infinity (growth divergence)**

- **h countries**
- **m sectors** of intermediate innovation goods in each country
- Cross country sector-specific spillovers
- A^*_{t-1} cross country max. **sector productivity** (subscript i omitted) at beginning of period t. If 1 innovation arrives in t:
- $A_t = \gamma A^*_{t-1} \quad \gamma > 1$
- No matter how low is country productivity A_{t-1} in this sector, if R&D is successful, the sector technology gap $A^*_{t-1} - A_{t-1}$ is closed, and the country improves upon the former technology frontier

  notice that this is a simplifying assumption: we expect that approaching the technology frontier is a more gradual process

A. Gershenkron: the advantage of backwardness

knowledge spillovers induce technology catching up in each sector i

$A_t = \gamma\, A^*_{t-1}$ with probability $\boldsymbol{\mu}$ (*subscript i omitted*)

$A_t = A_{t-1}$ with probability $1 - \mu$

$\boldsymbol{\mu = \lambda\phi(n)}$ $\quad$ $\mathbf{n} = n_t = R_t / A^*_t = R_t / \gamma A^*_{t-1} =$ *prod. adjusted R&D*

$A^*_t = \gamma A^*_{t-1}$ *target productivity level*

$\mu =$ *country probability of innovation arrival in each sector*

Sector technology frontier, worldwide

- $A^*_t = \gamma A^*_{t-1}$ with probability $\mathbf{\mu^*}$
- $A^*_t = A^*_{t-1}$ with probability $1 - \mu^*$
- $\mathbf{\mu^*} = \sum^{h}_{j=1} \lambda_j \phi(n_j)$ = *prob 1 innovation occurs in <u>some</u> country* < 1
- $EA^*_t = \gamma\mu^* A^*_{t-1} + (1 - \mu^*)A^*_{t-1} = A^*_{t-1}\, \mu^* (\gamma - 1) + A^*_{t-1}$
- $E(A^*_t - A^*_{t-1}) = \mu^* (\gamma - 1)\, A^*_{t-1}$

Expected frontier growth in sector i

$$g^* \quad = \quad E(A^*_t - A^*_{t-1}) / A^*_{t-1} \quad = \quad \mu^*(\gamma - 1)$$

Expected growth in one country is higher if distance to frontier is higher

for small g, $g \approx \log(1 + g)$

exp. growth $g \approx E[\log(1 + g_t)] = E[\log A_t / A_{t-1}] = E[\log A_t - \log A_{t-1}] =$

$= \quad \mu\log(\gamma A^*_{t-1}) + (1 - \mu)\log A_{t-1} - \log A_{t-1}$

$= \quad \mu\log\gamma + \mu\log A^*_{t-1} - \mu\log A_{t-1} = \mu\log\gamma + \mu\log(A^*_{t-1} / A_{t-1})$

$= \quad \mu(\log\gamma + d_{t-1})$

- where $d_{t-1} = \log(A^*_{t-1} / A_{t-1})$ = ‘distance to frontier’

advantage of backwardness:

expected growth increases with distance to frontier

Law of motion of expected distance in one country

$d_t = d_{t-1}$ with prob $(1 - \mu^*)$ *no sector innovation world-wide*

$d_t = 0$ with prob μ *sector innovation in the country, and possibly outside: no matter how large is the number of innovating countries*

$d_t = \log(\gamma A^*_{t-1} / A_{t-1})$
$= \log \gamma + d_{t-1}$ with prob $(\mu^* - \mu)$ *sector innovation outside, and not in the country*

