Finding a Green Nudge: An Evolutionary Perspective

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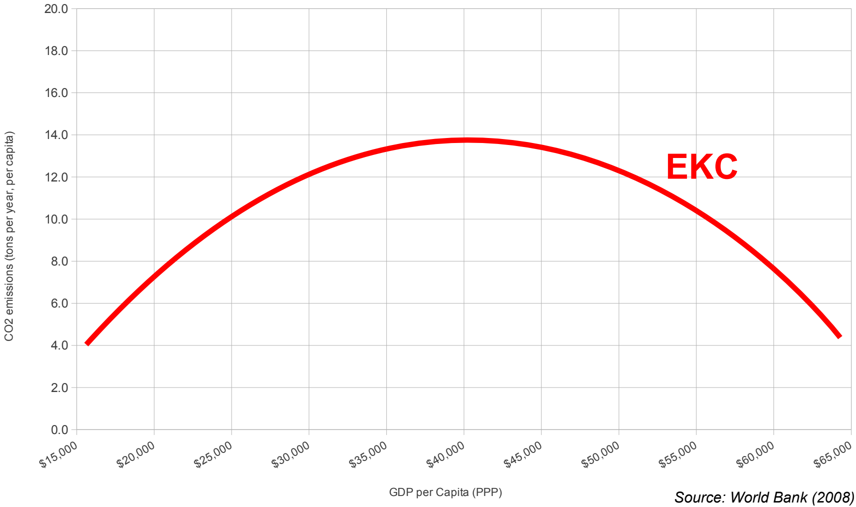
Motivation

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



Source: World Bank (2008)

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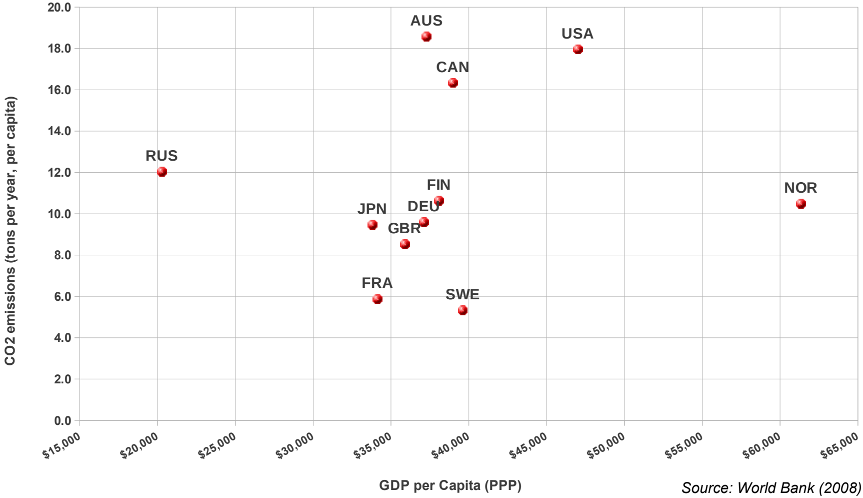

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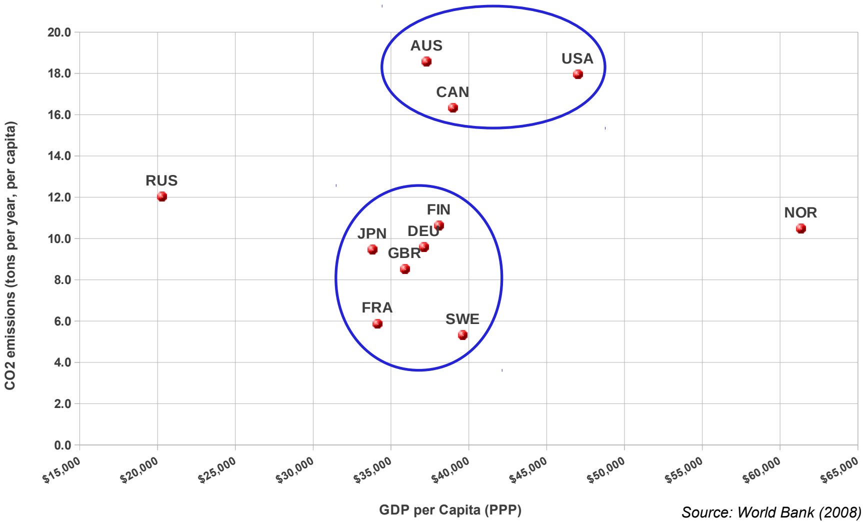

