The Natalist Bias of Pollution Control

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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?
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-like systems: taxing production
→ 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

Income per cap.

pollution saving
technical progress

Accumulated past pollution

Population
Historical Data and one Iso-pollution Curve

Income per cap.

Population

2007

1820
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 $k_{t+1}$

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

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
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

\[ N_{t+1} = N_t n_t \]

\[ k_{t+1} = \tau \left( \frac{\eta \phi}{1 - \eta} \right)^\eta N_t^{\eta \alpha} k_t^{\nu + \eta} \]

\[ N_{t+1} = \frac{\gamma (1 - \eta)}{(1 + \delta + \gamma) \phi} N_t^{1 - \alpha} \]

Globally stable steady state \( \{ \bar{k}, \bar{N} \} \)
Pollution

$S^*_t$ can be achieved by imposing an emission target $E^*_t$

Exogenous objective of total emissions $\{E^*_t\}_{t \geq 0}$

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

$$\max_{\ell_t, n_t, b_t} \mathcal{L}_t = \ln \left( (1 - a_t p_t)(1 - \ell_t - \phi n_t)k_t - n_t b_t + p_t q_t \right)$$

$$+ \varphi \ln \ell_t + \gamma (\ln(n_t) + \nu \ln(k_t) + \eta \ln(b_t) + \ln(\tau))$$
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:

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

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

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

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%:

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

\[ \frac{N_{t+1}}{N_t} = \left( \frac{N_t}{N_{t-1}} \right)^{1-\alpha} \Rightarrow \frac{8.88}{8.18} = \left( \frac{8.18}{6.67} \right)^{1-\alpha} \]
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# Simulation with a Constant Pollution Cap - 1983-2208

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Income per cap.

thousands usd

1983

2208

benchmark

constant cap

increasing cap

iso-pollution locus

$E^* = 100$
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.