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Macroeconomics II

Lecture 08 (March 2020)

Romer model
Extensions

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Theoretical Lecture 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, ch. 5, pp. 97-119.

Classical

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

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exogenous **models of economic growth: main concepts**

Solow model: **<u>exogenous</u>** model of economic growth

the concept of steady state; there are endogenous mechanisms that drive the economy towards the steady state:
substitutable production factors;
capital accumulation is characterized by diminishing returns (declining marginal product of each unit of capital).

in steady state, the economy grows due to exogenous factors (technological progress at the rate “g”; population at the rate “n”), which are not “explained” by the model;

in the Solow model, economic policy has only temporary effects on the rate of economic growth; **it has no long-run effects on the rate of economic growth.**

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growth theory since the 1950s

neoclassical growth models (Solow, etc), in the 1950s and 1960s:

<u>savings</u> (= investment) rate is <u>exogenous</u> (it is crucial to explain the steady state income level) (there is a social planner who decides?)

<u>technological progress</u> is <u>exogenous</u> (it is crucial to explain the long-run per capita growth rate) (does the technological progress come from heaven?)

they are called <u>**exogenous growth models**</u>

unsatisfactory! -> two theoretical reactions towards <u>**endogenous growth models**</u>:

growth models with <u>**endogenous savings**</u> (mid 1960s)
  Cass (1965) and Koopmans (1965), that go back to Ramsey (1928), Young (1928), Knight (1944)

growth models with <u>**endogenous technological progress**</u> (mid 1980s)
  Arrow (1962), Romer (1986, 1987, 1990), Lucas (1988), Rebelo (1991)

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growth theory in the 1970s

in between the two theoretical contributions (1970s): a great vacuum of growth economic theory of about 15 years!

main emphasis on short-term analysis in the 1970s (real business cycles, rational expectations, general equilibrium models, etc);

very much technical approaches and very little empirical applications on economic growth;

development economists emerged with great emphasis on the study of growth in less developed countries;

growth economics *vs*. **development** economics

The “new” models of endogenous growth

The models of exogenous growth are not adequate to explain economic growth if the long-run growth rate of GDP is explained by (endogenous) technological progress

In the 1970s and up to the mid-1980s, macroeconomics was focused mainly in short term issues.

By mid-1980s some economists made theoretical work devoted to fill gaps in the explanatory models of growth; for instance Romer (1986, 1987) deals with technological progress as an endogenous variable (the process of generation of new ideas, research and innovation, R&D);

These models tend to consider as well population growth as an endogenous variable (dependent on GDP per capita)

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endogenous growth models: the role of technological progress

difficulty of incorporation of technological progress in neoclassical models because competitive assumptions cannot be made regarding the creation of new ideas (imperfect competition/ideas as quasi-public goods)

main contribution of **Paul Romer**:

Romer, P. (1986). "Increasing returns and long-run growth". *Journal of Political Economy*, 90: 6 (Dec.), 1257-1278

Romer, P. (1990). "Endogenous technological change". *Journal of Political Economy*. 98:5 (October), Part II, S71-S102

author of the incorporation of R&D theories and imperfect competition into the growth models. That was the reason for the **Nobel 2018.**

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endogenous growth models: the role of technological progress (cont.)

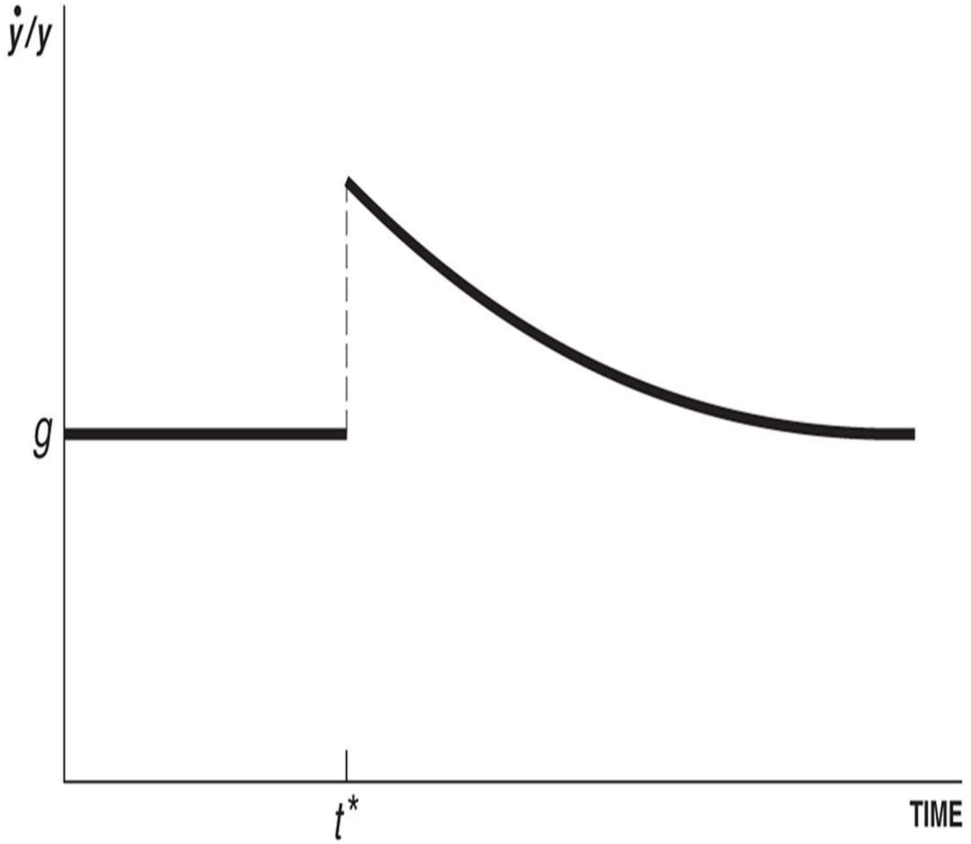
incorporation of Schumpeterian ideas of progress (as "creative destruction")

