Can Policy Uncertainty derail the Transition to Clean Technologies?

Preliminary work

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Outline

Does policy uncertainty matter?

- Germany is in many ways a suboptimal place for Tesla to manufacture cars due to
  - High wages
  - Stringent labor laws
  - Relatively strong unions
  - One of the highest electricity prices in the world Evidence
- Yet, the factory is moved there.

Does policy uncertainty matter?

- Elon Musk: *"Brexit [uncertainty] made it too risky to put a Gigafactory in the UK"*.

- 80% of the UK's environmental laws come from the EU.

My contribution

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  - **Friction**: convex adjustment cost of switching sectors (preliminary exercise with results),
  - **Patent horizon**: extending the scientist's patent horizon to infinity but with risk of replacement (work-in-progress),
  - **Policy uncertainty**: risk around the friction-optimal policy (work-in-progress).

Results

Equilibrium dynamics are very sensitive to even a tiny friction.

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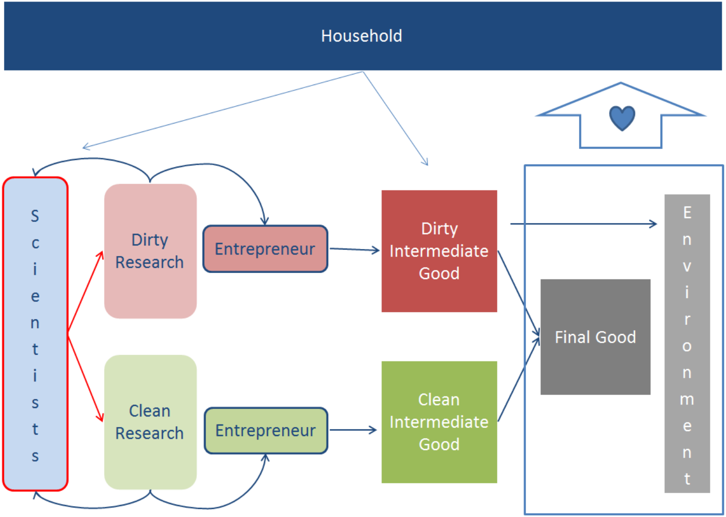
- If the world is not exactly as in AABH, then optimal policy leads to an environmental disaster.
- But the social planner can implement the socially optimal equilibrium by committing to more aggressive and longer-lasting policy intervention.
  - **Policy implication I**: If policy makers are not perfectly aware of all frictions in the economy, then focusing on 'optimal' policy might lead to an environmental disaster.
  - **Policy implication II**: the risk of getting environmental policy wrong is highly asymmetric such that 'robust' environmental policy implies erring on the side of stringency.

Literature

- **Endogenous growth via increasing returns**: Arrow (1962); Romer (1986); Lucas (1988); Jovanovic and Lach (1989).
- **Industrial innovation**:Grossman and Helpman (1994).
- **Factor-specific technical change**:Atkinson and Stiglitz (1969), Acemoglu (2002).
- **Directed technical change and the environment**: Acemoglu et al. (2012, 2014, 2016); Aghion et al. (2014); Hémous (2016).

Model setup



▸ Details ▸ How to find an equilibrium

Main mechanism: scientist's choice

- Law of motion of technology in each sector $j = c, d$ with the entails path dependence:

$$A_{j,t} = (1 + \gamma \eta_j s_{j,t})\, A_{j,t-1}$$

- Scientists follow profit-maximization incentives and 'invest' based on relative equilibrium profits from researching in the clean vs. dirty sector:

$$\frac{\Pi_{ct}}{\Pi_{dt}} = \left(\frac{\eta_c}{\eta_d}\right) \times \underbrace{\left(\frac{p_{ct}}{p_{dt}}\right)^{\frac{1}{1-\alpha}}}_{\text{Price effect}} \times \underbrace{\frac{L_{ct}}{L_{dt}}}_{\text{Market size effect}} \times \underbrace{\frac{A_{ct-1}}{A_{dt-1}}}_{\text{Building on giants}}$$