$(\mu^* - \mu) + \mu + (1 - \mu^*) = 1$

Remark: country innovation probability μ is independent of what other countries are doing and of the number of countries competing in the innovation arena *no innovation world-wide* | *innovation abroad but not at home* | *innovation at home possibly also abroad*

$$E(d_t) = d_{t-1}\,\mathbf{(1-\mu^*)} + (\log\gamma + d_{t-1})\,\mathbf{(\mu^* - \mu)} + 0 \cdot \boldsymbol{\mu}$$

$$= d_{t-1}\,(1-\mu^*) + d_{t-1}\,(\mu^* - \mu) + \log\gamma\,(\mu^* - \mu)$$

$$= d_{t-1}\,(1-\mu) + (\mu^* - \mu)\log\gamma$$

- μ is uniform across sectors in one country
- innovation arrival is independent across sectors
- number of sectors is large

exp. sector distance in country $E(d_t)$ **=** *average sector distance in country* z_t

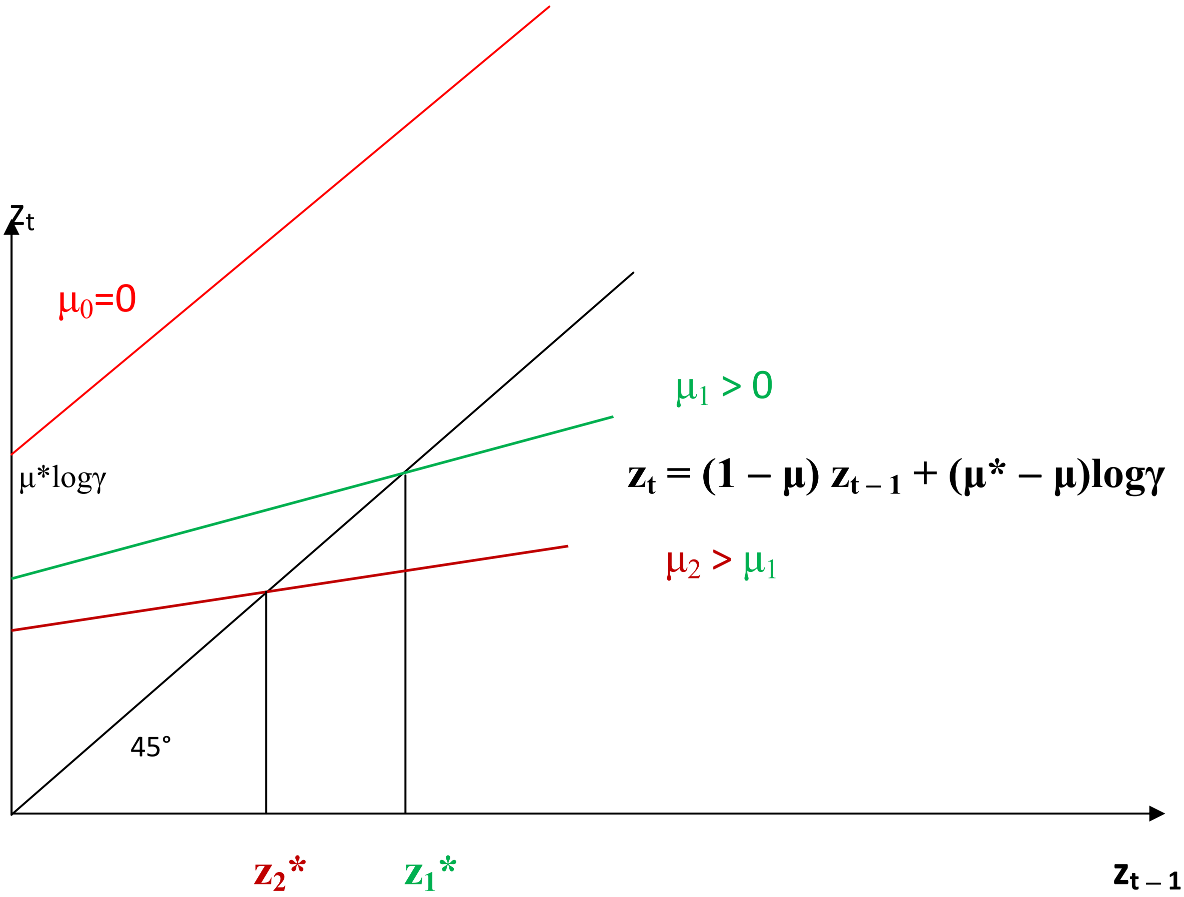
$z_t = E(d_t)$

$z_t = (1 - \mu)\, d_{t-1} + (\mu^* - \mu)\log\gamma =$

$E(z_t) = z_t = (1 - \mu)\, z_{t-1} + (\mu^* - \mu)\log\gamma$

