Lecture 3

Competitive output markets

Ivan Rudik
AEM 7510

Roadmap

So far we have ignored output markets in our analysis

But firms actually have production costs in addition to abatement costs, and sometimes these costs cannot be disentangled

Now we explore models where output and abatement may not be separable

This captures a wider range of potential abatement methods and technologies

The competitive output model

This model is simply an extension of our previous one

For now drop firm-specific subscripts but we assume firms are asymmetric

A firm's production technology is given by:

$$x = f(l_1, \ldots, l_K)$$

where x is how many units of output are produced using production function f and vector of inputs $\{l_1, \ldots, l_K\}$

The competitive output model

A firm's emission technology is given by:

$$e = g(l_1, \ldots, l_K)$$

where e is how many units of emissions resulting from using the vector of inputs $\{l_1, \ldots, l_K\}$

Note that the marginal product of l_k for either f or g could be positive, negative, or zero

Why?

An input that reduces emissions could reduce output, output-enhancing inputs could increase emissions or be emission-neutral

The competitive output model

Next we need the cost functions

The cost function $C(x, e)$ is derived from the firm's cost minimization problem

We want to minimize the costs of producing a given combination of output (x, e)

$$C(x,e) = \min_{l_1,...,l_k} \left\{ \sum_{k=1}^{K} w_k l_k + \lambda \underbrace{[x - f(l_1, \ldots, l_K)]}_{\text{x units of output}} + \mu \underbrace{[e - g(l_1, \ldots, l_K)]}_{\text{e units of emissions}} \right\}$$

where $\{w_1, \ldots, w_K\}$ is a vector of input prices

The competitive output model

Let $\hat{e}^x$ be the freely chosen level of emissions at output level x

We need two sets of assumptions to continue

Assumption Set 1 **(general case)**

1. $C(x, e)$ is twice continuously-differentiable with $C_x > 0$ and for any x there is an emission level $\hat{e}^x$ such that $C_e(x, \hat{e}^x) = 0$
2. $C_e(x, \hat{e}^x) < 0 \ \ \forall e < \hat{e}^x$ and $C_e(x, \hat{e}^x) \geq 0 \ \ \forall e \geq \hat{e}^x$
3. $C_{xe} = C_{ex} < 0 \ \ \forall e < \hat{e}^x$
4. $C_{xx} > 0, C_{ee} > 0, C_{xx}C_{ee} - C_{ex}^2 > 0$

The competitive output model

What do these tell us?

1. MC of production is positive and there is a cost-minimizing emission level $\hat{e}^x$ for all x in the absence of environmental regulation
2. MAC is increasing in abating below $\hat{e}^x$
3. MC of production is smaller with higher emissions $\leftrightarrow$ MAC shifts up if output rises
4. Production and abatement costs are convex (marginal costs are increasing)

The competitive output model

We can also see that the non-regulated emission level $\hat{e}^x$ rises with x from the $C_e(x, \hat{e}^x) = 0$ assumption

Differentiate $C_e(x, \hat{e}^x) = 0$ wrt x to get: $C_{ex}(x, \hat{e}^x)\frac{dx}{dx} + C_{ee}(x, \hat{e}^x)\frac{d\hat{e}^x}{dx} = 0$

Rearrange to get: $\frac{d\hat{e}^x}{dx} = -\frac{C_{ex}}{C_{ee}} > 0$

The competitive output model

Assumption Set 2 **(specific case)**

We will be directly linking emissions to output in the **specific case** so we make these assumptions:

- Cost function $C(x)$ is twice continuously-differentiable
- $C'(x) > 0, C''(x) > 0$
- Emissions are given by $e = \delta(x)$ where $\delta'(x) > 0$
- In some cases we will assume $\delta(x) = \delta \cdot x$ to simplify

The competitive output model

What do these tell us?

The MAC function is tired directly to the firm's marginal profit

If p is the output price of x, profit is:

$$\Pi = px - c(x)$$

and if $e = \delta x$ we have that:

$$\frac{d\Pi}{de} = \frac{p - C'(e/\delta)}{\delta}$$

The competitive output model

At an unregulated optimum it must be that $p - C'(x) = 0$ so $p - C'(\hat{e}^x/\delta) = 0$ defines the unregulated level of emissions

For $e < \hat{e}^x$: $p - C'(e/\delta) > 0$ since $\hat{e}^x$ is privately optimal for the firm

Thus $\frac{d\Pi}{de}$ is the marginal abatement cost where $\frac{d\Pi}{de} > 0$ for $e < \hat{e}^x$