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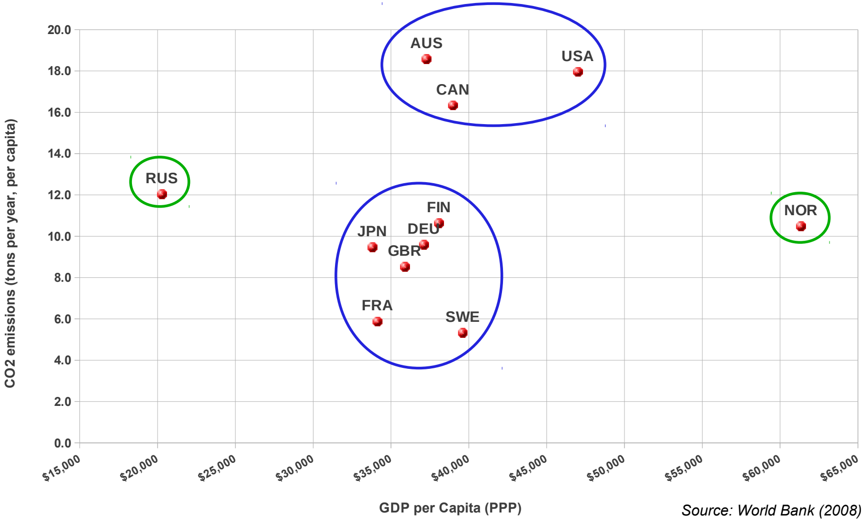

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Motivation

- 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.

Motivation

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]).

[1]Concept from Schelling's book *'Micromotives and Macrobehavior'* (1978) and with *'The Tipping Point'*, book by Malcolm Gladwell, 2000. Formal definition: Lamberson & Page (2012), *'Tipping Points'*.)

General Framework - The People

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.

[2] As in from Brekke, Kverndokk & Nyborg (2001): *'An economic model of moral motivation'*.

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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).

[2] As in from Brekke, Kverndokk & Nyborg (2001): *'An economic model of moral motivation'*.

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]

[3]Sethi and Somanathan: 'Evolution of Social Norms' (1996).
[4]Taylor and Jonker: 'Evolutionarily Stable Strategies and Game Dynamics' (1978).

General Framework - The Goods and Environment

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 $= 1 + \rho$.

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Pollution level answers a stock equation:

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

(d_t: 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.
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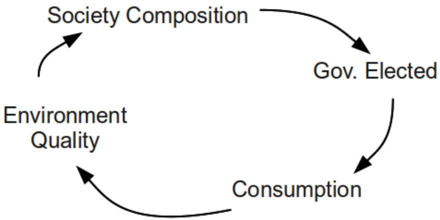
The cycle:



The General Framework

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: $\mathbf{x_G}$ green prod $+$ $\mathbf{y_G}$ brown prod $=$ $\mathbf{c_G}$ products
- Brown person: $\mathbf{x_B}$ green prod $+$ $\mathbf{y_B}$ brown prod $=$ $\mathbf{c_B}$ products

They have a fixed income w:

- Budget constraint: $x_i(1 + \rho) + y_i = w \qquad i \in \{G, B\}$

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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$m(r, p_t)$: Moral gain coming from:

- r: their **contribution** to the environment $\equiv$ the **share** of green products bought: $r = x_G / c_G$.
- $m_3(p_t)$: their awareness/worry about the environment.

