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Macroeconomics II

Lecture 09

Romer model
Extensions

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Theoretical Lecture 09

Chap 08 The Romer model

- **the model of endogenous growth by Romer: main assumptions;**
- **production function;**
- **production of new ideas and productivity of research (externality due to duplication; the spillover effect of research);**
- **economic growth in the *steady state;***
- **long-run effect of research policy.**

Reading

Jones, C., Vollrath, D. (2013), *Introduction to Economic Growth*, Norton, capítulo 5, pp. 97-119.

Classical

Romer, P. (1990), "Endogeneous Technological Change", *Journal of Political Economy*, 98, October 1990: S71-S102

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The Romer model

To endogenize the technological progress: **research as an economic activity** (R&D)

<u>production function</u>:

(1) $Y = K^{\alpha} (A.L_Y)^{1-\alpha}$

A(t) – level of technology in the economy, which is measured by the stock of ideas accumulated until the present; the model intends to explain the growth of A(t).

for a given level of technology A, the production function has <u>constant</u> returns to scale in K e L_Y

A is an **<u>input</u>** for production (*stock* of ideas: the use of *patents*)

production function has <u>increasing</u> returns to scale in K, L_Y and A

the generation of the inputs: physical capital (K), labour (L) and ideas (A)

physical capital

(2) $dK/dt = s_k Y - \delta K$

labour

(3) $(dL/dt)/L = n$ n is exogenous

(4) $L = L_Y + L_A$ labour in the production of final goods (L_Y) and in research (L_A)

(5) $L_A/L = s_R$ s_R constant; exogenous? endogenous?

ideas

A – the growth of A is **endogenous**

A(t), the growth of the stock of ideas

$$dA/dt = \theta^* . L_A$$

dA/dt the evolution of the discovery of new ideas

θ^* productivity of research (the rate of producing new ideas by the researchers)

L_A number of researchers

$\theta^* = \theta(A)$, the productivity of researchers is a function of the **stock of ideas**

increasing function? a large set of accumulated ideas (large stock) facilitates the discovery of new ideas; positive spillover (much of what has been discovered so far facilitates the generation of new ideas);

decreasing function? a large set of accumulated ideas (large stock) becomes more difficult to discover "new" ideas (hardly you can discover new things since so much is already known …)

$\theta^* = \theta . A^{\Phi}$ rate at which new ideas are produced, with $\Phi > 0$ (increasing) ou $\Phi < 0$ (decreasing)

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$\theta^* = \theta(L_A)$, the productivity of the researchers is a function of the **number of researchers**

a large number of researchers facilitates the creation of research networks and then strengthens the ability of each research and his/her team to make more and better research ($\lambda > 1$ below)

externality associated to **duplication**: some ideas may be not new ideas, since they may have been already discovered/or being discovered simultaneously by other researchers ($\lambda < 1$ below)

(6) $dA/dt = \theta . L^{\lambda}_{A} . A^{\Phi}$ using L^{λ}_{A} because the productivity of research depends on the number of researchers looking for new ideas

$\lambda < 1$ (***duplication*** or repetition effect), or $\lambda > 1$

$\Phi < 0$ (decreasing with A), or $1 >$ **$\Phi > 0$** (increasing with A, ***spillover*** effect)

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The Romer model

(1) $Y = K^{\alpha} (A.L_Y)^{1-\alpha}$

(2) $dK/dt = s_k Y - \delta K$

(3) $(dL/dt)/L = n$

(4) $L = L_Y + L_A$

(5) $L_A/L = s_R$

(6) $dA/dt = \theta L^{\lambda}{}_{A}.A^{\Phi}$

growth of the economy in *steady state*

Assuming s_R constant, the growth of GDP per capita in *steady state* is explained by the technological progress (as in Solow model):

$$g_y = g_k = g_A$$

What is (and what explains) the **rate of technological progress**, g_A?

Rem: this growth rate is **endogenous** in the model!

$$dA/dt = \theta L^{\lambda}_{A}.A^{\Phi}$$

$$(dA/dt)/A = \theta \,.\, (L^{\lambda}_{A}.A^{\Phi})/A = \theta \,.\, L^{\lambda}_{A}/A^{1-\Phi}$$

or $$\mathbf{g_A = \theta \,.\, L^{\lambda}_{A}/A^{1-\Phi}}$$

the rate of technological progress in *steady state*

$$g_A = \theta \,.\, L^{\lambda}_{A}/A^{1-\Phi}$$

in *steady state* g_A is <u>constant</u>: growth rate of the numerator = growth rate of denominator

$$\lambda \,.\, (dL_A/dt)/L_A = (1 - \Phi) \,.\, (dA/dt)/A$$

in *steady state* $(dL_A/dt)/L_A = n$ (growth rate of population)

$$\lambda \,.\, n = (1 - \Phi) \,.\, g_A$$

Technological progress $\boldsymbol{g_A = \lambda \,.\, n / (1 - \Phi)}$

g_A is explained by the parameters of the production function of ideas (λ e Φ) and the growth rate of population (n)

$g_A = \lambda \, . \, n \, / \, (1 - \Phi)$

(6) $dA/dt = \theta L^{\lambda}_{A} . A^{\Phi}$

interpretation

let the special case $\lambda = 1$ and $\Phi = 0$ (for an easier explanation)

then: $dA/dt = \theta \, . \, L_A$, from equation (6)

If L_A is constant, in each period $\theta . L_A$ new ideas are created. This means that the growth rate of A, g_A, is decreasing (the stock rises by equal amounts, so that the growth rate decreases). The possibility to get a non-decreasing growth rate of g_A is to prevent the decrease of the number of researchers and, instead, to rise. This requires the population to rise. This explains **n** in the equation above.

conclusion

If the population does not increase, **economic growth will not happen**, even keeping research activity and technological progress in the economy.