The MC of abatement is the forgone marginal profits from reducing emissions

We can also see that the MAC is increasing:

$$\frac{d^2\Pi}{de^2} = \frac{C''(e/\delta)}{\delta^2} \geq 0$$

The competitive output model

Next we need to model the demand side of the market

Let consumer utility be:

$$U^i = U_i(x_i) + z_i - D_i(E)$$

where

- x_i is the person's consumption level
- z_i is spending on all other non- x goods
- $D_i(E)$ are damages from aggregate emissions E
- There are $i = 1, \ldots, J$ consumers

The competitive output model

The consumer has a budget constraint:

$$y = px_i + z_i$$

where the price of z_i is normalized to 1, p is the price of x in terms of z

Utility maximization gives us that $u_i'(x_i) = p$

This defines the inverse demand for x as: $p_i(x_i) = u_i'(x_i)$

We can then derive gross benefits from consumption: $\int_0^{x_i} u_i'(s)ds = u_i(x_i)$

The competitive output model

Next we want to derive **aggregate** market benefits

Let $X = \sum_{i=1}^{I} x_i$ be aggregate consumption, $P(X)$ be the market inverse demand curve, and $D(E)$ be the aggregate damage curve

- You get $P(X)$ by just horizontally summing $p_i(x_i)$ like we did in previous classes

$P(X)$ and $D(E)$ allow us to **fully** characterize benefits and damages to households

The competitive output model

Now we have both sides of our model, next we need to define **social welfare** so we can find efficient outcomes

Social welfare in the **general case** is given by:

$$W(x_1, \ldots, x_J, e_1, \ldots, e_J) \equiv \int_0^{X \equiv \sum x_j} P(s)ds - \sum_{j=1}^{J} C^j(x_j, e_j) - D(E)$$

where j are specific firms, and household costs and firm revenues cancel out because they are just a transfer from households to firms

Welfare is CS minus total cost, minus damages

The competitive output model

Social welfare in the **specific case** when $e_j = \delta_j(x_j)$ is given by:

$$W(x_1, \ldots, x_J) \equiv \int_0^{X \equiv \sum x_j} P(s)ds - \sum_{j=1}^{J} C^j(x_j) - D(E)$$

where $E = \sum_{j=1}^{J} \delta_j(x_j)$

Now we can derive the efficiency conditions for our model to understand what defines the optimal allocation

The competitive output model: Efficiency

Begin with the **general case**, the FOCs are defined by:

$$\frac{\partial W}{\partial x_j} = P(X) - C^j_{x_j}(x_j, e_j) = 0 \rightarrow P(X) = C^j_{x_j}(x_j, e_j)$$

where $\frac{\partial}{\partial x_j} \int_0^{X \equiv \sum x_j} P(s) ds = P(X) \frac{\partial X}{\partial x_j} = P(X)$ by the fundamental theorem of calculus, and

$$\frac{\partial W}{\partial e_j} = C^j_{e_j}(x_j, e_j) + D'(E) = 0 \rightarrow D'(E) = -C^j_{e_j}(x_j, e_j)$$

These $2J$ equations give us the solutions x_j^*, e_j^* for $j = 1, \ldots, J$

The competitive output model: Efficiency

The conditions are pretty straightforward, right?

- $P(X) = C^j_{x_j}(x_j, e_j)$ tells us that marginal benefit of consumption must equal marginal cost of consumption
- $-C^j_{e_j}(x_j, e_j) = D'(E)$ tells us that marginal abatement cost must equal marginal damage

For efficiency, we need to balance the environmental and production costs of producing the good with the benefits of consuming it

The competitive output model: Efficiency

The **specific case** can give us some more insight

Here only the x_js are choice variables so we get the following FOCs:

