Promoting Clean Technologies

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Design and Evaluation of Innovation Policy in Developing Countries
Royal Scientific Society, Amman–Jordan
June, 10-12 2008

Set up

Environmental and economics debate

- Energy in growth and development:
  - Concerns about global climate change and its impacts on human bell-being.
  - A growing interest is deserving to the ability of public policies to reduce energy consumption from the combustion of fossil fuels.
  - Facts: international agreements like the Kyoto.
- Discussion on the broader concept of sustainable development (Arrow et al., 2004).
- Current economic challenge: macroeconomics effects of energy price shocks may encourage the switch to renewable energy, and support R&D investment towards cleaner technologies.

Set up

Policy tools to favor switch to cleaner technologies

- Quotas and pollution permit:
  - Emergence of a new market: regulation of emissions.
  - Is there an optimal rule both for developed and developing countries?
- Fiscal policies:
  - Emission taxes designed to limit the use of dirty technologies.
  - Investment subsidies in new and cleaner technologies.
  - Scrapping subsidies which favor the dismantlement.of the oldest and most polluting technologies.

Question: how to save energy consumption, given that the latter is one of the most important sources of pollution, and an important input for production as well.

Set up

Issues related to technological change

- The environmental impact of social and economic activity is profoundly affected by the rate and direction of technological change.
  - New technologies may create or ease increased pollution, or may mitigate or replace existing polluting activities.
  - The cumulative impact of technological changes is likely to be large.
- Environmental policy interventions themselves create new constraints and incentives that affect the process of technological change.
  - Cost-benefit or cost-effectiveness analyses of policies.
  - Implications for welfare analysis (the process of technological change is characterized by externalities and market failures).

Outline of the presentation

Economics of technological change

Schumpeter and the 'creative destruction'

- Schumpeter distinguished three stages in the process by which a new, superior technology permeates the marketplace.
  - Step 1. ***Invention***: first development of a scientifically or technically new product or process.
  - Step 2. ***Innovation***: commercialization of new product or process (organizational, managerial, marketing etc).
  - Step 3. ***Diffusion***: adoption by firms or individuals.
- However, environmental impacts of a new technology need a fourth step: ***utilization***.

Economics of technological change

Technological change and technological frontier

- The measurement of the rate and direction of technological change:

$$T(Y = outputs, I = inputs, t = time) \leq 0$$

  This relation describes a production possibility frontier: a set of combinations of inputs and outputs that are technically feasible at a point in time.

- Economy's production technology:

$$Y = f(K, L, E; t)$$

  - $Y =$ measure of aggregate output (ex. gross domestic product).
  - Inputs: capital (K); labor (L); Environmental inputs (E: energy use, waste assimilation, etc.); time (t).

Economics of technological change

Technological change and endogenous economic growth

- R&D is an **endogenous** equilibrium response to Schumpeterian profit incentives (Romer, 1990, 1994; Grossman and Helpman, 1994).
- Spillovers associated with R&D generate a form of dynamic increasing returns, which allows an economy endogenously investing in R&D to grow indefinitely.
- Endogenous technological change and induced technological change or induced innovation.
    - **Endogenous technological change** refers to the concept that technological change is the result of activities within the economic system, which are presumed to respond to the economic incentives of the system.
    - **Induced technological change** or **induced innovation** refers to the more specific idea that changes in relative factor prices affect the rate and the direction of innovation.

The induced innovation hypothesis

Origin of the hypothesis: Hicks (1932)

- R&D as a profit-motivated investment activity that leads to the hypothesis that the rate and the direction of innovation are likely to respond to changes in relative prices.
- Environmental policies makes environmental inputs more expensive. Then, the 'induced innovation' hypothesis suggests an important pathway for the interaction of environmental policy and technology.
- Sir John Hicks (1932, p.124):
  - *'a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind - directed to economizing the use of a factor which has become relatively expensive'.*

Further formalization of the hypothesis: Ahmad (1966); Kamien and Schwartz (1968); Binswanger (1974).

The induced innovation and the environment

Empirical evidence: literature (cond't)

- The relationship between innovation and the shadow price of pollution or environmental inputs:
  - Shadow price: maximum price that management is willing to pay for an extra unit of a given limited resource.
  - Problem: shadow prices are not easily observed.
  - Proxies for shadow prices: characteristics of environmental regulations, expenditures on pollution abatement, or prices of polluting inputs (for example, energy).

The induced innovation and the environment

Empirical evidence: literature findings

- Findings on the impact of environmental regulation on productivity and investment:
  - Lanjouw and Mody (1996): pollution abatement expenditures and the rate of patenting in related technology fields.
  - Jaffe and Palmer (1997): correlation between pollution expenditures and indicators of innovation.
  - Newell et al. (1999): movements in the energy efficiency of home appliances available for sale in response to energy prices between 1958 and 1993.
  - Poop (2001, 2002): energy prices and energy-related innovation.

