A demand-based mechanism for the Environmental Kuznets Curve

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Aim

- A theoretical characterization of the relationship between pollution and income along development process.

  "*During the early stages of economic growth, degradation and pollution increases, but beyond some level of income per capita the trend reverses.*" (Stern, 2004)

- Is it possible to obtain a non-monotonic relation between pollution and income at some stage of the development process?

- How does sustainable economic growth affect the evolution of pollution?

Empirical evidence

- Some empirical studies support an inverted-U relationship between pollution and income. Other papers even obtain an N-shaped relationship.
- However, there is not conclusive evidence of the existence of an EKC.
- In any case, we should look for the existence of economic foundations that may drive the relationship between pollution and income along development process.

A general result

Consider an economy with

$$U(\underset{+}{c}, \underset{-}{P}),$$

with

$$P = P(\underset{+}{c}, \underset{-}{e}).$$

Result. $\frac{\partial P}{\partial R} \lesseqgtr 0$ if and only if

$$\underbrace{\frac{\varepsilon_c^R}{\varepsilon_e^R}}_{(+)} + \underbrace{\frac{\varepsilon_P^e}{\varepsilon_P^c}}_{(-)} \lesseqgtr 0.$$

Revisiting literature

$$\frac{\varepsilon_c^R}{\varepsilon_e^R} + \frac{\varepsilon_P^e}{\varepsilon_P^c} \lesseqgtr 0.$$

- In general, the literature has focused on the technology of pollution by considering:

  1. Homothetic preferences: $\frac{\varepsilon_c^R}{\varepsilon_e^R} = 1$.
  2. At least for some level income: $\frac{\varepsilon_P^e}{\varepsilon_P^c} < -1$. Note that $\left|\varepsilon_P^e\right| > \varepsilon_P^c$. (See, for instance, Andreoni and Levinson, 2001)

- **Our contribution:** By assuming non homothetic preferences we obtain $\frac{\varepsilon_c^R}{\varepsilon_e^R} < 1$. Hence, a negative relationship between pollution and income may arise *even when* $\left|\varepsilon_P^e\right| < \varepsilon_P^c$.

A stylized model

Given R, a representative consumer solves:

$$\max_{\{c,e\}} \left\{ U(c,P) = \gamma \log(c - \bar{c}) - \lambda \log\left[P(c,e)\right] \right\}$$

subject to

$$P(c,e) = c^{\theta} (\varphi + e)^{-\pi},$$

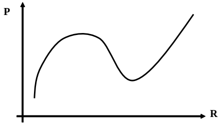
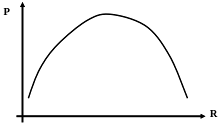
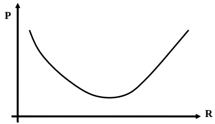
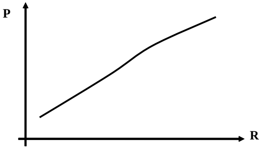
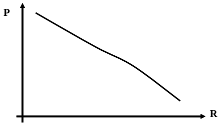
$$R = c + e.$$

- Observe:

$$\varepsilon_c^R = \frac{\gamma R}{\gamma (R + \varphi) + \lambda \pi \bar{c}} < 1,$$

$$\varepsilon_e^R = \frac{\lambda \pi R}{\lambda \pi (R - \bar{c}) - \gamma \varphi} > 1.$$

Income-pollution relation

$\theta > \pi$		$\pi > \theta$
$\bar{c} > 0$ and $\varphi > 0$ 		$\varphi > 0$ 
$\varphi = 0$ 	$\bar{c} = 0$ 	$\varphi = 0$ 

The ingredients

We insert the previous mechanism into a DGE model:

- Agents: a representative consumer and competitive firms.
- A homogenous final good produced by a CRS technology that uses capital and labor as inputs. This good can be used for consumption, investment and abatement.
- Net pollution increases with emissions, which is a by-product of production, and decreases with abatement.
- Labor is exogenously supplied and population is constant.
- There is exogenous technical progress.

Model

- Firms' problem:

$$\max_{\{k_t, l_t\}} \{y_t - r_t k_t - w_t l_t\}, \text{ s.t. } y_t = k_t^{\alpha} \left[(1+\eta)^t \, l_t\right]^{1-\alpha}.$$

- Consumer's problem:

$$\max_{\{c_t, e_t, k_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\left[(c_t - \overline{c}_t)^{\gamma} P_t^{-\lambda}\right]^{1-\sigma} - 1}{1-\sigma} \right\}$$

subject to

$$P_t = y_t^{\theta} (\varphi_t + e_t)^{-\pi},$$

$$r_t k_t + w_t = c_t + e_t + k_{t+1} - (1-\delta) k_t,$$

$$\overline{c}_t = (1+\eta)^t \, \overline{c}_0,$$

$$\varphi_t = (1+\eta)^t \, \varphi_0.$$

Competitive equilibrium

Given $\{k_0, \overline{c}_0, \varphi_0\}$, a *competitive equilibrium* is defined as a set of paths for prices $\{r_t, w_t\}$, allocations $\{c_t, e_t\}$ and capital stock $\{k_t\}$, such that:

(i) the path $\{c_t, e_t\}$ solves the consumer's problem, i.e.,

$$u_c(c_t, P_t) = -u_p(c_t, P_t)\left[\pi y_t^{\theta}(\varphi_t + e_t)^{-(\pi+1)}\right],$$

$$u_c(c_t, P_t) = \beta u_c(c_{t+1}, P_{t+1})(1 - \delta + r_{t+1});$$

(ii) the path $\{k_t\}$ maximizes the firms' profits, i.e.,

$$r_t = \alpha(1+\eta)^{(1-\alpha)t} k_t^{\alpha-1},$$

$$w_t = (1-\alpha)(1+\eta)^{(1-\alpha)t} k_t^{\alpha};$$

(iii) the market clearing conditions hold, i.e.,

$$y_t = c_t + e_t + k_{t+1} - (1-\delta) k_t.$$

Long-run equilibrium

Our economy exhibits a *balanced growth path (BGP) equilibrium*, along which y_t, k_t, c_t and e_t grow at the constant rate $1+\eta$, and P_t grows at rate $(1+\eta)^{\theta-\pi}$.