Effects of Economic Policy

Economic policy may have effect on long-run economic growth?

example of an economic policy measure: incentives to research, creating/increasing research subsidies; **rise of s_R**

$(dA/dt)/A = = \theta \, . \, L^{\lambda}_{A}/A^{1-\Phi}$

let us assume that $\lambda = 1$ and $\Phi = 0$

then:

$$(dA/dt)/A = \theta \, . \, L_A/A = \boldsymbol{\theta \, . \, s_R \, . \, L/A}$$

We know that in *steady state*, with $\lambda = 1$ and $\Phi = 0$, $\mathbf{g_A = n}$
What is the effect of a policy of incentives to research by rising s_R?

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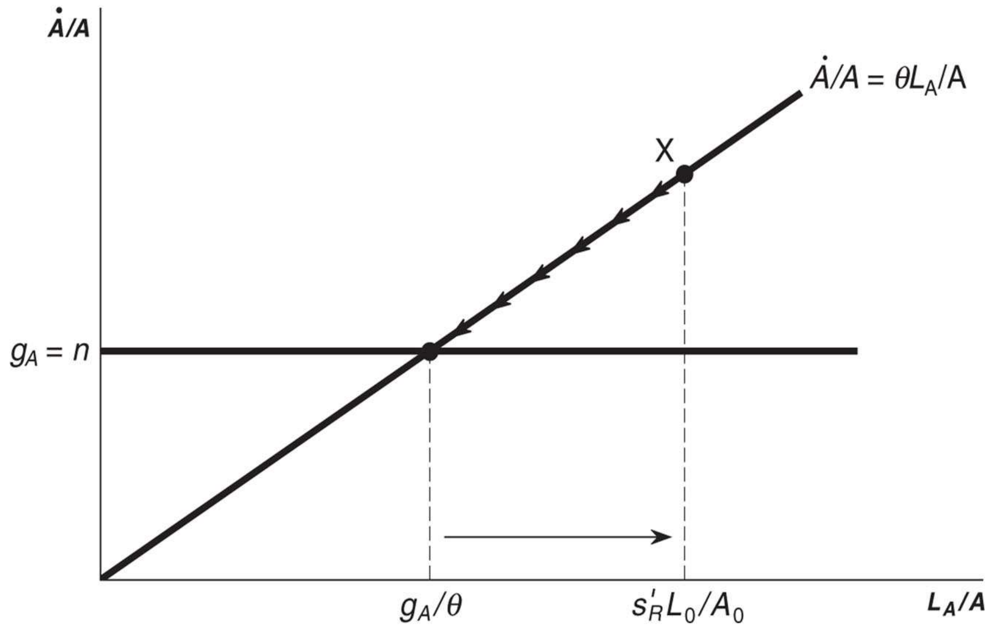
FIGURE 5.1 **TECHNOLOGICAL PROGRESS: AN INCREASE IN THE R&D SHARE**



$s'_R > s_R$ s_R increased (number of researchers in I&D)

$s'_R \,.\, L_0 > s_R \,.\, L_0$, the number of ideas increases;

technological progress > population growth (n)

=> L_A/A decreases

=> g_A decreases

the economy returns to the previous *steady state*

steady state: $\theta \,.\, s_R \,.\, L_0/A_0 = g_A$ => $s_R \,.\, L_0/A_0 = g_A/\theta$

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FIGURE 5.2 $\dot{A}/A$ **OVER TIME**

