Market-Based Emissions Regulation and Industry Dynamics

Meredith Fowlie, Mar Reguant, and Stephen P. Ryan

Journal of Political Economy, 2016

Motivation

The big picture

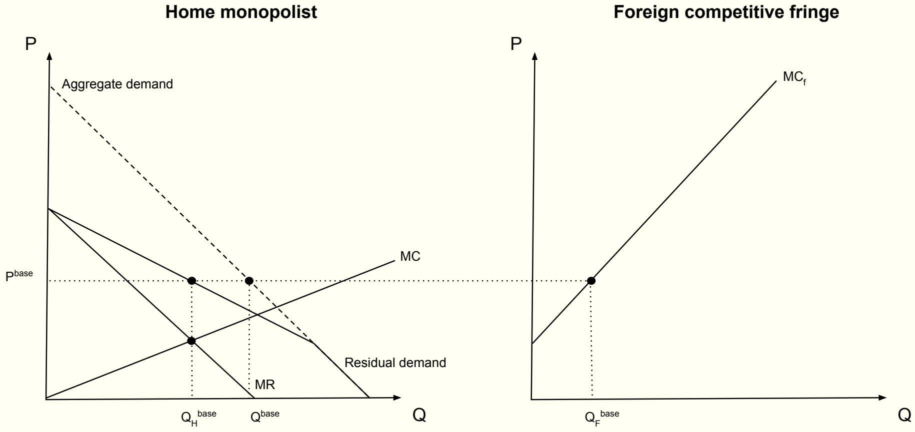
- Pigouvian taxes decentralize the first best when the only source of market failure is the environmental externality
- But in the real world...
  - markets are plagued with many imperfections other than the environmental externality (e.g. market power)
  - environmental regulation is imperfectly enforced (e.g. leakage, pollution havens)

How do these market imperfections interact, and what do they imply for the optimal design of environmental policy?

- Does a Pigouvian tax designed to internalize environmental externalities exacerbate other market imperfections?

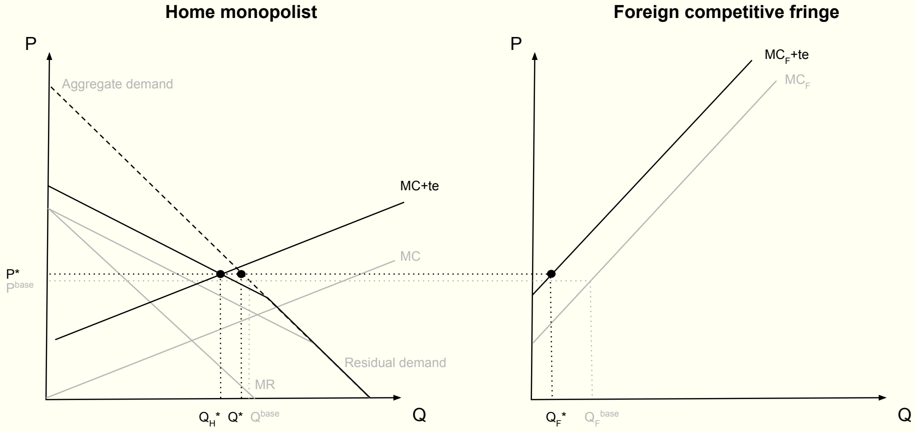
Motivating example

A monopolist and a competitive fringe (no environmental externality)



