The Environment and Directed Technical Change in a North-South Model

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Context

- Climate is a global public good: countries have an incentive to free-ride $\longrightarrow$ little impact for unilateral actions
- Knowledge spillovers can boost the impact of local actions.

$\longrightarrow$ Do we need global coordination to avoid climate change?

- Extend Acemoglu et al. (2012) (AABH):
  - 2 substitute sectors clean and dirty,
  - directed technical change with building on the shoulder of giants,
  - innovation in the North - imitation in the South,
  - two situations: autarky and trade.

Main results

- If dirty technologies initially ahead of clean, then, in laissez-faire, innovation targets dirty technologies and the economy moves towards a disaster.
- In autarky, Northern policy redirecting towards clean innovation can avoid an environmental disaster if elasticity of substitution between clean and dirty is large enough,
  - $\longrightarrow$ no need for global coordination to avoid worse consequences of climate change but optimal policy requires coordination.
- Trade makes policy coordination more necessary as the South may get stuck in producing the dirty good.

Related literature

- Empirical evidence on directed technical change in clean versus dirty innovation: Newell et al (1999), Popp (2002), Aghion et al (2012), Calel and Dechezleprêtre (2013),...
- Theoretical papers have integrated directed technical change in the analysis of optimal environmental regulation: Bovenberg and Smulders (1995, 1996), Goulder and Schneider (1999), Popp (2002),...
  - here we extend AABH to consider a 2 country set-up.
- Large literature on trade and the environment, mostly static models.
- Directed Technical Change in an international context:
  - Di Maria and Smulders (2004), Di Maria and van der Werf (2008),
  - Hemous (2013) considers trade between two goods which are complement and where the polluting good is produced as in AABH.

Roadmap

1. **Model**
2. Autarky
3. Trade
4. Conclusion

Preferences and production

- Representatives households in each country with standard preferences over national consumption C_t^k and global environmental quality S_t.
- Environmental quality $S_t \in [0, \overline{S}]$, with $\overline{S}$ a pristine level and 0 a "disaster" level ($u(C, 0) = -\infty$),
  - environmental quality is depleted by worldwide production of a dirty input and partly regenerates.
- In each country there is a unique final good, produced competitively using "clean" and "dirty" inputs Y_c^k and Y_d^k:
  - with the elasticity of substitution between the two sectors $\varepsilon > 1 \Rightarrow$ the two sectors are substitutes.

Intermediate inputs production

- Clean and dirty inputs are produced similarly in both countries with labor and sector-specific machines:
  - machines are of different quality and technological progress occurs as the quality of machines increases,
  - the productivity of a sector is the average productivity of machines in that sector.
- For the moment, the clean and dirty inputs are non-tradeable, later on consider the trade case.
- Machines are produced monopolistically with the final good.

Innovation and imitation,

- Property rights last for one period in both countries, mass 1 of scientists in each country.
- In the North, scientists decide in which sector to innovate,
  - successful innovation for a given machine push the frontier by a factor $1+\gamma$ and happens with probability η_j,
  - innovation is short-sighted: simple way to capture building on the shoulder of giants effect.
- In the South, scientists decide in which sector to imitate,
  - successful imitation for a given machine allows to catch up with the North and happens with probability κ_j,
  - South is technologically less advanced and adopts the innovations developed in the North.
- In both countries, the share of scientists allocated to each sector determines the growth rate of sectors' productivity.

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Scientists allocation in laissez-faire

- In the North, ratio of expected profits in clean versus dirty innovation, depends on 3 forces:
  - direct productivity effect: the more advanced sector reaps bigger profits, which increases the incentive to innovate it,
  - market size effect: the more advanced sector has a bigger market size, which increases the incentive to innovate in it,
  - price effect: the less advanced sector is more expensive, which increases the incentive to innovate in it,
  - overall path dependence: higher incentive to innovate in the most advanced sector.
- In the South, ratio of expected profits in clean versus dirty innovation, depends on:
  - direct productivity effect: the more advanced sector *in the North* reaps bigger profits, which increases the incentive to innovate it,
  - market size and price effects, which depend on South technologies.

Avoiding an environmental disaster (1)

- Dirty input production,
  - increases in the productivity of dirty input A_{dt},
  - decreases in the productivity of clean input A_{ct} if and only if $\varepsilon > 1/(1-\alpha)$ (substitution and scale effects, α is the share of machines in production).
- Assume that clean technologies are sufficiently less advanced in the North than dirty ones so that innovation occurs in dirty sector:
  - innovation keeps occurring in the dirty sector in the North,
  - dirty input production grows unboundedly,
  - economy reaches an environmental disaster with $S = 0$ in finite time.

Avoiding an environmental disaster (2)

- Consider a policy carbon tax / research subsidy in the North $\left(\tau_t^N, q_t^N\right)$ such that innovation is redirected towards clean technologies,
- For $\varepsilon > 1$: imitation in the South switches to clean technologies in finite time.
- For $\varepsilon > 1/\left(1-\alpha\right)$: production of dirty input decreases in both countries and for sufficiently high initial environmental quality, environmental disaster is avoided,
  - for $1 < \varepsilon < 1/\left(1-\alpha\right)$: well adjusted carbon tax can ensure that emissions decrease in the North, and the South switches to imitate clean, but production of dirty input in the South still increases.

$\longrightarrow$ When clean and dirty inputs are sufficiently substitute, unilateral intervention by the technological leader is enough to decrease emissions in the long-run.

