Finding a Green Nudge: An Evolutionary Perspective

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General questions which motivate this work:

- Is it possible to obtain and sustain a good environment?
- Meaning: Are we able to auto-regulate ourselves and achieve this objective in the long term?
- Why do some countries behave 'green', whereas others behave 'brown'? Are the Environmental Kuznets Curves the (only) explanation?
Motivation

The relationship between CO2 emissions and GDP per capita is often described by the Environmental Kuznets Curve (EKC). The graph illustrates how CO2 emissions (tons per year, per capita) vary with GDP per Capita (PPP). The data is sourced from the World Bank (2008).

Motivation

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CO₂ emissions (tons per year, per capita) vs. GDP per Capita (PPP)

Motivation

The relationship between GDP per capita and CO2 emissions is a central focus of many policymakers and economists. This scatter plot illustrates the correlation between GDP per capita (in PPP) and CO2 emissions (tons per year, per capita) for several countries.

- **AUS**: Australia
- **CAN**: Canada
- **USA**: United States
- **RUS**: Russia
- **NOR**: Norway
- **FIN**: Finland
- **DEU**: Germany
- **JPN**: Japan
- **GBR**: United Kingdom
- **FRA**: France
- **SWE**: Sweden

The data is sourced from the World Bank (2008).

Why similar countries (from an economic point of view) like the U.S. and the Nordic countries can behave so differently with respect to the environment?

It looks like the environmental problem is not (only) a technical one, but a socio-political one.
The aim of the present work is:

- To analyse the possibility of having two similar countries ending up in different environmental conditions.
- Try to understand the possible reasons of this phenomenon.
- To find a way of shifting from a brown equilibrium (path) to a green one (maybe through some tipping points?\(^1\)).

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A society with types of people: Those who are concerned about the environment and those who are not.

- $n \rightarrow 2$ (to keep it simple): The green and brown people.

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General Framework - The People

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Green people:

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Green people:

- Their utility will derive not only from consumption.

- But also from 'moral' motivation,\(^2\) coming from:
  - Their contribution to the environment \((r)\).
  - Their awareness/worry about the environment \((p_t)\).

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General Framework - The Society

The society is compounded by a share of green people \((q_t)\) and brown people \((1 - q_t)\).

An ‘evolving’ society.

- The proportion of these people will change in time (as observed in real life).
- As seen in Sethi and Somanathan:\(^3\) It will evolve in favour of those groups getting higher benefits.
- Which is based on replicator dynamics.\(^4\)

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There will be two types of goods in the society:

- A ‘brown’ good:
  - Which pollutes.
  - And is ’cheap’: price = 1.

- A ‘green’ good:
  - Which does not pollute.
  - But it is more expensive: price = 1 + \( \rho \).
General Framework - The Goods and Environment

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Pollution level answers a stock equation:

\[ \dot{p}_t = -\eta p_t + \gamma d_t \]

\((d_t: \text{Total brown product consumption})\)
General Framework

A government which answers to a simple majority rule:

- If $q_t < 1/2$ a brown government will be elected.
- Otherwise, a green government will be elected.
- A green government will implement a green policy.
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The cycle:
A proportion $q_t$ of green people and conversely $(1 - q_t)$ of brown people.

The society can consume two types of goods:
- A green good ($x_i$): which does not pollute, but price $= 1 + \rho$.
- A brown one ($y_i$): which does pollute, but cheaper: price $= 1$.

Each agent can consume both:
- Green person: $x_G$ green prod $+ y_G$ brown prod $= c_G$ products
- Brown person: $x_B$ green prod $+ y_B$ brown prod $= c_B$ products

They have a fixed income $w$:
- Budget constraint: $x_i(1 + \rho) + y_i = w \quad i \in \{G, B\}$
The People

The difference between green and brown people is:
Brown people are pure homo-economicous:

\[ U_B = u(c_B) \quad \rightarrow \quad c_B = y_B = w \]
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The People

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Green people get moral gain from helping the environment:
\[ U_G = m(r, p_t) + u(c_G) \]

\( m(r, p_t) \): Moral gain coming from:
- \( r \): their \textit{contribution} to the environment \( \equiv \) the \textit{share} of green products bought: \( r = x_G / c_G \).
- \( m_3(p_t) \): their awareness/worry about the environment.

\( m(r, p_t) \rightarrow u(c_G) \): Trade-off between contributing and the consumption level.
The green agent’s program

Let’s recall that \( r = \frac{x_G}{c_G} \)

- Amount of green product: \( x_G = r c_G \)
- Amount of brown product: \( y_G = (1 - r)c_G \)

So the budget constraint becomes: \( (1 + \rho)r c_G + (1 - r)c_G = w \)

Giving the quantity of products consumed by the green person:

\[
c_G = \frac{w}{(1 + r\rho)} = c_G(r) \quad \rightarrow \quad \frac{\partial c_G}{\partial r} < 0
\]

the trade-off of being green

The more he contributes \((r \uparrow)\), the less he consumes \((c_G \downarrow)\).
Moral gain

\[ m(r, p_t) = \alpha_1 m_1(r) \cdot m_3(p_t) \]

**Contribution:**
- I fell better when I contribute: \( m_1(r) \) is an increasing function.

**Awareness:**
- The idea: The worse the environment, the **worrier** or more **aware** people get.
  - \( m_3(p_t) \) is an increasing function of \( p_t \).
  - For simplicity: \( m_3(p_t) = \Omega_3 p_t \)
  - \( \Omega_3 > 0 \) is the perception bias of the pollution level.
  - \( \alpha_1 > 0 \) being a weighting parameter.
The green agent’s program

Therefore they solve the following maximization program:

$$\max_r m(r, p_t) + u(c_G(r))$$

s.t.  $0 \leq r \leq 1$ and $q_t, p_t$ given.

