# The Natalist Bias of Pollution Control

David de la Croix[1] Axel Gosseries[1]

[1]Univ. cath. Louvain (UCL)

June 2010

# Starting point

Concern about climate change

Policies aimed at reducing greenhouse gas emissions

Kyoto has set up a cap-allocate-and-trade regime

In fully certain environment, this system is the same as a (Pigovian) tax-subsidy scheme

Our question: long-term demographic impact of a Kyoto-like regime?

# Literature

Demographic impact of pollution control may make future generations poorer

Grubb (1995), Garvey (2008): Natalist bias if pollution quotas are allocated on a per capita basis

Negligible ?

We have another mechanism in mind

# Idea

Two ways to achieve low pollution when technology is given

- low production per capita
- low population size

Kyoto-lie systems: taxing production
$\rightarrow$ lead agents to substitute tax free activities such as reproduction and leisure to production.

But reproduction generates pollution tomorrow... more taxes are needed

Capping emissions gradually impoverishes the successive generations

## Two key assumptions

1. "Autonomous technology"

Even if technology responds to price and tax changes, it will not be enough to keep pollution under control

The scale of environment-saving improvements required to stabilize pollution is daunting

2. "Production-reproduction substitution"

Raising children: opportunity cost because of the time it takes

Is this substitution effect strong enough?

The impact of substitution effect is cumulative

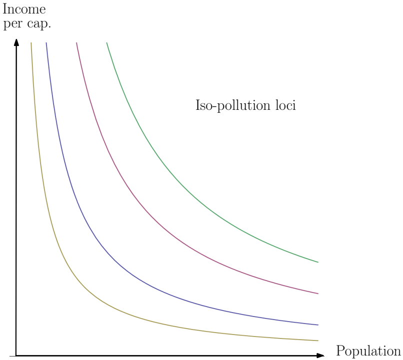
# Pollution

Emissions: $E_t = a_t Y_t$
$a_t$: pollution coefficient,
$Y_t$: output

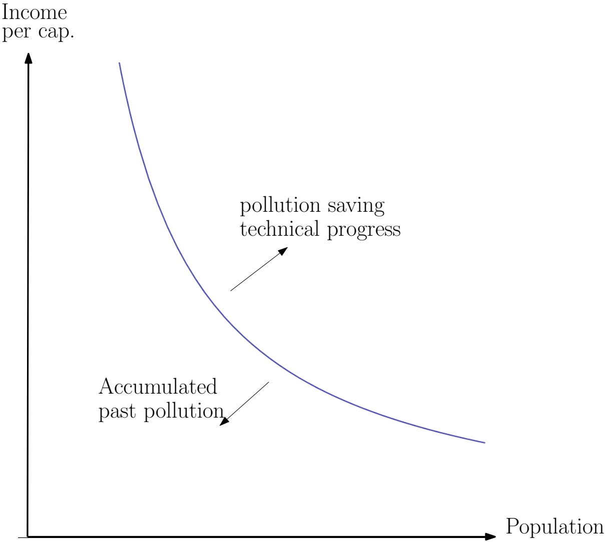
$$E_t = a_t N_t y_t$$

$N_t$: adult population size,
$y_t$: output per person
Stock of pollution $S_t$:

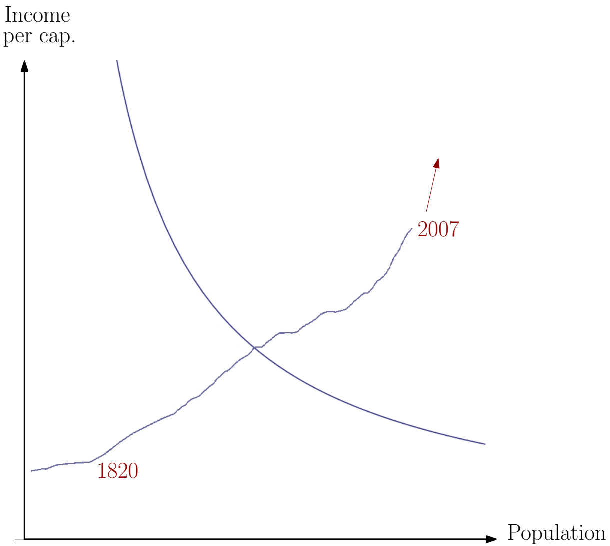
$$S_t = (1 - \delta(S_{t-1}))S_{t-1} + E_t.$$