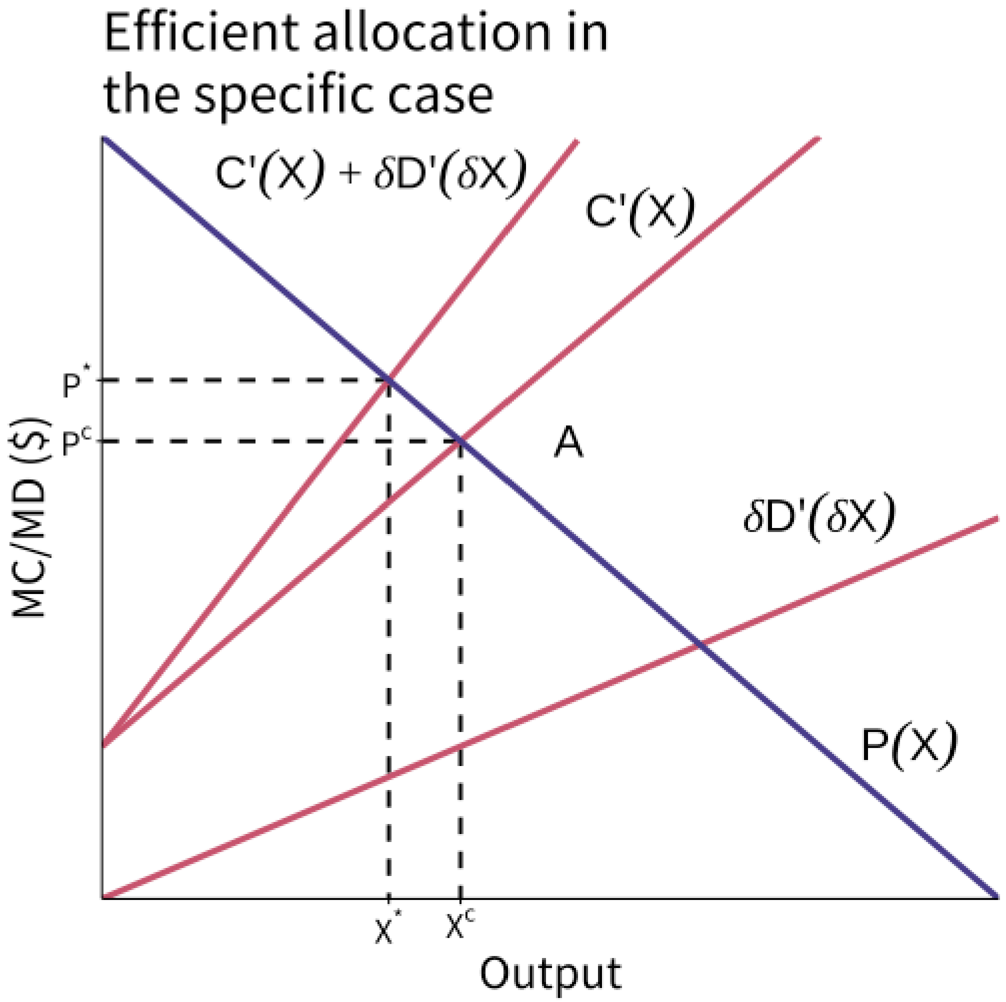
$$P(X) = C_j'(x_j) + D'(E)\delta_j'(x_j) \quad j = 1, \ldots, J$$

The left hand side is the marginal benefit of consumption

The right hand side is the total marginal cost:

- Private production costs
- External damage costs

Efficiency in the specific case



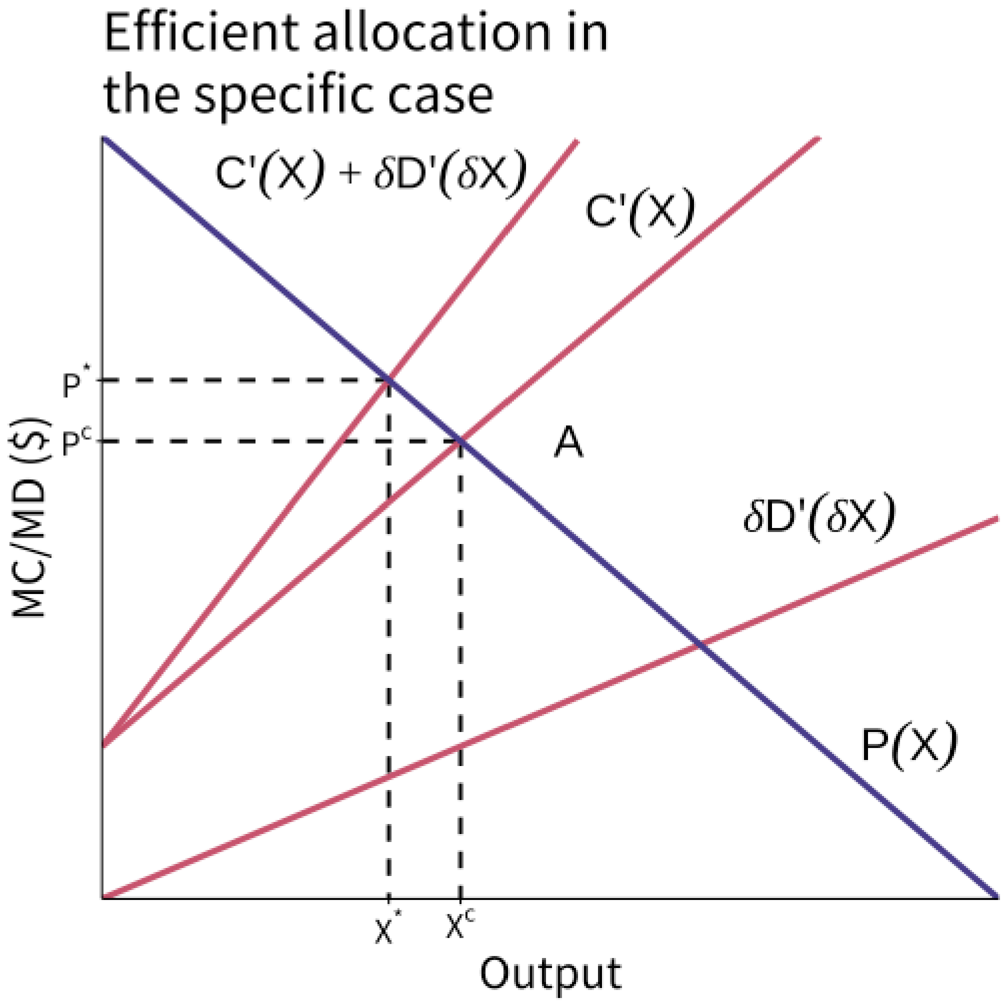
X^c is the competitive allocation, this results in:

