II. Technology and its diffusion

Two sector model

- Labour split into two sectors
  - Production $Y = AK^{\beta} N_Y^{1-\beta}$ $N_Y = (1-\mu)N$
  - Education/research μN
- Productivity growth

$$\gamma = \frac{\dot{\lambda}}{\lambda} = b\mu$$

  - Standing on shoulders
  - Proportion vs number of reserachers

Standing on shoulders

The cumulative nature of knowledge

- Isaac Newton: “If I have been able to see further, it was only because I stood on the shoulders of giants”

- Examples
  - James Watt’s discovery of the steam engine in 1769 came about while James Watt was repairing an earlier steam engine invented 57 years earlier by Thomas Newcomen, which was an improvement of a steam engine patented in 1698 by the Englishman Thomas Savery, which followed another designed by the Frenchman Denis Papin around 1680, which in turn had precursors in the ideas of the Dutchman Christiaan Huygens, and so on.
  - Windows vs Apple
  - Pepsi vs Coca-cola.

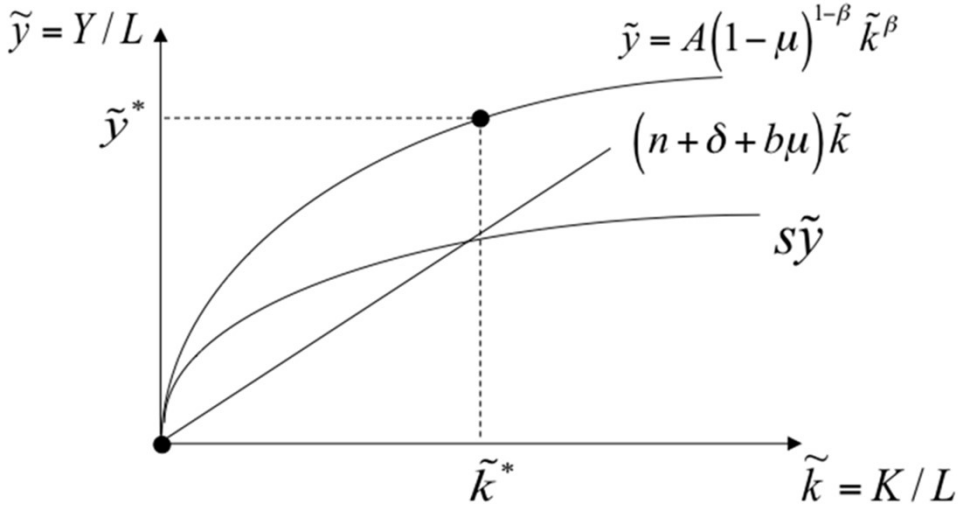
Two sector model

- Steady state

$$\dot{\breve{k}} = sAu^{1-\beta}\breve{k}^{\beta} - \left[n + \delta + b\left(1-u\right)\right]\breve{k}$$

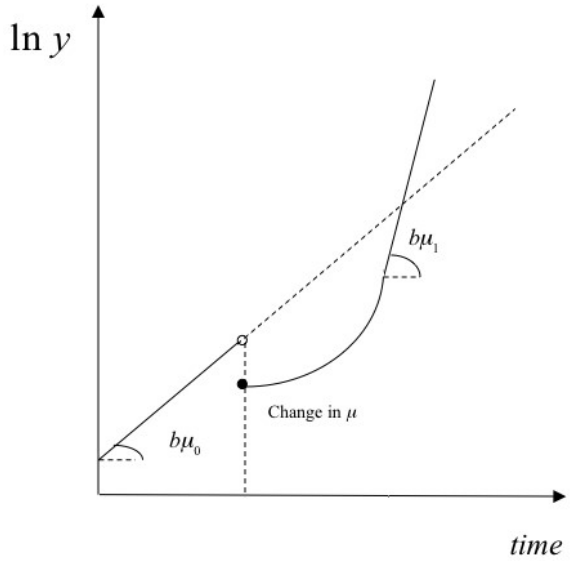
$$\left(\frac{Y}{N_Y}\right)^{*} = A^{\frac{1}{1-\beta}}\left(\frac{s}{n+\delta+\gamma}\right)^{\frac{\beta}{1-\beta}} e^{\gamma t}$$

$$y^{*} = \left(\frac{Y}{N}\right)^{*} = \left(1-\mu\right) A^{\frac{1}{1-\beta}}\left(\frac{s}{n+\delta+\gamma}\right)^{\frac{\beta}{1-\beta}} e^{b\mu t}$$



A hybrid model

- It shares with the neo-classical model the feature that it has a transitional dynamics and a stable steady state
  - The saving rate, *s*, determines the steady state and changes in *s* produce "level effects" (just like in the Solow model).
  - Contrasting to the Solow model, changes in the research effort produce "growth effects"



Creative destruction

The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process [Joseph Schumpeter].

Introduction

- This chapter addresses the question of why selfish economic agents devote time and energy to search for new ideas
- Joseph Schumpeter: entrepreneurs engage in R&D with the aim to achieve market power and, by then, to rip a return on their research effort.
- The argument presumes that technology can be made excludable, at least during a certain period of time

R&D taxonomy

- *Basic research, Applied Research and Development*
- *Horizontal innovations and vertical innovations*
- *Product Innovation and Process Innovation*