+ **new lines of research**:

Diffusion of technology and its role in economic growth (a line of empirical research in progress);

Notice the relevance of FDI and its growth in the last decades

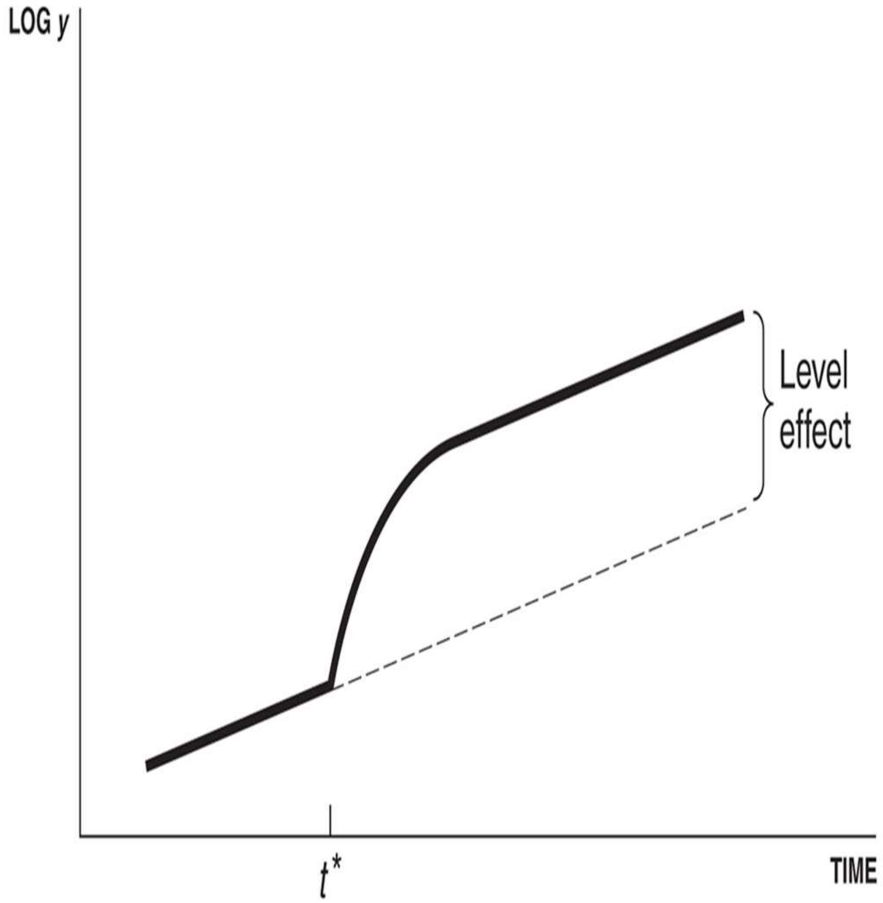
FIGURE 2.12 THE EFFECT OF AN INCREASE IN INVESTMENT ON GROWTH



Solow model:

the rise of the investment rate **has no effect** on the long-run **growth rate** of GDP *per capita*

FIGURE 2.13 THE EFFECT OF AN INCREASE IN INVESTMENT ON y



Solow model:

the rise of the investment rate

<u>has positive effect</u> on the long-run

level of GDP *per capita*

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The Romer model

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

production function:

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

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 constant returns to scale in K e L_Y (Labour in the production of final goods)

A is an **input** for production (*stock* of ideas: i.e., the use of *patents*)
The production function has increasing returns to scale in K, L_Y and A

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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?

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

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

dA/dt is 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 facilitates the discovery of new ideas; positive spillover (what has been discovered facilitates new ideas);

decreasing function? Given a large set of accumulated ideas, it becomes more difficult to discover "new" ideas (since so much is already known …)

$\theta^* = \theta . A^{\Phi}$ rate at which new ideas are produced, with $\Phi > 0$

(increasing) or $\Phi < 0$ (decreasing)

$\theta^* = \theta(LA)$, 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)

$dA/dt = \theta . L^{\lambda}_{A} . A^{\Phi}$ 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) $dK/dt = sk_Y - \delta K$

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

(4) $L = L_Y + L_A$

(5) $L_A/L = s_R$

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

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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?