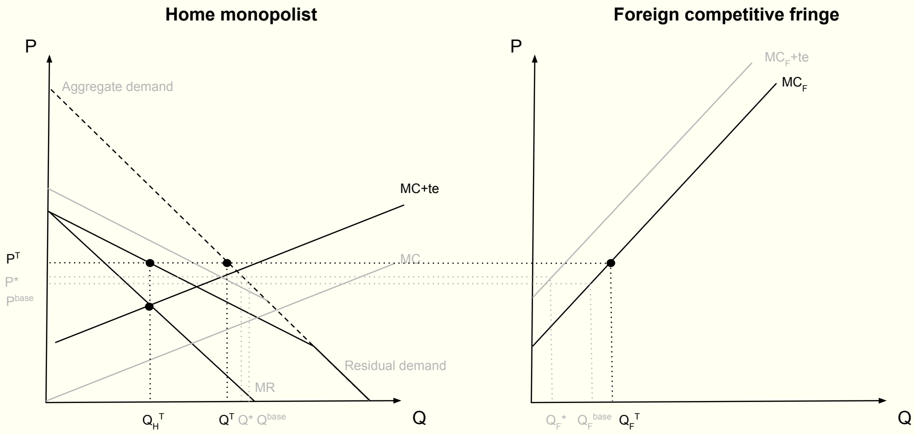
Motivating example

Now consider a per-unit-of-output environmental externality *e* with social cost *t*