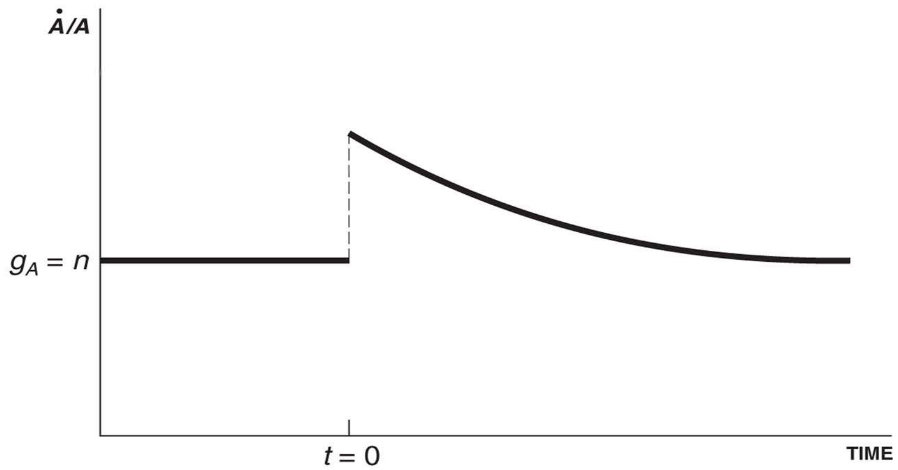
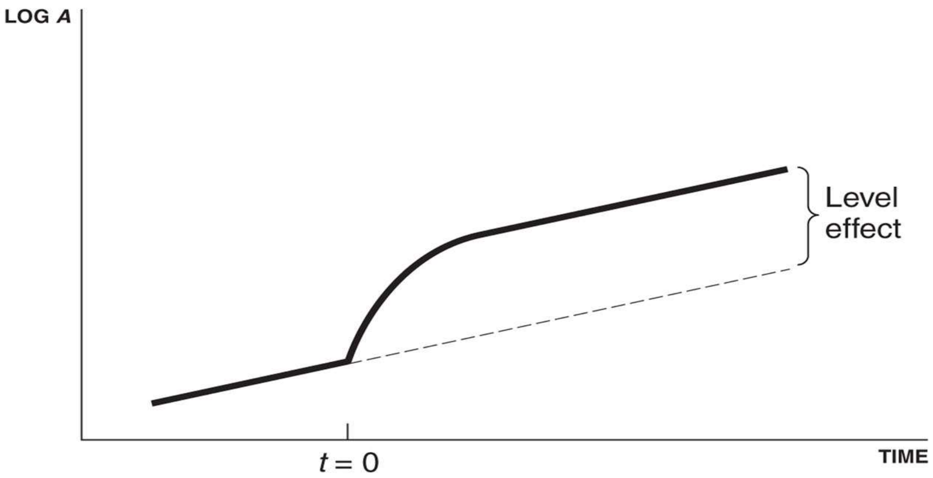


FIGURE 5.3 **THE LEVEL OF TECHNOLOGY OVER TIME**



A permanent increase of s_R increases the technological progress (and economic growth) only in a temporary way, not permanently in the long-run.

But it increases permanently (in the long-run) the level of technology.

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technological progress and growth
(to remind)

growth accounting: growth of factors and of TFP (TFP, total factor productivity)

growth of TFP trough technological progress

technological progress in the models of <u>exogenous growth</u>

growth in steady state: rate *g*

rate *g* is exogenous

technological progress in the models of <u>endogenous growth</u>

rate *g* is endogenous

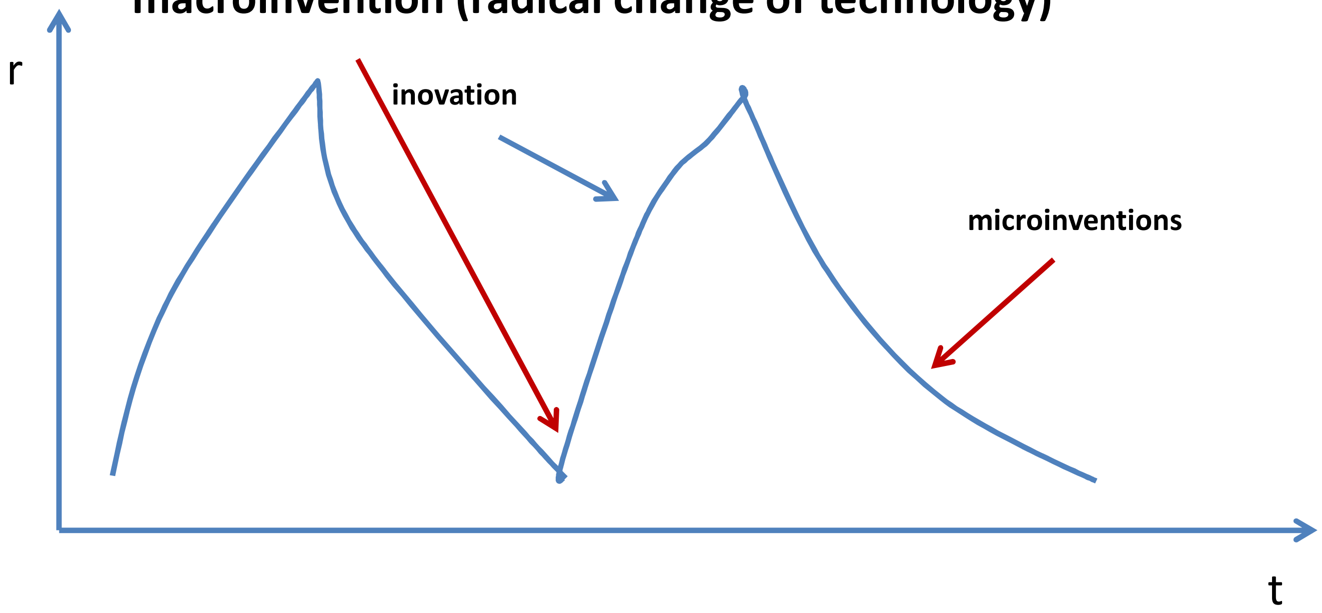
technological progress is “explained” by the working of the economy (it is an output of a sector of economic activity)

what is <u>technological progress</u> ?