Model with horizontal and vertical innovations

$$Y = B\sum_{j=1}^{m} x_j^{1-\beta}$$

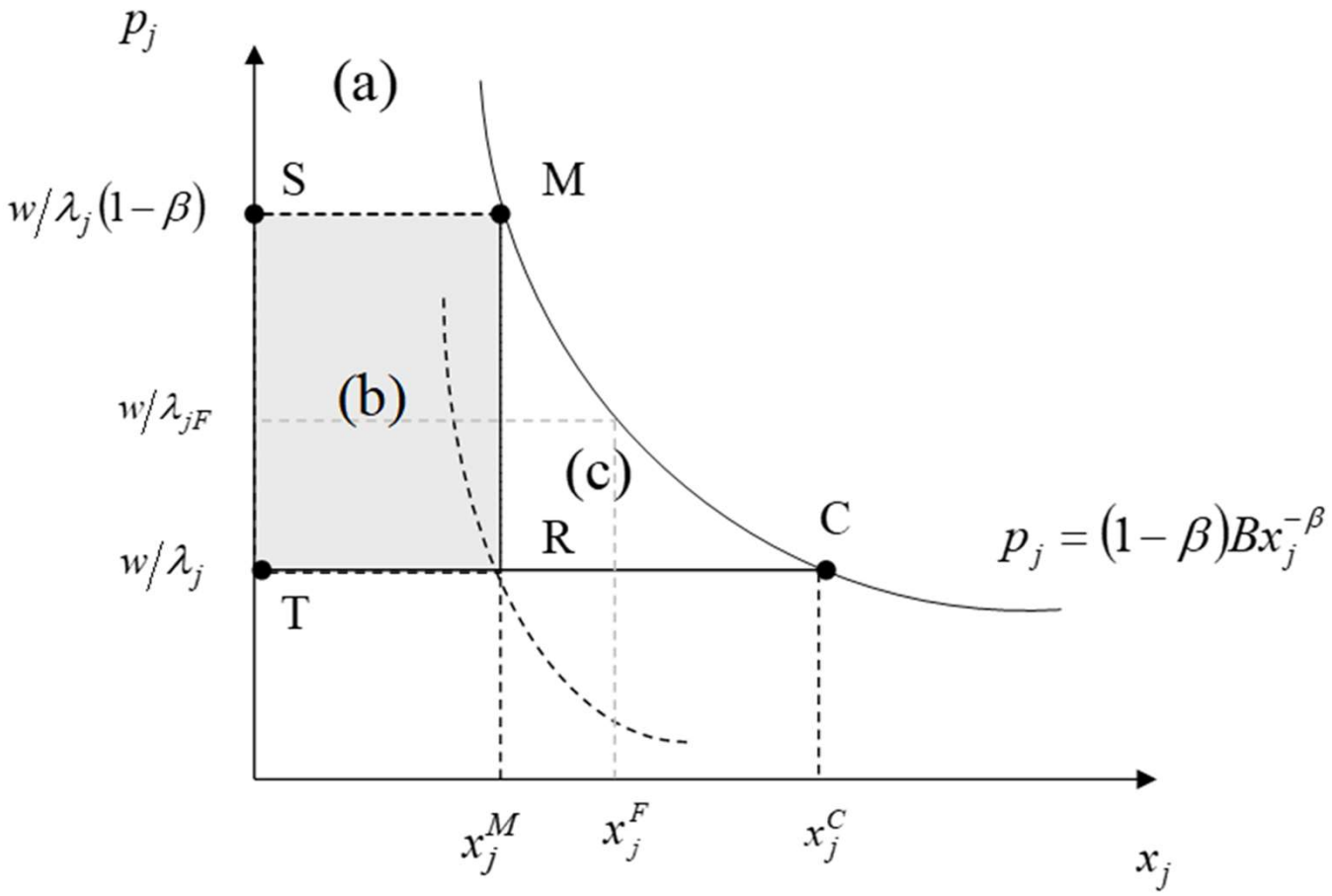
$$N_Y = \sum_{j=1}^{m} N_j$$

$$x_j = \lambda_j N_j$$

$$N_Y = \left(1-\mu\right) N$$

$$Y = Bmx^{1-\beta} = Bm\left(\lambda \frac{N_Y}{m}\right)^{1-\beta} = Bm^{\beta}\left(\lambda N_Y\right)^{1-\beta}$$

Innovation


p_j
(a)
S
M
$w/\lambda_j(1-\beta)$
w/λ_{jF}
(b)
(c)
C
R
w/λ_j
T
$p_j = (1-\beta)Bx_j^{-\beta}$
x_j^M
x_j^F
x_j^C
x_j

