Emissions Trading
and
Profit-Neutral Permit Allocations

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Bear in mind that...

these are slides prepared for a half-hour talk. I have posted them on my webpage in the hope that they may give a quick and gentle introduction to the paper. But reading the slides is not the same as attending the talk during which these slides were shown - I say a lot more than I put on the slides - and reading them alone can be slightly misleading.

In particular, results may be stated in a way that focuses on the main ideas, ignoring secondary assumptions (or conclusions). I also tend not to make citations on my slides.

That said, I do hope you will find them helpful. And your comments would be very welcome.

John Quah

Economics of Cap-and-Trade Schemes

Examples:

The EU's Emissions Trading Scheme (ETS) for controlling CO_2 emissions;
Acid Rain Program in the U.S.

Economic justification:

Emissions permits imposes a marginal cost on emissions. Trading in emissions permits allows a single market clearing price for emissions to emerge. This ensures that different firms face the same marginal cost of emissions, leading to cost efficiency.

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In particular, superior to command-and-control approaches.
But compared to CAC approach, it imposes an additional burden on industry in the form of payments for emissions permits.

May affect the scheme's political viability.

Economics of Cap-and-Trade Schemes

Solution: To ensure buy-in from industry, give all or part of the emissions permits for free. Practice known as grandfathering.

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(Flip side: How many could be sold at auction?)

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More generally...

∗ What is the impact of a cap-and-trade scheme, like the EU's ETS, on emissions, costs, and profits?
∗ What is its relative impact across firms?
∗ What are its efficiency properties?

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These are natural assumptions to make when one has the EU ETS in mind, but a significant departure from the standard literature. Latter assumes:

- Perfect competition in both markets

- Narrow markets in both permits and output, leading to strategic issues when allocating permits, etc

- GE setting with price-taking behavior but limited factor mobility across sectors.

Impact of ETS on a monopoly

The introduction of the ETS constitutes a change in the price of an input - from zero to some positive number t.

Monopoly adjusts its production decision, substituting away from CO_2 if possible.

Revealed preference guarantees that emissions fall.
It also guarantees that profits are lower, but by how much?

Optimal profit at price t is $\Pi^*(t)$, with emissions $\zeta^*(t)$.

Initial profit and emissions are $\Pi^*(0)$ and $\zeta^*(0)$.

Impact of ETS on a monopoly

By definition, profit-neutral permit allocation $\mathcal{X}(t)$ obeys

$$\Pi^*(t) + t\,\mathcal{X}(t) = \Pi^*(0)$$

How does $\mathcal{X}(t)$ compare with $\zeta^*(0)$?

Define $\gamma(t)$ by

$$\mathcal{X}(t) = \gamma(t)\zeta^*(0).$$

We refer to $\gamma(t)$ as the profit neutral allocation (PNA).

If $\gamma(t) \leq 1$, then PNA is partial.

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Result: For a monopoly, PNA is partial, but

$$\mathcal{X}(t) = \gamma(t)\zeta^*(0) > \zeta^*(t),$$

i.e. monopoly is a net supplier of permits.

Completely robust result, with no auxiliary assumptions.

Impact of ETS on an oligopoly

Assume constant marginal cost at each firm.

Firm i's marginal cost of all inputs (excluding CO_2) at permit price t is $\bar{c}_i(t)$.

It's total marginal cost is $c_i(t) = \bar{c}_i(t) + t\, z_i(t)$,
where $z_i(t)$ is firm i's emissions intensity.

Both $c_i(t)$ and $\bar{c}_i(t)$ rises with t.
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$\bar{c}_i(t)$ rises with t because firms will tend to substitute CO_2 with other inputs.

Average marginal cost (excluding CO_2) is

$$\bar{c}(t) = \sum_{i=1}^{N} \sigma_i(t)\bar{c}_i(t),$$

where $\sigma_i(t)$ is market share of firm i.

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(1) output has an inelastic demand function;
with the introduction of the ETS,
(2) equilibrium output falls and
(3) average marginal cost falls, i.e., $\bar{c}(t) < \bar{c}(0)$.

Then PNA is partial, i.e., $\gamma(t) < 1$.
Furthermore, industry is a net demander of permits even if it is given PNA.

Impact of ETS on an oligopoly

By definition,

$$\Pi^*(t) + t\left[\gamma(t)\zeta^*(0)\right] = \Pi^*(0)$$

Suppose $\gamma(t) < 1$ and $\tilde{\gamma} = \lim_{t\to 0}\gamma(t) < 1$. Then for small t,

$$\Pi^*(t) + t\zeta^*(t) > \Pi^*(0).$$

Interpretation:

If PNA is partial, then ETS has ‘facilitated collusion’.

