EC1340 Topic #11

More on regulation

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Introduction

- During the first part of the course we worked up to a characterization of the optimal time path for CO_2 emissions.
- Last time, we investigated the incentive problem that leads a market or decentralized economy to emit too much CO_2 relative to these optima.
- Next, we examine two of the basic regulatory instruments, taxes and quotas, available for reducing emissions (and talk briefly about 'privatization').
- Both are widely used for non-CO_2 pollutants, and both are commonly proposed in the context of CO_2 emissions, e.g., Hansen's quota of zero on coal, Kyoto's cap on CO_2 emissions for signatories.

Our objective is to understand how costly it is to achieve a given reduction in pollution/emissions with each instrument as conditions vary. This will help us to choose the least costly approach to mitigation.

Outline

- Regulation of one firm under certainty
- Regulation of one firm under uncertainty
- Regulation of two firms
- Tradable quotas
- Problems with tradable quotas
- Quota with pressure valves
- Regulation in a general equilibrium model
- Taxes vs subsidies and the problem with complicated policies.

Regulating a single firm under certainty

A steel mill which pollutes ‘too much’ because it does not account for the fish killed by pollution/effluent. Consider three candidate solutions:

- ‘privatization’ – steel mill buys the fishery (or vice-verse)
- A quota on steel or pollution production
- A (Pigouvian) tax on steel or pollution production

Example:

- y – units of steel
- p – price of steel
- $C(y) = \alpha y^2$ - cost of a unit of steel (for example)
- $C_s(y) = \beta y^2$ - social cost of pollution from a unit of steel (for example)

Note that we have increasing marginal cost of steel and pollution. Each unit is more expensive than the one before.

A profit maximizing steel mill owner solves

$$\max_y py - c(y)$$

The first order condition is

$$p = c'(y)$$

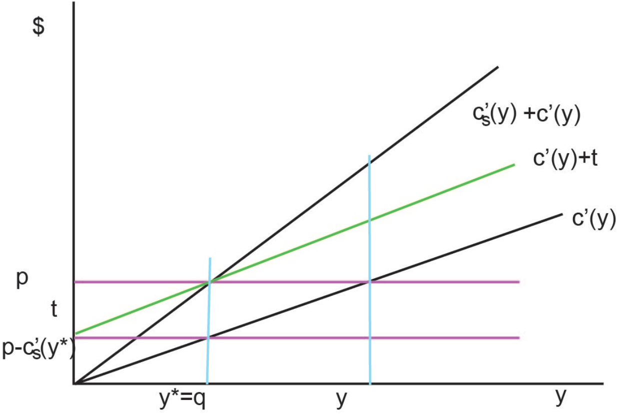
If we account for the cost of pollution, the socially optimal production of steel solves:

$$\max_y py - c(y) - c_s(y)$$

The first order condition is

$$p = c'(y) + c_s'(y)$$

These are not the same, and since c' and c_s' are increasing, we'll have too much steel in the market equilibrium.


$
c'_s(y) +c'(y)
c'(y)+t
c'(y)
p
t
p-c'_s(y*)
y*=q
y
y

Privatization

- Economists often talk about ‘privatization’ as a solution to externality/incentive problems, but it is not very well defined.
- Privatization requires reorganization of ownership so that the same people own the steel mill and the fishery. In this case, this new owner solves,

$$\max_y py - c(y) - c_s(y)$$

  Since this is the planner’s problem, this will give us the optimal amount of pollution.
- The implied assumption is that the steel mill owner is just as good at running a fishery as was the old owner of the fishery. This is not obviously true.
- It is not obvious how this intuition is useful if we replace ‘pollution’ with CO_2 in this example. Who would buy what?

Quota

The second fix is to impose a quota. If q^* is the solution to the planner's problem, then we can impose a 'quota' on steel prohibiting the production of more steel than q^*.
Then the profit maximizing steel mill owner solves

$$\max_{y} py - c(y)$$
$$\text{s.t. } y \leq q^*$$

Since the quota is binding, the solution to this problem is for the mill to produce $y = q^*$.