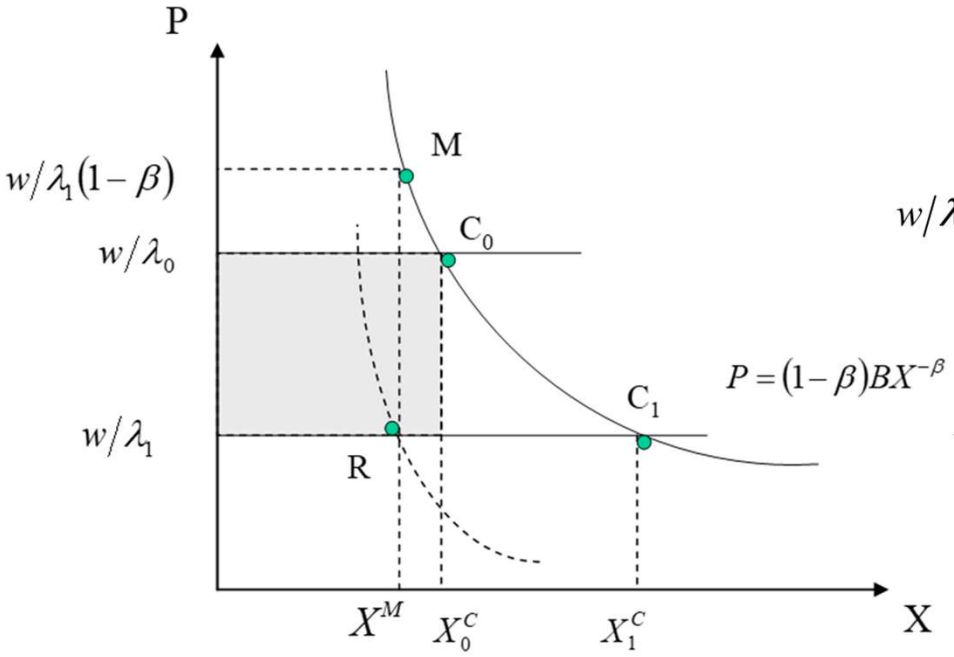
Static and dynamic efficiency

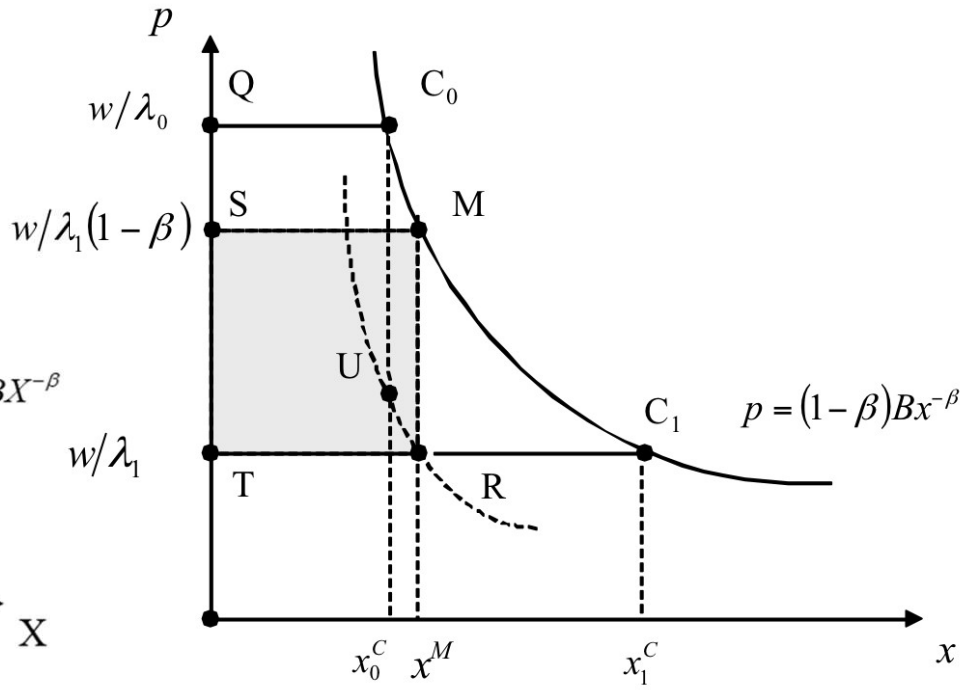
- The classical economic theory tells us that monopolies are bad for welfare
- The monopoly involves a transfer from consumers to the innovating firm (b) and a deadweight loss to the economy as a whole equal to (c).
- But without excludability, there are no market incentives for R&D.

Limit pricing

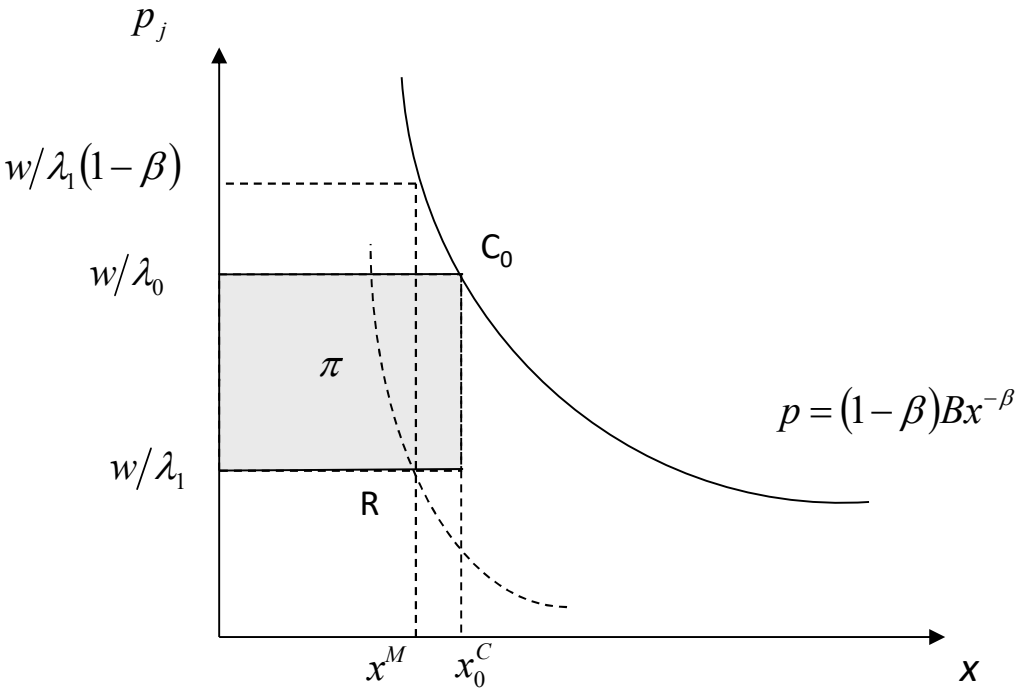
- The possibility of these competitors entering the market may force the incumbent to set a *limit price*, so as to prevent the fringe from stealing its costumers.
- Setting the limit price, the incumbent is still able to undercut its rivals and capture the entire market. But his operating profits will be smaller than in the unconstrained case.