$$\mathbf{z_t = (1 - \mu)\, z_{t-1} + (\mu^* - \mu)\log\gamma}$$

linear law of motion of average distance $\mathbf{z_t}$



$z^* = [(\mu^* - \mu) / \mu] \cdot \log\gamma$ **if** $\mu > 0$

$z^* = +\infty$ **if** $\mu = 0$

representation in terms of 'proximity' to the frontier and small country assumption: frontier *A** is exogenous for a small country

proximity to the frontier: $a_t = A_t / A^*_t =$ $0 \leq a \leq 1$

assume for simplicity that the number of countries is large and 1 innovation arrives with probability 1 in at least 1 country: $\mu^* = 1$

- $A^*_t = (1 + \gamma) A^*_{t-1}$

expected technology level in 1 sector:

- $E(A_t) = \mu A^*_t + (1 - \mu) A_{t-1}$
- divide by $A^*_t = (1 + \gamma) A^*_{t-1}$
- $E(a_t) = \mu + (1 - \mu) (1 + \gamma)^{-1} a_{t-1}$

Cross-sector average:

- $\mathbf{a}_t = \mu + (1 - \mu) (1 + \gamma)^{-1} \mathbf{a}_{t-1}$

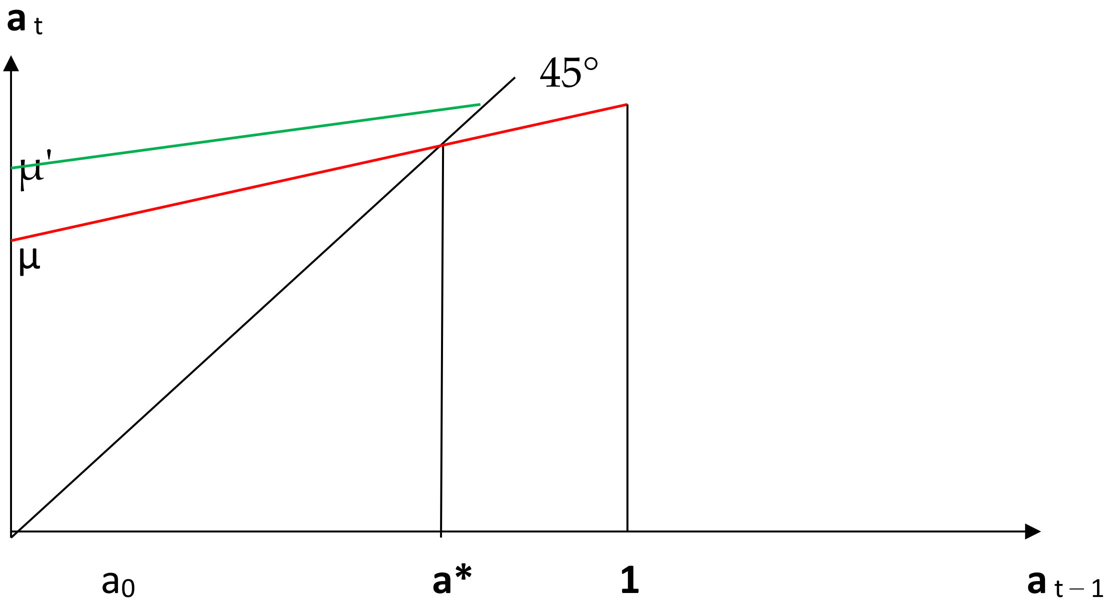
- $\mathbf{a}_{\mathbf{t}} = \mu + (1 - \mu)(1 + \gamma)^{-1}\mathbf{a}_{\mathbf{t-1}}$