Pigouvian tax

- The third fix is to impose a tax on steel (called a Pigouvian tax after Pigou) that causes the profit maximizing mill owner to reduce output to the socially optimal level.
- With a tax τ per unit of steel, the profit maximizing mill owner solves

$$\max_{y}(p-\tau)y-c(y)$$

The first order condition is

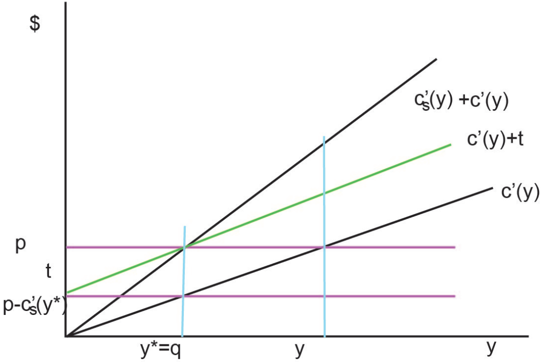
$$p-\tau=c'(y)$$

If we choose $\tau=c_s'(q^*)$, then this is

$$p-c_s'(q^*)=c'(y)$$

the solution to this is to choose $y=q^*$.

We can show the effect of this tax graphically by either reducing the price line by $c_s'(q^*)$ or by shifting $c'(y)$ up by $c_s'(q^*)$.



- There is a strong preference among professional/academic economists for taxes over quotas. However, in this model, there is no basis for this preference.
- Both quotas and taxes get to the optimum at the same cost, so there is no basis to prefer one to the other.
- The firm, however, will prefer quotas. (Why?)

Regulation of a single firm under uncertainty I

We have seen that taxes and quotas accomplish a given reduction in pollution at the same cost when we regulate a single firm with no uncertainty, although their distributional consequences differ.

Now suppose that the regulator is uncertain about the social costs and benefits of regulation.

Notation

- y – air quality (note change from talking about pollution)
- $B(y)$ – social benefit of air quality y
- $C(y)$ – firm's cost to produce air quality y.

Story: We want to regulate a smoke stack which produces a local pollutant like fine particulates. As soot goes down, air quality goes up. $C(y)$ is the firm's cost of reducing soot to achieve air quality y. $B(y)$ is the value to society of air quality y.

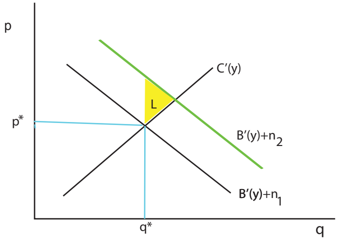
In this problem, the firm solves

$$\max_y py - C(y)$$

The planner wants

$$\max_y B(y) - C(y)$$

The planner can enforce this optimum by imposing $p = p^*$ or $y = q^*$.



- This is just like the steel mill example, but with different notation: price and quantity regulation are equivalent.
- p^* is 'price based regulation'. Rather than choosing a tax to change the price, to make things simpler, we're just choosing the price.
- Imposing q^* is 'quantity based regulation', like a quota. To simplify things, however, we're not allowing the production of less (more). The firm does exactly what we tell it.

Aside: Why triangles measure welfare

The area between the marginal benefit and marginal cost curves for $y \in [y_0, y_1]$ is

$$\begin{aligned}\Delta W &= \int_{y_0}^{y_1} B'(z) - C'(z)dz \\ &= [B(z) - C(z)]_{y_0}^{y_1} \text{ (by the fundamental theorem of calculus)} \\ &= [B(y_1) - C(y_1)] - [B(y_0) - C(y_0)]\end{aligned}$$

which is the change in welfare, as required.