Facts and concepts, technological progress: invention and innovation

- **<u>invention</u>**: discovery of new ideas
- **<u>innovation</u>**: implementation of the new ideas in the economic activity

macroinvention (radical change of technology)



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data **research & development** (R&D)

Expenditure on R&D as % of GDP **in** 2001 (OECD):

Portugal	0,83
Spain	0,96
Germany	2,49
USA	2,82
Japan	3,09

other indicators:

- nr. of scientists
- nr. of registered patents

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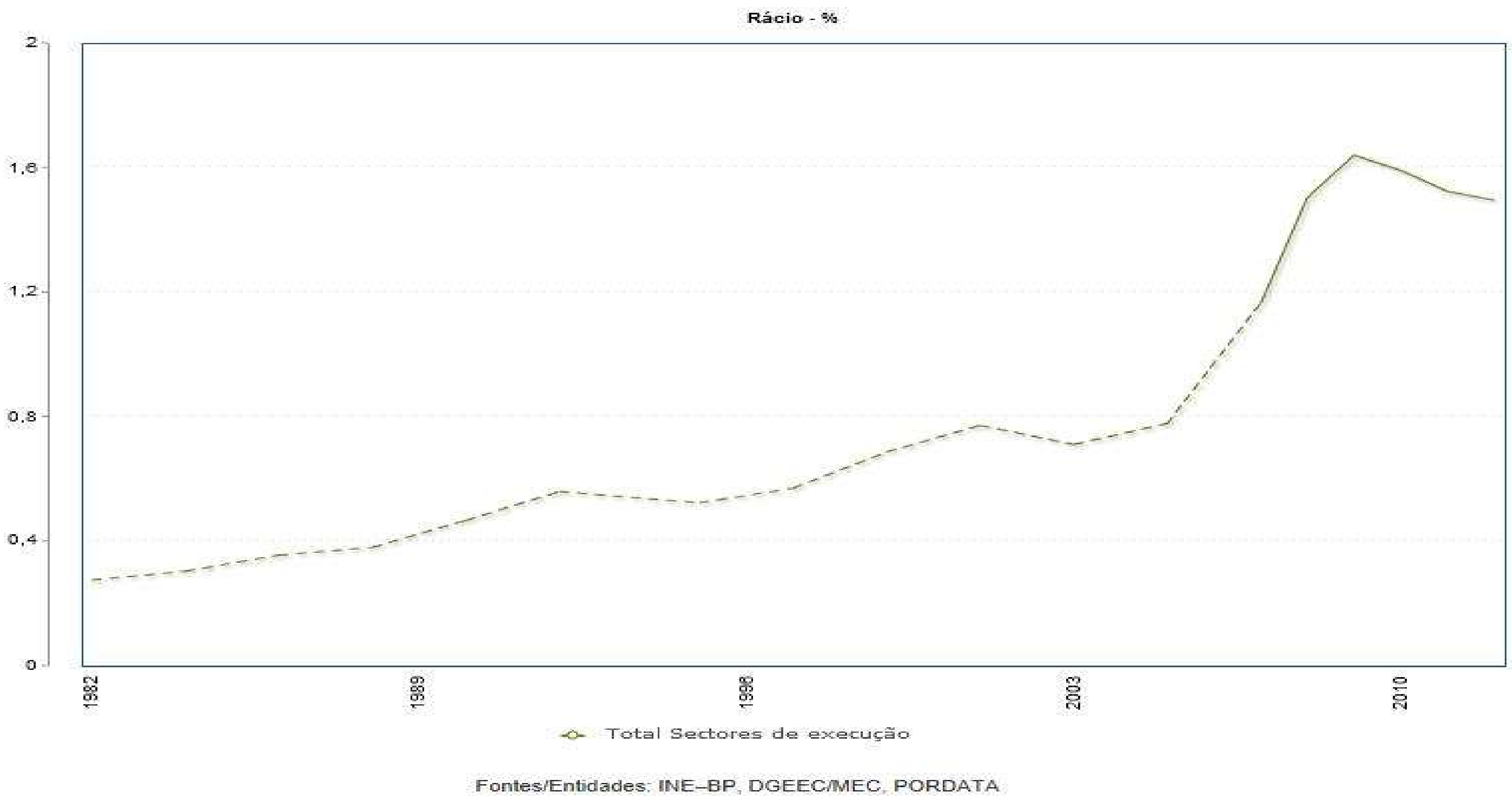
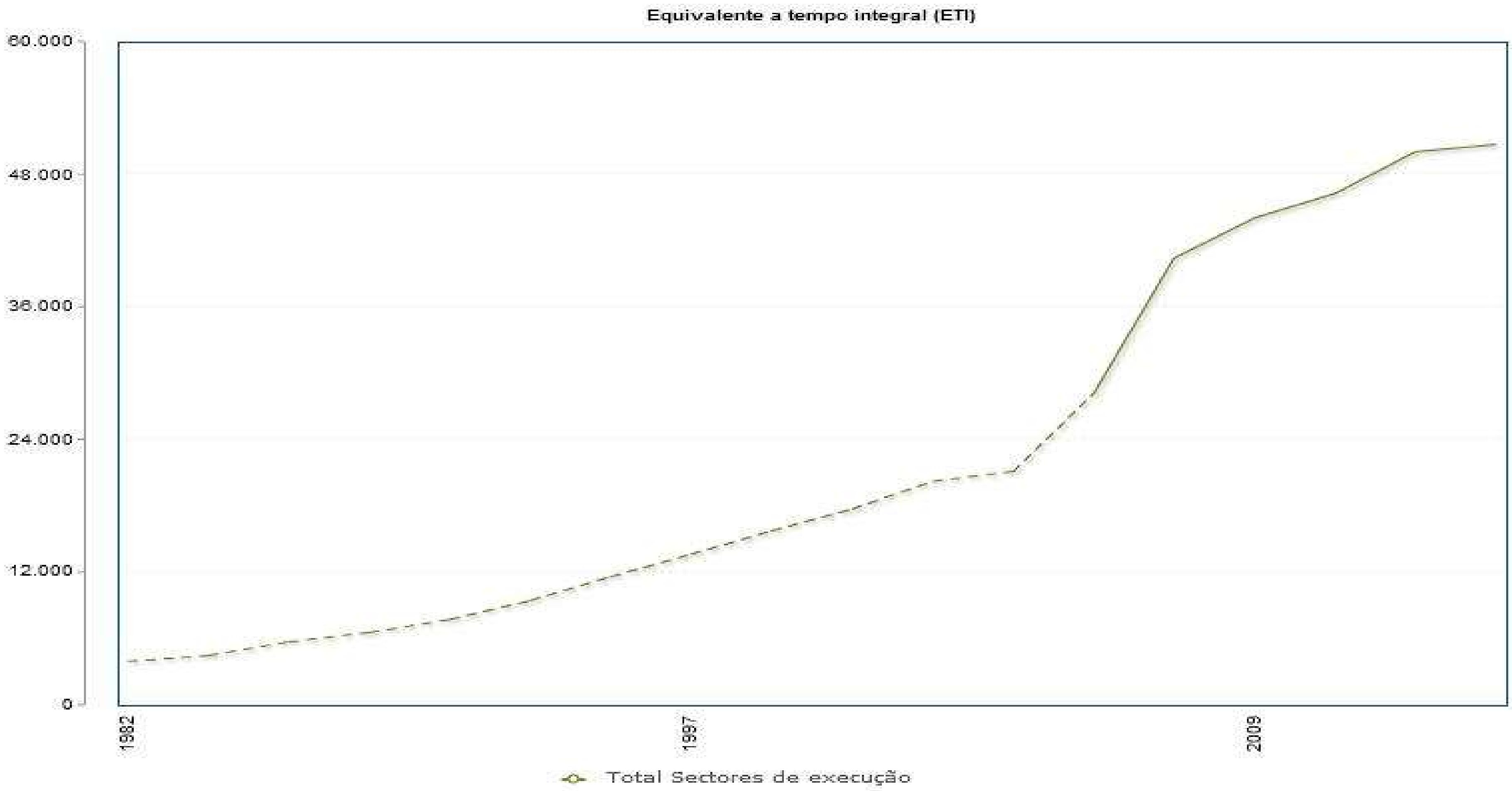
PORTUGAL: Expenditure on R&D as % of GDP