- Too much production
- Too low of an output price

X^* is the optimal allocation where SMB = SMC

- This results in less production than the competitive allocation at a higher price

Efficiency in the specific case



Where do the aggregate curves come from?

We get aggregate private MC $C'(X) = \sum_{j=1}^{J} C_j'(x_j)$ by *horizontally* summing firm MCs

We get SMC by *vertically* summing PMC and MD

Policy instruments

Now we will take another look at our environmental policy instruments in this model with output markets

We will see that:

- There are additional results related to the output market that we didn't have before

- The previous results all still hold: taxes, subsidies, permits can all achieve the efficient allocation

Policy instruments: taxes

When facing an emission tax τ a competitive firm's problem in the **general case** is:

$$\Pi_j(x_j, e_j) = px_j - C^j(x_j, e_j) - \tau e_j$$

where p is the market price of x

The firm's FOCs are:

$$\begin{aligned} p &= C'_{x_j}(x_j, e_j) \\ \tau &= -C'_{e_j}(x_j, e_j) \end{aligned}$$

Policy instruments: taxes

The firm's FOCs are:

$$p = C'_{x_j}(x_j, e_j)$$
$$\tau = -C'_{e_j}(x_j, e_j)$$

The firm equates MR to MC of production

The firm equates the marginal abatement cost to the tax level

So if the regulator sets $\tau = D'(E^*)$ **we can achieve the efficient allocation**

Policy instruments: taxes

When facing an emission tax τ a competitive firm's problem in the **specific case** where $e_j = dx_j$ is:

$$\Pi_j(x_j) = px_j - C^j(x_j) - \tau\delta x_j$$

with FOC:

$$p = C_j'(x_j) + \tau\delta$$

If the regulator sets $\tau = D'(E^*)$ then firms behave as if

$$P(X) = C_j'(x_j) + \delta D'(E^*)$$

which matches our social efficiency condition

Comparative statics

Now that we have an output market in our model we can study how taxes influence it

To start we will assume all firms are identical and we are in the **specific case** of the model so our profit-maximizing firm FOC is:

$$P(X) = C'(x) + \delta\tau$$

where $X = x \cdot J$

Differentiate the FOC with respect to τ to get how output and emissions respond to a change in the tax rate

Comparative statics

Differentiating gives us:

$$\left[P'(X)J - C''(x)\right] \frac{dx}{d\tau} = \delta$$

which implies that:

$$\frac{dx}{d\tau} = \frac{\delta}{P'(X)J - C''(x)} < 0$$

and $\frac{dX}{d\tau} = J\frac{dx}{d\tau} < 0$

Emission taxes reduce output

Comparative statics

With $E = \delta \cdot X$ we have how emissions respond to the tax:

$$\frac{dE}{d\tau} = J\delta \frac{\delta}{P'(X)J - C''(x)} < 0$$

and since $p = P(X)$ is the market price of output, we can determine the relationship between output prices and the tax:

$$\frac{dp}{d\tau} = P'(X)\frac{dX}{d\tau} > 0$$

Comparative statics

Recap: What do the comparative statics tell us?