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Interpretation:

If PNA is partial, then ETS has ‘facilitated collusion’.

Reverse is also true (globally):

if the ETS causes firms to move closer to the collusive outcome, then PNA is partial.

Cost efficiency of ETS

Recall that average marginal cost (excluding CO_2) is

$$\bar{c}(t) = \sum_{i=1}^{N} \sigma_i(t)\bar{c}_i(t).$$

Is it reasonable to assume that $\bar{c}$ falls with t?

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Introduction of ETS raises $\bar{c}_i$, but it also changes σ_i. Indeed

the second effect is of *first* order while
the first effect is of *second* order (because of the Envelope Theorem).
Consequently,

$$\frac{d\bar{c}}{dt}(0) = \sum_{i=1}^{N} \bar{c}_i(0)\frac{d\sigma_i}{dt}.$$

A cost efficiency argument for the ETS

It follows from

$$\frac{d\bar{c}}{dt}(0) = \sum_{i=1}^{N} \bar{c}_i(0) \frac{d\sigma_i}{dt}$$

that, locally, the impact on $\bar{c}$ is *solely* driven by the strategic impact of the ETS. Thus

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$\bar{c}\,'(0) < 0$ if firms with lower initial marginal costs gain market share.

Result: In a Cournot oligopoly $\bar{c}\,'(0) < 0$ if
(i) market demand is log-concave and
(ii) (co-monotonicity) firms with lower marginal cost have lower emissions intensity.

This gives a theoretical justification for using the ETS when the output market is imperfect: it leads to greater cost efficiency.

ETS in the Cournot Model

In a Cournot model, it is possible to derive simple formulae for $\tilde{\gamma} = \lim_{t \to 0} \gamma(t)$ and $\tilde{\gamma}_i = \lim_{t \to 0} \gamma_i(t)$.

By definition, $\gamma_i(t)$ satisfies

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When is $\tilde{\gamma}_i < 1$?

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When is $\tilde{\gamma}_i < 1$?

Result: $\tilde{\gamma}_i < 1$ if and only if total output of all other firms falls with the introduction of ETS, i.e., firm i faces a more favorable residual demand curve.

ETS in the Cournot Model

Formula:

$$\tilde{\gamma}_i = 2z_i - \frac{N\left[2 - \sigma_i E\right]}{\left[N + 1 - E\right]}$$

where z_i is firm i's emissions intensity, σ_i its market share, and

$$E = -Q^* P''(Q^*)/P'(Q^*)$$

is the curvature of demand.

In general, $\tilde{\gamma}_i$ is not constant across firms. Exceptions:
$*$ firms are symmetric (in which case $\tilde{\gamma}_i < 1$) or
$*$ demand is linear and emissions uniform.

Note: It is possible for $\tilde{\gamma}_i < 0$.

ETS in the Cournot Model

Formula:

$$\tilde{\gamma} = 2 - \frac{N\,[2 - EH]}{[N + 1 - E]\,[\,\sum_{i=1}^{N} \sigma_i z_i\,]}$$

where H is the Herfindhal index.

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Result: Suppose firms with lower marginal costs also have lower emissions intensity. Then PNA is partial, i.e., $\tilde{\gamma} < 1$, if

$*$ industry is sufficiently fragmented $H < 2/(N+1)$ *or*

$*$ demand is (locally) log-concave.

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$*$ demand is (locally) log-concave.

Result: If demand is (locally) log-concave, the introduction of an ETS

(i) lowers emissions,

(ii) lowers average marginal cost, and

(iii) requires only partial PNA.

((i) and (iii) also true for large t.)

Estimating PNA

It is possible to estimate $\tilde{\gamma}$ and $\tilde{\gamma}_i$ using available data. Recall

$$\tilde{\gamma} = 2 - \frac{N\,[2 - EH]}{[N + 1 - E]\,[\,\sum_{i=1}^{N} \sigma_i z_i\,]}$$

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Chief difficulty has to do with estimating E.

One solution is to assume constant elasticity of demand, in which case E is related to elasticity by a simple formula and there are lots of estimates for the latter.

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But what are reasonable values for E? Note that cost pass-through

$$\frac{dP^*}{dt} = \frac{N}{N + 1 - E}.$$

So E can be replaced with dP^*/dt in the formulae.

Estimating PNA

	Cement (UK)	
dP^*/dt	Industry-level $\tilde{\gamma}$	Max. firm-level $\tilde{\gamma}_i$
20%	-0.136	1.445
40%	-0.032	1.090
60%	0.072	0.735
80%	0.176	0.380
100%	0.280	0.400
120%	0.384	0.720
140%	0.488	1.040
160%	0.592	1.360
180%	0.696	1.680
200%	0.800	N/A