The Government Role in Technology Innovation: Lessons for Climate Change Policy

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Motivating Questions

- What kinds of technology innovations are needed to reduce greenhouse gas emissions?
- What do we know about the process of technology innovation?
- How do government actions influence technology innovation?
- What types of policies can stimulate innovations that mitigate climate change and reduce future costs?
What innovations are needed to mitigate greenhouse gas emissions?

CO₂ Emissions from Energy Use are the Principal Source of GHGs

Current U.S. emissions

Source: Based on USDOE, 2002

Transportation and power generation together account for 75% of current U.S. emissions

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Technology Innovations Needed to Mitigate CO₂ Emissions

- More efficient technologies for energy conversion and utilization
- Technologies to produce and utilize alternative energy sources with lower or no GHG emissions
- Technologies for CO₂ capture and storage at large stationary sources
- Technologies that reduce demand for transport and other energy-intensive services

Technology deployment is required on a large scale . . . This won’t happen overnight!

What do we know about the process of technology innovation?
Elements of Technological Change

• Invention
  - Discovery; creation of knowledge; new prototypes

• Innovation
  - Creation of a commercial product or process

• Adoption
  - Deployment and use of the new technology

• Diffusion
  - Increasing adoption and use of the technology

The Linear Model of Technological Change
A More Realistic Model

Invention → Innovation (new or better product) → Adoption (initial design) → Diffusion (improved technology)

R&D  Learning By Doing  Learning By Using

How do government actions influence technology innovation?
U.S. “Technology Policy” Tools

Direct Government Funding of Research and Development (R&D)
- R&D contracts with private firms
- R&D grants and contracts with universities
- Intramural R&D conducted at gov’t laboratories
- R&D contracts with consortia (2 or more of the actors above)

Direct or Indirect Support for Commercialization and Production; Indirect Support for Development
- Patent protection
- R&D tax credits
- Production subsidies or tax credits to firms bringing new technologies to market
- Tax credits or rebates for new technology buyers
- Government procurement
- Demonstration projects

Support for Learning and Diffusion of Knowledge and Technology
- Education and training
- Codification and transfer of knowledge
- Technical standard-setting (non-regulatory)
- Technology and/or industrial extension services
- Publicity and consumer information

- These policies influence different phases of the innovation process
- Provide “carrots” to incentivize technological change & innovation

Technology Policies Have Reduced the Cost of GHG-Friendly Energy Systems

Source: IIASA, 1996
What About Environmental Technology Innovation?

- Most innovation research has focused on technology policies for economic development; comparatively little study of gov’t role in innovation for environmental goals
- Retrospective studies can provide useful insights
- At Carnegie Mellon we have conducted case studies of:
  - Power plant emission control systems (SO$_2$, NO$_x$, Hg, CO$_2$)
  - Automotive emission control systems (CO, HC, NO$_x$)
  - A set of energy technologies and industrial processes relevant to climate change mitigation

U.S. Patenting Activity in SO$_2$ Control Technology

Patent trends suggest that regulatory policies can stimulate innovations that reduce emissions significantly ...
...with significant declines in cost as technologies are deployed

**Experience Curve for Flue Gas Desulfurization Cost**

- Cumulative World Capacity of Wet FGD Systems (GWe)
- FGD Capital Cost (% of base value)
- Cost reduction = 11% per doubling of installed capacity; 50% reduction over 20 years

(Based on 90% SO$_2$ removal, 500 MW plant, 3.5%S coal)

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**Innovations in DeNOx technology also coincided with strict emission limits**

**Patenting Activity Index for Flue Gas NO$_x$ Control**

- Patenting Activity Index for U.S. remained flat over this period at ~1

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Historical Cost Reductions for Flue Gas DeNOx Technology

Cost reduction = 12% per doubling of installed capacity

(Based on 80% NOx removal, 500 MW plant, medium S coal)

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Technological Evolution of Emission Control Systems

U.S. Patenting Activity in Automotive Emission Controls
Estimated Cost of Automotive Emission Control System

Estimated Emissions Control Cost Excluding Cost of Precious Metals
What types of policies can stimulate innovations that mitigate climate change?
### Conclusions from Case Studies of Environmental Technologies

- The stringency of emission reduction requirements is a major factor in both *stimulating* and *directing* innovations and deployment of cleaner technologies.
- The cost of achieving a given level of emissions reduction tends to fall with increasing technology deployment and sustained R&D.
- No strong empirical basis for comparing alternative environmental policy instruments.
- Firms that innovate tend to be more successful and enduring in the marketplace.

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### Lessons Learned from Study of U.S. Technology Policies

- To realize the benefits of technology innovation, a balanced policy portfolio must support not only R&D, but also promote **technology deployment** and **diffusion of knowledge**.
- Technology innovations cannot be planned or programmed; because outcomes are uncertain, policies and programs should support a **suite of options and approaches** rather than specific technologies or designs.
- Gov’t support for **education and training**, as well as research, enhances the infrastructure necessary to support innovation.
- Effective policies and programs require **insulation from short-term political pressures** that impede steady progress that is critical to long-term innovations.
Innovation Policies to Mitigate Climate Change

- Global climate change is an environmental problem that cannot be addressed by voluntary technology policies alone — *regulatory policies that limit GHG emissions* also are needed

- *Energy policies* can further help—or impede—progress and innovations that reduce GHG emissions

- A *combination* of traditional technology policies and regulatory policies that limit GHG emissions can most effectively foster innovations favored or required by markets in a carbon-constrained world