Output and emissions decline in the tax:

- A tax on emissions raises the marginal cost of production for firms
  - Supply shifts left
- Output price p goes up, quantity x goes down

Comparative statics

The **incidence** of the tax is also made clear by:

$$\frac{dp}{d\tau} = P'(X)\frac{dX}{d\tau} > 0$$

Incidence is how the tax burden is distributed between consumers and producers

The more the price of x increases in response to a tax, the more the consumers pay for x because of τ, the higher their tax incidence

Recall from Econ 101 that it doesn't matter who is taxed, the burden is shared by the consumers and producers

Comparative statics

$$\frac{dp}{d\tau} = P'(X)\frac{dX}{d\tau} > 0$$

If $P'(X)$ is small, demand is **elastic (flat)**, and consumers have low incidence because the price they pay does not change much in the tax, firms bear most of the cost of the tax

If demand is perfectly elastic $P'(X) = 0$ and there is no associated price increase from a tax increase

Comparative statics

$$\frac{dp}{d\tau} = P'(X)\frac{dX}{d\tau} > 0$$

If $P'(X)$ is large, demand is **inelastic (steep)**, and consumers have high incidence because the price they pay for x increases substantially in the tax, firms pass-through most of the tax to consumers

If demand is perfectly inelastic, then consumers bear the entire cost of the tax

Comparative statics: taxes recap

What did we learn?

Increasing a tax:

1. Decreases firm and aggregate emission levels
2. Decreases firm and aggregate output (even in the general case, see pg 103-104 in the book)
3. Increases output prices

Policy instruments: permits

Now suppose the regulator issues $L = E^*$ permits instead of setting a tax

The regulator knows that the permit price σ that clears the permit market will be $\sigma(L) = \sigma(E^*) = D'(E^*)$

Similarly, the output price will then be $p = P(X^*)$

The regulator can achieve the first-best efficient outcome

Policy instruments: permits

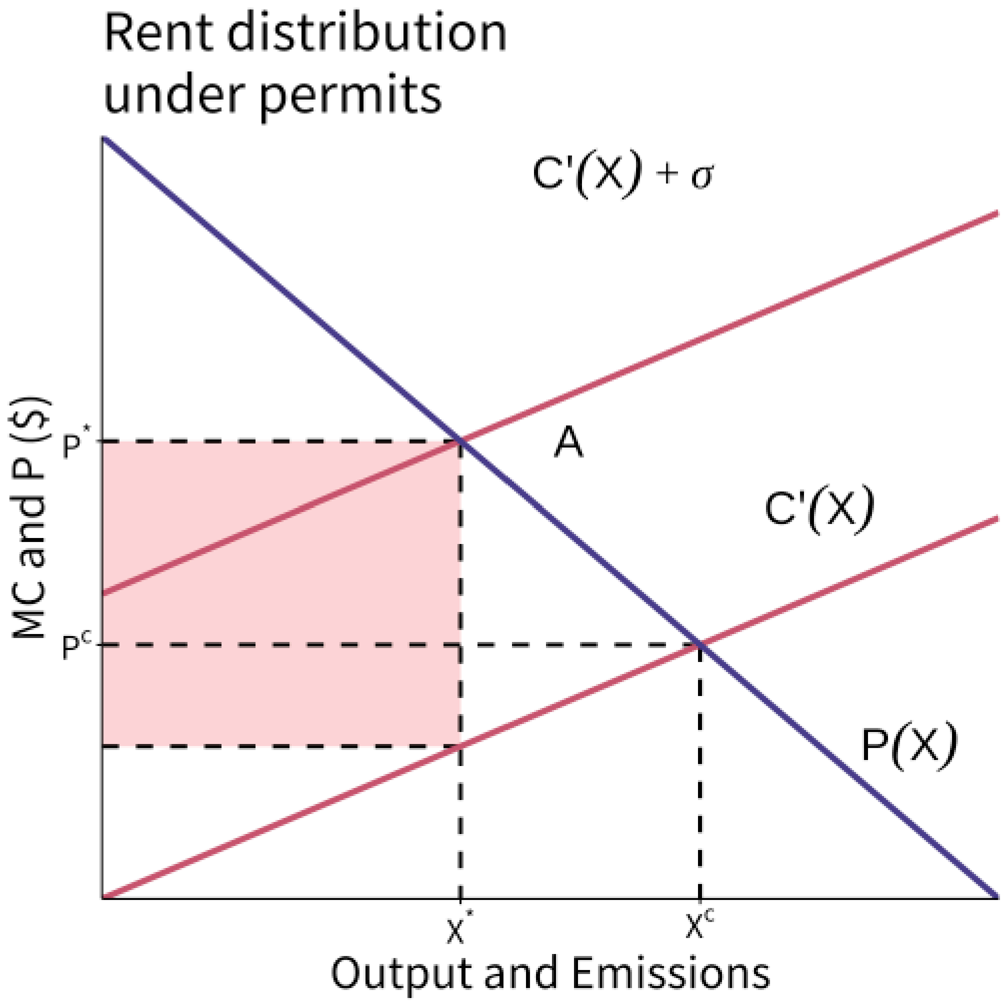
Auctioned versus freely-distributed permits are equivalent in this model in terms of **efficiency**