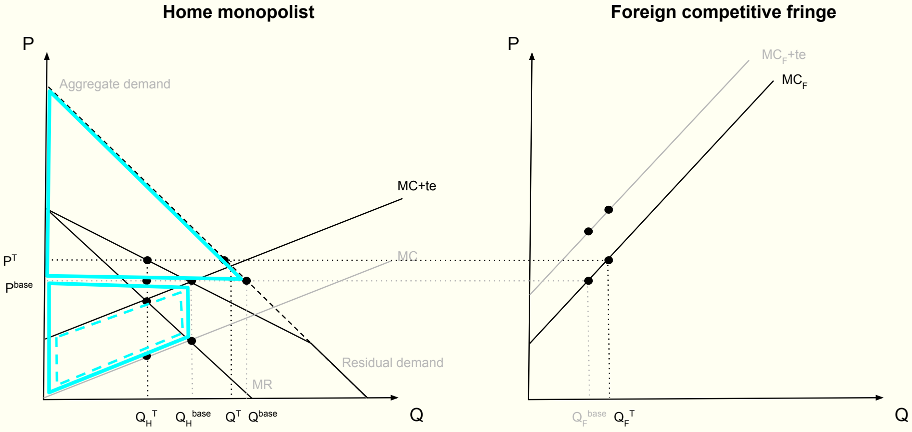
Motivating example

Assume we have only 1 policy tool: Pigouvian tax on domestic monopolist



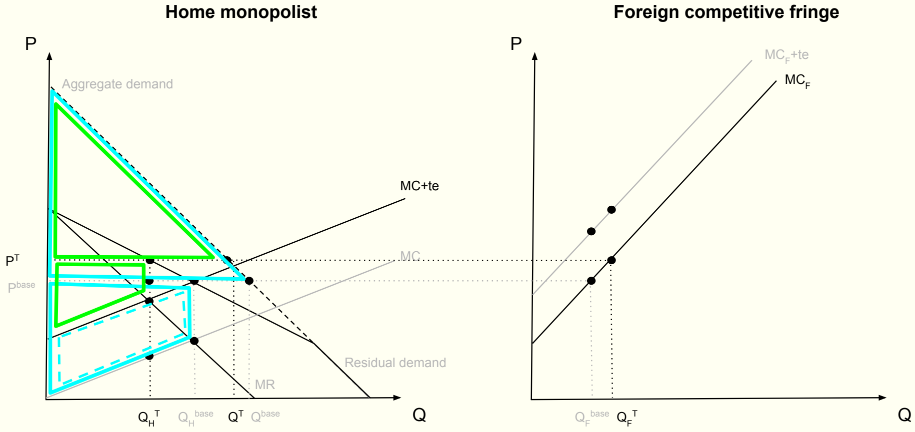
Motivating example

Private and social surplus without Pigouvian tax



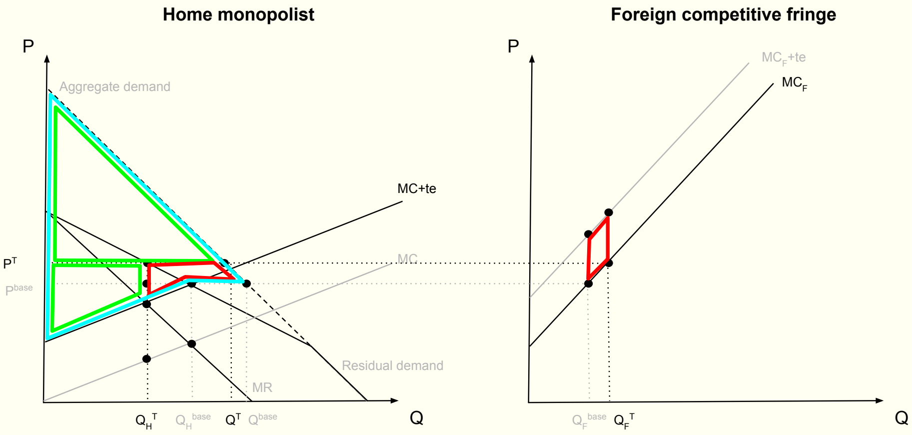
Motivating example

Private and social surplus with Pigouvian tax



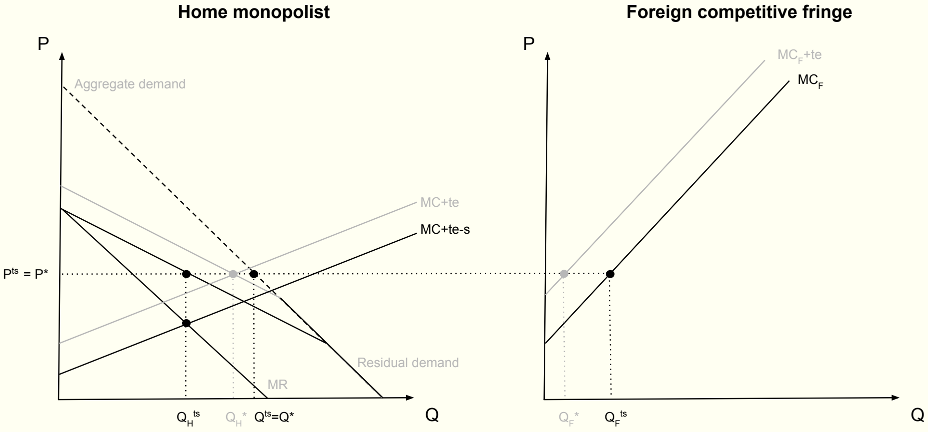
Motivating example

Social welfare loss from Pigouvian tax : Market power is exacerbated + Leakage



Motivating example

Now assume we have 2 policy tools: Pigouvian tax + production subsidy



Motivating example

Summary

Three market imperfections

- Environmental externality
- Market power
- Leakage due to imperfect enforcement

Two policy tools

- Pigouvian tax
- Production subsidy

General lesson - we need as many policy instruments as market imperfections to attain the first best

The rest of the paper

- Extension to oligopoly
- Extension to dynamics
  - Entry/exit and investment responses to regulation
- Policy analysis
  - Cap-and-trade, implemented via auctioning, grandfathering, or with dynamic updating rule
  - Border tax adjustment for dirty foreign imports

Today's plan

Model

Estimation

Policy counterfactuals

Timing

Firms decide exit/entry, investment, and quantities produced.

1. Incumbents draw scrap values and make exit decisions
2. Incumbent-stayers draw investment costs. Potential entrants draw both entry and investment costs and decide to enter or not.
3. Entry and investment decisions are made simultaneously
4. Incumbent stayers and exiters compete over quantities
5. Entry/exit decisions are implemented and define the new pool of incumbents, and investments mature

Firm's static decisions

$s =$ vector of maximum productive capacities of all incumbents
$e =$ vector of emissions rates of all incumbents (3 discrete values/kiln types)
$\tau =$ policy regime
$\alpha =$ aggregate demand parameters
$\rho =$ import supply parameters
$\delta =$ variable cost parameters
$P(\cdot) =$ inverse of residual demand