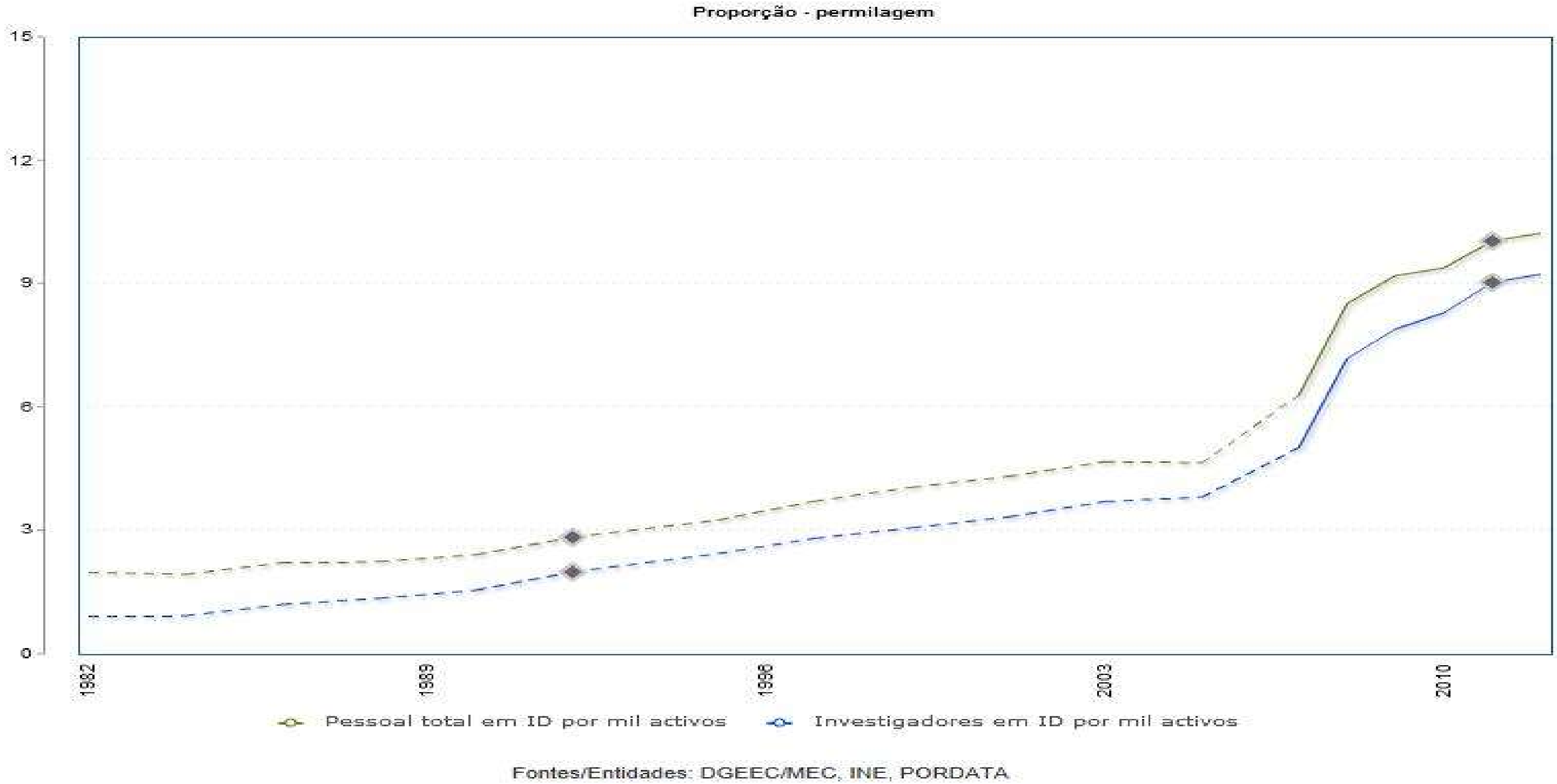


PORTUGAL: Nr de researchers (Full Time Equivalent) in R&D

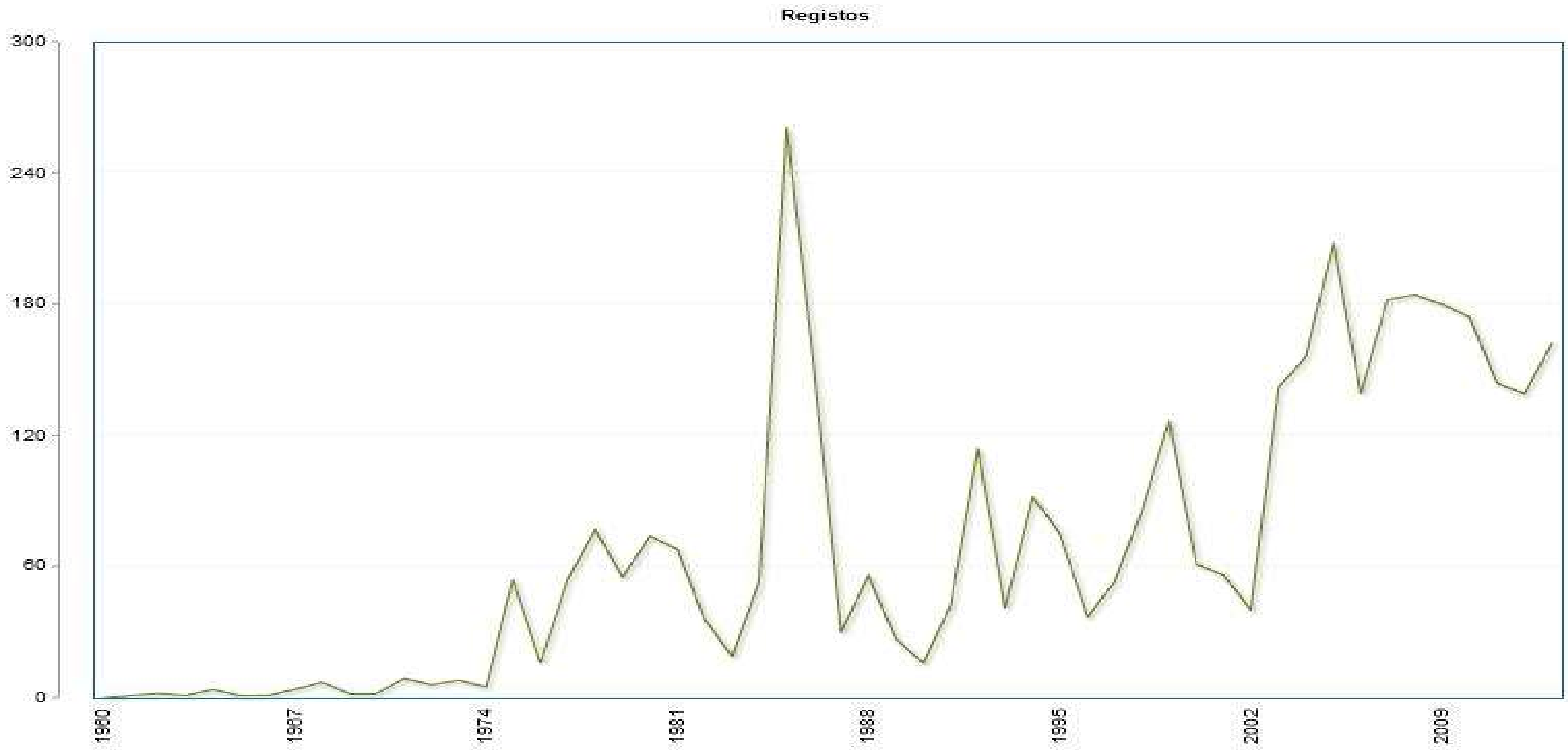


Fontes/Entidades: DGEEC/MEC, PORDATA

Nr of workers in R&D as % of active population



Nr of inventions/patents issued in Portugal



Fontes/Entidades: INPI/MJ, PORDATA

output of I&D: ideas (or "*knowledge*")

