Regulating GHG emissions from transportation: emission cap versus emission intensity standard

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Outline

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Motivation

* Transportation contributes 23% of energy-related CO_2 emissions world-wide and is the fastest growing source of emissions (IPCC AR4)
* Major GHG regulations so far have either targeted emissions from electricity and industrial sources (ETS, RGGI etc) or only indirectly targeted transportation emissions through Renewable fuel standards
* The first policy to directly target carbon emissions exclusively from transportation is California's Low Carbon Fuel Standard. At the same time economy-wide cap and trade is being proposed

Motivation

* In theory, a variety of different policy instruments are available to regulate pollution
  * Price-based: Emission fees
  * Quantity: Emission caps or emission intensity standard (performance-based)
* Being able to predict the effect of different types of policies on variables such as abatement cost, price, output, and pollution is necessary for making good decisions.

Literature

- Pollution pricing albeit more efficient is less popular than direct controls
  - Buchanan and Tullock *AER* (1975)
  - Hochman and Zilberman *Econometrica* (1978)
- Often the choice comes down to choosing between different quantity based policies
  - Helfand *AER* (1991)
    - Performance standards are the more preferred
    - But for climate change what matters is emissions
  - Much of the literature focuses on direct controls versus marked-based regulation (cap and trade)
- Emission cap or performance standards
  - Newell and Pizer *JEEM* (2008)
    - They look at an economy-wide policy and on uncertainty abatement cost
    - However they recognize results will differ depending on conditions within any sector

Objective and approach

* Compare the cost-effectiveness of regulating emission intensity versus regulating aggregate emissions
* Approach
  * Compare the firm's cost of achieving pollution reduction under the two policies
  * I will compare an emission intensity standard to an emission cap
  * I will assume quotas are non-tradable. Implications for tradable quota will follow from this

The Model

* Firm level
* Price-taking region
* Production is fixed-proportion
* Firms are heterogeneous in efficiency and pollution intensity

$$\begin{aligned} \pi_i^0 &= (p - c_i^0) q_i^0 \\ Z_i^0 &= \gamma_i^0 q_i^0 \end{aligned}$$

Firm's abatement options

A firm's options can be grouped under three categories

(A) **Adopt** cleaner technologies

- Switch to less polluting technology
- Fuel switching

(B) **Blend** – mix with cleaner fuels, two cases

1. Firm produces both dirty and clean fuels
2. Firm produces only dirty fuel

(C) **Cut production** – lower output to reduce emissions

Firm's objective

The optimization problem of the firm is

$$\max_{\Delta\gamma_i, \Delta q_i^*, \Delta q_i} \pi_i = \{\underbrace{p(q_i^0 + \Delta q_i + \Delta q_i^*)}_{\text{Revenue}} - \underbrace{(c_i^0 + \Delta c_i(\Delta\gamma_i))(q_i^0 + \Delta q_i)}_{\text{Production cost}} - \underbrace{(p + c_i^t)\Delta q_i^*}_{\text{Blending cost}}\}$$

such that, emission intensity of output is below a standard

$$\frac{\gamma_i^0 q_i^0 + \Delta\gamma_i q_i + \gamma_i^* \Delta q_i^*}{q_i^0 + \Delta q_i + \Delta q_i^*} \leq \overline{z}$$

(OR)

such that, emissions are below a cap

$$Z_i^0 + \Delta\gamma_i q_i + \gamma_i^* \Delta q_i^* \leq \overline{Z_i}$$

Ex ante equivalence of cap and standard

- For any intensity standard we can determine the *ex ante* equivalent emission cap for a given level of output

$$\overline{Z}_i = \bar{z} * \overline{Q}_i$$

- We can now proceed to comparing the two types of policies

Proposition : cost effectiveness

1. For any firm, an emission cap imposes lower cost or in the worst case the same cost as an emission intensity standard

Proof:

$$C_{cap} = \min\{AC_A, AC_B\}$$

$$C_{ES} = \min\{AC_A, AC_B, AC_c\}$$

$$\Rightarrow C_{cap} \geq C_{ES}$$

The intuition is that the choice set under an emission quota has more lower cost options than the choice set under an emission intensity standard.