Hence the optimal level of contribution for the agent $r^*(p_t)$ will be given by solving $\frac{\partial U(r,p_t)}{\partial r} = 0$. 
Using the *replicator dynamics* we have that the growth rate of a trait is proportional to the pay-off’s difference with respect to the population. Generally speaking:

\[ \dot{q}_i = q_t(U_i - \bar{U}) \]

(with \( \bar{U} = \sum_i q_i U_i \))

In this case we have: \( \dot{q}_t = q_t(1 - q_t)(U_G - U_B) \)

Where \( U_G - U_B = m(r^*, p_t) + u(c_G) - u(c_B) \)

\( \Delta_u: \) the cost of being green

(Depending on the functional form of \( u(c_i) \), \( \frac{\partial \Delta u}{\partial w} \leq 0 \))
The Evolution of Society

\[ \dot{p}_t = -\eta p_t + \gamma d_t \quad \text{and} \quad \dot{q}_t = q_t (1 - q_t) [m(r^*, p_t) + \Delta u] \]
The Evolution of Society

The Governments:

- If $q_t < 1/2$, we will have a brown government: nothing will happen.

- If $q_t \geq 1/2$, we will have a green government, which will subsidy the green product.$^5$
  - This will lower $\rho$.
  - Which in turn will change the dynamics equilibrium.

$^5$Or equivalently, it will tax the brown product.
The Evolution of Society

$q_t < 1/2 \rightarrow \text{Brown government}$

$\rightarrow \text{usual } \rho$

$q_t \geq 1/2 \rightarrow \text{Green government}$

$\rightarrow \text{subsided } \rho$
The Evolution of Society

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Final Dynamics

- $\dot{q}_t = 0$ and $\dot{p}_t = 0 \Rightarrow \hat{p}_t(q_t)$ and $\tilde{p}_t(q_t)$
- $\dot{p}_t = -\eta p_t + \gamma d_t$ and $\dot{q}_t = q_t(1 - q_t)[m(r^*, p_t) + \Delta u]$
Final Dynamics

- \( \dot{p}_t = -\eta p_t + \gamma d_t \) and \( \dot{q}_t = q_t(1 - q_t)[m(r^*, p_t) + \Delta u] \)
- \( \dot{q}_t = 0 \) and \( \dot{p}_t = 0 \) \( \rightarrow \) \( \hat{p}_t(q_t) \) and \( \tilde{p}_t(q_t) \)
Final Dynamics

\[ \dot{p}_t = -\eta p_t + \gamma d_t \quad \text{and} \quad \dot{q}_t = q_t(1 - q_t)[m(r^*, p_t) + \Delta u] \]

\[ \dot{q}_t = 0 \quad \text{and} \quad \dot{p}_t = 0 \quad \rightarrow \quad \hat{p}_t(q_t) \quad \text{and} \quad \tilde{p}_t(q_t) \]
Final Dynamics

- \( \dot{p}_t = -\eta p_t + \gamma d_t \) and \( \dot{q}_t = q_t(1 - q_t)[m(r^*, p_t) + \Delta u] \)
- \( \dot{q}_t = 0 \) and \( \dot{p}_t = 0 \) → \( \hat{p}_t(q_t) \) and \( \tilde{p}_t(q_t) \)
Final Dynamics

\[ \dot{p}_t = -\eta p_t + \gamma d_t \quad \text{and} \quad \dot{q}_t = q_t(1 - q_t)[m(r^*, p_t) + \Delta u] \]

\[ \ddot{q}_t = 0 \quad \text{and} \quad \ddot{p}_t = 0 \quad \rightarrow \quad \hat{p}_t(q_t) \quad \text{and} \quad \tilde{p}_t(q_t) \]
Example of a limit trajectory. Possibility of *tipping points*.
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Searching for a environmental nudge

Example of a limit trajectory. Possibility of tipping points.
Searching for a environmental nudge
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\[ \dot{q}_t = 0 \rightarrow \hat{p}_t(q_t) \]

The limit trajectory can be 'defined' by

\[ \lim_{q_t \to 1/2} \hat{p}_t(q_t) \]

And we can make sensibility analysis (work in progress):
How does it shift with \( \Omega_3 \) (perception bias of the pollution level)?
Searching for a environmental nudge

For example: A (temporary) change in $\Omega_3$ could switch the system into the green path.
Summing up - Conclusions

• The present model is compatible with the fact that we can have **similar countries behaving differently** with respect to the environment.

• Also people behave differently → possible explanation: a **moral motivation**.

• Using this idea, we can find a way to **switch** from a brown trajectory into a green one.

• Therefore we could find **where** to **nudge** in order to produce this change (work in progress).

• **Drawback:** It is difficult to measure some of these variables (real behaviour, motivation).
The End

Thank you
For your attention