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

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

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

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

the rate of technological progress in *steady state*

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

In the ***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 the ***steady state*** $(dLA/dt)/L_A = n$ (growth rate of population)

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

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

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

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

<u>interpretation</u>

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 emerge. Then the growth rate of A, g_A, is **decreasing** (the stock rises by equal amounts, so that the growth rate decreases). The alternative to get a non-decreasing growth g_A is to prevent the decrease of the number of researchers. **This requires the population to rise** and <u>explains **n** in the equation above</u>.

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**

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

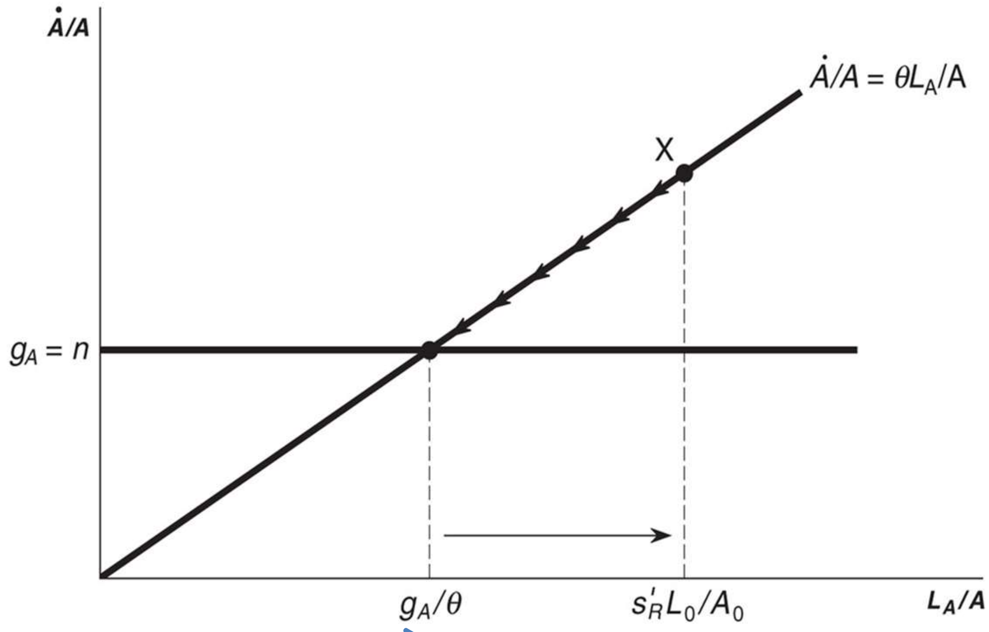
let us assume that $\lambda = 1$ and $\Phi = 0$

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 sR?

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 . L0 > sR . L0, 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: $\theta \cdot s_R \cdot L_0/A_0 = g_A \Rightarrow s_R \cdot L_0/A_0 = g_A/\theta$

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

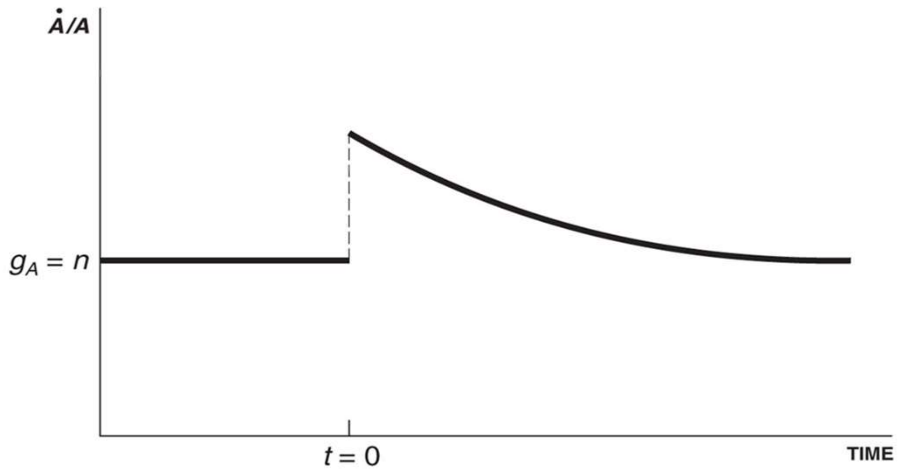
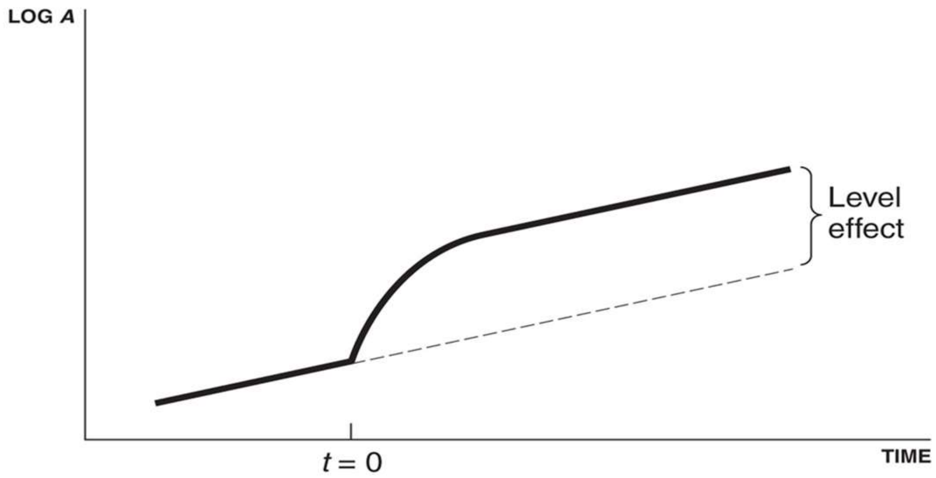


