“The Role of Technological Change in Green Growth: 5 Lessons from the Literature”

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Technological Change & the Environment

- Technological change proceeds in three stages:
  - *Invention:* an idea must be born
  - *Innovation:* new ideas are then developed into commercially viable products
    - Often, these two stages of technological change are lumped together under the rubric of research and development (R&D)
  - *Diffusion:* to have an effect on the economy, individuals must choose to make use of the innovation

- This presentation presents five key lessons from the literature on technological change & the environment

#1: Policy Support is Vital

- At all three stages, market forces provide insufficient incentives for the development and diffusion of environmentally friendly technologies
  - *Environmental Externalities*
    - Pollution created in the production or use of a product is not normally included in the price of the product
      - Thus, neither firms nor consumers have incentive to reduce pollution on their own
    - This limits the market for technologies that reduce emissions
      - Note that there may be *some* private benefits (e.g. lower fuel costs, increased demand from green consumers), so demand is not necessarily zero
    - Addressed by environmental policy

#1: Policy Support is Vital

- At all three stages, market forces provide insufficient incentives for the development and diffusion of environmentally friendly technologies
  - *Environmental Externalities*
  - *Knowledge as a Public Good*
    - New technologies must be made available to the public for the inventor to profit
    - Public knowledge may lead to *knowledge spillovers*—additional improvements, or even copies of the current innovations, that provide benefits to the public as a whole, but not to the innovator
    - Addressed by science and technology policy
      - May be general (IP) or specific (subsidies for renewable R&D)

#1: Policy Support is Vital

- Both technology policy and environmental policy are needed
  - Environmental policy creates demand for green technologies
    - "(t)he main reason cleaner and more energy-efficient technologies (for autos) were not transferred (to China) is that there simply were no compelling policy incentives for the US firms to do so, and the foreign firms did not voluntarily transfer better technologies" (Gallagher, 2006, p. 387)

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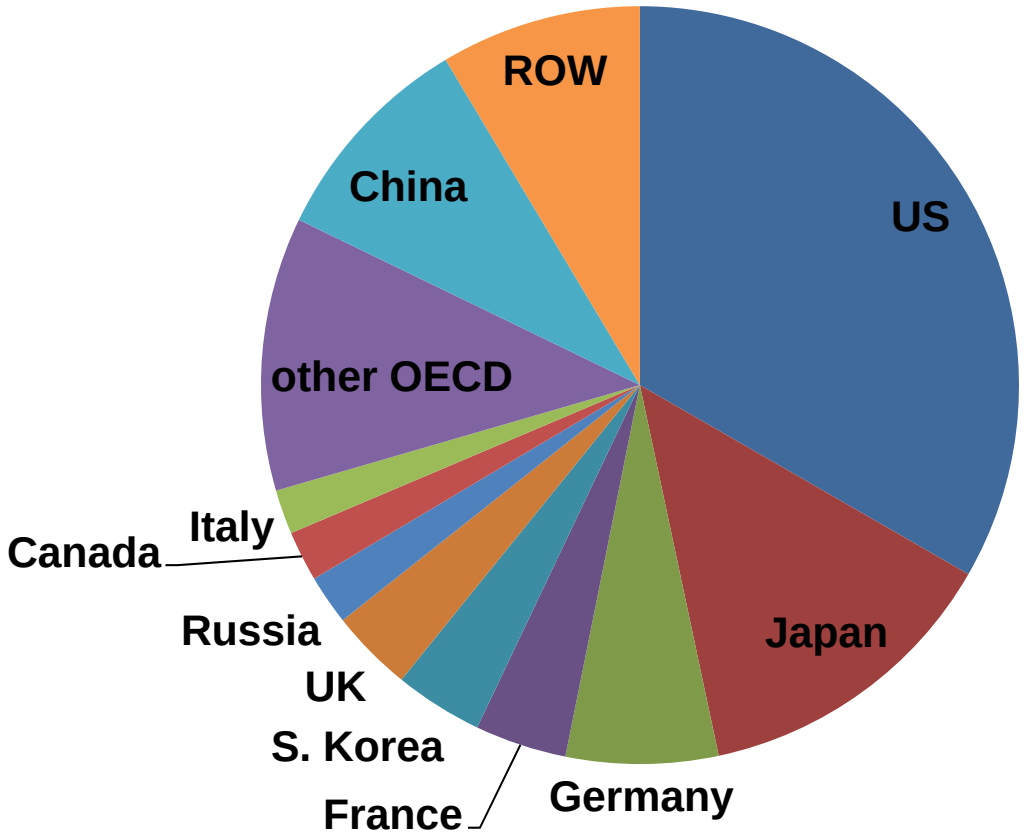
- For developing countries, attracting technology transfer and promoting adaptive R&D is important
  - Thus, the mix of technologies used may differ from high-income countries
    - Promising direction for future research