Implications

Contribution: the role of the friction

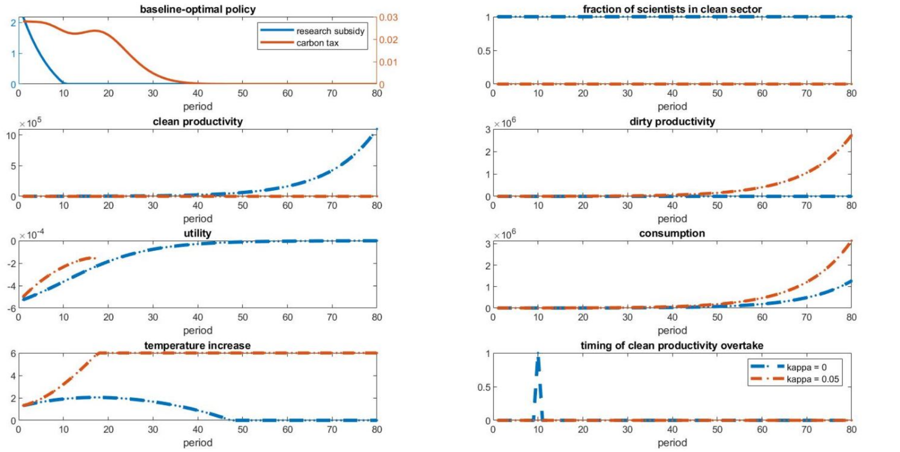
- Law of motion of technology in each sector $j = c, d$ with the friction of intensity κ:

$$A_{j,t} = \left(1 + \left(1 - \left(\frac{\kappa}{2}\right)\Delta^2_{s_{j,t}}\right)\gamma\eta_j s_{j,t}\right) A_{j,t-1}$$

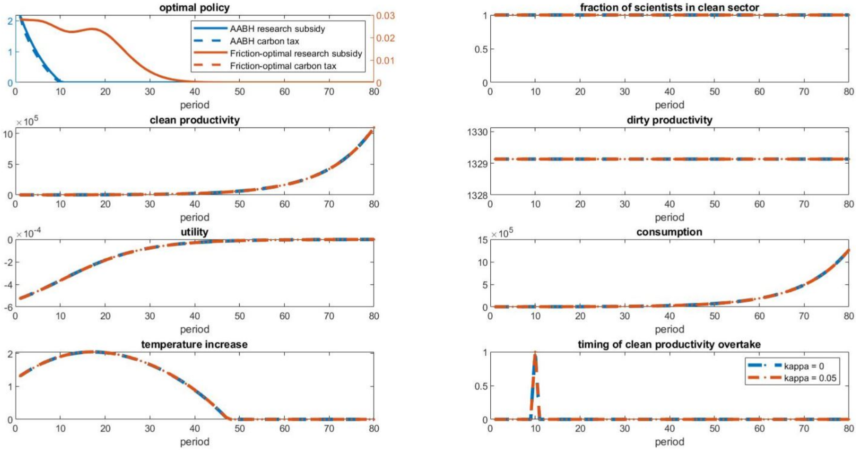
- Relative profits of the scientist with the friction and the research subsidy:

$$\frac{\Pi_{ct}}{\Pi_{dt}} = (1 + \nu_{c,t})\frac{\left(1 - \left(\frac{\kappa}{2}\right)\Delta^2_{s_{c,t}}\right)}{\left(1 + \left(\frac{\kappa}{2}\right)\Delta^2_{s_{c,t}}\right)}\left(\frac{\eta_c}{\eta_d}\right)\left(\frac{p_{ct}}{p_{dt}}\right)^{\frac{1}{1-\alpha}}\left(\frac{L_{ct}}{L_{dt}}\right)\left(\frac{A_{ct-1}}{A_{dt-1}}\right)$$