The permit price in the market under free distribution will match the price that clears the permit auction

Output prices will also be the same because all firm and consumer decisions will be identical

The one way they will be different is how the **rents (economic profits)** are distributed: who gets the value from the scarcity of permits, the firms or the government?

Distribution of rents in permit markets



Assume $x = \delta e$ and $\delta = 1$ so we can plot them on the same scale

The red shaded area is the rents from the permit scheme

If freely allocated: they remain with firms

If auctioned: they go to the government as revenue

Relative/intensity standards

A common form of standards is called a **relative standard**

Relative standards regulate firms based on the concentration of pollution relative to some measurable output

A relative standard would look something like:

$$e/x \leq \alpha$$

or equivalently: $e \leq \alpha x$ where α is the policy variable

Relative standards are often called intensity standards because e/x measures the pollution intensity of output

Relative/intensity standards

Relative standards are only interesting in the **general case** of our model, in the **specific case**:

- If $\delta > \alpha$, the firm has to shut down
- If $\delta \leq \alpha$, the firm complies with the regulation no matter its actions

Assume the regulation is binding in the **general case** (i.e. it actually affects firm behavior), then the firm will always set $e = \alpha x$[1]

This lets us re-write a firm's profit function as: $\Pi(x) = px - C(x, \alpha x)$

[1]Choosing e strictly less than αx strictly raises costs and reduces profits.

Relative/intensity standards

$$\Pi(x) = px - C(x, \alpha x)$$

If the regulation is binding, the firm really is only choosing one variable, x

The FOC is:

$$p = C_x(x, \alpha x) + \alpha C_e(x, \alpha x)$$

The implicit solution to this, $x(\alpha)$, is the firms supply function, dependent on the policy α

Relative standards vs quantity standards

Suppose the regulator wants to hit $e = \bar{e}$ and she knows $x(\alpha)$

All the regulator has to do is set $\alpha = \bar{e}/x(\alpha)$

Now suppose the firm just uses a quantity standard and directly sets $e = \bar{e}$

The firm's profit function is:

$$\Pi(x, \bar{e}) = px - C(x, \bar{e})$$

and the firm's supply $x(\bar{e})$ is defined by $p = C_x(x, \bar{e})$

If the regulator chooses $\bar{e} = e^*$ the regulator can achieve the efficient outcome

Relative standards vs quantity standards

Recall the relative standard FOC if we wanted to set $e = \bar{e}$:

$$p = C_x(x(\alpha), \bar{e}) + \alpha C_e(x(\alpha), \bar{e})$$

and notice that this means that:

$$p - \alpha C_e(x(\alpha), \bar{e}) = C_x(x(\alpha), \bar{e}) > p$$

since $-C_e$ is positive

What does this mean?

Relative standards vs quantity standards

This means that:

$$C_x(x(\alpha), \bar{e}) > C_x(x(\bar{e}), \bar{e})$$

It follows pretty simply that: $x(\alpha) > x(\bar{e})$ and that:

- $C(x(\alpha), \bar{e}) > C(x(\bar{e}), \bar{e})$ since $C_{xx} > 0$
- $-C_e(x(\alpha), \bar{e}) > -C_e(x(\bar{e}), \bar{e})$ since $C_{ex} < 0$

Total cost and marginal production and abatement costs are higher under a relative standard

Relative standards vs quantity standards

Takeaways:

If a regulator sets an emission goal of $\bar{e}$ for a single firm or J firms, then a relative standard will lead to:

- higher output
- higher total cost
- higher marginal abatement cost relative to a quantity standard

Why?

Relative standards vs quantity standards

How can the firm achieve compliance under a relative standard $(e/x \leq \alpha)$?