ideas (or "*knowledge*") as an **economic good:**

não-rivalry (knowledge is shared by several people)

excludability (not possible to exclude the access to knowledge; but may have restrictions to the access: secret, patent, copyright)

consequences?

non-rivalry => **high fixed cost of production** and **low marginal cost** for its production (almost null) (ex: the production of a software)

- **increasing** returns to scale
- **imperfect** competition

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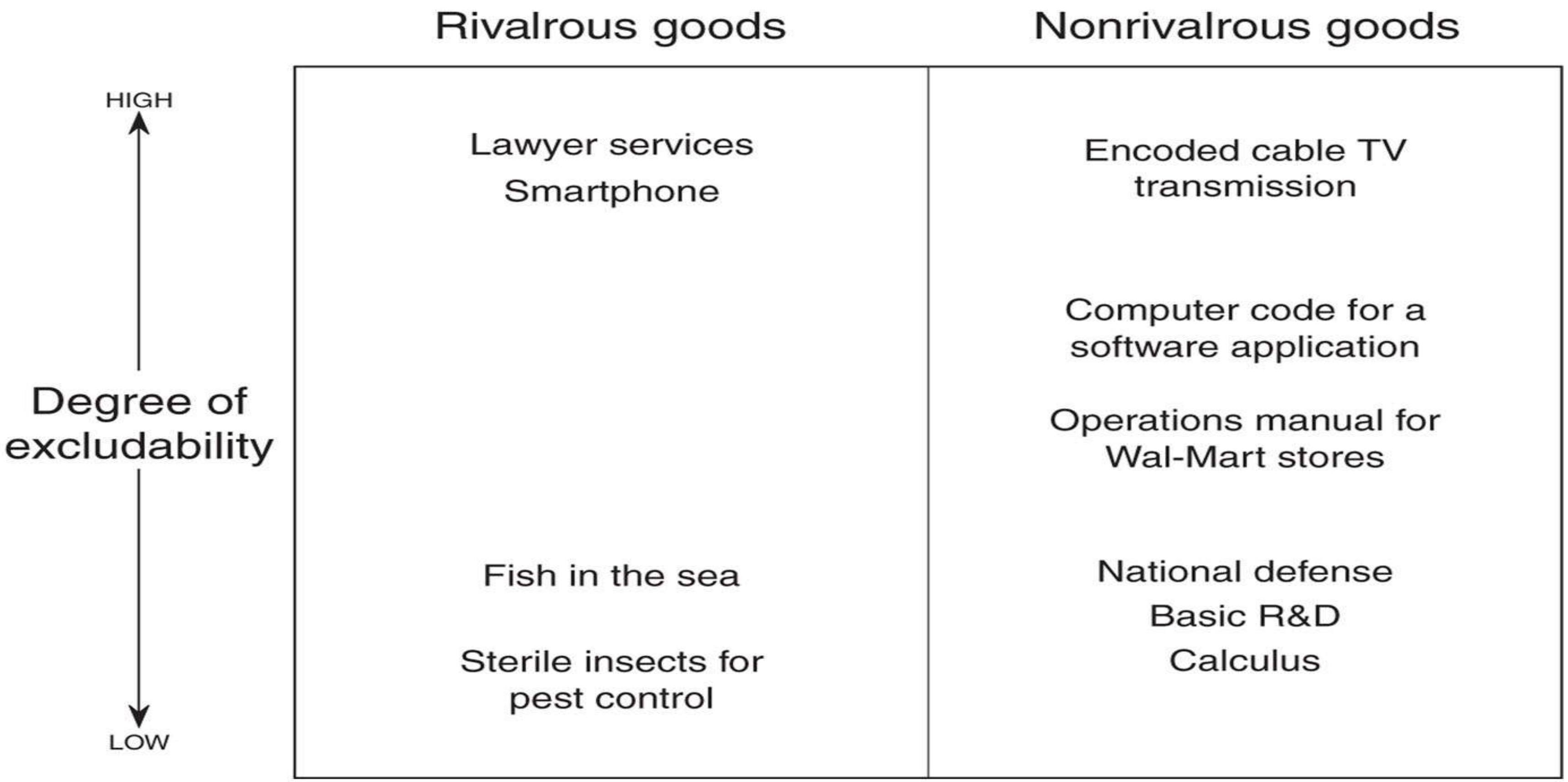
FIGURE 4.1 ECONOMIC ATTRIBUTES OF SELECTED GOODS