- equilibrium μ depends on R&D effort n*, hence on π and λ but does not depend on a_{t-1}

- this implies that the relation between a_t and a_{t-1} is linear!

sector average proximity converges to $\boldsymbol{a}^* = \mu + \frac{1-\mu}{1+\gamma}\boldsymbol{a}^*$

$\boldsymbol{a}^* = \frac{\mu(1+\gamma)}{\mu+\gamma} = \frac{(1+\gamma)}{1+(\frac{\gamma}{\mu})}$ **μ' > μ' causes higher $\boldsymbol{a}^*$**



During transition to long run proximity level a* we have $a_t < a^*$

- country sector-average technology growth rate g is higher than frontier growth rate $\gamma = g^*$
- a country further away from its long run proximity a* can exploit greater advantage from backwardness and grows faster
- this is a 'conditional convergence' prediction

In the long run:

- 'absolute convergence' to the same steady state and GDP per capita does not obtain
- countries converging to different proximity level a* have different long-run average technology level A_t
- A_t is closer to or more distant from A_t^* depending on R&D effort
- if $\mu > 0$ the country growth rate $g = g^*$

Conditions for optimum R&D > 0

optimal R&D effort R^*_t maximizes expected innovation pay-off:

$$\text{Max}_R: \quad \Pi_t \cdot \lambda\phi(R_t / A^*_t) - R_t = \Pi_t \cdot \lambda\phi(n_t) - R_t$$

where $\phi'(n_t) > 0$

$\phi''(n_t) < 0$ decreasing returns to R&D

1^{st} ord. cond. for optimum $n_t^* = R^*_t / A^*_t$

$\Pi_t \cdot \lambda\phi'(n^*_t) / A^*_t \leq 1$

strict equality holds if n* > 0

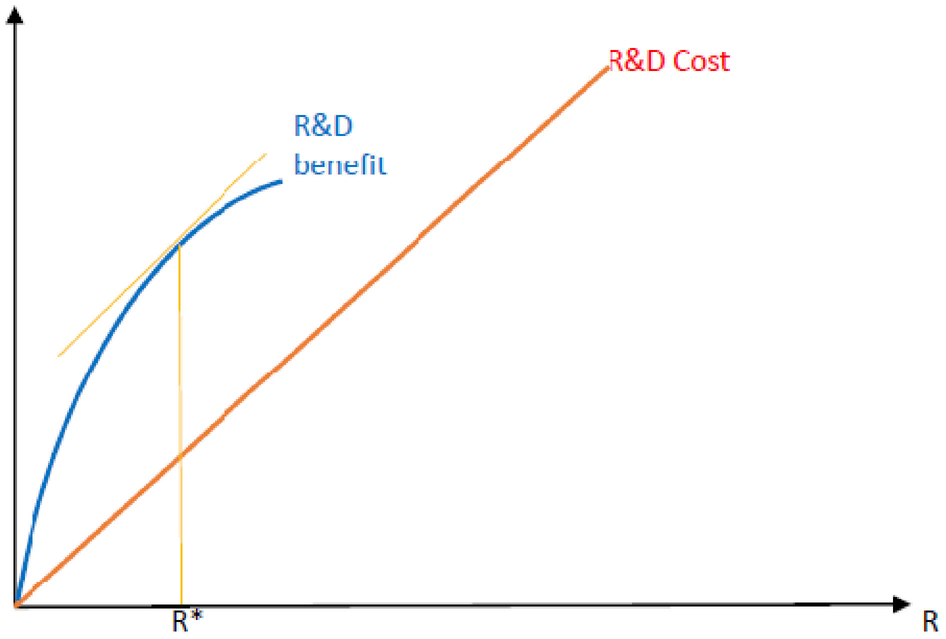
strict inequality holds if n* = 0

$\pi \cdot \lambda\phi'(n_t) \leq 1$ *where* $\pi = \Pi_t / A^*_t$

if $\pi \cdot \lambda\phi'(0) > 1$ then $\pi \cdot \lambda\phi'(n^*_t) = 1$ and $n^*_t > 0$

if $\pi \cdot \lambda\phi'(0) \leq 1$ then $n^*_t = 0$

- If $\phi'(0) < +\infty$, then→ no R&D when research productivity λ and/or monopoly profit π are too low