# Shifts over Time of one Iso-pollution Curve



# Historical Data and one Iso-pollution Curve



# Preferences

One generation is active during one period

Utility from consumption, leisure, fertility, and assets left for the future generation

$$u(c_t, \ell_t, n_t, k_{t+1}) = \ln c_t + \delta \ln \ell_t + \gamma \ln(n_t k_{t+1}),$$

ad-hoc altruism

logarithmic preferences (no secular trend in leisure)

# Technology

Bequest $b_t$ are invested in a productive asset $k_{t+1}$

$$k_{t+1} = G\left(k_t, b_t\right) = \tau k_t^{\nu} b_t^{\eta}$$

Producing $x$ children requires time and space (land per household), with the following technology:

$$x = A\left(\frac{L}{N_t}\right)^{\alpha} T$$

Hence, to produce $n_t$ children one needs

$$\phi\, N_t^{\alpha} n_t$$

units of time

# Budget constraint without pollution cap

Households are self-employed and produce using assets $k_t$ and hours of work $(1 - \ell_t - \phi N_t^\alpha n_t)$. The production function is

$$y_t = (1 - \ell_t - \phi N_t^\alpha n_t) k_t$$

Budget constraint:

$$y_t = c_t + n_t b_t$$

# Dynamics in the benchmark case

Population dynamics

$$N_{t+1} = N_t n_t$$

$$\begin{aligned} k_{t+1} &= \tau \left( \frac{\eta\phi}{1-\eta} \right)^{\eta} N_t^{\eta\alpha} k_t^{\nu+\eta} \\ N_{t+1} &= \frac{\gamma(1-\eta)}{(1+\delta+\gamma)\phi} N_t^{1-\alpha} \end{aligned}$$

Globally stable steady state $\{\bar{k}, \bar{N}\}$

# Pollution

$S_t^\star$ can be achieved by imposing an emission target $E_t^\star$

Exogenous objective of total emissions $\{E_t^\star\}_{t\geq 0}$

Kyoto-like systems

- impose each household to buy pollution rights at price $p_t$ in proportion to their output
- provide some endowment of pollution rights $q_t$

$$y_t = c_t + n_t b_t + p_t(a_t y_t - q_t)$$

Lagrangian to solve the household problem

$$\max_{\ell_t, n_t, b_t} \mathcal{L}_t = \ln((1 - a_t p_t)(1 - \ell_t - \phi n_t)k_t - n_t b_t + p_t q_t) \\ + \varphi \ln \ell_t + \gamma(\ln(n_t) + \nu \ln(k_t) + \eta \ln(b_t) + \ln(\tau))$$

# Partial equilibrium results

Non market activities, leisure and procreation, increase with the price of the pollution permit, as their opportunity cost is decreased by this implicit tax:

$$\frac{\partial \ell_t}{\partial p_t} > 0, \quad \frac{\partial n_t}{\partial p_t} > 0$$

Leisure and procreation increase with the endowment of pollution permits. This is because they are both normal goods:

$$\frac{\partial \ell_t}{\partial q_t} > 0, \quad \frac{\partial n_t}{\partial q_t} > 0$$

# Dynamics with pollution permits

The equilibrium on the market for tradable pollution rights:

$$p_t(N_t a_t y_t - N_t q_t) = 0$$

Assuming binding pollution caps, the dynamic system is:

$$k_{t+1} = \tau k_t^{\nu} \left( \frac{\eta \phi N_t^{\alpha} k_t}{1-\eta} \left( 1 - \frac{k_t(1+\gamma\eta) - q_t(1+\varphi+\gamma)}{(k_t - q_t)(1+\gamma\eta)} \right) \right)^{\eta}$$

$$N_{t+1} = N_t \left( \frac{\gamma(1-\eta)}{(1+\varphi+\gamma)\phi N_t^{\alpha}} \left( 1 + \frac{\frac{k_t(1+\gamma\eta)-q_t(1+\varphi+\gamma)}{(k_t-q_t)(1+\gamma\eta)}}{1 - \frac{k_t(1+\gamma\eta)-q_t(1+\varphi+\gamma)}{(k_t-q_t)(1+\gamma\eta)}} \frac{q_t}{k_t} \right) \right)$$

# Main result

**Proposition**

For stringent enough $E^\star$, there is a locally stable steady state population $N$, decreasing in $E^\star$.