Static profits given by,

$$\bar{\pi}(s, e, \tau; \alpha, \rho, \delta) \equiv \max_{q_i \leq s_i} \quad P\left(q_i + \sum_{j \neq i} q_j^*; \alpha, \rho\right) q_i - C_i(q_i; \delta) - \varphi(q_i, e_i, \tau)$$

where $C_i(q_i; \delta) = \delta_{i1} q_i + \delta_2 1(q_i > \nu s_i) \left(\frac{q_i}{s_i} - \nu\right)^2$ and $\varphi(\cdot)$ is the compliance cost

Firm's dynamic decisions

Firms decide to invest x_i at cost,

$$\Gamma(x_i;\gamma) = \gamma_{i1} + 1(x_i > 0)(\gamma_2 x_i + \gamma_3 x_i^2) + 1(x_i < 0)(\gamma_4 x_i + \gamma_5 x_i^2)$$

Firms make market participation decision a_i, receiving transfer,

$$\Phi(a_i;\kappa_i,\phi_i) = \begin{cases} -\kappa_i & \text{if the firm is a new entrant} \\ \phi_i & \text{if the firm exits} \end{cases}$$

Per period profits are given by,

$$\pi_i(a, x, s, e, ; \theta, \tau) = \bar{\pi}(s, e, \tau; \alpha, \rho, \delta) - \Gamma(x_i;\gamma) + \Phi(a_i;\kappa_i,\phi_i)$$

Equilibrium

Markov Perfect Nash equilibrium

Strategies are anonymous, symmetric, Markovian

See paper for details $\rightarrow$ nothing new here, follows a long literature in dynamic games

Today's plan

Model

Estimation

Policy counterfactuals

Static parameters

1. Static demand equation estimated using supply-side cost shifters
   - coal, gas and electricity prices, wages
2. Static import supply equation estimated using demand shifters
   - construction, unemployment, state GDP
3. Variable cost function $C_i(q_i; \delta)$ estimated using the static oligopoly restrictions
   - given estimates from 1 and 2 and a guess for δ, the oligopoly model predicts $\hat{q}_i$
   - iterate on δ until $\hat{q}_i \approx q_i^{data}$

Dynamic parameters

Two step method (Bajari, Benkard, Levin, 2007; Ryan, 2012)

1. Estimate policy functions (i.e., regress firm decisions on state variables)
    - Investment: (s,S) model

$$s_{t+1} = \begin{cases} T(s_t) & \text{if } s_t \notin [T(s_t) - B(s_t), T(s_t) + B(s_t)] \\ s_t & \text{else} \end{cases}$$

      $T(s_t)$ and $B(s_t)$ regressed on firm previous capacity and market capacity
    - Entry/exit: probit regressions on same variables as in $T(s_t)$ and $B(s_t)$
2. Project policy functions onto the model via forward simulation
    - Guess parameters θ
    - Compute value functions using estimated policy functions from step 1 and θ
    - Iterate on θ until the estimated policy functions are optimal