$m(r, p_t) \rightarrow\leftarrow u(c_G)$: Trade-off between contributing and the consumption level.

The green agent's program

Lets recall that $r = x_G / c_G$

- 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:

$$c_G = \frac{w}{(1 + r\rho)} = c_G(r) \quad \rightarrow \qquad \underbrace{\frac{\partial c_G}{\partial r} < 0}_{\text{the trade-off of being green}}$$

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

Moral gain

$$m(r, p_t) = \underbrace{\alpha_1 m_1(r)}_{contribution} \cdot \underbrace{m_3(p_t)}_{awareness}$$

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:

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

$$\text{s.t.} \qquad 0 \leq r \leq 1 \text{ and } q_t, p_t \text{ given.}$$

Hence the optimal level of contribution for the agent $r^*(p_t)$ will be given by solving $\frac{\partial U(r,p_t)}{\partial r} = 0$.

The Evolution of Society

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:

$$\dot{q}_i = q_t(U_i - \overline{U})$$

$$\text{(with } \overline{U} = \textstyle\sum_i q_i U_i\text{)}$$

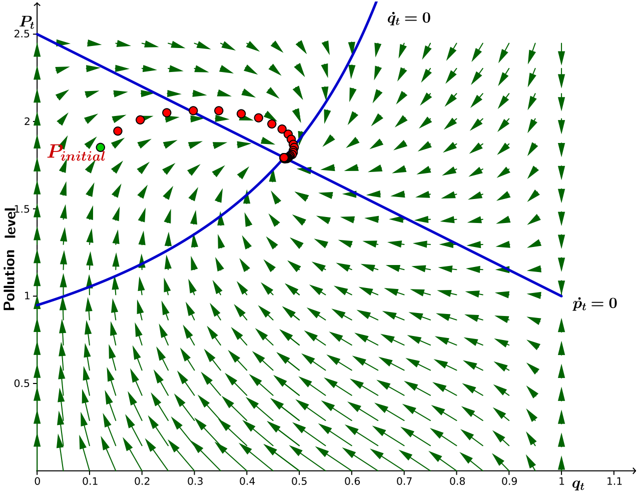
In this case we have: $\dot{q}_t = q_t(1 - q_t)(U_G - U_B)$

Where $U_G - U_B = m(r^*, p_t) + \underbrace{u(c_G) - u(c_B)}_{\Delta_u:\ \text{the cost of being green}}$

(Depending on the functional form of $u(c_i)$, $\frac{\partial \Delta_u}{\partial w} \gtreqless 0$)

The Evolution of Society

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



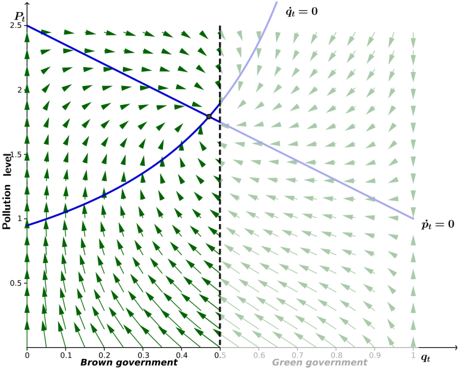
The Evolution of Society

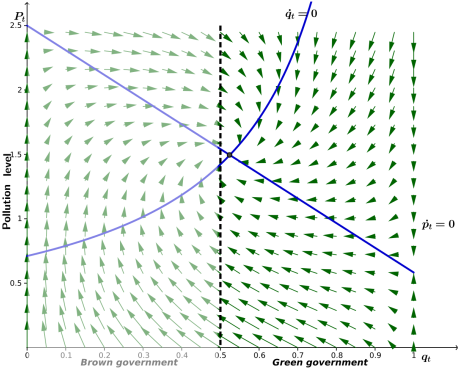
The Governments:

- 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 ρ.
  - Which in turn will change the dynamics equilibrium.

[5] Or equivalently, it will tax the brown product.