#2: High income countries do most R&D

- Nearly all of the world's R&D is performed in the developed OECD economies
  - Dechezleprêtre *et al*. (2011) find that 2/3 of climate-friendly innovations from 1978-2003 come from the U.S., Japan, or Germany

2007 Global R&D Expenditures



#2: High income countries do most R&D

- Nearly all of the world's R&D is performed in the developed OECD economies

=> In many cases, technologies needed to promote green growth will already be available

  - Most pollution control patents in developing countries come from developed country inventors

#2: High income countries do most R&D

- Remaining questions
  - Stimulating R&D for technologies with limited markets in high-income countries
  - The role of adaptive R&D to fit technologies to local conditions
  - Encouraging technology transfer of green technologies

#2: High income countries do most R&D

- How should we encourage R&D on technologies with limited markets in high-income countries?
  - Example: Technologies for use off electricity grids, such as improved cooking stoves
    - Can emerging economies fill the gap?
      - Most patents and publications on these come from China and India
    - Can commitments of funding from developed countries help?
      - Example: In health care, advance purchase commitments helps encourage development of treatments for neglected tropical diseases

#3: Adaptive R&D is necessary

- Another role for developing country R&D is adaptive R&D
  - Countries do not simply take advantage of technologies "off the shelf" that have been developed elsewhere (Popp 2006)
  - Green innovations in developing countries are smaller inventive steps, typically done to modify existing technologies to local conditions
    - Lanjouw and Mody (1996): developing country environmental patents most likely for water treatment, where local conditions matter

#3: Adaptive R&D is necessary

- Implications
  - Policymakers must make allowances for adaptive R&D to fit technologies to local conditions, or else be prepared for less than desired results when transferred technology is not a perfect fit for the local market
  - More work needed to understand the full potential of adaptive R&D for green technologies
    - What new and unexpected uses might arise for green technologies in developing countries?
      - Consider, for example, how cell phones play a more important role in many low-income countries
    - Adapting production processes, such as using more labor to produce PV cells in China, can spur new industries

#4: The Importance of Spillovers

- Turning to diffusion, there are two issues:
  1. Technology transfer across national borders
  2. Diffusion of technologies within nations

- Successful examples of technology transfer illustrate the importance of spillovers
  - Wind in India & China:
    - Suzlon (India) established R&D facilities in Germany & Netherlands
    - Goldwind (China) sends employees abroad for training
    - Both use licensing agreements with European firms to gain access to technology

#4: The Importance of Spillovers

- The role of patents provide an example of technology policy tradeoffs
  - Patents encourage innovation but slow diffusion (and thus spillovers) once inventions exist
  - This has led to calls for weaker patent rights for green technologies
  - However, there is little evidence this would help
    - Lack of demand is more important, although most work focuses on other technologies (e.g. Attaran and Gillespie-White 2001 on pharmaceuticals)
    - Subsidies for fossil fuels and tariffs on renewable energy technologies do more to slow spread of green technologies than patents (Copenhagen Economics 2009)

