Impacts of Environmental Policy Instruments on Technological Change

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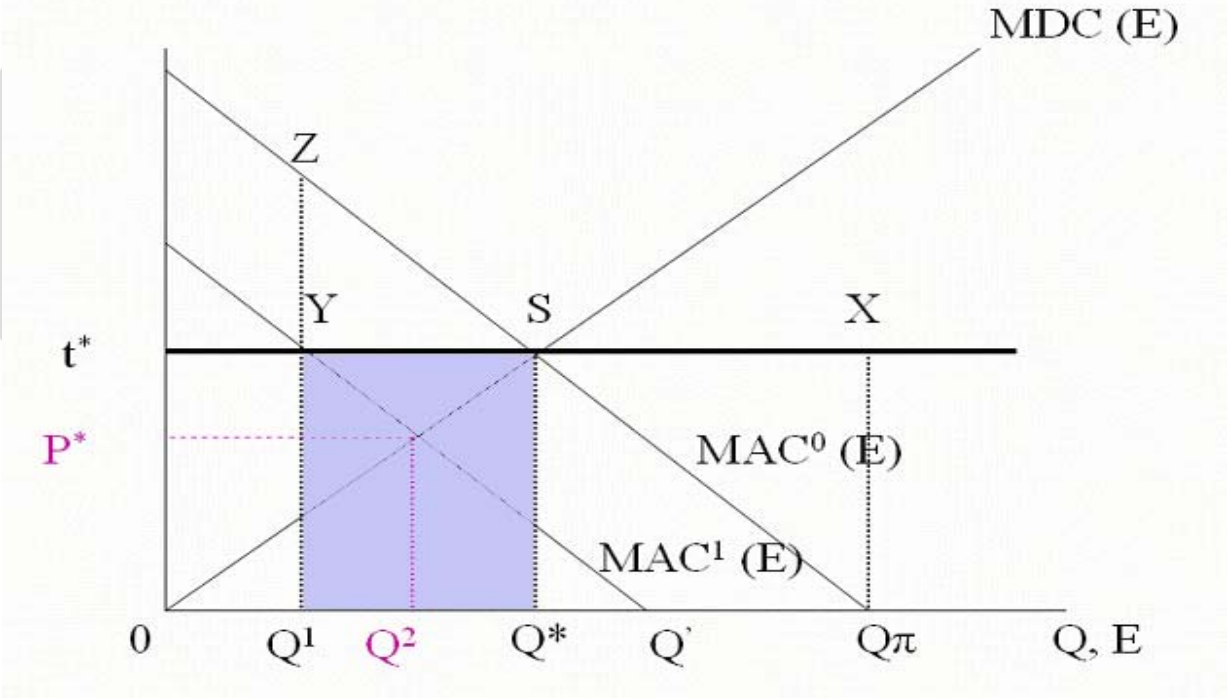
Background

- Herman Vollebergh prepared a review of empirical studies of impacts of environmental policy instruments on technological change for OECD's Joint Meetings of Tax and Environment Experts: www.olis.oecd.org/olis/2006doc.nsf/linkto/com-env-epoc-ctpa-cfa(2006)36-final
- My paper draws heavily on that study, but also includes a few more recent studies – and some additional suggestions for further research.

Incentives for innovation: Economic theory



- CAC: No incentive to reduce *emissions* below Q* – but there could still be an incentive to reduce *operating costs*.
- With MAC at MAC^0, tax-payments = 0t*SQ*
- *If* innovation could shift MAC to MAC^1, the firms would save Q^1YSQ^* in tax-payments – and emissions in a tax regime would be reduced to Q^1.

Empirical studies: measurement issues

- Proxies for "strictness" of environmental policies:
  - PAC expenditures (incomplete, sensitive to progress in abatement technologies)
  - Number of enforcement actions
  - Binary variables, reflecting the existence of a certain instrument, or not. ("Continuous" variables, closer reflecting the "strictness" of each instrument would have been preferable.)
- Proxies for technical change:
  - Input measure: R&D expenditures
  - Output measure, inventions: Number of patents successfully filed
  - Output measure, diffusion: Adoption of benign technologies

Empirical studies: general impacts I

- Jaffe and Palmer (1997): US manufacturing between 1975 and 1991: correlation between PAC expenditure and the level of R&D spending within industries. Increases in PAC did not lead to increased patenting activity.
- Brunnermeier and Cohen (2003): US manufacturing sector between 1982 and 1992: environmental patents increased with increases in PAC expenditures. Increased enforcement did not provide additional incentive to innovate.
- Becker and Henderson (2000): Using US plant data for 1963-1992: Plant-births were reduced 26-45% in the more strictly regulated non-attainment areas, with polluting sectors being affected the most.