The Evolution of Society





$q_t < 1/2 \rightarrow$ Brown government $\rightarrow$ usual ρ

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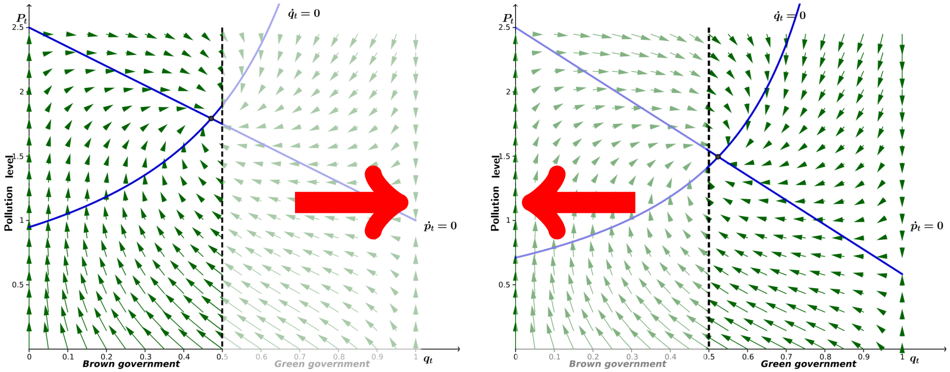

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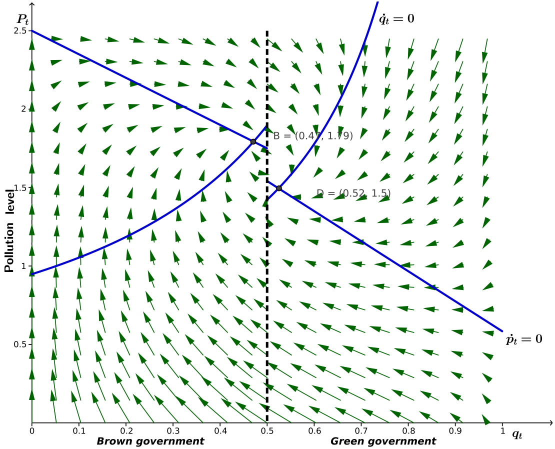
Final Dynamics

- $\dot{p}_t = -\eta p_t + \gamma d_t$ 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 $\tilde{p}_t(q_t)$



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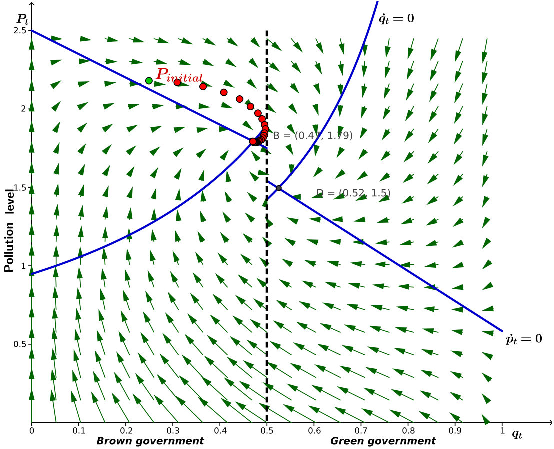

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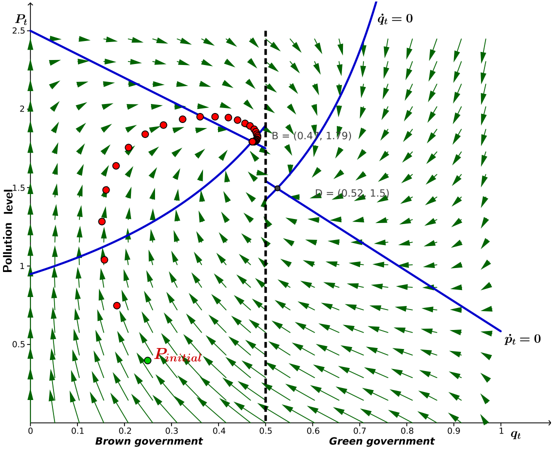