We now normalize the variables to remove the consequences of the long-run growth:

$$\begin{aligned}
\widehat{k}_t &= k_t\,(1+\eta)^{-t}, \\
\widehat{c}_t &= c_t\,(1+\eta)^{-t}, \\
\widehat{e}_t &= e_t\,(1+\eta)^{-t} \\
\widehat{y}_t &= y_t\,(1+\eta)^{-t}, \\
\widehat{P}_t &= P_t\,(1+\eta)^{-(\theta-\pi)t}.
\end{aligned}$$

Note that the normalized variables are stationary in the long run.

Parameter values

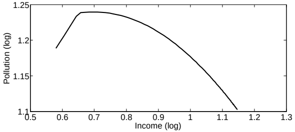
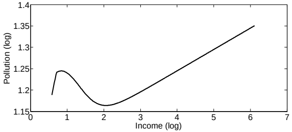
Technology						Preferences				
α	θ	π	δ	η	φ_0	β	σ	γ	λ	$\overline{c}_0$
0.36	0.7	0.65	0.025	0.01	0.3	0.99	1.5	1/3	1/3	1

This implies that the BGP satisfies:

- Capital income share in GDP: 36%
- Consumption-GDP ratio: 63%
- Investment-GDP ratio: 27%
- Abatement-GDP ratio: 10%
- Quarterly growth rate: 1%
- Investment-capital ratio: 3.5%
- Quarterly net interest rate: 2%
- $\overline{c}_0 / c_0 = 0.7$

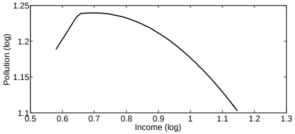
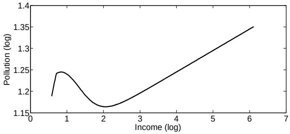
Income-pollution relation

Benchmark economy:

Normalized economy $\left(\widehat{P},\ \widehat{y}\right)$	Original economy $(P,\ y)$
	

The role of minimum consumption

Benchmark economy with $\overline{c}_0 = 0$

<table>
<tr><td>Normalized economy $\left(\widehat{P},\ \widehat{y}\right)$</td><td>Original economy $(P,\ y)$</td></tr>
<tr><td colspan="2">$\overline{c}_0 > 0$</td></tr>
<tr><td>
</td><td>
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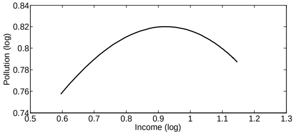
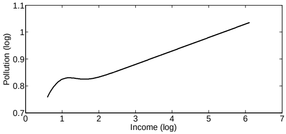
<tr><td>
</td><td>
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Elasticity of pollution wrt abatement

Benchmark economy with $\overline{c}_0 = 0$ and $\pi = 0.68$

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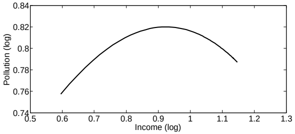

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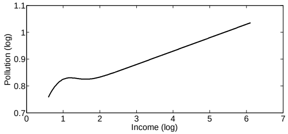

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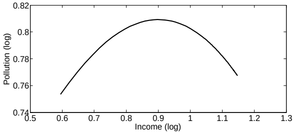

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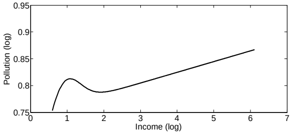

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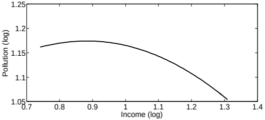
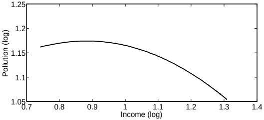
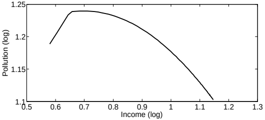
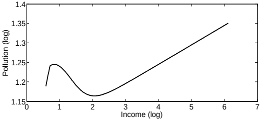
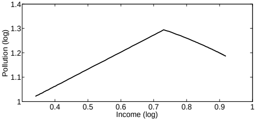
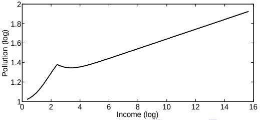
The role of sustainable growth

Normalized economy $\left(\widehat{P},\ \widehat{y}\right)$	Original economy $(P,\ y)$
$\eta = 0$	
	
$\eta = 0.01$ (benchmark)	
	
$\eta = 0.03$	
	

Concluding remarks

- Non homothetic preferences seem to be a crucial assumption to understand the pattern of pollution along the development process.
- If the scale of emissions in pollution is larger than that of abatement $(\theta > \pi)$, sustainable growth leads pollution to be increasing in income in the long run. Can this pattern be reverted?
  - Technological innovations can alter this relative scale.
  - Structural change may reduce emissions. (This is in our agenda)