CAN DIRECTED TECHNICAL CHANGE BE USED TO COMBAT CLIMATE CHANGE?

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Carbon emissions scenarios

Source: IPCC 2014
The challenge

• Just stabilizing emissions in 2050 (3° pathway) requires 60% reduction in carbon intensity of GDP
  – Assuming 2.5% annual GDP growth

• To achieve long term decarbonization, we need a large change in the mix of technology we use
  – or dramatic social and cultural changes
Innovation is key

• The low-carbon transition requires massive investments in innovation
  1. Developing new breakthrough technologies (hydrogen, fusion?)
  2. Making the transition possible with enabling technologies (smart grids, storage)
  3. Bringing down the cost of existing technologies (wind, solar) below the costs of environmentally damaging technologies
Glimmers of hope: e.g. solar PV module price reductions, 1976-2015 (USD/MW)

Source: BNEF (2017)
Note: Prices inflation indexed to US PPI.
Market failures

• 2 major market failures (Jaffe, Newell & Stavins 2005)
  – Knowledge externality (innovators are not rewarded for all the benefits of their inventions) at innovation stage
  – Pollution externality (carbon emissions induce damages that are not paid for) hampers the demand for green innovations

• Many more:
  – Learning-by-doing (through the production process)
  – Imperfections in capital markets (financing of R&D)
  – Long lived capital, high upfront costs, imperfect competition, behavioral gaps, regulatory barriers ...
  – Lock-in / path-dependence
Building on the shoulders of giants: Knowledge stocks in clean vs dirty

4x higher
Public policies are needed

- At least 2 policy instruments to address this efficiently:
  - Carbon pricing (tax / emissions permit market)
  - Technology support policies (R&D subsidies, deployment support e.g. investment subsidy)
- Optimal policy includes R&D subsidies + emissions pricing + other instruments
Emissions pricing and DTC

• Induced innovation hypothesis (Hicks 1932):
  • When firms expect to face a higher price on emissions relative to other costs of production, this provides them with an incentive to reduce the emissions intensity of their output
  • Part of this new investment will be directed toward developing and commercializing new emissions-reducing technologies
  • Lots of recent empirical evidence on this
The impact of the EU carbon market on low-carbon innovation

The paper

• Empirically analyse the impact of the EU carbon market on low-carbon technological change

• Across Europe: 5,000 companies

• Use patents filed with the European Patent Office (EPO) to measure innovation
  – Common measure of innovation
  – Quality threshold
An appealing case study

• Policy relevant
  • The largest carbon market in the world
  • Europe’s main climate change policy
  • Similar markets in US, NZ, China

• Inclusion criteria at installation level mean we can compare regulated with similar but unregulated companies
  • Steel: production capacity > 2.5 tonnes per hour
  • Combustion of fuels: annual thermal input > 20 MW
  • Glass: melting capacity > 20 tonnes per day

• EPO’s ‘low carbon patents’ classification
EPO’s low-carbon patent class

TECHNOLOGIES OR APPLICATIONS FOR MITIGATION OR ADAPTATION AGAINST CLIMATE CHANGE

CAPTURE, STORAGE, SEQUESTRATION OR DISPOSAL OF GREENHOUSE GASES
- CO2 capture or storage
- Capture or disposal of greenhouse gases other than CO2

REDUCTION OF GREENHOUSE GASES EMISSION, RELATED TO ENERGY GENERATION, TRANSMISSION OR DISTRIBUTION
- Energy generation through renewable energy sources
- Combustion technologies with mitigation potential
- Energy generation of nuclear origin
- Technologies for an efficient electrical power generation, transmission or distribution
- Technologies for the production of fuel of non-fossil origin
- Technologies with potential or indirect contribution to GHG emissions mitigation
- Other energy conversion or management systems reducing GHG emissions
Share of low-carbon patents at EPO
Determining causality

• Identify regulated companies
• Compare them with unregulated companies in the same economic sectors and countries
  – Owners of smaller installations
• Use this control group as an estimate of what regulated firms would have experienced in the absence of the ETS
• Data
  – 5’521 regulated companies in 18 countries (80% of the ETS)
  – 30 million potential comparators
Constructing the control group