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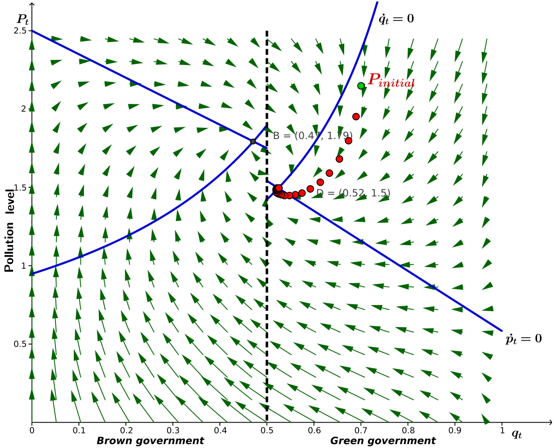

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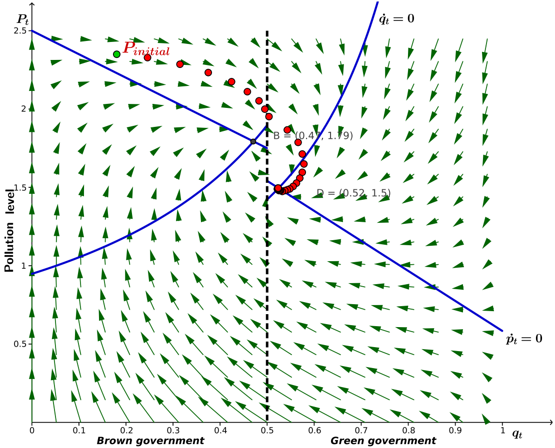
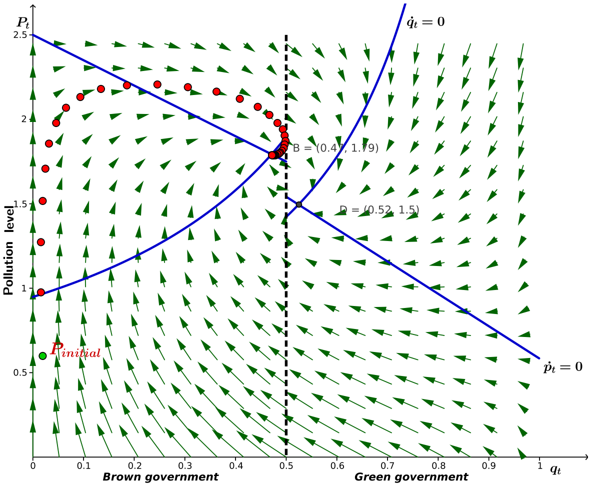


Example of a limit trajectory



Example of a limit trajectory. Possibility of *tipping points*.

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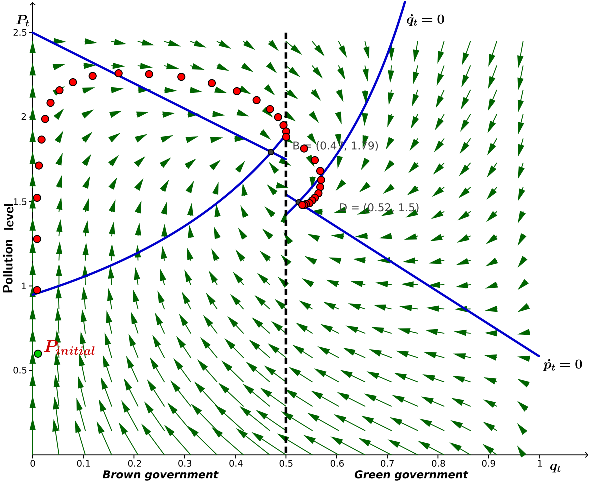