microeconomic analysis

FIGURE 4.2 FIXED COSTS AND INCREASING RETURNS

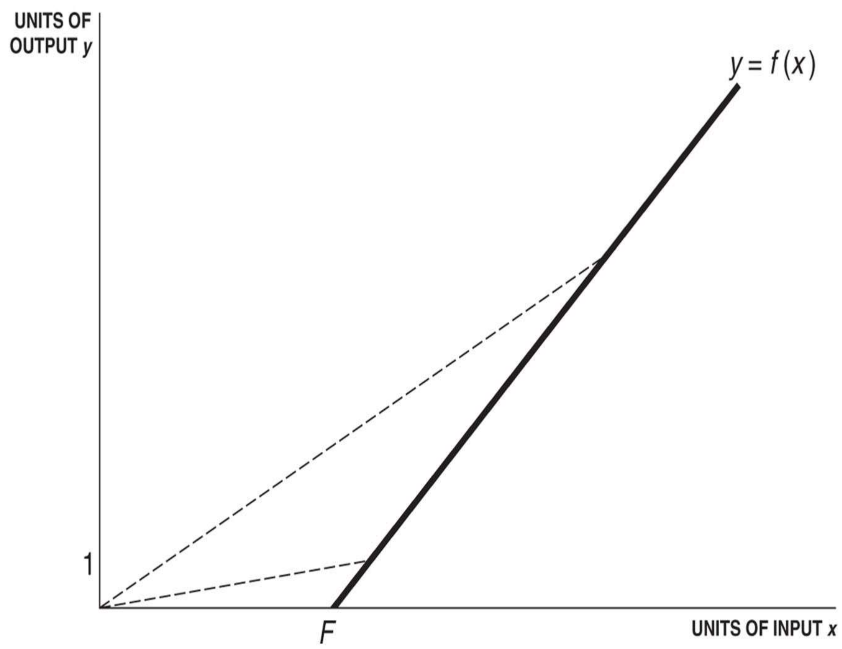
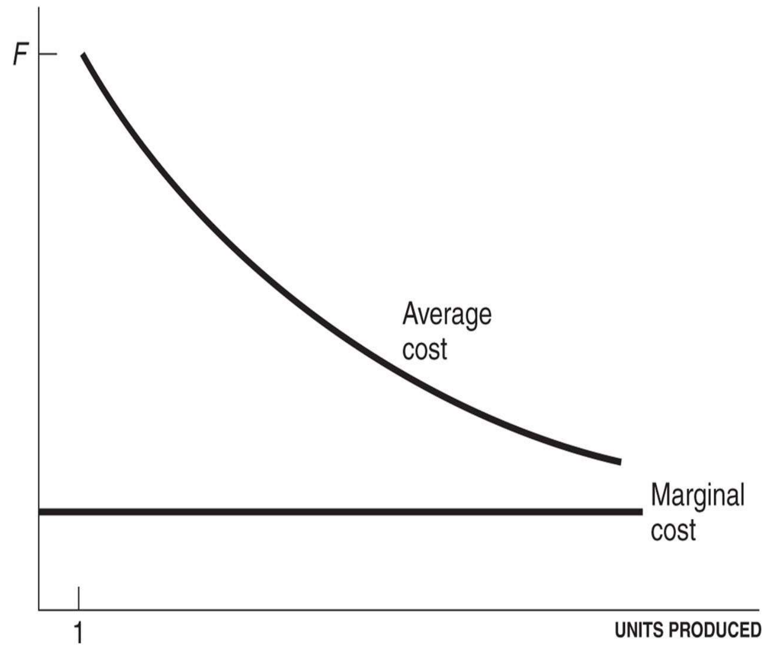


FIGURE 4.3 FIXED COSTS AND INCREASING RETURNS



average cost > marginal cost and then there is not a competitive equilibrium with p = marginal cost (because in that case profits < 0); to have producers, it requires that p > marginal cost (it is **not perfect competition**)

the **production of new ideas** requires the possibility of generating surplus, what is **not compatible** with perfect competition

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The Romer model (summary)

to endogenize the technological progress:

- **production function** (it has ideas/"*knowledge*" as a production factor)
- equations to describe the creation of inputs (including the ideas/"*knowledge*")

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(1) $Y = K^{\alpha} (A.L_Y)^{1-\alpha}$

(2) $dK/dt = s_k Y - \delta K$

(3) $(dL/dt)/L = n$

(4) $L = L_Y + L_A$

(5) $L_A/L = s_R$

(6) $dA/dt = \theta^* . L_A$

(7) $\theta^* = \theta . A^{\Phi}$

$$\mathbf{dA/dt = \theta L^{\lambda}_{A} . A^{\Phi}}$$

p.f. constant returns to scale in K and L_Y; increasing returns in K, L_Y and A.

A(t) *stock* of knowledge
(nr of ideas invented until moment t)

θ* productivity of research (nr. of new ideas produced per researcher)

$0 < \lambda < 1$ externality associated with duplication

$\Phi > 0$ positive knowledge *spillover* in research

some of the ideas created by a researcher may be not new ($\lambda<1$); but may also exist a network effect ($\lambda>1$)

much of what has been discovered so far facilitates the generation of new ideas (positive spillover); a large set of accumulated ideas becomes more difficult to discover “new” ideas (negative spillover)