FIGURE 5.3 THE LEVEL OF TECHNOLOGY OVER TIME



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 (total factor productivity)

growth of TFP trough technological progress

technological progress in the models of **exogenous growth**

growth in steady state: rate *g*

rate *g* is **exogenous**

technological progress in the models of **endogenous growth**

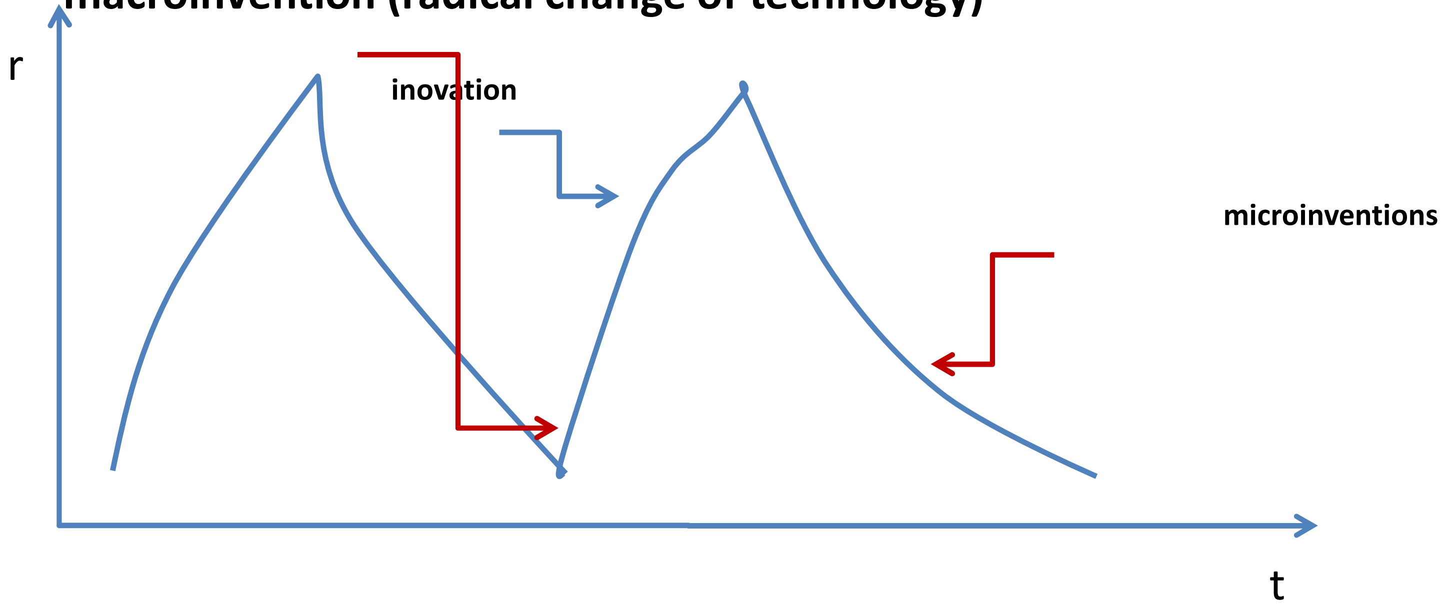
rate *g* is **endogenous**

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

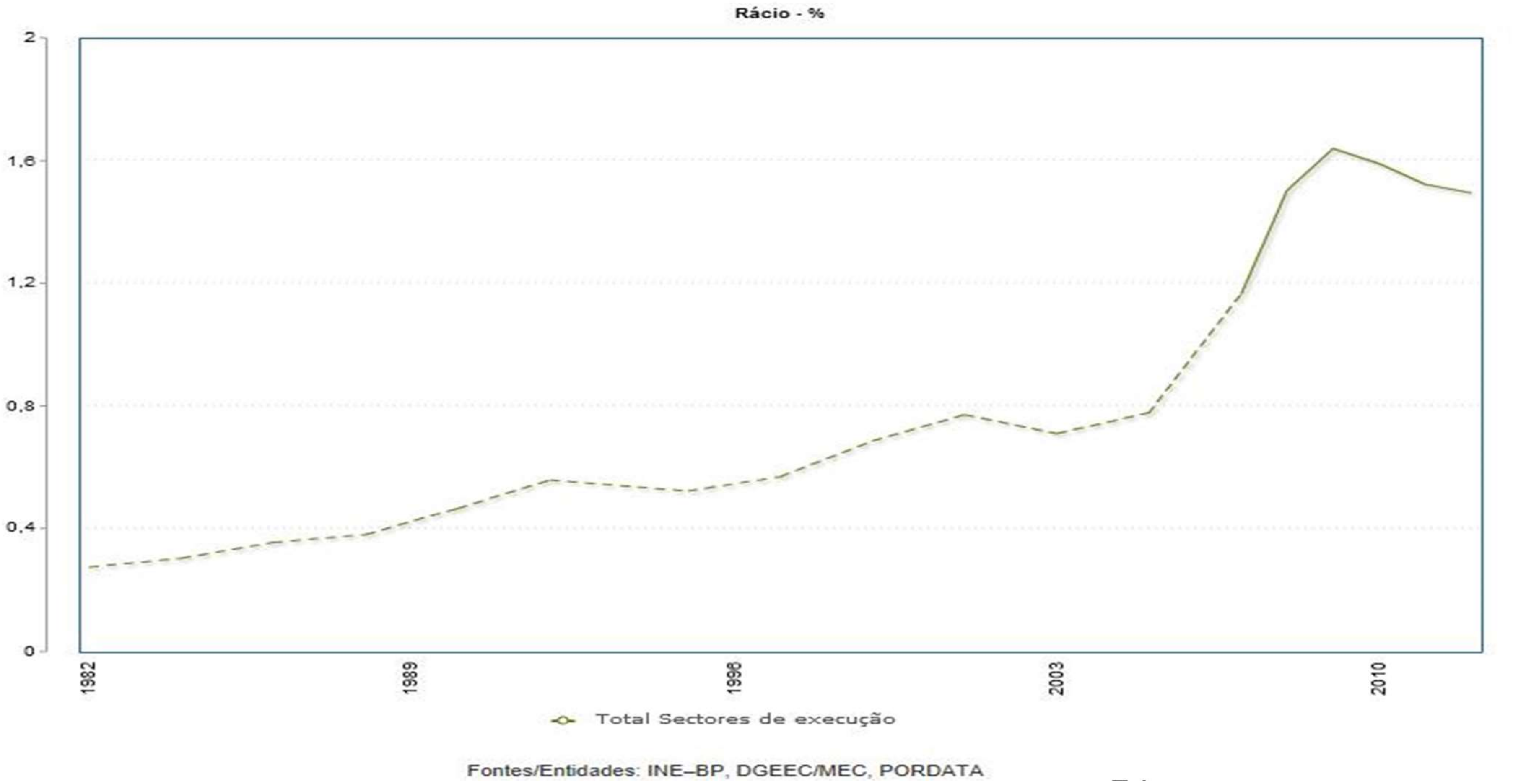
Facts and concepts, technological progress: invention and innovation

- **invention**: discovery of new ideas
- **innovation**: implementation of the new ideas in the economic activity