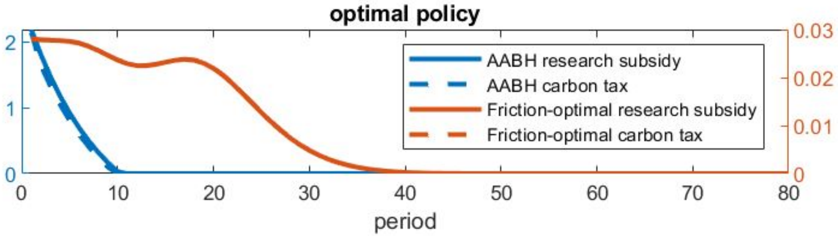
1) A tiny friction under AABH optimal policy leads to an environmental disaster.



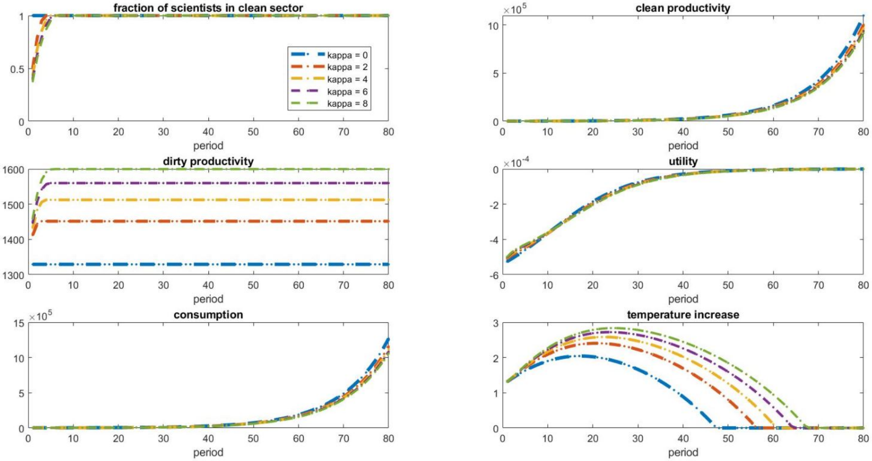
2) However, a perfectly-informed social planner can implement the socially optimal outcome under a tiny friction...



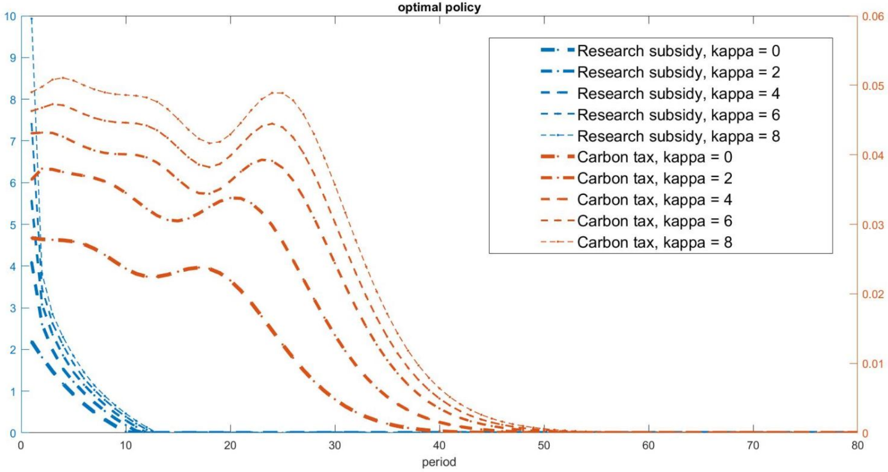
2) ... cheaply!


optimal policy
2
1
0
0
10
20
30
40
50
60
70
80
period
0.03
0.02
0.01
0
AABH research subsidy
AABH carbon tax
Friction-optimal research subsidy
Friction-optimal carbon tax

3) Under a stronger friction, the socially optimal switch to clean research is slower...



3) ...and its implementation is more costly and requires longer-lasting policy intervention.