Two ways:

1. Decrease emissions e
2. Increase output x

Relative standards allow the firm to meet the standard *in ways we don't want them to,* so we end up with too much output

This limits us to **second-best** outcomes

Relative standards: optimal policy

If we need to use a relative standard due to political or technical reasons what standard should we set to maximize welfare?

The regulator's problem is:

$$W(\alpha) = \int_0^{x(\alpha)} P(t)dt - C(x(\alpha), \alpha x(\alpha)) - D(\alpha x(\alpha))$$

The FOC is:

$$[P - C_x - \alpha C_e]x'(\alpha) - C_e x - D' \times [x + \alpha x'(\alpha)] = 0$$

where the term in the first bracket is 0 from the firm's π-max FOCs

Relative standards: optimal policy

This gives us that:

$$-C_e = \frac{x + \alpha x'(\alpha)}{x} D'$$

This is not MAC = MD!

$x'(\alpha)$ tells us how output responds to policy and its sign tells us whether MAC $>$ MD or vice versa

Suppose $x'(\alpha) > 0$, then the second best policy sets MAC $>$ MD:

- The second-best quantity of emissions is lower than the first-best / optimal level that sets MAC = MD

Environmental policy in the long run

So far we have assumed a fixed number of firms J

In the long run, firms may enter or exit the market, and this may affect the efficiency properties of our policies

Econ 101 tells us that in perfectly competitive markets:

- Firms are identical
- Firms enter or exit until profits are driven to zero
- Firms produce at minimum average cost
- Optimal number of firms is endogenous (usually)

We will now look at long run properties of policy with identical firms

Environmental policy in the long run

In the long run, firms have fixed and variable costs:

$$C(x,e) = \begin{cases} VC(x,e) + F \text{ if } x,e \neq 0 \\ 0 \text{ if } x,e = 0 \end{cases}$$

where F is the fixed cost of entry, and VC denotes variable costs of operation

In the long run, social welfare will depend on x, e **and the number of firms** J

Environmental policy in the long run

Social welfare is given by:

$$W(x, e, J) = \max_{x,e,J} \int_0^{x \cdot J} P(t)dt - J \cdot C(x, e) - D(e \cdot J)$$

The FOCs for a social optimum are:

$$\begin{aligned} P(X^*) =& C_x(x^*, e^*) && \text{(x FOC)} \\ D'(E^*) =& -C_e(x^*, e^*) && \text{(e FOC)} \\ P(X^*)x^* =& C(x^*, e^*) + D'(E^*)e^* && \text{(J FOC)} \end{aligned}$$

The last expression is the new one for **long-run efficiency**

Environmental policy in the long run

With some slight rearranging of the J FOC we can get:

$$P(X^*) = \frac{C(x^*, e^*) + D'(E^*)e^*}{x^*}$$

What does this say?

First, for a small firm: $D'(E^*)e^*$ is approximately the damage caused by that firm because for sufficiently small e^*, $D'(E^*)$ will be approximately constant (δ) (by a Taylor expansion argument)

Environmental policy in the long run

With some slight rearranging of the J FOC we can get:

$$P(X^*) = \underbrace{\frac{C(x^*, e^*) + \delta e^*}{x^*}}_{\text{average social cost}}$$

This means that it is socially efficient for firms to enter or exit until the price of output (approximately) equals the **average social cost curve**

Standards in the long run

In the short run we had that standards were equivalent to taxes and tradable permits

Is this true in the long run?

Suppose the regulator wants to cap total emissions at E^*

She sets an emission standard $e^* = E^*/J^*$ for all firms where J^* is the optimal long run number of firms

Firms can now only choose x since e is fixed at e^*

Standards in the long run

Firms choose output according to:

$$p = C_x(x, e^*)$$

In the long run competitive equilibrium we will have $\hat{J}$ firms all producing $\hat{x}$ units of output such that:

$$\begin{aligned} P(\hat{x}\hat{J}) &= C_x(\hat{x}, e^*) && \text{(MR = MC)} \\ P(\hat{x}\hat{J})\hat{x} - C(\hat{x}, e^*) &= 0 && \text{(Zero Profit)} \end{aligned}$$

MR = MC, and zero profits are our two equilibrium conditions

MR = MC maximizes firm profit, zero profits ensures no change in # of firms

Standards in the long run

Recall that long run efficiency required that:

$$P(X^*)x^* - C(x^*, e^*) = D'(E^*)e^* > 0$$

so we have that $\hat{J} \neq J^*$ and $\hat{x} \neq x^*$! What's the intuition?