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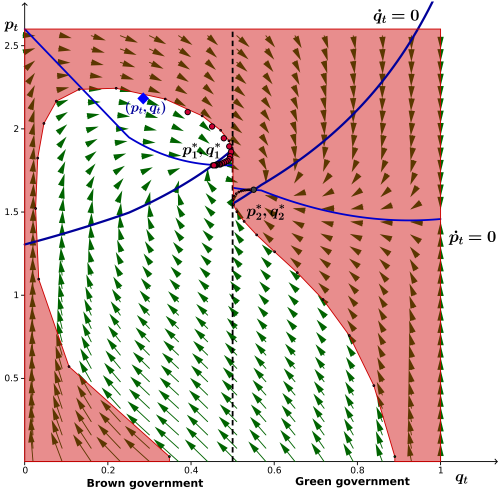
Searching for a environmental nudge



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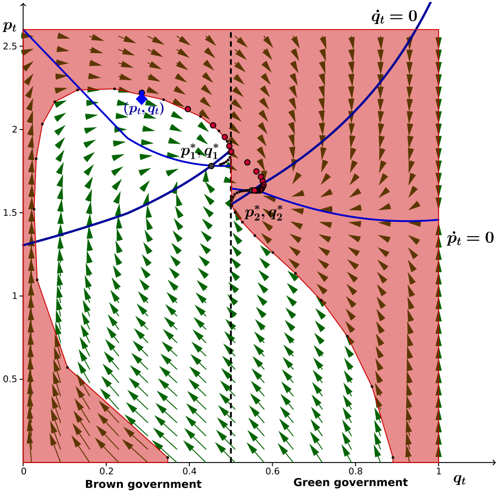

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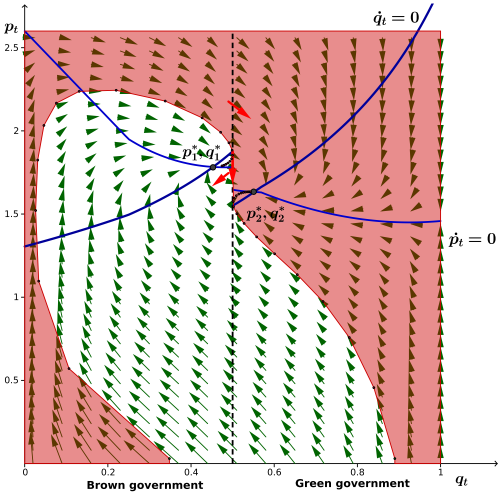
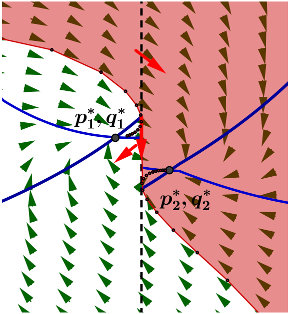


Searching for a environmental nudge

$\dot{q}_t = 0 \rightarrow \hat{p}_t(q_t)$

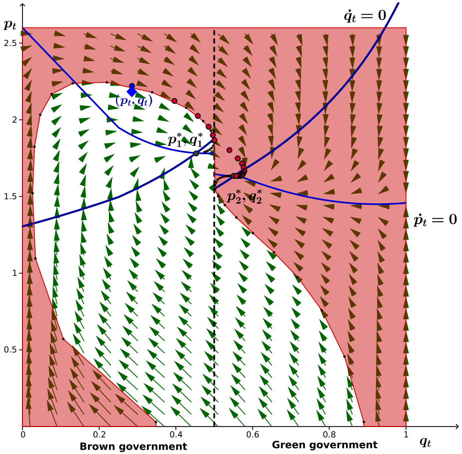


The limit trajectory can be 'defined' by

$$\lim_{q_t \rightarrow 1/2} \hat{p}_t(q_t)$$

And we can make sensibility analysis (work in progress):
How does it shift with Ω_3 (perception bias of the pollution level)?

Searching for a environmental nudge



For example: A (temporary) change in Ω_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