Next steps

- **Patent horizon**: extending the scientist's patent horizon to infinity but with risk of replacement (work-in-progress),

$\Longrightarrow$ Make *current* investment decisions sensitive to *future* policy variables.

$$\frac{\Pi_{c,t}}{\Pi_{d,t}} = (1+\nu_{c,t}) \frac{\left(1 - \left(\frac{\kappa}{2}\right) \Delta^2_{s_{c,t}}\right)}{\left(1 + \left(\frac{\kappa}{2}\right) \Delta^2_{s_{c,t}}\right)} \left(\frac{\eta_c}{\eta_d}\right)$$

$$\mathbb{E}\left(\frac{\sum_{k=0}^{\infty} \prod_{v=0}^{k} \left(\frac{1-\iota_{c,t+v}}{1+r_{t+v}}\right) p_{c,t+k}^{\frac{1}{1-\alpha}} L_{c,t+k}}{\sum_{k=0}^{\infty} \prod_{v=0}^{k} \left(\frac{1-\iota_{d,t+v}}{1+r_{t+v}}\right) p_{d,t+k}^{\frac{1}{1-\alpha}} L_{d,t+k}}\right) \left(\frac{A_{c,t-1}}{A_{d,t-1}}\right)$$

Next steps

- **Policy uncertainty**: risk around the friction-optimal policy (work-in-progress).

  $\Longrightarrow$ Account for imperfect commitment of policy makers over longer time horizons.

$$\tau_v = \begin{cases} \tau_v^* + \zeta & \text{w.p.} \quad = \frac{1}{2} \\ \tau_v^* - \zeta & \text{w.p.} \quad = \frac{1}{2} \end{cases} \; \forall \; v = t$$

Conclusions

Question: How robust is the optimal policy derived in AABH to the introducing a friction? Not at all.

Answers:

1. If the world is not exactly as modeled in AABH (if the policy maker is not perfectly aware of existing frictions), optimal policy leads to an environmental disaster.
2. When the government takes the friction into account, it can prevent a disaster by implementing a *higher* and *longer-lasting* carbon tax and clean research subsidy.

Policy implication: The risk of getting environmental policy wrong is highly asymmetric and 'robust policy' implies erring on the side of stringency.

The end

Thanks for your attention

References

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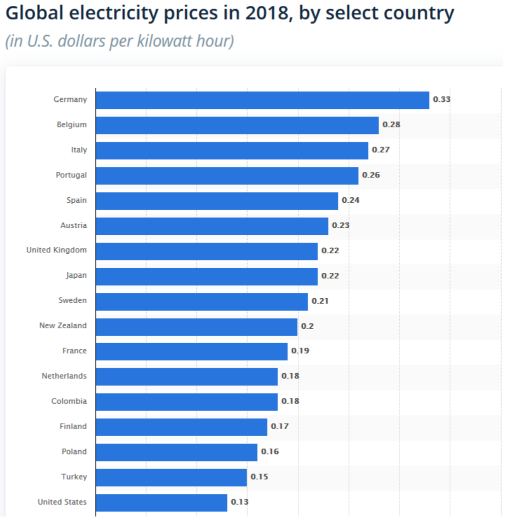
Global electricity prices



Back

Households

- Households care about consumption of the final good and the quality of the environment:

$$\sum_{t=1}^{\infty} \frac{1}{(1+\rho)^{t-1}} u(C_t, S_t) \tag{1}$$

- They comprise scientists, entrepreneurs and workers.

Firms

- The final good is produced competitively using a CES technology combining a clean and a dirty input:

$$Y_t = \left((Y_{ct})^{\frac{\varepsilon-1}{\varepsilon}} + (Y_{dt})^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}} \qquad \varepsilon > 1 \tag{2}$$

- Production of the clean (dirty) input requires labour and the use of a continuum of sector-specific machines:

$$Y_{jt} = (L_{jt})^{1-\alpha} \int_0^1 (A_{jit})^{1-\alpha} (x_{jit})^{\alpha} \, di \qquad j = \{c, d\} \tag{3}$$