Today’s plan

Model

Estimation

Policy counterfactuals

Policy formulas

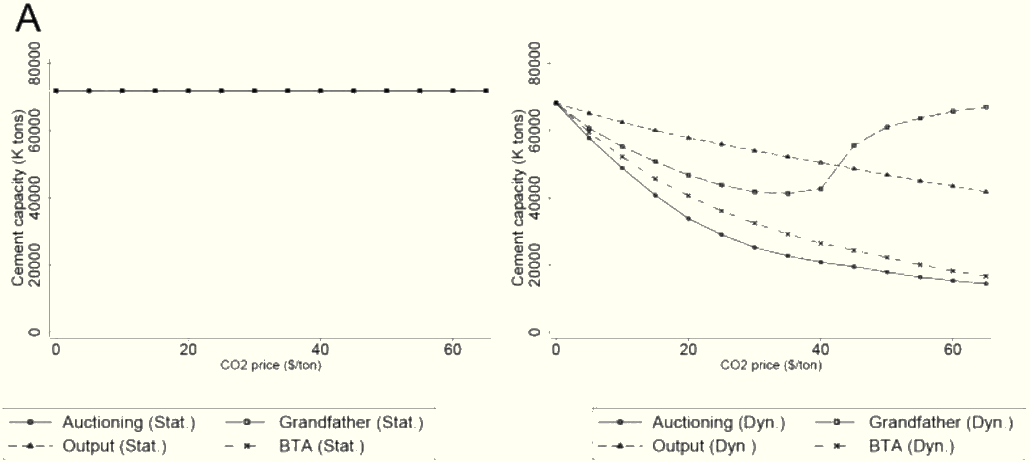
Cap-and-trade designs

$$\varphi(q_i, e_i, \tau) = \begin{cases} \tau e_i q_i & \text{Auctioning} \\ \tau(e_i q_i - A_i) & \text{Grandfathering, based on } s_{i0} \text{ of incumbents} \\ \tau(e_i - \psi_d) q_i & \text{Output-based rebating} \end{cases}$$

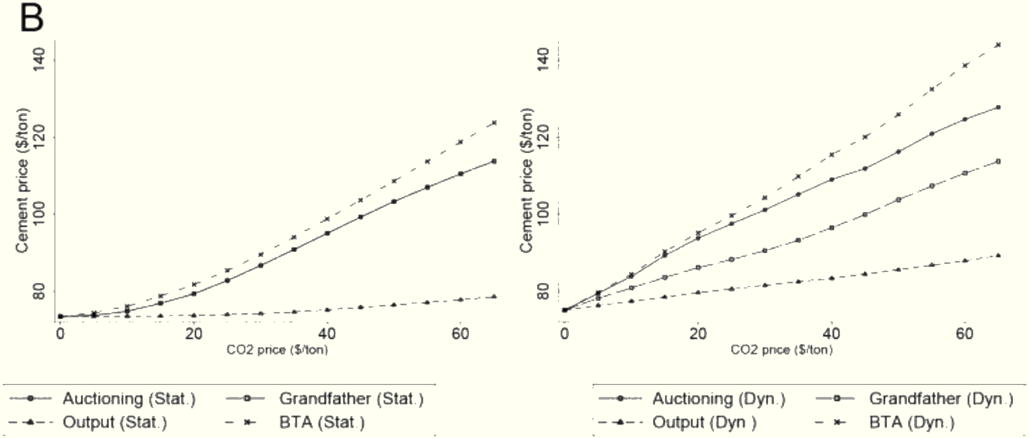
Border-tax adjustment

$$\ln M(P; \rho, \delta) = \rho_0 + \rho_1 \ln(P - \tau e_M)$$

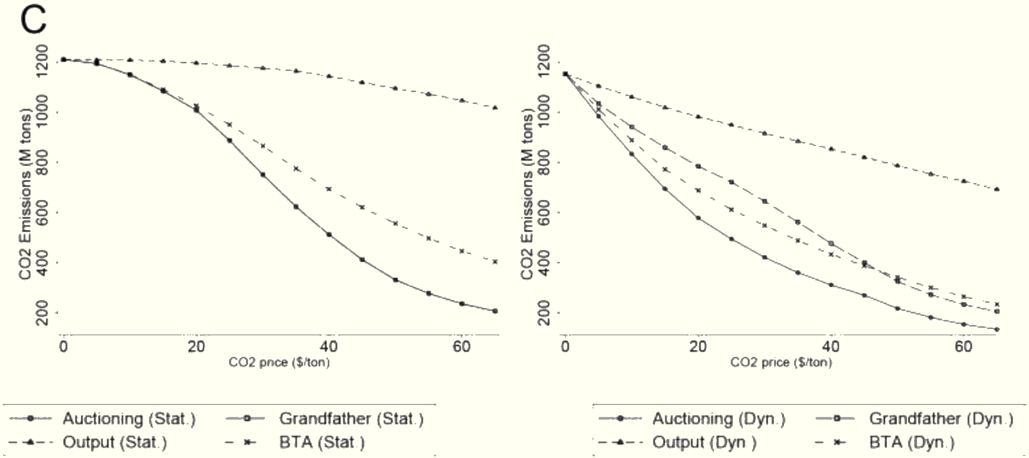
Capacity (000s tons)