The induced innovation and the environment

Application to sectoral data

1. Aim: empirical investigation of induced innovation and vintage effect
   - vintage effect: closely related to embodied technological change, i.e. technological progress is embodied in new vintages, which makes them better or of higher quality than older vintages.
   - Induced innovation (effect of energy price).
2. Data (OECD countries):
   - Sources: *Structural Analysis Database* (STAN) of the OECD; *Energy Balances* and *Energy Prices and Taxes* of the International Energy Agency (IEA).
   - Period: Unbalanced panel data over period 1978–2003.
   - Sectors: 14 sectors (10 manufacturing sectors) + mining and quarrying; transport and storage; construction; agriculture, hunting, forestry and fishing.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

3. Variables in the Database

Variable	Unit	Source
Gross fixed capital formation (GFCF)	PPP, US$, base 2000	STAN
Value added (VA)	PPP, US$, base 2000	STAN
Energy consumption	ktoe	IEA
Sectoral energy price	PPP, US$, base 2000	IEA
Real index of end-use energy prices	PPP, US$, base 2000	IEA

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

4. Variables:
   - Energy intensity (efficiency) $= \frac{\text{energy consumption (in ktoe)}}{\text{value added (ppp, 2000 US\$)}}$
   - Investment share (vintage) $= \frac{\text{gross fixed capital formation (ppp, 2000 US\$)}}{\text{value added (ppp, 2000 US\$)}}$
   - Sectoral energy price (induced) $= \frac{\text{sectoral expenditure based on 4 main energies}}{\text{sectoral energy consumption}}$
   - Time trend: account for autonomous technological change in energy consumption.
     - ⋆ sectoral expenditure = consumptions of 4 main energies (fuel, natural gas, coal, electricity) multiplied by corresponding prices (i.e. prices of high sulfur fuel, gas, stem coal, electricity; in PPP 2000 US$).
     - ⋆ sectoral energy consumption = total final energy consumption (including consumptions of 4 main energies).

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

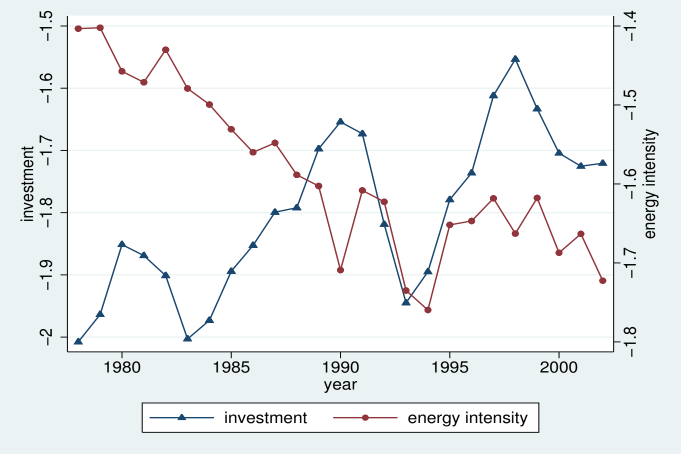

Figure: Energy intensity and investment share (both in log) for total manufacturing. Values displayed correspond to sample average.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

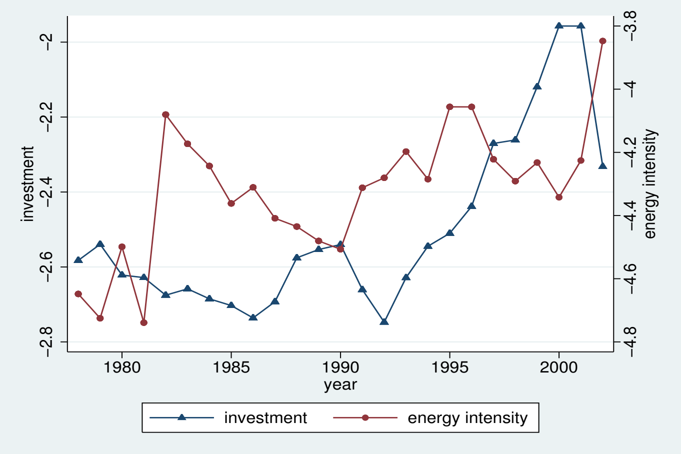

Figure: Energy intensity and investment share (both in log) for construction. Values displayed correspond to sample average.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Food and tobacco[a]	investment	-0.033	0.122	154
	sect. energy price	0.076*	0.040	
	time trend	0.003	0.002	
	intercept	-2.097**	0.236	
Textile and leather[a]	investment	-0.165	0.150	153
	sect. energy price	0.113**	0.046	
	time trend	0.007**	0.003	
	intercept	-2.950**	0.370	

Notes: Energy intensity, investment, and energy prices are in log.
[a]: results from random effects model.
[b]: results from fixed effects model.

