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Environmental Regulation and Economic Growth under Education Externalities

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Abstract

Using an extension of Lucas' model of endogenous growth with education externality, we show that an environmental tax may increase growth. This is because the tax makes physical capital accumulation less attractive, thereby correcting for the underinvestment by agents in human capital.

Keywords: Regulation, Environment, Growth, Human Capital

JEL Codes: O11, O13, Q28

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1. Introduction

The impact of environmental regulation and taxation on economic growth is uncertain a priori. Gradus and Smulders (1993) and Ligthart and van der Ploeg (1994) suggest that environmental policy may reduce growth, while Bovenberg and Smulders (1995) and van Ewijk and van Wijnbergen (1994) suggest the reverse on the basis that pollution may affect production negatively. In a model with leisure, Oueslati (2002) provides another rationale for a positive impact of a tax. If regulation induces firms to reduce output, households will compensate by substituting education time for leisure, which has negative short run impacts but positive long term impacts due to higher human capital accumulation.

In this paper, we provide yet another argument for the possibility of a beneficial impact on growth from regulation. Following Lucas (1988), we assume that human capital produces a positive externality which is not taken into account by maximizing agents. If pollution is an increasing function of the quantity of physical capital used in the production process (Forster, 1973), the appropriate environmental tax is also an increasing function of the capital stock. Then, by making human capital accumulation more attractive as compared to physical capital accumulation, the tax may increase growth thanks to the externality from human capital. In other words, the tax corrects for the fact that agents do not incorporate the externality of human capital in their own optimization decisions.

2. Lucas' Model of Endogenous Growth

To focus the discussion on the impact of environmental regulation on growth, we simplify Lucas' (1988) model by assuming no population growth. At each period, each agent decides on his/her level of consumption, $c(t)$, and on the time allocated to work $u(t)$. The agent has a dotation of 1 unit of time, and the remaining time

$1 - u(t)$ is spent on human capital accumulation. The production function is

$$y(t) = Ak(t)^\beta [u(t)h(t)]^{1-\beta} h_a(t)^\gamma, \quad (1)$$

where $k(t)$ is per capita capital, $h(t)$ is human capital and $h_a(t)$ is the average level of human capital in the economy at time t . For the agent, $h_a(t)$ is exogenously determined, implying a positive externality from the human capital accumulation of others. The agent's own human capital accumulation function is

$$\dot{h}(t) = h(t)\delta[1 - u(t)]. \quad (2)$$

The agent's optimization problem is

$$\begin{aligned} & \max_{\{c(t), u(t)\}_{t=0}^{\infty}} \int_0^{\infty} e^{-\rho t} \frac{c(t)^{1-\sigma} - 1}{1-\sigma} dt \\ & \text{subject to} \\ & \dot{k}(t) = Ak(t)^\beta [u(t)h(t)]^{1-\beta} h_a(t)^\gamma - c(t), \text{ and} \\ & \dot{h}(t) = h(t)\delta[1 - u(t)]. \end{aligned} \quad (3)$$

Market clearing conditions ensure that $h_a(t) = h(t)$, hence the second constraint becomes

$$\dot{k}(t) = Ak(t)^\beta [u(t)h(t)]^{1-\beta} h(t)^\gamma - c(t) \quad (4)$$

With per capita consumption and per capita capital growing at the same rate κ , and denoting by ν the growth rate of human capital, Lucas shows that the agent will chose

$$\kappa = \left(\frac{1 - \beta + \gamma}{1 - \beta} \right) \nu, \text{ with } \nu = \frac{(1 - \beta)(\delta - \rho)}{\sigma(1 - \beta + \gamma) - \gamma} \quad (5)$$

This path, while optimal for each agent, is not optimal for the economy, because it does not take into account the positive externality from human capital accumulation. The optimal path is instead

$$\kappa^* = \left(\frac{1 - \beta + \gamma}{1 - \beta} \right) \nu^*, \text{ with } \nu^* = \frac{1}{\sigma} \left[\delta - \frac{(1 - \beta)\rho}{1 - \beta + \gamma} \right]. \quad (6)$$

Lucas shows that we must have $\nu^* \geq \nu$ because there is a restriction on σ :

$$\sigma \geq 1 - \frac{1 - \beta}{1 - \beta + \gamma} \frac{\rho}{\delta} \quad (7)$$

3. Introducing Environmental Regulation

Assume now that pollution is a byproduct of the physical capital stock used in the production process, and that the damage to the environment increases with $k(t)$. To reduce pollution, an environmental tax τ is imposed as an increasing function of $k(t)$ (Forster, 1973). For simplicity, we assume that the net product available for consumption and saving is $n(t) Ak(t)^\beta [u(t)h(t)]^{1-\beta} h_a(t)^\gamma$ with $n(t) = 1 - \tau(k(t)) = k(t)^\phi$ and $\phi < 0$. The agent's problem becomes

$$\begin{aligned} & \max_{\{c(t), u(t)\}_{t=0}^{\infty}} \int_0^{\infty} e^{-\rho t} \frac{c(t)^{1-\sigma} - 1}{1-\sigma} dt \\ & \text{subject to} \\ & \dot{k}(t) = n(t) Ak(t)^\beta [u(t)h(t)]^{1-\beta} h_a(t)^\gamma - c(t), \text{ and} \\ & \dot{h}(t) = h(t) \delta [1 - u(t)]. \end{aligned} \quad (8)$$