Drastic versus non-drastic process innovations



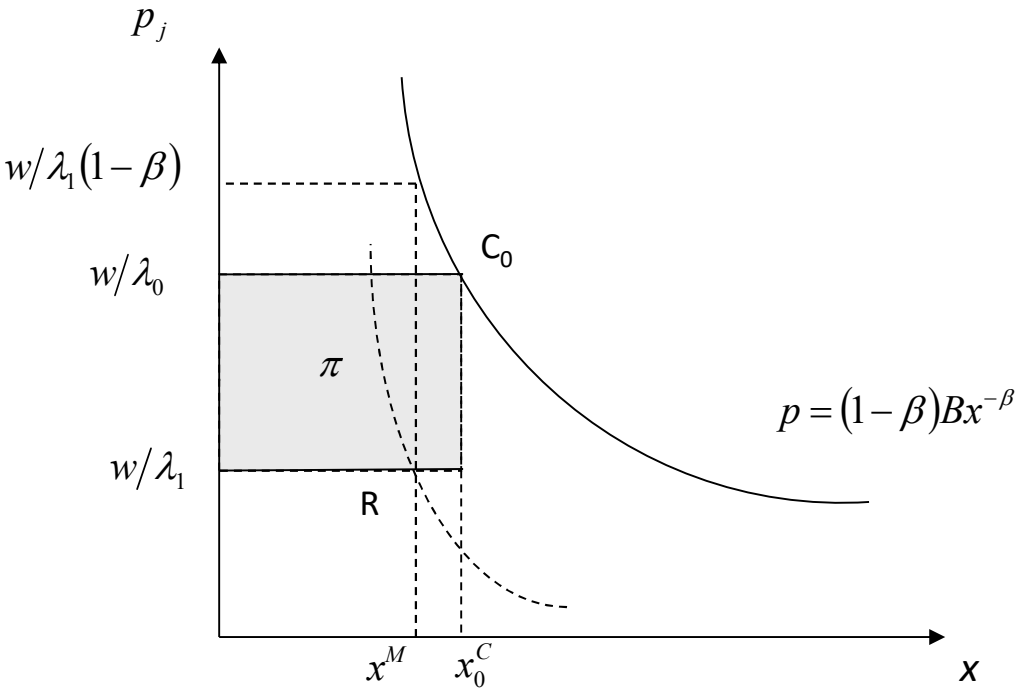


Business Stealing



- "Business stealing effect": An entrepreneur from the fringe that successfully innovates and joins the leader, deviates rents from the leader, without creating any value.
- Private gain, social loss

Competition and innovation



- "Schumpeterian effect": increased competition at the front discourages innovation from the fringe
- "Escape competition effect": positive relationship between product market competition and innovation

Incentives

- The sunk cost of R&D (F)
- The discount rate (r)
- Market size (Y)
- How long will profits last? (T)
  - q=0, q=1, or halfway?
  - Erosion in profits
    - Horizontal innovations
    - Imitation (competitive fringe)
  - Creative destruction
    - Superior technology

$$E[NPV] = b\frac{\pi_1}{r+q} - F$$

$$q = b\mu$$

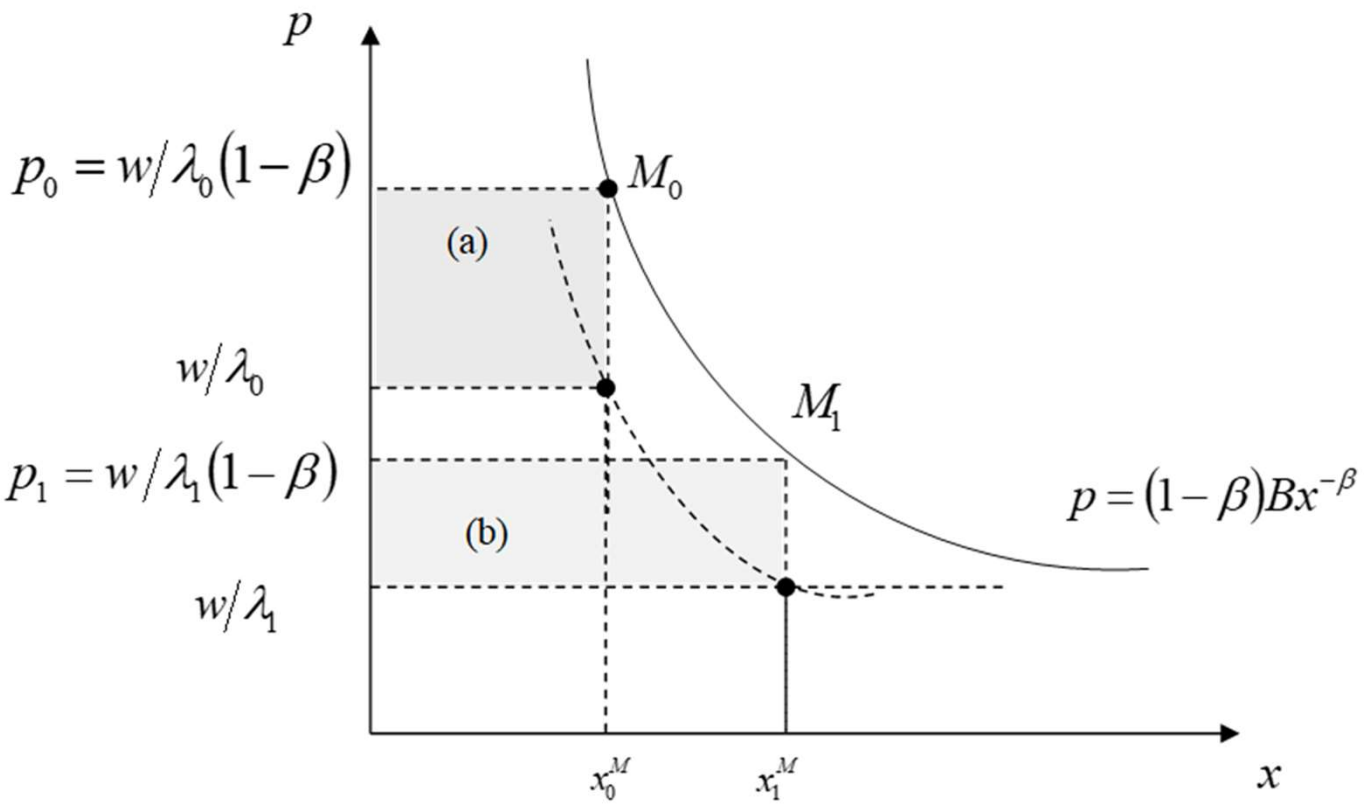
Peas, dark moths and the theory of natural selection