Empirical studies: general impacts II

- Greenstone (2002): Effects on employment, capital stock and shipments for existing and newly opened plants in the US: Substantial decline in manufacturing activity in non-attainment counties.
- Snyder *et al.* (2003): US chlorine manufacturing plants 1976-2001: Regulation contributed to the exit of facilities using environmentally inferior options.
- Shadbegian and Gray (2005): PAC in paper mills, oil refineries and steel mills: Abatement expenditures contribute little or nothing to production, but also have no significant effect on the productivity of non-abatement expenditures.

Empirical studies: general impacts III

Hamamoto (2006): Looked at the effect of capital costs for complying with environmental regulations, as well as by payments of an SO_x charge on R&D expenditures, the average age of capital stock and on total factor productivity (TFP) in some highly-polluting sectors in Japan. Found that command-and-control regulations triggered R&D activity, but the (relatively modest) SO_x charge did not seem to provide an additional incentive to innovate.

Regulatory stringency had downsizing and modernisation effects, which decreased the average age of the capital stock. The effect of changes in the average age of capital stock on TFP was insignificant while increases in R&D investment stimulated by regulatory stringency had a significant positive effect on TFP and produced a high rate-of-return.

Empirical studies: impacts of *specific* instruments I

- Bellas (1998): Found no technological progress from standards on Flue-Gas Desulphurisation units at coal-burning plants in the US, 1970-1991.

  The stringency of regulation of *new* units was determined by BAT in abatement. Any cost reduction stemming from a new and better unit would be subsumed by the regulator (by increasing the stringency). *Existing* units were governed by the standards that existed when the unit began operation. Any cost saving would be retained by the firm itself, giving the firm a strong incentive to improve operation – which is exactly what was observed.

Empirical studies: impacts of *specific* instruments II

- Popp (2006a): Studied effects of standards for NO_x- and SO_2-emissions on patenting in the US, Germany and Japan 1970-2000. Found that inventors respond to environmental regulatory pressure in their own country, but not to foreign environmental regulations.
- Popp (2006b): Studied NO_x patents developed 1970-2002 and *adoption* of the same technologies in power plants 1990-2002. Found that technological advances were important for the adoption of new post-combustion treatment technologies, but had little effect on the adoption of older combustion-modification techniques. The effect of other explanatory variables was dominated by the effect of environmental regulations.

Empirical studies: impacts of *specific* instruments III

- Millock and Nauges (2006): Studied a tax-cum-rebate scheme in three industrial sectors in France 1995-1998. SO_2, NO_x, and HCl-emissions were taxed, and the revenue was returned through abatement subsidies. Emissions were reduced, but the abatement elasticity was quite *small*.
- Höglund Isaksson (2005): Studied the effects of the (100 times higher) Swedish charge on NO_x emissions from energy-producing plants. The revenues from this charge are refunded to the firms based on the amount of energy they produce. Looked at cost changes abatement measures. Found *extensive emission reduction at very low cost*. Also found learning and technological development in abatement. Technology diffusion was somewhat hampered because firms tried to prevent information disclosure.

Empirical studies: relative impacts of *different* instruments I

- Newell, Jaffe and Stavins (1999): Studied impacts of energy prices and efficiency standards on energy characteristics of air conditioners and gas water heaters 1958-1993. Found that the *rate* of innovation was independent of energy prices and regulations, whereas its *direction* was induced for some products. Energy price changes affected the models offered for sale, especially after product labelling was required. Regulations worked largely through "exit" of inefficient models.
- Jaffe and Stavins (1995): Looked at the role energy prices and building codes had on adoption of thermal insulation technologies in new residential construction in the US 1979-1988. *Ad valorem energy taxes* of 10-25% would quickly have *noticeable impacts*. Adoption-subsidies of similar magnitude would have larger impact, as adoption-decisions are sensitive to up-front costs. *Direct regulation had no discernable effects* on building practices. Illustrates that new standards set below existing practices will have no effect on the margin, whereas energy taxes (and subsidies) always do.