Population is increasing with the restrictiveness of the pollution cap.

# Overview

Each period lasts 25 years. 1983: $t = 0$. 2008: $t = 1$. 2033: $t = 2$

Initial conditions: $N_0 = 4.68$ and $y_0 = 4.541$ (i.e. $k_0 = 16.0271$.)

We identify $\gamma$, $\varphi$, $\eta$, $\nu$ and $\alpha$ with five restrictions at steady state (next slide)

Productivity parameters, $\tau$ and $\phi$, determine the size of population and income per capita.

To obtain $N_1 = 6.67$ and $y_1 = 4.541$ in 2008, we need to have $\phi = 0.0164$ and $\tau = 24.0417$.

# Five restrictions

1. The share of consumption in GDP is 80%

$$\frac{c_t}{y_t} = \frac{1}{1+\gamma\eta} = 0.8$$

2. the time spent on leisure ($\ell_t$) and procreation ($\phi\bar{N}^\alpha$) amounts to 2/3 of total available time:

$$\ell_t + \phi\bar{N}^\alpha = \frac{\varphi}{1+\varphi+\gamma} + \frac{\gamma(1-\eta)}{1+\varphi+\gamma} = \frac{\varphi+\gamma(1-\eta)}{1+\varphi+\gamma} = \frac{2}{3}$$

3. At steady state, time spent rearing children equals 15%:

$$\frac{\phi N^\alpha}{1-\ell_t} = \frac{\gamma(1-\eta)}{1+\gamma} = 0.15$$

# Five restrictions

1. Convergence speed of income per capita is 2% per year:

$$\frac{k_{t+1}}{k_t} = \left(\frac{k_t}{k_{t-1}}\right)^{\nu+\eta} \left(\frac{N_t}{N_{t-1}}\right)^{\alpha\eta} \Rightarrow \nu + \eta = 0.98^{25}$$

2. Dynamics of population match 2007 IIASA World Population Projection:

$$\frac{N_{t+1}}{N_t} = \left(\frac{N_t}{N_{t-1}}\right)^{1-\alpha} \Rightarrow \frac{8.88}{8.18} = \left(\frac{8.18}{6.67}\right)^{1-\alpha}$$

# Benchmark Simulation - World Economy 1983-2208

| $t$ | $N_t$ | $c_t$ | $n_t$ | $\ell_t$ | $y_t$ | $Y_t$ |
|---|---|---|---|---|---|---|
| 1983 | 4.68 | 4.27 | 1.425 | 0.608 | 5.342 | 25.0 |
| 2008 | 6.67 | 7.81 | 1.153 | 0.608 | 9.769 | 65.2 |
| 2033 | 7.69 | 12.59 | 1.059 | 0.608 | 15.737 | 121.0 |
| 2058 | 8.15 | 17.56 | 1.023 | 0.608 | 21.954 | 178.8 |
| 2083 | 8.34 | 21.87 | 1.009 | 0.608 | 27.334 | 227.9 |
| 2108 | 8.41 | 25.14 | 1.004 | 0.608 | 31.428 | 264.4 |
| 2133 | 8.44 | 27.43 | 1.002 | 0.608 | 34.290 | 289.6 |
| 2158 | 8.46 | 28.95 | 1.001 | 0.608 | 36.185 | 306.1 |
| 2183 | 8.46 | 29.92 | 1.000 | 0.608 | 37.397 | 316.5 |
| 2208 | 8.46 | 30.52 | 1.000 | 0.608 | 38.155 | 323.0 |

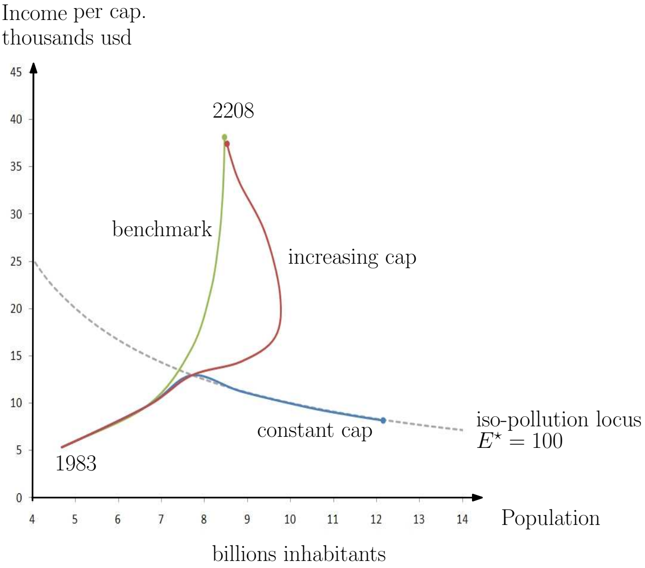
# Simulation with a Constant Pollution Cap - 1983-2208