- In its primitive form, the pea plant evolves a gene that makes its pods explode when peas are ready for germination.
- This mechanism allows peas to be scattered on the ground, ensuring the survival of the species.
- In each generation of pea plants, however, a number of mutants grow without this key genetic ingredient.
- Pods of mutant peas fail to pop up: in the wild, mutant peas die entombed in their pods. The natural selection assures that only the healthy pods pass on their genes.
- When the human kind man invented agriculture, the direction of natural selection was changed.
- Humans were not interested in the primitive version of the pea plant, because it is much more convenient to gather pods with peas enclosed than to search for scattered peas on the ground.
- Farmers reversed the direction of natural selection: the formerly successful gene became lethal and the formerly lethal mutant became successful.

Creative destruction

- Like living species, economic agents respond to changes in the economic environment. Each moment in time, agents tend to use strategies that they observed, or they learned to be successful in the past.
- Occasionally, agents experiment new strategies. This is innovation. When the new strategy fails, agents retreat to the old strategies. Whenever the new strategy succeeds, the innovating agent gains a competitive advantage. This advantage will render the previous strategies obsolete.
- As time goes by, other agents copy the more efficient strategy, until it becomes dominant in the market. This is Creative Destruction.

Creative destruction



Excludability sources

- Trade secret
- First move advantage
  - Knowledge leaks gradually
  - Customer loyalty
  - Benefits of experience
- Encryptation
- Non-disclosure agreements with workers
- Patents copyrights, trade marks

How effective are patents?

Effectiveness of alternative means of protecting advantages of new or improved processes and products

Method of Appropriation	Sample means	
	Processes	Produtcs
Patents to prevent duplication	3,52	4,33
Patents to secure royalty income	3,31	3,75
Secrecy	4,31	3,57
Lead time	5,11	5,41
Moving quickly dow n the learrning curve	5,02	5,09
Sales or services effort	4,55	5,59

Sub-optimal R&D

- The appropriability effect (b<a+b)
  - A socially beneficial invention may fail to occur if a+bF>b
  - Even if perfectly excludable
- Standing on shoulders
  - Isaac Newton ("If I have been able to see further, it was only because I stood on the shoulders of giants").
  - Simple ideas may induce independent efforts to achieve similar results:
    - MS Windows; atomic bomb, Pepsi Cola , transistor
- Financial market frictions
  - Uncertainty; Moral hazard (strategic default) lack of collateral
  - Venture capital

Scope for intervention

- Subsidies
- Prizes and research grants
- Patronage
- Procurement

Technology Adoption

"…it is a matter not of individual inventiveness but of the receptivity of whole societies to innovation". [Jared Diamond].

Introduction

- How to improve the state of technology is a policy question that confronts all modern societies.
- For an industrial country, keeping the lead requires a continuous effort to invent new products and processes.
- For an emerging economy, however, the issue is not as much of pushing forward the world technological frontier, as of benefiting from the world technological diffusion

Taking opportunity

- The advantage of adopting foreign technologies is that these do not need to be invented again.
- Technologies have the *potential* to be transferred across firms and country borders, but whether they are implemented or not in each particular environment depends on incentives.
- These incentives, in turn, differ across the space, depending on economic, political, cultural and geographical circumstances.

Imperfect Technological Diffusion

- The wheel (Black Sea, 3.400 B.C.)
  - Easy to copy
  - Geographical distance
- The Fire (1.4 million B.C.)
  - Potential for secrecy
  - But it disseminated across the humanity
  - Knowledge leaks? Independent discoveries?
- Writing (Mesopotamia, 3.000 B.C.)
  - Complex technology
  - Requires incentives to be transmitted
  - Diffused asymmetrically across societies
- Democracy (Athens, 508 B.C.)
  - Collective actions
  - Strategic complementarities
  - Complementary institutions

This chapter

Why available technologies do not flow uniformly across the space?

1. Economic openness (trade, FDI)
2. Characteristics of the country (Absorptive capacity)
3. Characteristics of the technology (Adapting to the country needs)

1. Economic openness

- International trade
  - Imported equipment
  - Competition (matching best performances)
  - Springing up of exporting sectors
  - The identity of the trading partner matters
- Foreign direct investment
  - Vehicle for cross-border transfer of technology
  - New machinery, demonstration effects, training
  - Demand for high quality intermediate inputs
  - Face to face contacts (tacit knowledge)

2. Barriers

1. Complementarities:

   The slow adoption of new technologies in developing countries may be an optimal response to differences in endowments

   - Human capital
   - Physical infrastructure
   - Specialized intermediate inputs (business services, financial services, appropriate legislation)
   - Culture, Geography

   ➢ Role for intervention

   - Education, infrastructure, regulation of new activities
   - But some factors are not easy to change