#4: The Importance of Spillovers

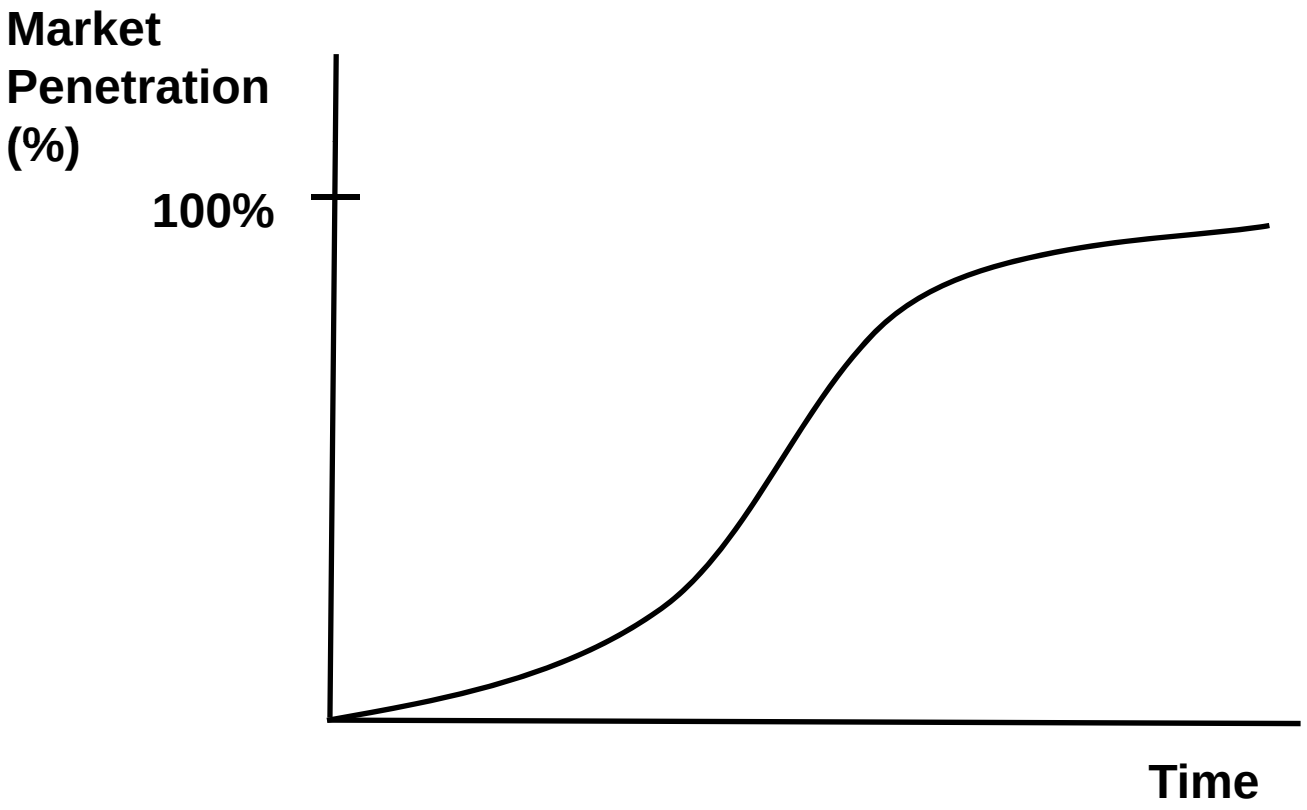
- Availability of technology also affects environmental policy
  - As pollution control technologies improve, the costs of adopting environmental regulation fall
    - Late adopters can learn from early adopters
  - As technologies improve, countries adopt regulation at earlier levels of development (Lovely & Popp 2011)
    - International trade improves access to technology, leading to earlier adoption of regulation

#4: The Importance of Spillovers

- Moving forward, identifying limits to spillovers is important
  - Can other countries follow India & China's lead?
    - Policies attracting technology transfer must balance encouraging spillovers with discouraging investors
      - Policy needs are not one size fits all
      - IPR protection becomes more important as countries advance
    - Will policies promoting spillovers discourage multinational investment in smaller countries?
  - What about when technological distance is greatest?
    - Could be a role for BRICS as suppliers of technologies
      - India as a supplier of pharmaceuticals to Africa is an example

#5: Limits to Diffusion Within Countries

- Most studies of diffusion find that diffusion is gradual, follows S-shaped curve



#5: Limits to Diffusion Within Countries

- Differences in developing countries
  - In high-income countries, once technologies are introduced they almost always achieve mass-market scale
    - Not so in developing countries (e.g. World Bank 2008)
  - Factors limiting diffusion in developing countries
    - Financing and affordability
      - Income disparities may slow diffusion
        - » e.g. spread of appliances after on-grid electrification (Winkler *et al*. 2011)
      - High start-up costs are a barrier
      - Financial sector development aids the spread of green technologies (Brunnschweiler 2010)

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    - Financing and affordability
    - Ease of use is important
      - Barry *et al*. (2011): maintenance must be planned for and kept simple
      - Romijn and Caniëls (2011): inadequate on-site technical support holds back adoption of small-scale biomass gasification in India

Concluding Thoughts

- Promoting secondary benefits of technologies is important
  - Improved cooking stoves reduce black carbon, which contributes to climate change, and reduce indoor air pollution
  - Reduced resource use lowers costs

- Learn from other fields, but keep externality problem in mind
  - Advances in agriculture reduce resource usage
  - Health care and neglected tropical diseases

Concluding Thoughts

- Green growth should also plan how to cope with a changing environment
  - While mitigation of climate emissions is a global problem, adaptation is often a local problem
    - Will adaptation technological advances provide global benefits?

Thank You!