| $t$ | $q_t$ | $N_t$ | $p_t$ | $c_t$ | $n_t$ | $\ell_t$ | $y_t$ | $Y_t$ |
|---|---|---|---|---|---|---|---|---|
| 1983 | 21.37 | 4.680 | 0.00 | 4.27 | 1.425 | 0.608 | 5.342 | 25.0 |
| 2008 | 14.99 | 6.670 | 0.00 | 7.81 | 1.153 | 0.608 | 9.769 | 65.2 |
| 2033 | 13.00 | 7.692 | 0.24 | 10.40 | 1.151 | 0.661 | 13.000 | 100.0 |
| 2058 | 11.29 | 8.855 | 0.51 | 9.03 | 1.171 | 0.731 | 11.294 | 100.0 |
| 2083 | 9.65 | 10.366 | 0.56 | 7.72 | 1.087 | 0.746 | 9.647 | 100.0 |
| 2108 | 8.87 | 11.272 | 0.57 | 7.10 | 1.042 | 0.752 | 8.871 | 100.0 |
| 2133 | 8.51 | 11.746 | 0.58 | 6.81 | 1.020 | 0.754 | 8.513 | 100.0 |
| 2158 | 8.35 | 11.982 | 0.59 | 6.68 | 1.010 | 0.755 | 8.346 | 100.0 |
| 2183 | 8.27 | 12.097 | 0.59 | 6.61 | 1.005 | 0.756 | 8.266 | 100.0 |
| 2208 | 8.23 | 12.153 | 0.59 | 6.58 | 1.002 | 0.756 | 8.229 | 100.0 |

# Simulation with technical progress - 1983-2208

| $t$ | $q_t$ | $N_t$ | $p_t$ | $c_t$ | $n_t$ | $\ell_t$ | $y_t$ | $Y_t$ |
|---|---|---|---|---|---|---|---|---|
| 1983 | 12.99 | 4.680 | 0.00 | 4.27 | 1.425 | 0.608 | 5.342 | 25.0 |
| 2008 | 11.69 | 6.670 | 0.00 | 7.81 | 1.153 | 0.608 | 9.769 | 65.2 |
| 2033 | 13.00 | 7.692 | 0.24 | 10.40 | 1.151 | 0.661 | 13.000 | 100.0 |
| 2058 | 14.48 | 8.855 | 0.32 | 11.59 | 1.089 | 0.680 | 14.483 | 128.2 |
| 2083 | 17.06 | 9.641 | 0.26 | 13.65 | 1.012 | 0.665 | 17.058 | 164.5 |
| 2108 | 21.62 | 9.755 | 0.14 | 17.30 | 0.964 | 0.638 | 21.622 | 210.9 |
| 2133 | 28.77 | 9.402 | 0.00 | 22.53 | 0.939 | 0.608 | 28.167 | 264.8 |
| 2158 | 39.28 | 8.831 | 0.00 | 26.60 | 0.975 | 0.608 | 33.249 | 293.6 |
| 2183 | 51.66 | 8.611 | 0.00 | 28.82 | 0.990 | 0.608 | 36.025 | 310.2 |
| 2208 | 66.92 | 8.525 | 0.00 | 30.01 | 0.996 | 0.608 | 37.511 | 319.8 |

# Picture


Income per cap.
thousands usd
45
40
35
30
25
20
15
10
5
0
4
5
6
7
8
9
10
11
12
13
14
2208
benchmark
increasing cap
constant cap
1983
iso-pollution locus
$E^\star = 100$
Population
billions inhabitants

# Conclusion

Pollution control should not be at the cost of those in the future.

The natalist bias we identified is worrying in the latter respect.

Is our story quantitatively significant ? e.g. if we impose such a rule in India, by how much would we delay the demographic transition ?

Population could be capped directly through a separate scheme, be it in the absence of or as a complement of the pollution capping scheme.