When we impose a standard:

1. Firms cut back output
2. This raises (short-run) profit above zero
3. Firms enter the market until profits go to zero: so $\hat{J} > J^*$ and we will have that $\hat{x} < x^*$

Standards in the long run

This is important!

Conventional wisdom tells us that taxes, permits, and standards can all achieve the efficient outcome

This is only true in the short run

In the long run: standards do not appropriate the damage to the environment $D'(E^*)e^*$ from firms, so we get **excess entry** and standards are no longer first-best

Taxes in the long run

Can taxes achieve the efficient outcome in the long run?

Yes and it is pretty easy to see, suppose the regulator sets a tax of:

$$\tau = D'(E^*)$$

Firm profit is then:

$$\Pi = px - C(x, e) - \tau e$$

Giving us FOCs:

$$p = C_x(x^*, e^*) \qquad - C_e(x^*, e^*) = \tau$$

Taxes in the long run

In the long run firms enter until profits are zero so:

$$\Pi = P(X^*)x^* - C(x^*, e^*) - \tau e^* = 0$$

so $\tau = D'(E^*)$ implies that

$$P(X^*)x^* = C(x^*, e^*) + D'(E^*)e^*$$

The firm FOCs for production and the entry zero-profit condition map exactly to the social welfare maximizing conditions!

The payment of tax rents from the firms to the regulator of $\tau e^* = D'(E^*)e^*$ limits entry and is what makes taxes efficient in the long run

Permits in the long run

Now what about permit systems?

Suppose the regulator auctions off $L = E^* = e^*J$ permits and let σ be the market-clearing permit price

The long run equilibrium is defined by the two firm FOCs and the entry condition:

$$
\begin{aligned}
&P(x^*J) = C_x(x^*, e^*) \\
&\sigma = -C_e(x^*, e^*) \\
&P(x^*J)x^* - C(x, e) - \sigma e^* = 0
\end{aligned}
$$

Permits in the long run

Similar to the short run we will have that $\sigma = -C_e(x^*, e^*) = D'(L) = D'(E^*)$

Thus the three long run efficiency conditions are satisfied again if we auction off the permits:

- MR = MC
- MAC = MD
- P = ASC

Now what if we freely distribute permits? What do you think?

It seems like it might not be long run efficient: firms are not paying the environmental rent, so zero profit and P = ASC might not occur

Permits in the long run

Suppose we allocate $\bar{e}$ permits to the incumbent identical firms, profit for the incumbent firms given permits is then:

$$\Pi = px - C(x,e) - \sigma(e - \bar{e})$$

and profit for any future entrants who were not given an allocation is:

$$\Pi = px - C(x,e) - \sigma e$$

What two things do you notice?

First, for any given σ, entrants and incumbents cannot both have zero profit!

Our P = ASC condition can't hold for all firms

Permits in the long run

Our efficiency condition is now **new firms enter until profits are zero (P=ASC for entrants)**:

$$\Pi = px - C(x, e) - \sigma e = 0$$

so that incumbent firms sustain long run profits of:

$$\sigma \bar{e}$$

What is this saying?

Operating profits of any firms in the market are zero, incumbents had long run profits **only** from their initial permit allocation

Permits in the long run

The second thing you should have noticed is that the firm FOCs will be identical to the auctioned permit case, firms face the **exact same** incentives for output and emissions

This means that freely allocated permits are also long run efficient

This is just an application of the Coase theorem: the initial assignment of property rights to pollute does not matter for efficiency

Subsidies in the long run

Now what about subsidies?

In the short run they are equivalent to taxes, are they still equivalent in the long run?

Think about the incentives for entry...

Denote the reference level of emissions as $\hat{e}$, firm profits under a subsidy per unit ξ are:

$$\Pi = px - C(x, e) - \xi(e - \hat{e})$$

Subsidies in the long run

For damage efficiency we need to set the subsidy equal to MD: $\xi = D'(E^*)$

In the long run equilibrium, firms enter until profits are zero

$$\Pi = P(X^*)x^* - C(x^*, e^*) - D'(E^*)(e^* - \hat{e}) = 0$$

which implies that

$$P(X^*)x^* - C(x^*, e^*) - D'(E^*)e^* = -D'(E^*)\hat{e} < 0$$

Too many firms have entered!

Subsidies in the long run

Why did too many firms enter?

Payments are available to **all** firms and induces excess market entry

Permits do not have these problems because the payment was only to incumbent firms, not entrants

Incumbent firms are already in the market: giving them the rents from freely distributed permits does not lead to excess entry