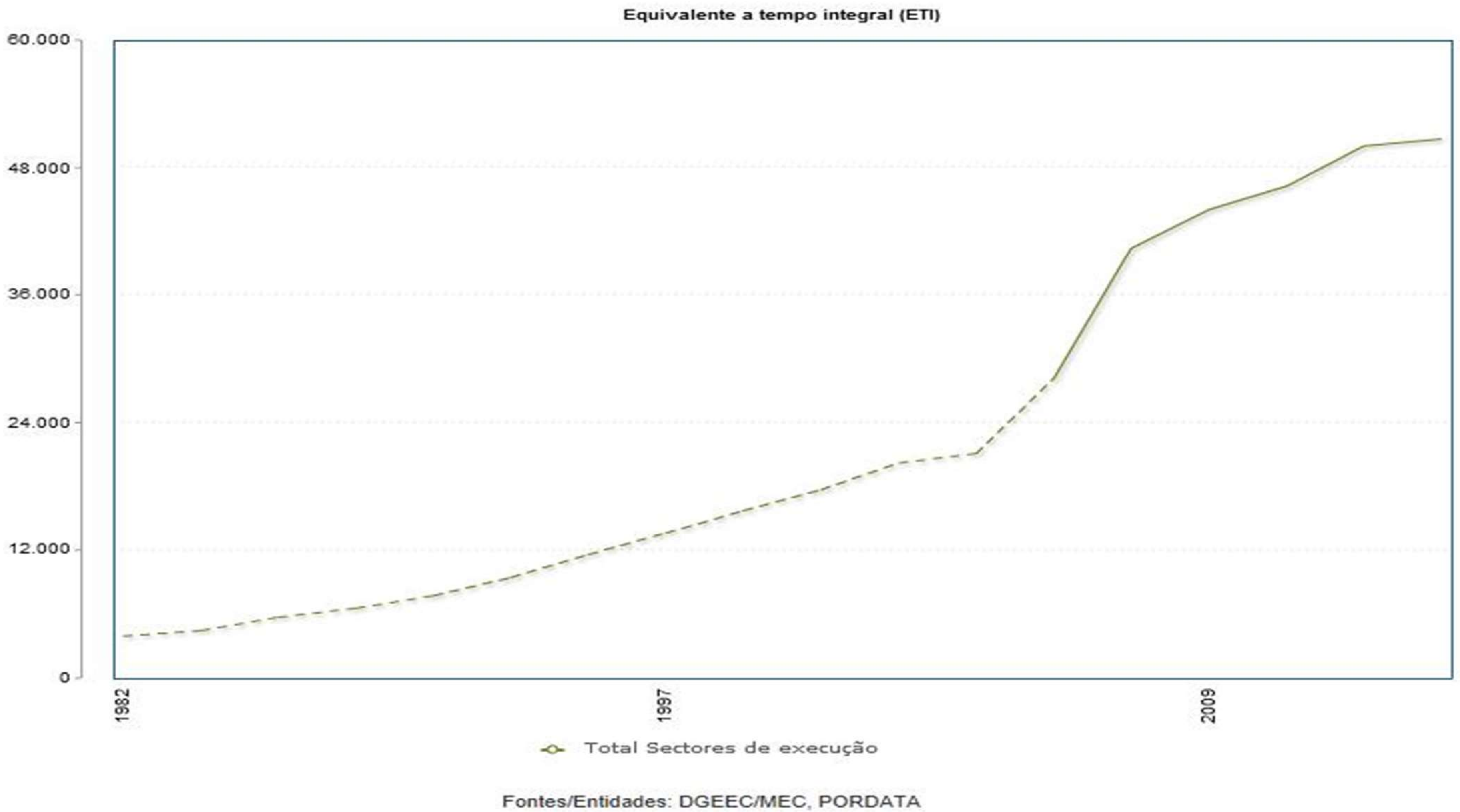
macroinvention (radical change of technology)