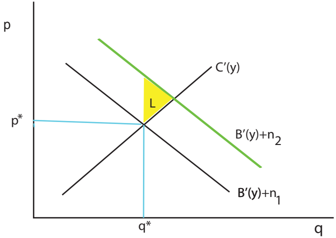
Benefits uncertainty

- Now suppose the planner is uncertain about benefits, say because the health benefits of reductions in fine particulates are not well known, or because there is uncertainty about the benefits of reducing CO_2 .
- To formalize this, let η be a random variable, $\eta = (\eta_1, \eta_2, \rho, 1 - \rho)$ and suppose that

$$B'(y) = \eta + B''y$$

- That is, the intercept of marginal benefit $B'(y)$ is unknown, but the slope is certain.

- Suppose the planner chooses q^*. Then if η_1 occurs, the planner is at the optimum. If η_2 occurs, then air quality is 'too low' and there is a loss of welfare with value L.
- Exactly the same thing occurs if the planner chooses p^*!



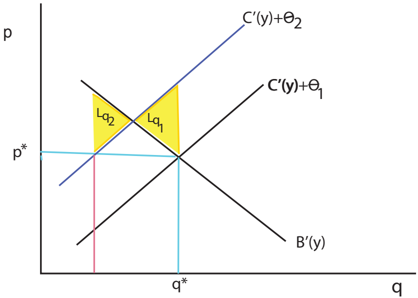
- With benefits uncertainty, there is still no basis for preferring one type of regulation to the other. Each elicits the same behavior in both states of the world.
- Why? Uncertainty does not affect the firm's behavior.

Cost uncertainty

- Now suppose that benefits are certain, but costs are uncertain.
- Let θ be a random variable, $\theta = (\theta_1, \theta_2; \rho, 1 - \rho)$ and let the cost function depend on θ:

$$C'(y) = \eta + C''y$$

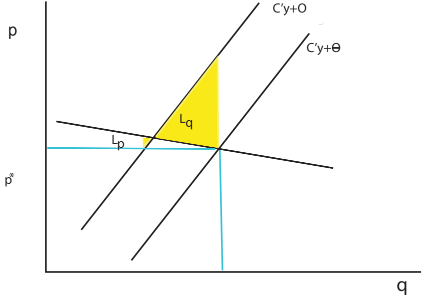
  This is similar to the way we described benefits uncertainty. The intercept of C' is random but slope is certain.
- In this case, with price based regulation, the firm will choose y so that $C'(y) = p^*$. This means that the firm chooses different y's as θ varies.
- With quantity based regulation, the firm always does what it's told, it chooses $y = q^*$.



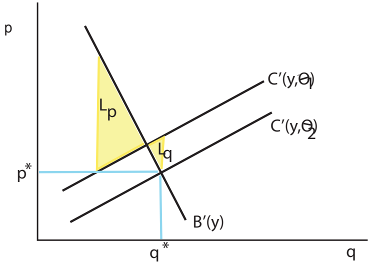
- As drawn (not optimal), with $\theta = \theta_1$ there is no loss with either type of regulation.
- With $\theta = \theta_2$ lose L_{q_2} under price based regulation and L_{q_1} under quantity based regulation.
- Thus, in this figure, choose price or quantity regulation depending on whether $L_{q_1} < L_{q_2}$ or not.

p vs q?

When marginal cost curves are steep relative to marginal benefit curves, this calculation favors price regulation.



Conversely, when marginal benefit curves are steep relative to marginal cost curves, this calculation favors quantity regulation.

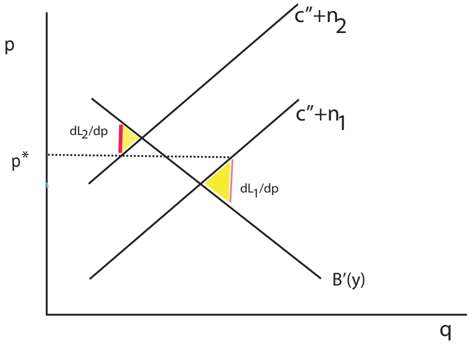


Loosely, if there is a ‘threshold’ value of benefits, we don’t want to goof around with price based regulation that could land us on the wrong side of the threshold. Conversely, if there is a threshold in costs.