The current-value Hamiltonian is

$$\begin{aligned} H(k, h, \theta_1, \theta_2, c, u; t) &= \frac{c(t)^{1-\sigma} - 1}{1-\sigma} \\ &+ \theta_1(t) \left\{ n(t) Ak(t)^\beta [u(t)h(t)]^{1-\beta} h_a(t)^\gamma - c(t) \right\} \\ &+ \theta_2(t) h(t) \delta [1 - u(t)], \end{aligned} \quad (9)$$

where $\theta_1(t)$ and $\theta_2(t)$ are respectively the current shadow prices of physical and human capital. The optimal growth path is described by the Pontryagin conditions

$$c(t)^{-\sigma} - \frac{\theta_1(t)}{\theta_1(t)} = 0, \quad (10)$$

$$\theta_1(t) n(t) (1 - \beta) Ak(t)^\beta u(t)^{-\beta} h(t)^{1-\beta} h_a(t)^\gamma - \theta_2(t) h(t) \delta = 0, \quad (11)$$

$$\dot{\theta}_1(t) = \rho\theta_1(t) - \theta_1(t)n(t)\beta Ak(t)^{\beta-1}[u(t)h(t)]^{1-\beta}h_a(t)^\gamma, \quad (12)$$

$$\begin{aligned} \dot{\theta}_2(t) = & \rho\theta_2(t) - \theta_1(t)n(t)(1-\beta)Ak(t)^\beta u(t)^{1-\beta}h(t)^{-\beta}h_a(t)^\gamma \\ & - \theta_2(t)\delta[1-u(t)], \end{aligned} \quad (13)$$

$$\dot{k}(t) = n(t)Ak(t)^\beta[u(t)h(t)]^{1-\beta}h_a(t)^\gamma - c(t), \quad (14)$$

$$\dot{h}(t) = h(t)\delta[1-u(t)], \quad (15)$$

with the transversality conditions

$$\lim_{t \rightarrow \infty} e^{-\rho t} \theta_1(t) k(t) = 0, \quad (16)$$

and

$$\lim_{t \rightarrow \infty} e^{-\rho t} \theta_2(t) h(t) = 0. \quad (17)$$

Market clearing conditions still imply that $h_a(t) = h(t)$, so from now on, we only use $h(t)$.

Let κ^t denote the rate of growth of per capita consumption on a balanced growth path with environmental taxation. From (10), we find that $\dot{\theta}_1(t)/\theta_1(t) = -\sigma\kappa^t$. Using this result and (12) yields

$$n(t)\beta Ak(t)^{\beta-1}[u(t)h(t)]^{1-\beta}h(t)^\gamma = \rho + \sigma\kappa^t. \quad (18)$$

From (18) and (14), we get

$$\frac{c(t)}{k(t)} + \frac{\dot{k}(t)}{k(t)} = \frac{\rho + \sigma\kappa^t}{\beta}. \quad (19)$$

By definition of a balanced growth path, $\dot{k}(t)/k(t)$ is constant so that $c(t)/k(t)$ must also be constant. This implies that $\dot{k}(t)/k(t) = \kappa^t$. Per capita physical capital and per capita consumption grow at the same rate, as before. Since $n(t) =$

$k(t)^\phi$, we get $\dot{n}(t)/n(t) = \phi\kappa^t$. If ν^t is the rate of growth of human capital, by differentiating (18), we find

$$\kappa^t = \frac{1 - \beta + \gamma}{1 - \beta - \phi} \nu^t. \quad (20)$$

Differentiating (11), we get

$$\frac{\dot{\theta}_2(t)}{\theta_2(t)} = (\beta + \phi - \sigma)\kappa^t - (\beta - \gamma)\nu^t. \quad (21)$$

Using (11), we also find that

$$\frac{\theta_1(t)}{\theta_2(t)} = \frac{\delta}{n(t)(1 - \beta)Ak(t)^\beta u(t)^{-\beta} h(t)^{-\beta + \gamma}}. \quad (22)$$

Using (22) and (13), we get

$$\frac{\dot{\theta}_2(t)}{\theta_2(t)} = \rho - \delta. \quad (23)$$

Using (23) and (21) yields

$$\kappa^t = \frac{\rho - \delta + (\beta - \gamma)\nu^t}{\beta + \phi - \sigma}. \quad (24)$$

Finally, using (24) and (20), we get

$$\nu^t = \frac{(1 - \beta - \phi)(\delta - \rho)}{\sigma(1 - \beta + \gamma) - \gamma - \phi}. \quad (25)$$

By comparing (25) and (5), the impact of the environmental tax on growth is such that

$$\nu^t > \nu \iff \phi(\delta - \rho)\{(1 - \beta) - \sigma(1 - \beta + \gamma) - \gamma\} > 0 \quad (26)$$

To analyze this expression, we define two possible values for σ :

$$\sigma^- = 1 - \frac{1 - \beta}{1 - \beta + \gamma} \frac{\rho}{\delta} \quad (27)$$

and

$$\sigma^+ = \frac{1 - \beta - \gamma}{1 - \beta + \gamma} \quad (28)$$

It can be shown that, for low values of σ ($\sigma \in [\sigma^-, \sigma^+]$), the environmental tax increases economic growth if $\rho > \delta$. If $\rho = \delta$, the tax has no impact on growth. If $\rho < \delta$ the tax has an adverse impact on economic growth. For higher values of σ ($\sigma > \sigma^+$), the tax increases growth if $\rho < \delta$. If $\rho = \delta$, the tax has no impact on growth. If $\rho > \delta$ the tax has an adverse impact on growth. Thus, depending on the preferences of the agent, as captured by ρ and σ , there are cases where environmental regulation increases growth.

4. Conclusion

We have shown that it is theoretically possible that environmental regulation increases economic growth. However, even in our simple model, this conclusion depends on the preferences of the maximizing economic agent. In this context, whether or not an environmental tax will increase economic growth remains an empirical matter.

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