Barriers

2. The old blocking the new
   - New technologies turn older technologies obsolete
   - But there are switching costs ("Locked in"):
     - Learning: QWERTY
     - Network externalities: Windows
     - Vested interests (when the old technology generates economic rents)
   - ➢ "leapfrogging": Opportunity for countries that are not "hanged" on the old technology
     - But: experience with the old technology may help learning how to deal with the new technology
     - Balance between transferability of knowledge and "lock in" effects

Barriers

3. Matching specific needs
   - Different technologies perform differently in different environments
   - Thus, different countries should optimally adopt different technologies

   Issues:

- Self-discovery:
  - Finding out which of the many potential technologies better fits a country's specific circumstances is a process of trial and failure.
  - Externalities: information externalities, training workers
- Adapting foreign technologies
  - Directed technological change: Most technologies are invented targeting the conditions of advanced countries
  - Institutions, for instance, do not travel well (complementarities)
  - An effective technology transfer may involve an effective spending of resources by the recipient country, in order to master the foreign technology and adapt it to the local environment, preferences and believes

“Catch-up” model

Collection of models where

- Each country characteristics and innovation efforts determine how close the country gets to the frontier
- Long run growth is linked to the World rate of technological progress

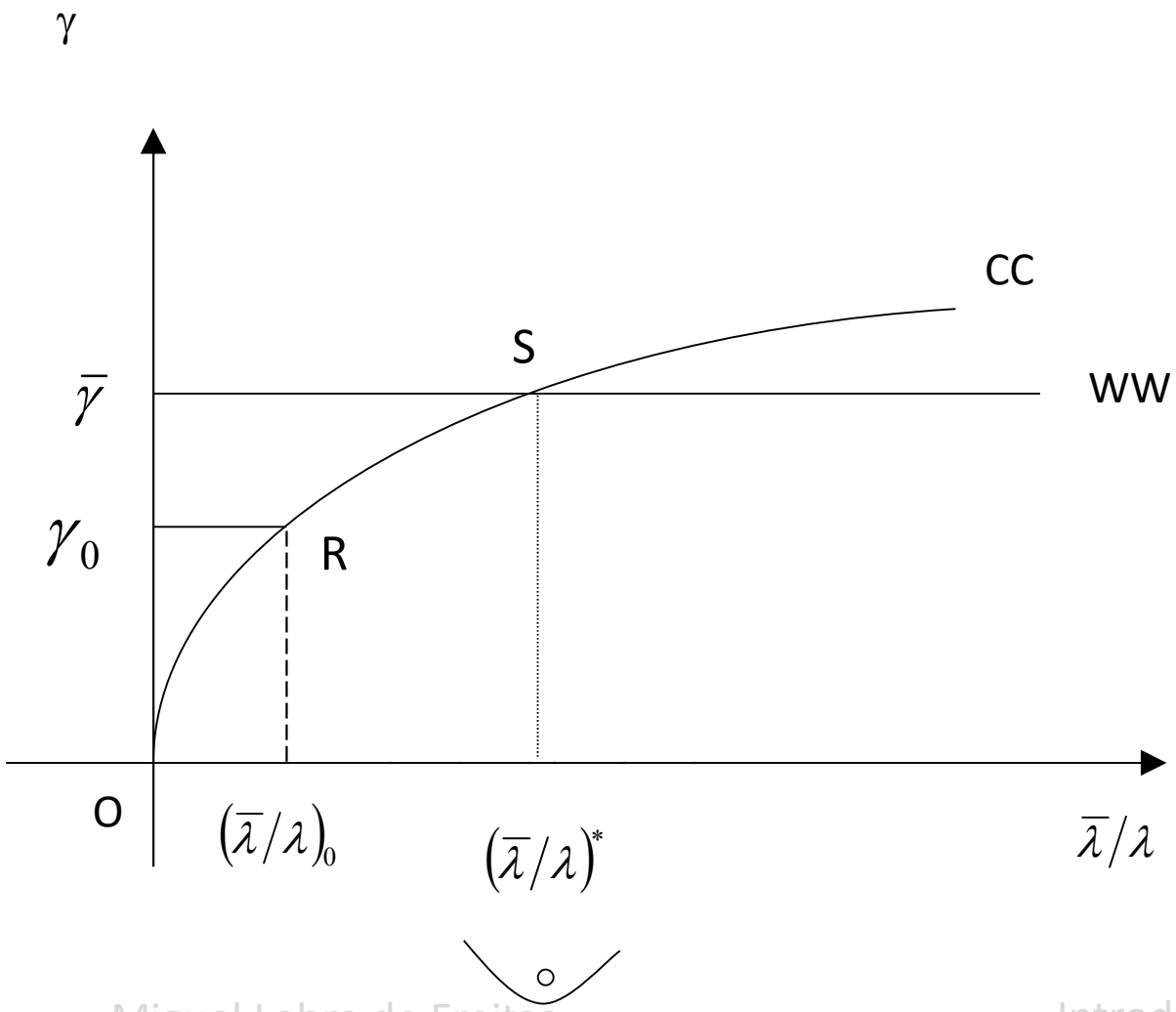
“Catch-up” model

$$\dot{\lambda} = b\mu\left[\lambda^{1-\sigma}\bar{\lambda}^{\sigma}\right]$$

$$\bar{\lambda} = e^{\bar{\gamma}t}$$

- Change in technology depends on:
  - Research, adoption effort
  - Productivity of effort (quality of engineers, barriers)
  - Available knowledge (“standing on shoulders effect”):
    - The Toyota “lean production system” adapted from Ford and then imitated by Ford
    - Atomic bomb
- The frontier technology expands at a constant rate