Optimal p vs optimal q?

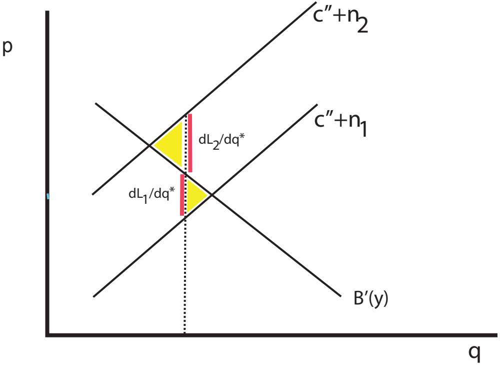
We would like to do is to compare OPTIMAL price and quantity regulation. For $\eta = (\eta_1, \eta_2, \rho, (1-\rho))$, choose *p* so that

$$\rho \frac{dL_1}{dp} = (1-\rho)\frac{dL_2}{dp}$$



To calculate optimal quantity regulation. For $\eta = (\eta_1, \eta_2, \rho, (1-\rho))$, choose q^* so that

$$\rho \frac{dL_1}{dq^*} = (1-\rho)\frac{dL_2}{dq^*}$$



p vs q analytic

$$
\begin{aligned}
B(y) &= y - \frac{1}{2}B''y^2, \quad B'' > 0, \ \text{marginal benefit} \\
C(y) &= \eta y + \frac{1}{2}C''y^2, \quad \text{marginal cost} \\
\eta &= (0, 1, \frac{1}{2}, \frac{1}{2})
\end{aligned}
$$

- Planner's objective is to solve

$$\max_y W = E(B(y) - C(y))$$

by choice of quantity or price regulation.

- To solve, compare welfare under best price and best quantity regulation.
    - Find best quantity regulation q^*
    - Find firm's response function for price regulation, e.g. $\hat{y}(\hat{p})$ that solves $\max_y py - C(y)$.
    - Choose $\hat{p}$ to solve $\max_p E(B(\hat{y}(p)) - C(\hat{y}(p)))$
    - Choose whichever type of regulation maximizes W
- NB: $E(\eta^2) = \frac{1}{2}0^2 + \frac{1}{2}1^2 = \frac{1}{2}$

Regulating two polluting firms

- Suppose we have two steel mills like the one we looked at last time.
- Then, for $i = 1, 2$ we have

$$\begin{aligned} y_i &\text{ output of firm } i \\ c_i(y_i) &\text{ cost function for firm } i \\ q_i &\text{ output quota for firm } i \end{aligned}$$

- Suppose the planner wants to restrict total production to $y_1 + y_2 = Q$ in order to reduce the quantity of jointly produced smoke/CO_2 .
- What happens if the planner regulates the industry with a (binding) aggregate industry level quota? Firms race to hit quota.

- What if the planner uses firm level quotas such that $q_1 + q_2 = Q$?
- The planner will want to minimize costs:

$$\begin{aligned}
& max_{q_1,q_2} pQ - c_1(y_1) - c_2(y_2) \\
& \text{s.t. } y_1 + y_2 = Q \\
\Longrightarrow & min_{q_1} c_1(y_1) + c_2(Q - y_1) \\
\Longrightarrow & c_1'(y_1) = c_2'(Q - y_1) \\
\Longrightarrow & c_1'(y_1) = c_2'(y_2)
\end{aligned}$$

  The planner has to pick q_1 and q_2 exactly right to solve this problem.
- Unless the planner has very good information about the firms' cost functions, firm level quotas lead to a situation where firms produce their last units at different costs. It follows that this is not a cost minimizing mitigation strategy.