Because the marginal expected R&D benefit is decreasing
Necessary condition for $R^* > 0$ at given A, hence $R^*/A = n^* > 0$ is:
Slope of expected R&D benefit > 1 at $R = 0$

If efficiency λ of R&D, and/or productivity adjusted profit π are too low…
so that the blue curve lies below the red curve, then $R^* = 0$

Long-run expected growth across countries

Two sets of countries: **n* = optimum $\frac{R_t^*}{A_t^*}$**

Set 1 n* > 0 $\mu > 0$ → $g_h = g^* = \mu^* \log\gamma$ = expected growth rate of technology frontier

- country convergence in growth rate
- conditional β convergence in GDP per capita
- steady-state Y/L relative to 'frontier' Y*/L increasing with n*

Set 2 n* = 0 $\mu = 0$ → $g_h = 0$

- divergence in growth rate with respect to set 1
- lack of β conditional convergence with respect to set 1
- σ divergence in GDP per capita with respect to set 1

Divergence Case $n^* = 0$ $\mu = 0$ $\rightarrow$ $g_h = 0$ **too restrictive**

More general: $n^* \geq 0$ $\mu \geq 0$ $\rightarrow$ $g_h < g^*$

- This case is discussed in Aghion, Howitt, Mayer-Foulkes (2005) introducing the possibility that **R&D is constrained by credit**

- **credit multiplier *v*** is an increasing function of the effectiveness of legal institutions in enforcing credit contracts and repayment of debt outsider's own funding of R&D depends on GDP/L

In a credit constrained economy: max R&D depends on outsider's funds and credit

R&D = own funds + credit < R&D maximizing net innovation pay-off

$\mathbf{R_t = \nu\, \omega}\ A_{t-1}$ R&D expenditure depends on A_{t-1} v = credit multiplier

proximity to the frontier: $a_t = A_t / A^*_t = 0 \leq a \leq 1$

R&D expenditure is lower if proximity to frontier is lower, because per-capita income is lower!

Lower proximity to the frontier causes tighter credit constraint hence lower R&D, lower innovation probability

productivity adjust. R&D $\mathbf{n_t} = \mathbf{R_t} / A^*_t = \boldsymbol{\nu}\, \boldsymbol{\omega}\, A_{t-1} / A^*_t = (1 + g^*)^{-1} \boldsymbol{\nu}\, \boldsymbol{\omega}\, \mathbf{a}_{t-1}$

innovation probability $\mu = \lambda\phi(\mathbf{n_t}) = \lambda\phi((1 + g^*)^{-1} \boldsymbol{\nu}\, \boldsymbol{\omega}\, \mathbf{a}_{t-1})$