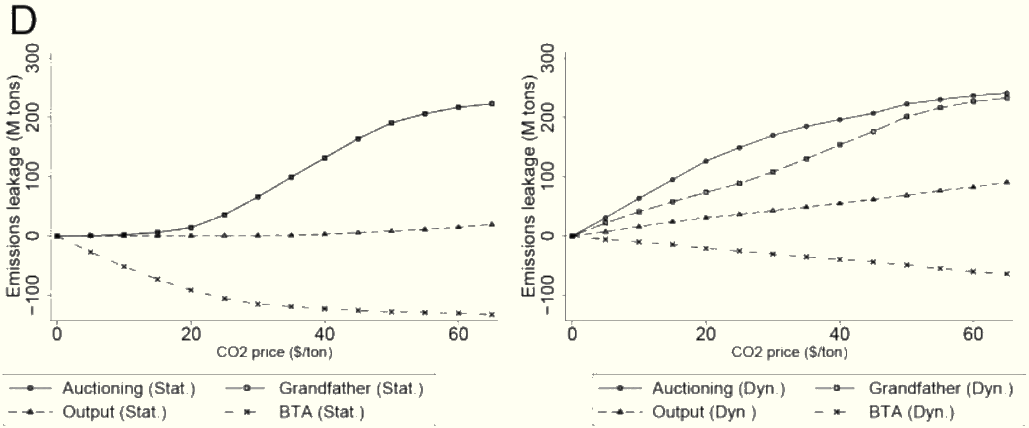
Cement price ($ per ton)



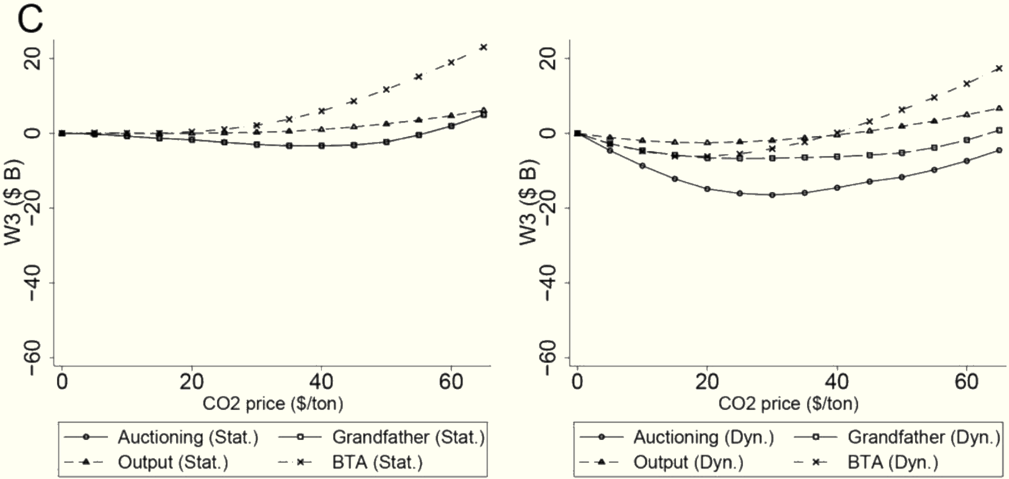
CO2 emissions (M tons)



Emissions leakage (Mtons)



Welfare = PS + CS + Govt Revenue - Domestic Env. Cost - Imported Env. Cost



Takeaways

Regulation can be incomplete in different ways

- only targets one of many market inefficiencies
- only targets one of many economic actors

Incomplete regulation intending to improve outcomes along one dimension (e.g, env. quality) can exacerbate other market failures leading to overall welfare losses

In general, we need as many policy tools as market failures to attain the first best