- It also means there is no marginal incentive for mitigation/abatement or innovation.
- An example of this sort of regulation are the Corporate Average Fuel Economy Standards (CAFE) in the US. These standards specify % increases in each companies fleet average fuel economy. This is harder for Honda than Cadillac, so the same overall improvement in US fleet fuel economy could be accomplished at lower cost.
- This is why economists don't like quotas.
- Industry quotas provide perverse incentives and firm level quotas don't lead to cost minimizing abatement.

- Now suppose the planner taxes output. Then each firm solves:

$$
\begin{aligned}
& max_{y_i}(p-\tau)y_i - c_i(y_i) \\
& \Longrightarrow p-\tau = c_i'(y_i) \\
& \Longrightarrow c_1'(y_1) = c_2'(y_2)
\end{aligned}
$$

- So a tax reduces output in the cost minimizing way (though we may be uncertain about exactly how much of a reduction will occur)
- Therefore, with many firms, regulating pollution with a Pigouvian tax assures that mitigation occurs in the cost minimizing way. Quotas don't.

Tradable quotas

Also called ‘tradable or transferable permits’ or ‘cap and trade’.
This regulatory instrument is beginning to be widely used for

- Fisheries
- Sulphur Oxides
- CO_2

Basic idea: Planner issues Q permits, each of which allows holder to emit 1 ton of smoke or catch 1 ton of fish. Smoke may not (legally) be produced without permits. Permits may be bought or sold, and a market is often encouraged.
How does this work?

- Keeping to our same model of steel producing firms,
  - y_i is firm i's production of steel
  - $C_i(y_i)$ firm i's cost for y_i pounds of steel.
  - p_s price of steel
  - p_Q price of quota.
- To keep things simple, the quota is on steel (just as in the past examples) rather than on smoke.
- Aside: To think about a quota on smoke explicitly, we would need a bit more hardware, e.g., $\pi_i = p_s y_i - c_i(y_i, s_i) - p_Q s_i$ where s_i is smoke and $\frac{\partial c_i}{\partial s_i} < 0$
- Profits for firm i are

$$\begin{aligned}\pi_i(y_i) &= p_s y_i - c_i(y_i) - p_Q y_i \\ &= (p_s - p_Q) y_i - c_i(y_i)\end{aligned}$$

- If we let τ denote a unit tax on steel, then a tax on steel leads to firm profits as follows:

$$\pi_i(y_i) = (p_s - \tau)y_i - c_i(y_i)$$

  That is, a tax enters the firm's problem exactly like the quota price. Thus, under tradable permits, we must also have $c_1' = c_2'$ and hence, cost minimizing abatement.
- Where does the price of quota come from? It's the price that clears the market.

- Example: Two firms with $c_i(y_i) = y_i^2$ for $i = 1, 2$. planner issues Q units of quota. Each firm's choice y_i^* satisfies

$$
\begin{aligned}
c_i'(y_i^*) &= p_S - p_Q \\
\Longrightarrow 2y_i^* &= p_S - p_Q \\
\Longrightarrow y_i^* &= \frac{p_S - p_Q}{2} \equiv \text{demand for quota}
\end{aligned}
$$

But demand has to equal supply, so

$$
\begin{aligned}
2y_i^* &= Q \\
\Longrightarrow p_s - p_Q &= Q \\
\Longrightarrow p_Q &= p_s - Q
\end{aligned}
$$

so the price of quota clears the quota market.

- The price of quota will exactly equal the Pigouvian tax that leads to Q units of aggregate production.

- If you want Q units of output in a multi-firm industry you can get it in the cost minimizing way, just as with a tax, but (unlike a tax) you don't need to know cost functions to hit your target output exactly.
- How do we choose between taxes and quotas when we are unsure about the marginal benefits of abatement and the shape of the aggregate marginal cost curve? This is just the price vs. quantity trade-off we've already looked at.
- What are the distributive implications of tradable permits? It depends who owns them. By tinkering with ownership structure you can get any distribution between that of taxes and quotas.