Empirical studies: relative impacts of *different* instruments II

- Kerr and Newell (2003): Studied the effectiveness of CAC and tradable permits in the US lead phase-down in the 1980s. Tradable permits were applied 1983-1987. Employed panel data for US refineries 1971-1995 to study adoption decisions regarding lead-reducing technologies under different regulatory regimes. Found that *in periods when flexible policy instruments were used, total abatement costs were held in check*, because the refineries that could reduce lead-use at lowest costs, did so the most.
- Carlson *et al.* (2000): Tried to distinguish between reduction in SO_2 abatement costs due to trading allowed in CAAA 1990, and other reasons. Estimated marginal SO_2 abatement costs for power plants 1985-1994. Found that the large decline in marginal abatement costs could be attributed to technical improvements, including advances in the ability to burn low-sulphur coal at existing generators, as well as improvements in overall generating efficiency – but mostly to a decline of fuel costs. *Cost savings from trade were considerable.*

Empirical studies: relative impacts of *different* instruments III

- Lange and Bellas (2005): Focused on the effects of different in policies on *scrubbing costs*. Found post-CAAA scrubbers to be *cheaper* to purchase and operate than older scrubbers, but these cost reductions reflected a *one-time drop*, rather than a continuing decline.
- Popp (2003): Combined information on the filing of new patents for scrubbing technology with the actual instalment of this technology in US power plants 1972-1997. Found that the number of successful patent applications per year was *higher* before the tradable permit system was introduced in 1990. However, patents from before 1990 focused only on reducing operating costs. After the trading system was introduced, innovation also improved removal efficiency. Hence, *emissions trading* did not induce *more* innovation, but *lead to more environmentally friendly innovation*.

Empirical studies: relative impacts of *different* instruments IV

Johnstone and Labonne (2006): Used a firm-level survey in 7 OECD countries to compare impacts of different policies on firms' decision to engage in environmental R&D. Found that *perceived policy stringency is a very strong driver*. Technical assistance programmes were also found to have a significant impact. Also found *qualified support* for the use of flexible performance standards and *environmental taxes*.

Johnstone and Hascic (2007): Studied impacts of different instruments on patenting activity regarding renewable energy technologies in OECD countries 1978-2003. Public policies have had a very significant influence. However, *taxes, renewables obligations and tradable certificates were the only policy instruments that had a significant impact* on the number of patents in renewables.

Frondel, Horbach and Rennings (Forthcoming): Looked at whether the existence of an environmental management system had an impact on firms' decisions to invest in environmental R&D. Found neither EMS adoption, nor any other single policy instrument, to be catalysts for innovation. This appears plausible in the *absence of sanctions for lack of environmental improvement*.

Conclusions I

- *Environmental policy has an impact* on at least the *direction* of technological change. This conclusion holds, regardless of the type of instrument being applied.
- Command-and-control standards can provide clear signals as to what physical properties of production processes are undesirable, which in turn could be targeted by inventors.
- Innovators look carefully for rent opportunities, which depend on the *specific incentives* given by the type of (environmental) instrument being applied.
  - If a standard is set in “gram emissions per unit of time”, inventors are likely to focus on new technologies that address this particular target.
- The greater flexibility provided by both taxes and tradable permit systems seems to direct both R&D and innovation away from fundamental research on entirely new opportunities, towards *using the flexibility opportunities* provided by these instruments.

Conclusions II

- *Proper design of instruments is extremely important*.
- The broad distinction between CAC and MBI can be too general.
- Nevertheless, *financial incentives* for innovation are usually stronger under market-based instruments.
- Moreover, technology-related *information requirements* for public authorities are much *lower* when using a tax, compared to when using technology standards.
- This reduces the “space” for rent-seeking and the risk of misdirecting innovation.
- In addition, MBI allow for more flexibility on the part of the regulated agents, therefore reducing adjustment costs and optimising entry/exit and capital-turnover rates.

Some ideas for further research

- Research on the timing and commitment by the *regulator* is important.
- Research on the effects of *specific designs of instruments* is important.
- *Empirical research* on the impacts of *specific instruments* is possible:
  - It should gradually become possible to estimate impacts of the EU ETS on technologies to limit CO_2-emissions in the sectors covered by this scheme.
  - It should also be possible to use the strong increases in crude oil prices as a proxy to study innovation impacts of higher energy or carbon taxes.
  - One could estimate impacts of tax incentives to promote the sale of low-sulphur petrol and diesel on innovation in desulphurisation technologies for use in petroleum refineries.
  - One could analyse the impacts of EPR schemes, financed by various "advanced disposal fees", on technological developments.
  - In the longer term, it could be possible to estimate impacts of CO_2-differentiation of in motor vehicle taxes used in some countries on the vehicles' CO_2 emissions – although it will be difficult to isolate these impacts from the impacts of the (much larger) recent changes in motor fuel prices.