$\phi' > 0 \qquad \phi'' < 0$

$\mu = \Phi(\mathbf{a}_{t-1}) \qquad \Phi' > 0 \qquad \Phi'' < 0$

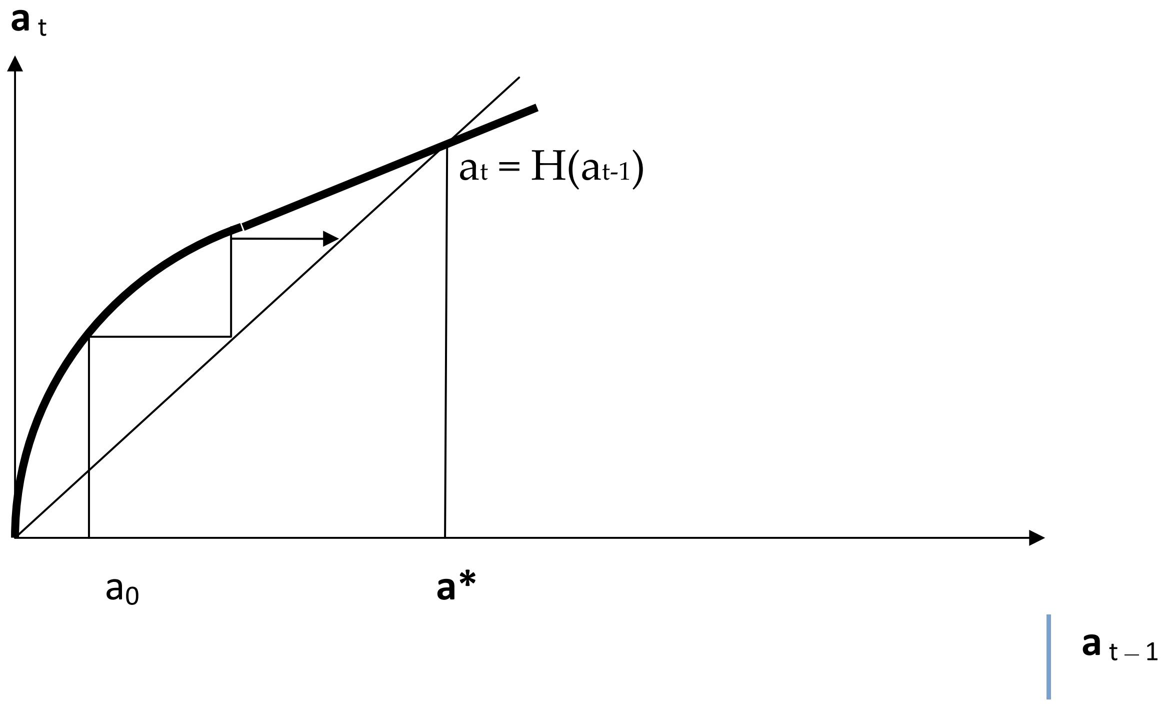
$\partial\mu / \partial\, \mathbf{a}_{t-1} = \lambda\phi' \cdot (1 + g^*)^{-1} \boldsymbol{\nu}\, \boldsymbol{\omega}$

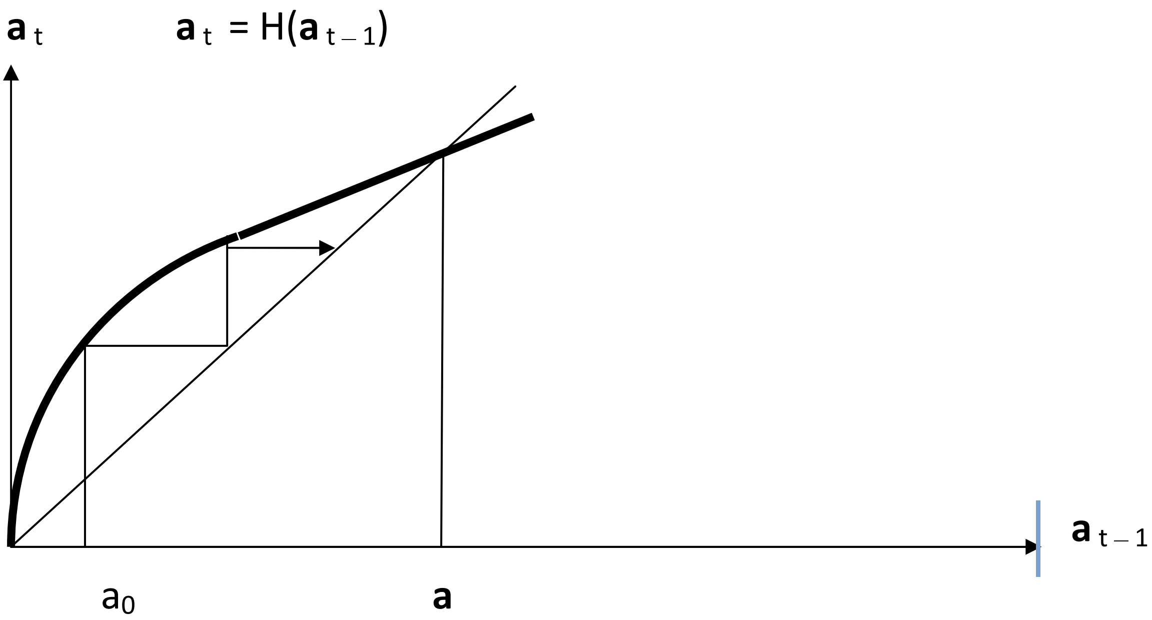
- **Lower proximity to frontier causes lower innovation probability**
- **Marginal innovation probability Φ' is lower if credit multiplier is lower**
- **The relation between $\mathbf{a}_{t-1}$ and $\mathbf{a}_t$ is non-linear**