* and ** mean significant coefficients at 10% and 5% levels, respectively.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Wood and wood products[a]	investment	-0.126	0.308	121
	sect. energy price	-0.109	0.101	
	time trend	0.016**	0.008	
	intercept	-2.824**	0.595	
Pulp, paper, and printing[b]	investment	0.127	0.137	156
	sect. energy price	0.170**	0.079	
	time trend	0.006*	0.003	
	intercept	-1.344**	0.284	

Notes: Energy intensity, investment, and energy prices are in log.
a: results from random effects model.
b: results from fixed effects model.

* and ** mean significant coefficients at 10% and 5% levels, respectively.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Chemicals[b]	investment	0.087	0.106	152
	sect. energy price	0.008	0.081	
	time trend	-0.004	0.004	
	intercept	-1.303**	0.201	
Non-metallic minerals	investment	-0.048	0.062	156
	sect. energy price	0.075*	0.042	
	time trend	-0.014**	0.002	
	intercept	-0.532**	0.168	

Notes: Energy intensity, investment, and energy prices are in log.
a: results from random effects model.
b: results from fixed effects model.

* and ** mean significant coefficients at 10% and 5% levels, respectively.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Iron and steel[a]	investment	0.182*	0.096	85
	sect. energy price	0.436**	0.093	
	time trend	0.015**	0.005	
	intercept	0.420	0.291	
Non-ferrous metals[a]	investment	0.166	0.168	85
	sect. energy price	0.057	0.092	
	time trend	-0.012*	0.006	
	intercept	-0.138	0.415	

Notes: Energy intensity, investment, and energy prices are in log.
[a]: results from random effects model.
[b]: results from fixed effects model.

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The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Machinery and equipment[b]	investment	-0.469**	0.188	154
	sect.energy price	0.024	0.090	
	time trend	0.004	0.004	
	intercept	-3.830**	0.397	
Transport equipment[b]	investment	0.048	0.117	154
	sect. energy price	0.097	0.070	
	time trend	0.005	0.005	
	intercept	-2.939**	0.200	
Total manufacturing[a]	investment	-0.188**	0.079	161
	sect. energy price	-0.015	0.033	
	time trend	-0.006**	0.002	
	intercept	-1.675**	0.195	

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Mining and quarrying[a]	investment	-0.089	0.242	137
	sect. energy price	-0.564**	0.178	
	time trend	0.016*	0.010	
	intercept	-3.344**	0.653	
Transport and storage[b]	investment	-0.025	0.065	100
	sect. energy price	-0.033**	0.015	
	time trend	-0.001	0.001	
	intercept	-0.299**	0.079	

Notes: Energy intensity, investment, and energy prices are in log.
a: results from random effects model.
b: results from fixed effects model.

* and ** mean significant coefficients at 10% and 5% levels, respectively.

The induced innovation and the environment

Application: sectoral analysis of vintage effect and induced innovation

Sector	Variable	Coefficient	Std.Err.	Obs.
Construction[a]	investment	-1.227**	0.304	157
	sect. energy price	0.019	0.119	
	time trend	0.013	0.009	
	intercept	-7.365**	0.804	
Agriculture, hunting, forestry and fishing[a]	investment	0.125	0.227	161
	sect. energy price	-0.086	0.056	
	time trend	0.024**	0.005	
	intercept	-2.389**	0.325	

Notes: Energy intensity, investment, and energy prices are in log.
[a]: results from random effects model.
[b]: results from fixed effects model.

* and ** mean significant coefficients at 10% and 5% levels, respectively.

The role of market structure: The case of energy market

Effect of investment (in new capital goods) subsidies on investment and output

Effect on investment

- Under perfect competition with free entry:
  - Positive supply effect which will reinforce the demand effect, and boosting investment.
- Under natural monopoly:
  - The supply effect is negative, and can eventually offset the positive demand effect.

Effect on long-run output

- Under perfect competition with free entry:
  - Long-run output is an increasing function of the subsidy.
- Under natural monopoly:
  - If large enough increasing returns, long-run output is a decreasing function of the subsidy.

Policy implications (1/2)

Environmental policy instruments and technological change

- Instruments:
  - **Market-based approach**: mechanisms that encourage behavior through market signals rather than through explicit directives regarding pollution control levels or methods.
  - **Command-and-control approach**: conventional approaches to regulating the environment (uniform control target for firms such as emissions per unit of output), while allowing some latitude in how this target is met.
- Limitations:
  - Standards must either be made unambitious, or else run the risk of being ultimately unachievable, leading to great political and economic disruption.
  - The case of 'Best Available Control Technology' (BACT) standard.

Policy implications (2/2)

Consequences of induced innovation for environmental policy

- Intuitively, if environmental policy intervention induces innovation, this in some sense reduces the social cost of environmental intervention, suggesting that the optimal policy is more stringent than it would be if there were no induced innovation.
- General equilibrium effect of induced environmental innovation on innovation elsewhere in the economy (Schmalensee, 1994):
  - If supply of R&D inputs is inelastic, any induced innovation must come at the expense of other forms of innovation, creating an 'opportunity cost'.
  - The consequences for welfare analysis depend on the extent of R&D spillovers or other market failures.

End!

Thank you for your attention !