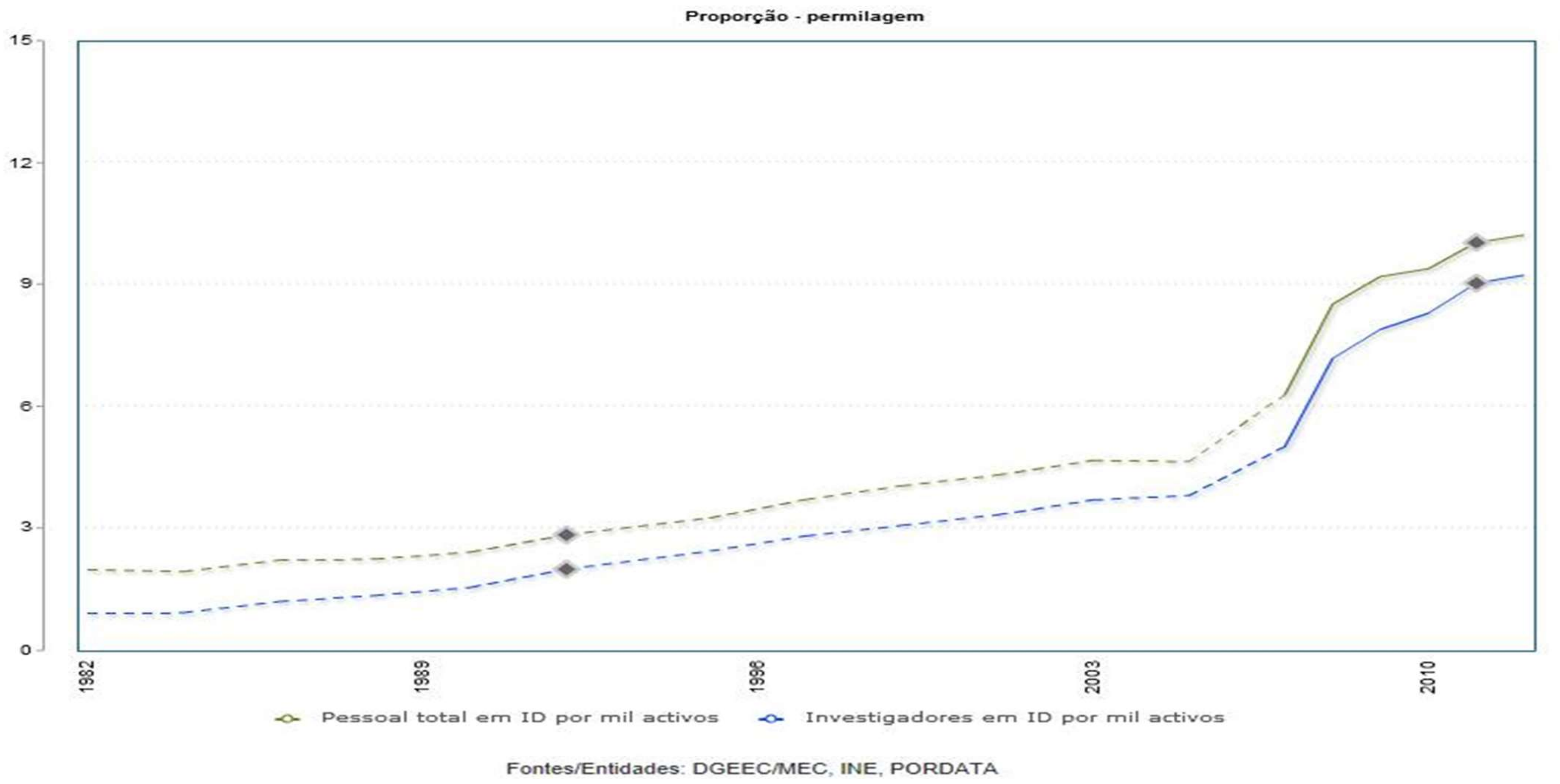
PORTUGAL: Expenditure on R&D as % of GDP