Cost of abatement options

Table 1: Cost-benefit analysis of firm's choices for emission reduction per unit output

Option	Profit (π_i^1)	Loss in profit ($\pi_i^0 - \pi_i^1$)	Emission reduction ($Z_i^1 - Z_i^0$)	Reduction in emission intensity	Average cost of abatement
$A_k, k \in (1..K_i)$	$p - c_{ik} + \Delta c_{ik}$	Δc_{ik}	$\Delta\gamma_{ik}$	$\Delta\gamma_{ik}$	$\frac{\Delta c_{ik}}{\Delta\gamma_{ik}}$
B_{own}	$p - [(1-\alpha)c_i + \alpha(c_i^* + c_i^t)]$	αc_i^t	$\alpha(\gamma_i^0 - \gamma_i^*)$	$\alpha(\gamma_i^0 - \gamma_i^*)$	$\frac{c_i^t}{(\gamma_i^0 - \gamma_i^*)}$
B_{market}	$p - [(1-\alpha)c_i + \alpha(p + c_i^{t*})]$	$\alpha(p + c_i^{t*} - c_i^0)$	$\alpha(\gamma_i^0 - \gamma_i^*)$	$\alpha(\gamma_i^0 - \gamma_i^*)$	$\frac{(p + c_i^{t*} - c_i^0)}{(\gamma_i^0 - \gamma_i^*)}$
C	-	$p - c_i^0$	γ_i^0	0	$\frac{p - c_i^0}{\gamma_i^0}$

Numerical example: Regulation of ethanol producers

Five scenarios

1. Base case – using 2007 data
2. Ethanol price is 50% higher than base case
3. Natural gas is 2.5X costlier relative to coal than base case
4. Transportation cost is 2X than base case
5. Ethanol price and transportation cost are 1.5X of base case

Scenarios*	I	II	III	IV	V
Price of ethanol ($/liter)	0.628	0.942	0.628	0.628	0.942
Coal-based ethanol production cost ($/liter)	0.430	0.430	0.430	0.430	0.430
Ethanol transportation cost - rail ($/liter)	0.050	0.050	0.050	0.100	0.075
Ethanol transportation cost - road ($/liter)	0.130	0.130	0.130	0.260	0.195
Energy used in biorefining (MJ/liter)	13.85	13.85	13.85	13.85	13.850
GHG intensity of coal-based corn ethanol in gCO2e/liter	89	89	89	89	89.000
GHG intensity of gas-based corn ethanol in gCO2e/liter	61	61	61	61	61.000
Price of coal energy ($/MJ)	0.0020	0.0020	0.0020	0.0020	0.002
Price of natural gas energy ($/MJ)	0.0105	0.0105	0.0262	0.0105	0.010

Numerical example

Cost under intensity standard	0.0042	0.0042	0.0103	0.0042	0.0042
Cost under emission quota	0.0022	0.0042	0.0022	0.0022	0.0042
Relative cost of intensity standard	188%	100%	463%	188%	100%

Emission intensity standard is costlier than emission cap

Corollary:
The relative inefficiency of an emission standard decreases as output price increases or as input costs decline. This is because as fuel price increases or as input costs decline firms are less likely to exercise the option of reducing output

Proposition: output

2. Aggregate output under an emission quota can be higher or lower than that under an intensity standard depending on the cost-effectiveness of reducing emissions by reducing output relative to other options (option A and option B).

Proof: If reducing emission intensity is costly

$\Pi_i^A < 0$ and $\Pi_i^B < 0$ it will force inefficient firms to exit. However under an emission cap these firms can just lower output and continue to operate. If production capacity of other firms is fixed then they caps will result in higher output

Proof continued

If reducing emission intensity is not costly enough to force firms to exit, then emission intensity standard will result in more output than emission caps.

This is because if allowed firms will reduce output rather than cleanup, but an emission intensity standard will not allow this

Discussion

- An emission cap will achieve emission reduction at a lower cost or in the worst case at the same cost as an emission intensity standard
  - The result stems from the additional flexibility of an emission policy which is that emission reduction can be achieved by reducing output
  - Allowing for trading will not affect this result as trading only allows firms to take advantage of inter-firm heterogeneity but not intra-firm flexibility

Discussion

- This flexibility is important when there is variability in macro-economic conditions
  - During bad times, demand or margins are low. In such cases emission reduction is achieved by lower output. An emission intensity standard will impose higher cost. Emission will decrease under both policies
  - During good times, caps can be a binding upper-bound on emissions, whereas under an emission intensity standard emissions can increase.
    - If firms want to expand capacity then the relative cost of a cap increases

Discussion

* An emission cap can lead to more or less output than an emission intensity standard
* For a price taking region, consumer surplus will be unchanged and so a policy that achieves emission reduction at lower abatement cost if more efficient
* To the extent that reduction in output can lead to unemployment policy makers will prefer a policy that results in higher output

Future research

* Large region
* Capacity not fixed
* Efficiency of different sectoral policies under a larger economy wide policy