Optimal policy

- Optimal policy requires intervention in both countries:
  - carbon tax with the same price of carbon if social welfare function is additive in the utility of the representative consumer,
  - research subsidies in the North to correct building on the shoulders of giants externality & the knowledge externality to the South,
  - research subsidies in the South to correct building on the shoulders of giants in imitation.
- If $\varepsilon > 1/(1-\alpha)$ and the discount rate is sufficiently low, innovation and imitation switches to clean in finite time,
  - optimal environmental taxes are temporary (if first unit of pollution has negligible welfare effects).

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Pattern of trade

- Consider international trade in the clean and dirty inputs,
  - the North follows an environmental policy $\left\{\tau_t^N, q_t^N\right\}$ that redirects innovation towards the clean technologies,
  - the South remains under pure laissez-faire.
- Ricardian trade model, the South has a comparative advantage in dirty input production
  - if North's carbon tax is large,
  - or if North is relatively cleaner than the South,
  - 3 possibilities: North fully specializes, South fully specializes or both countries fully specialize.

Strong pollution haven result

- If clean technologies are sufficiently backward in the South, South fully specializes in dirty technologies,
  - $\longrightarrow$ no incentive to imitate in clean technologies (even if clean is more advanced than dirty in the North),
  - production of dirty input in the South grows unboundedly (scale effect).

Proposition

When the two inputs are strong substitutes ($\varepsilon > 1/(1-\alpha)$) and A_{c0}^{S} is sufficiently small, there exists an equilibrium in which any environmental policy $\left\{\tau_t^N, q_t^N\right\}$ in the North redirecting technical change to the clean sector is insufficient to avoid an environmental disaster under free trade (though it would have avoided a disaster under autarky).

Weak pollution haven result

- The previous result relies on a lack of coordination by South imitators (there are multiple equilibria when clean technologies are sufficiently advanced in the North).

Proposition

Even if scientists in the South coordinate on clean imitation whenever it is possible, there are parameters for which the level of production of dirty inputs under free trade is always greater than under autarky, such that a policy $\left\{\tau_t^N, q_t^N\right\}$ *that directs innovation towards clean technologies in the North can avoid an environmental disaster under autarky but fails to do so under free trade.*

- There is a dynamic pollution haven effect on top of a static one.

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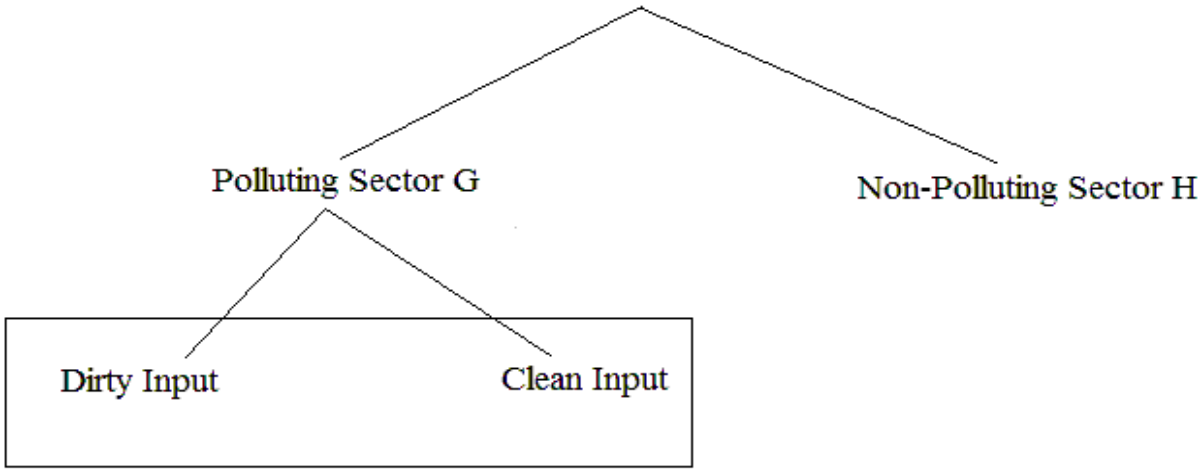
Conclusion

- Can unilateral actions in the North avoid an environmental disaster?
  2 forces:
  - knowledge spillovers: as clean technologies become more competitive in the North, South has an incentive to imitate them,
  - with trade, market size effect: diffusion of technologies is not automatic and responds to incentives, the market for clean technologies must remain large enough.

$\longrightarrow$ Argument to develop clean technologies in the North and foster their diffusion.

$\longrightarrow$ Carbon tariffs can be used not only to reduce "static" pollution haven effect but also to affect imitation / innovation in the South.

Hemous (2013) (1)



- 2 countries (North and South) and 2 sectors (polluting and non-polluting),
- Local innovation, directed towards non-polluting sector, clean or dirty technologies.

Hemous (2013) (1)

- Carbon tax in the North cannot permanently reduce emissions if South has initially the comparative advantage in the polluting sector:
  - South specializes in the polluting sector,
  - faster specialization $\Rightarrow$ world emissions may increase.
- Temporary clean research subsidies + temporary tariff in the North can reduce emissions in the long-run:
  - North invests in clean technologies to reduce its emission rate and build comparative advantage,
  - South specializes in the non-polluting sector,
  - "clean infant industry argument."
- Broad results robust to the introduction of knowledge spillovers.