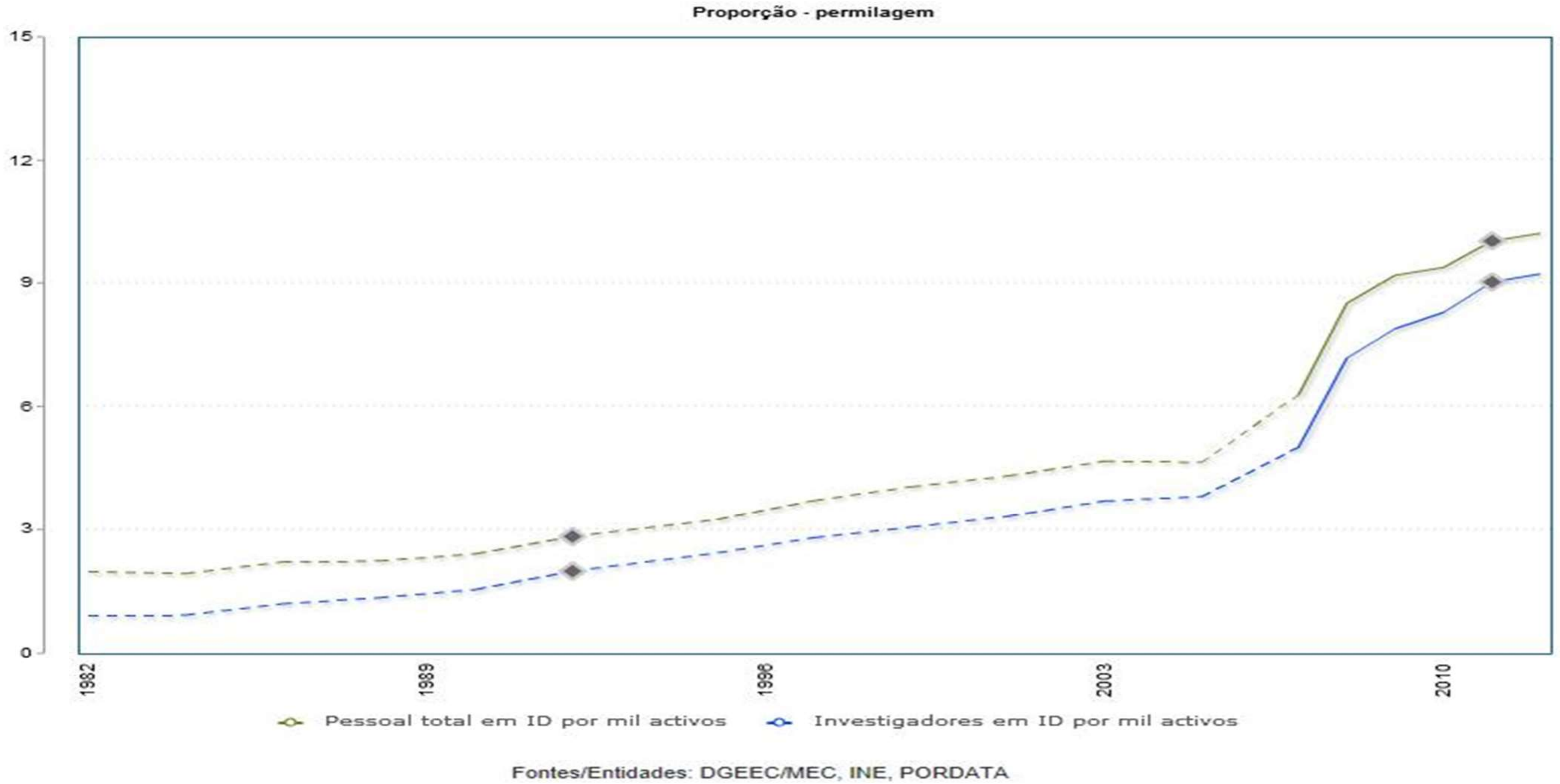
PORTUGAL: Nr of researchers (Full Time Equivalent) in R&D