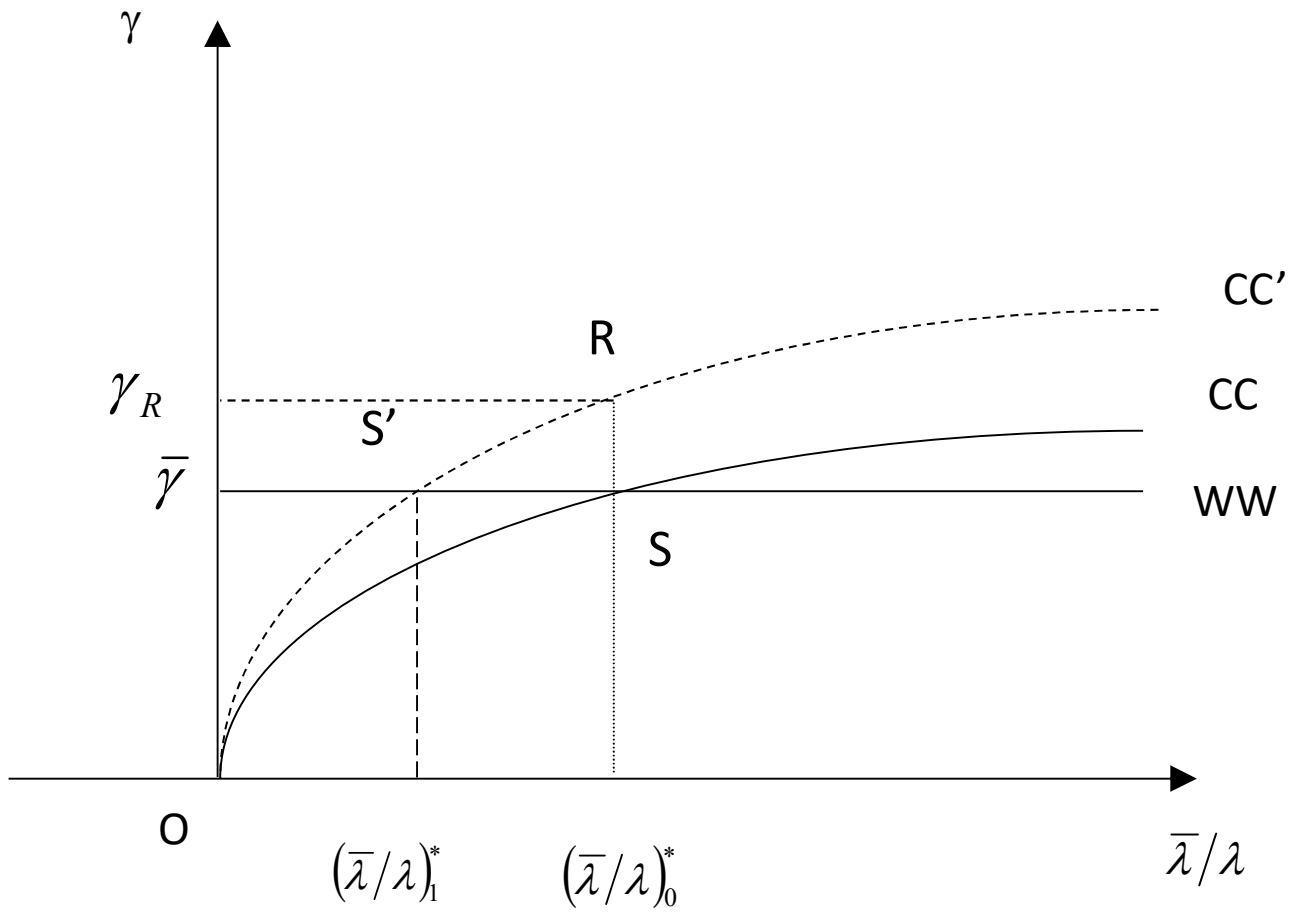
Steady state



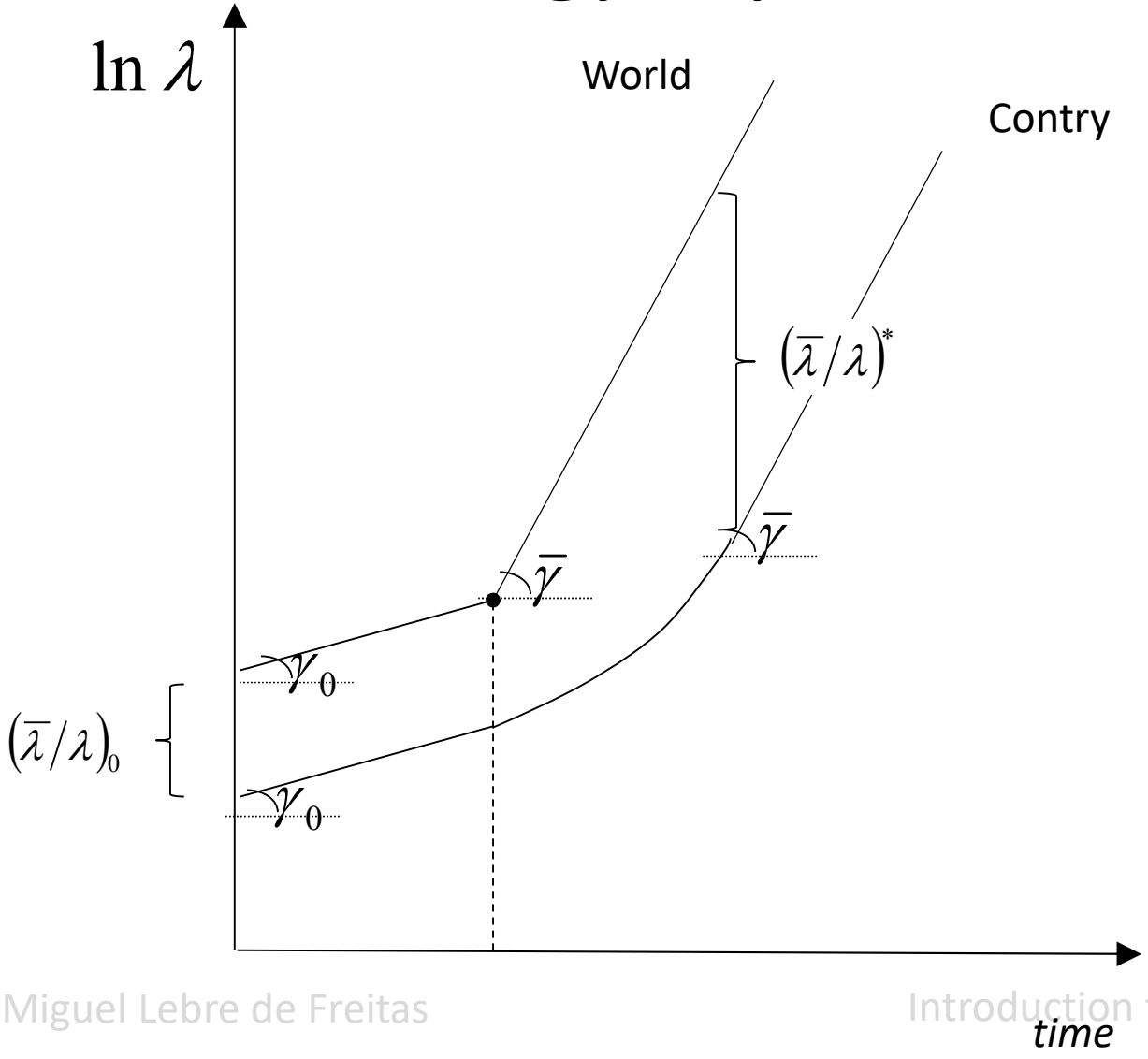
- In the long run the gap is constant

$$\frac{\bar{\lambda}}{\lambda} = \left(\frac{\bar{\gamma}}{b\mu}\right)^{\frac{1}{\sigma}}$$