$E(a_t) = \mu + (1 - \mu)\,(1 + g^*)^{-1} a_{t-1}$

Credit constrained economy : $\mu_t = \Phi(\mathbf{a}_{t-1})$ and $\mu_t = 0$ if $\mathbf{a}_{t-1} = 0$

this induces the non linear relation: $\mathbf{a}_t = H(\mathbf{a}_{t-1})$ $H' > 0$ $H'' < 0$



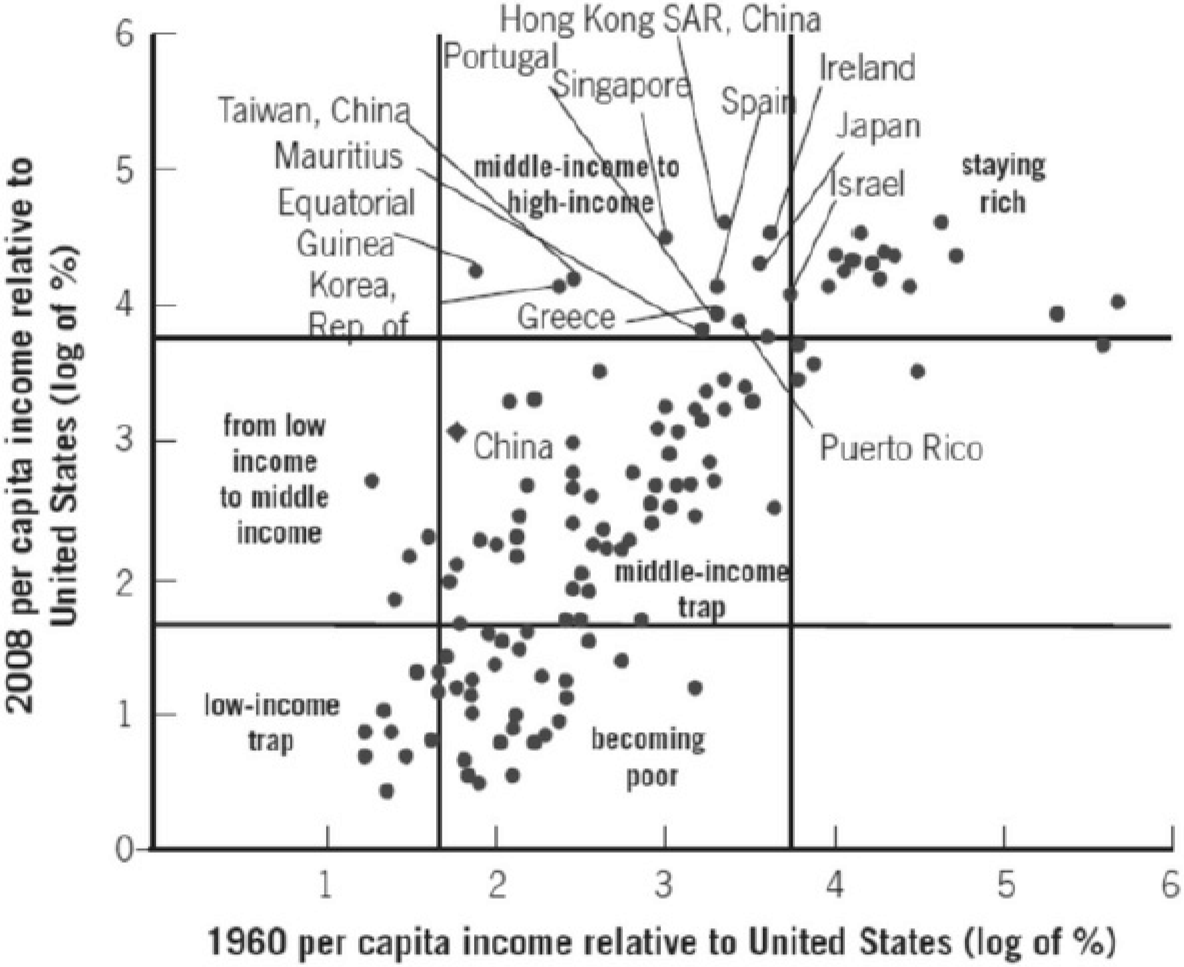


slope H'(0) increasing function of credit multiplier *v*

slope H'(0) > 1 → **growth convergence g = g*, β conditional convergence**

slope H'(0) < 1 → growth divergence $0 \leq g < g^*$

Convergence, divergence and 'middle-income trap'



Source: World Bank China 2030 Report

$$\begin{bmatrix} N_{3,1} & N_{3,2} & N_{3,3} \\ N_{2,1} & N_{2,2} & N_{2,3} \\ N_{1,1} & N_{1,2} & N_{1,3} \end{bmatrix}$$

N_{ij} = **number of countries in state j in 1960 that are in state i in 2008**

$N_j = \sum_i N_{i,j}$ **total number of countries in state j in 1960**

$f_{i,j} = \frac{N_{i,j}}{N_j}$ **= frequency of transitions from state j to state i**

This may interpreted as a transition probability yielding a matrix of transition probabilities between states:

$$\begin{bmatrix} f_{3,1} & f_{3,2} & f_{3,3} \\ f_{2,1} & f_{2,2} & f_{2,3} \\ f_{1,1} & f_{1,2} & f_{1,3} \end{bmatrix}$$

Hint:

If a country is not starting on the frontier, probability of falling behind or of staying still is higher than the probability of reaching the frontier.

Moreover,

Countries falling behind are increasing their distance from frontier

Possibly, R&D is too low to keep pace with frontier productivity growth

Growth rate g < frontier growth rate g*

A variation on Aghion and Howitt (2009):

Suppose that the size of the innovation step is not uniform across innovators, partly because innovations may be non-radical (incremental).

For every innovation event, the size of innovation step γ is randomly extracted from the interval (1, $\bar{\gamma}$], and will generally differ among innovating countries.

If the number of countries investing in R&D is higher:

- the probability of reaching the frontier as a result of an innovation success is lower.
- On average, an R&D success leaves the innovator at a higher distance from the frontier.
- country productivity dynamics converges to a higher distance from the frontier, and the probability of divergence is higher

a ‘Red Queen Paradox’?

As a result of economic development, the number of countries competing in the R&D arena becomes larger.

preserving the same probability of reaching the frontier requires an ever higher R&D effort.

To preserve their position, competitors have to run faster…

advantage from backwardness: exploiting knowledge spillovers

disadvantage from backwardness: entering a more crowded R&D arena, with a relatively weak innovation system