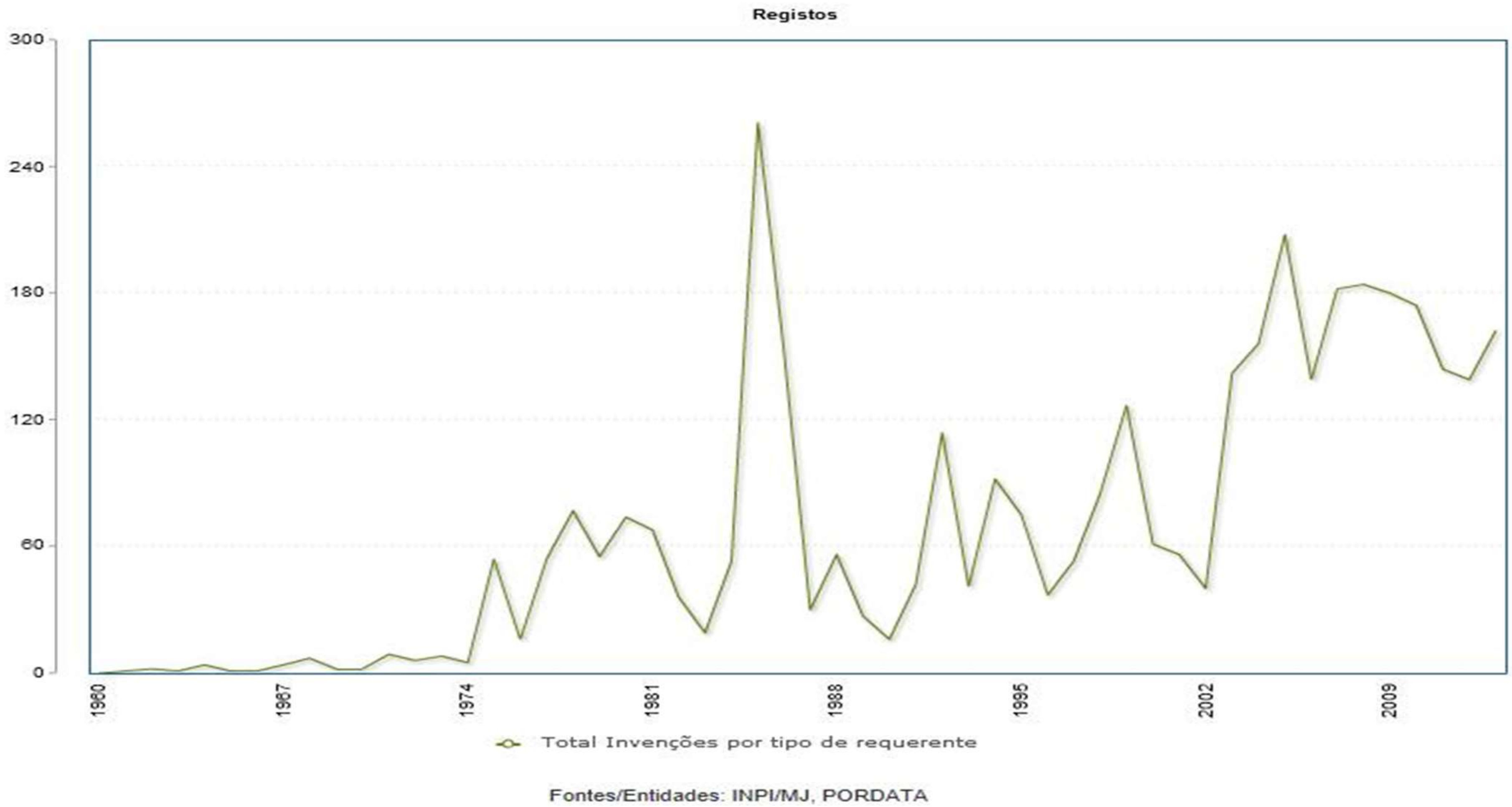
Nr of workers in R&D as % of active population



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



Nr of inventions/patents issued in Portugal



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 LY; increasing returns in K, LY and A.

A(t) *stock* of knowledge
(nr of ideas invented <u>until</u> moment t)

θ* <u>productivity</u> of research (nr. of new ideas produced per researcher)

0 < λ < 1 <u>externality</u> associated with duplication

Φ > 0 positive knowledge <u>*spillover*</u> in research

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