• Matching on:
  – Country
  – Sector
  – Total patents before 2005
  – Low-carbon patents before 2005
  – Turnover before 2005
  – Year of incorporation

• Good comparators for 3,428 EU ETS firms
  – Pre-2005 revenue data for 3,564 firms only
  – No comparators for very large firms
What we are comparing

Hammer GmbH
- NACE 1712 (Manufacture of paper and paperboard)
- 150 employees
- Turnover 26.9M
- Fixed assets 7.9M

Papierfabrik Hainsberg GmbH
- NACE 1712 (Manufacture of paper and paperboard)
- 152 employees
- Turnover 25.9M
- Fixed assets 9.7M

EU ETS impact?
A good control group

(a) Turnover of EU ETS firms (Mil. Euro)

(b) Patents by EU ETS firms

Turnover of non-EU ETS firms (Mil. Euro)

Patents by non-EU ETS firms
Low-carbon patents: treated (ETS) vs control group (non-ETS)
Emissions pricing works

- Difference-in-differences
  - Compare treatment (ETS) with control group

- The ETS had a strong impact on low carbon innovation by regulated companies: +2 patents per firm (+36% on matched companies)

- The effect happened when carbon prices were high and expected to remain so
Direct emissions pricing works, but it’s not the only option

- In theory, market-based instruments provide stronger incentives for innovation than technology mandates and performance standards
  - But the reverse has been found empirically (Popp 2003; Taylor 2012)
- Predictability vs flexibility
  - Cap and trade programmes can result in volatile prices, creating uncertainty; while command-and-control policies send clear signals to the market
  - Command and control instruments can be flexible (e.g. performance standards), while market-based instruments can be inflexible (e.g. tax level or emissions cap too high/low, difficult to adjust according to business cycle fluctuations or scientific information)
- Political economy considerations
Public R&D support

• Knowledge spillovers = a general problem of all technologies
• To be certain, level of subsidy may depend on magnitude of spillovers (greater in emerging industries - green, nano, AI - than in declining ones; greater in R&D with wider applicability)
  – R&D tax credits, direct grants, etc
• Industrial policy (policies targeted towards specific sectors, technologies, and even companies) can be done well
Supporting early-stage deployment

- Learning by doing, second mover advantage
  - Technical experience, training of personnel, legal contracts, financing...
- Again, a general problem of all technologies
- Can substitute for tech-neutral policies (pricing); more politically acceptable
- Can be justified by urgency of the problem (eg climate) when economically efficient policies would take too much time to deliver
- Used a lot in practice, highly costly when tech-specific (eg differentiated FITs)
In practice, many instruments coexist. Ex: renewable energy policies

Johnstone et al. 2010
How long do we need clean policies for?

- There is path-dependence in the direction of innovation (e.g. Acemoglu et al, 2012 AER; Aghion et al, 2016 JPE)
- This is consistent with a “tipping point” view of the world
  - Final resting point is complete dominance of one technology by another
- If this is true, clean policies only need to be temporary
Temporary policies: An example

But green policies also impact *dirty* innovation

- New technologies, even if designed to substitute for older ones, often complement them at least for some time
  - Hybrid cars
  - Fossil fuel as back up for renewable electricity
- Part of the response to a new technology is an improvement in the old
  - Clean coal, shale gas, oil sands, fuel efficiency...
- Older technologies retain some uses and markets for many years. Very few new technologies cannibalize old ones completely
  - Air transportation
• Pricing pollution (directly or indirectly) can redirect innovation towards clean

• Other market failures justify a portfolio of instruments, including R&D and deployment support, reduce financial barriers, etc

• Path-dependence means these policies should only be temporary, until clean becomes cheaper than dirty
Low-carbon innovation (patent filings) has declined recently.
Falling fossil fuel prices

**World crude oil prices**

$/bbl (real 2010 dollars, monthly average)

Low carbon prices

All non-transport sectors
Portion of CO2 emissions at different ECR intervals by country

OECD 2016
OECD public R&D spending in energy technologies (billion euros)
For more information:

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