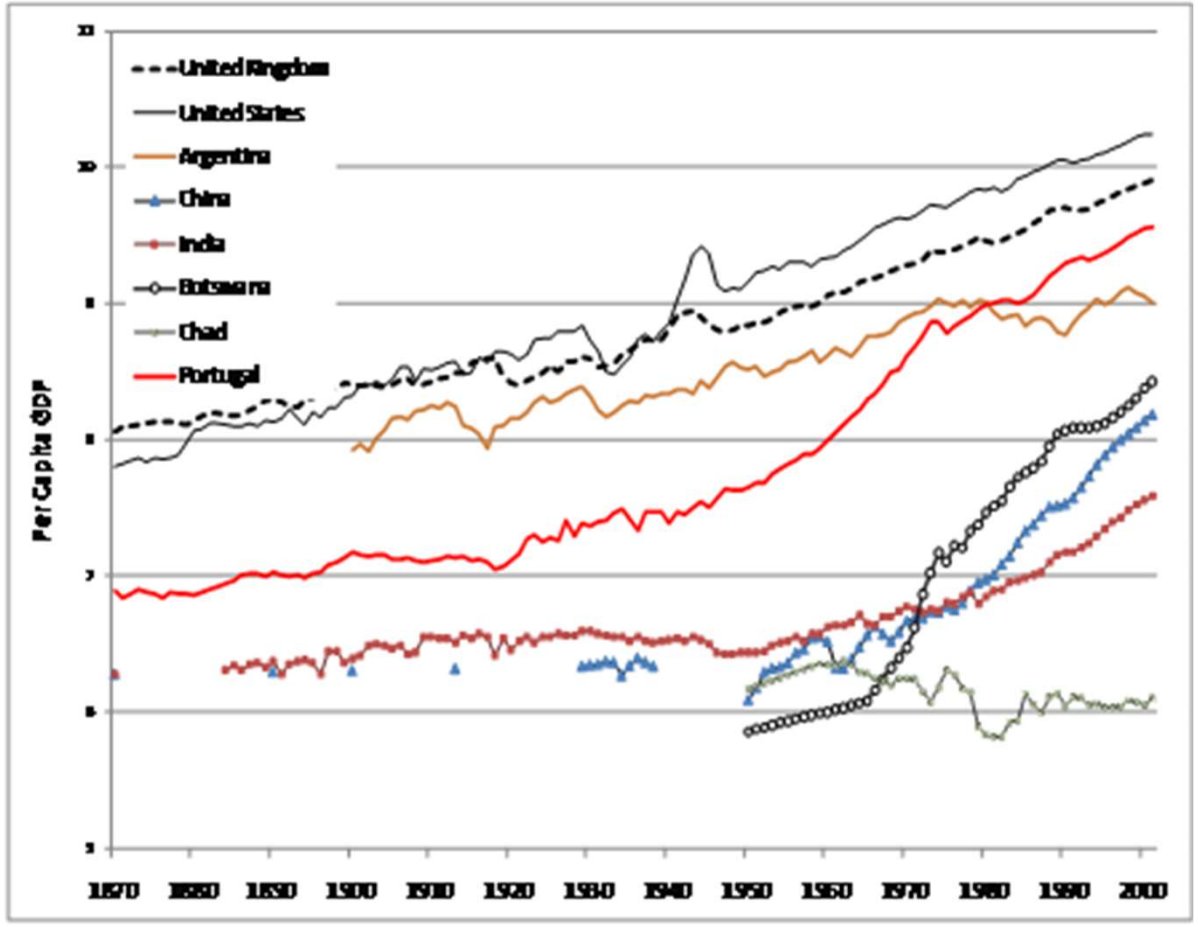
What happens when b increases?



What happens when foreign technology expands faster?



Miracles and disasters



The great divergence