- Machines are supplied by monopolistically competitive firms.
- Producing one unit of any machine costs ψ units of the final good so that market clearing of the final good is:

$$Y_t = C_t + \psi \left[\int_0^1 x_{cit} di + \int_0^1 x_{dit} di \right] \tag{4}$$

Firms cont'd

- The environment deteriorates proportionally to the use of the dirty input:

$$S_{t+1} = \underbrace{-\xi Y_{dt}}_{\text{Environmental Externality}} + (1+\delta) S_t \qquad \in (0, \bar{S}) \tag{5}$$

- Labour is supplied exogenously: $L_{ct} + L_{dt} \leq 1$

Innovation

- Scientists decide whether to direct research efforts towards the clean or dirty sector.
- They are then allocated to one machine and innovate with probability η_j.
  - If successful, the quality of the machine improves by $(1+\gamma)$ and the scientist obtains one-period patent.

    $\Longrightarrow$ *Monopoly profits*
  - If not, the unchanged machine is randomly allocated to a scientist.

    $\Longrightarrow$ *Zero profits*

Innovation cont'd

- Total mass of scientists is one:

$$s_{ct} + s_{dt} \leq 1$$

- Average sectoral quality is an aggregate over all individual machine productivities:

$$A_{jt} = \int_0^1 A_{jit} di \tag{6}$$

- Pace of quality improvements in each sector is driven by the mass of scientists choosing to invest their time into that sector:

$$A_{jt} = (1 + \gamma \eta_j s_{jt}) A_{jt-1} \tag{7}$$

$\Longrightarrow$ In choosing the clean or dirty sector, scientists are decisive for the *direction* of technical change.

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Finding an equilibrium

$$\frac{\Pi_{ct}}{\Pi_{dt}} = \left(\frac{\eta_c}{\eta_d}\right)\left(\frac{1+\gamma\eta_c s_{ct}}{1+\gamma\eta_d(1-s_{ct})}\right)^{1-\phi}\left(\frac{A_{ct-1}}{A_{dt-1}}\right)^{-\phi} \qquad \equiv f(s_{ct})$$

- It is an equilibrium for innovation at time t to occur in the clean sector only when $\Pi_{ct}|_{s_{ct}=1} > 1$.
- It is an equilibrium for innovation at time t to occur in the dirty sector only when $\Pi_{ct}|_{s_{ct}=0} < 1$.
- It is an equilibrium for innovation at time t to occur in both sectors when $\Pi_{ct}|_{s_{ct}=s^*} = 1$

The possibility of multiple equilibria

If $f(s_{ct})$ is strictly *increasing* in s_{ct}, then,

- if $1 < f(0) < f(1)$, that is, if when all scientists work in the dirty sector, profits in the clean sector are higher *and* if when everyone works in the clean sector, profits there are also higher, then $s_{ct} = 1$ is the unique equilibrium. The extra condition on $f(0)$ here is necessary because if we only had $1 < f(1)$, then scientists could raise profits in the dirty sector by moving workplace and we might have a multiplicity of equilibria (see next point).

- if $f(0) < 1 < f(1)$, then it is worthwhile to be in either corner because when all scientists are employed in the clean (dirty) sector, profits in the clean (dirty) sector are higher. But at the same time, by continuity of the profit function, there must be an $s^* \in (0, 1)$ such that $f(s^*) = 1$. Thus, there are three possible equilibria.

- if $f(0) < f(1) < 1$, then $s_{ct} = 0$ is the unique equilibrium.

▸ Back

Implications of the three effects

- The input produced with the more productive machines will be relatively cheaper:

$$\frac{p_{ct}}{p_{dt}} = \left[\frac{A_{dt}}{A_{ct}}\right]^{1-\alpha} \tag{8}$$

- The relatively more advanced sector attracts a relatively larger labor force and thus offers a larger market for any given innovation:

$$\frac{L_{dt}}{L_{ct}} = \left[\frac{A_{dt}}{A_{ct}}\right]^{-(1-\alpha)(1-\varepsilon)} \tag{9}$$

- The direct productivity effect leads to *path dependence* in the innovation process.

Back