Problems with Tradable permits

- With local pollutants, can get ‘hotspots’. This is not an issue for CO_2 .
- It’s hard to manage ambient standards with tradable permits. A pound of smoke in the West does not have the same impact on ambient air quality as in the East. This makes it harder to manage trading. Also not an issue for CO_2 .
- If there are transactions costs, the original allocation of the permits matters.
- Permit market can be used strategically if the number of firms is small. This is probably not an issue for CO, but is an issue for regulating sulphur oxides from power plants because there aren’t usually many in an airshed (e.g. Los Angeles)

- Loss of flexibility. Permits are a ‘right to pollute’ once you give it out, you can’t have it back, e.g, if you set Q incorrectly.
- Quotas can become concentrated. This can be bad if you want to preserve (inefficient) little fishing communities. Is this easy to fix with ownership restrictions?
- if sources are small or monitoring costs are high, then standards are a better choice.
- ‘highgrading’, probably not relevant for CO_2 ?
- The politics of distributing tradable permits is difficult. These are valuable assets. People fight about how they are handed out. This fight (between fishers and processors), for example, derailed ITQ programs in Alaska for many years.

Pressure valve quotas

This is Roberts and Spence (1976) and is close to the problem treated in 'Prices vs. Quantities', though the notation is a bit different.

Rather than look at the costs and benefits of y (air quality), we're going to look at the cost of reducing emissions x and the demand (benefit) from these reduced emissions.

Notation:

- x emissions (e.g. tons CO_2)
- $D(x) =$ damage from x, $D(0) = 0$, $D' > 0$
- $\phi =$ a random variable, observed by firm but not planner, that affects the firm's abatement costs.
- $C(X, \phi) =$ abatement costs.
  - For some $\overline{x}$ and all $x \geq \overline{x}$, $C(x, \phi) = 0$. That is, there is some maximum amount of pollution that the firm wants to make when pollution is free.
  - $C(0, \phi) > 0$, so we can't get rid of all pollution for free.
  - $C_x(x, \phi) < 0$, abatement costs are decreasing in the amount of pollution.

The planner chooses regulation to solve

$$\min E[D(x) + C(x, \phi)]$$

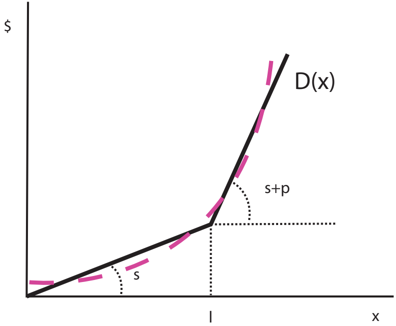
Regulation is a 'penalty function' $P(x)$. This function determines how much the firm pays for smoke x.
Thus, the firm's problem is

$$\min_x P(x) + C(x, \phi)$$

Note that the firm knows ϕ, but the planner has to guess.
If $P(x)$ is a Pigouvian tax, then $P(x) = \tau x$. If $P(x)$ is a quota then $P(x) = 0$ for $x \leq q$ and a very large number for $x > q$.
The optimal penalty function is $P(x) = D(x)$. In this case, firm solves the planner's problem.

We restrict attention to piecewise linear penalty functions, also called ‘pressure valve quotas’.

In this case, $P(x) = sx + p \max\{x - l, 0\}$, which looks like this:



Story: hand out l permits. Buy back unused permits at ‘subsidy’ s. Sell extra permits at ‘penalty’ p. Thus there is a ‘pressure valve’ if the cost of abatement is unexpectedly high, firm unit abatement cost is capped at $s + p$. A piecewise linear penalty function always fits the damage function at least as well as a tax or quota, generally strictly better.

- there is no gain over taxes if $D(x)$ is linear.
- there is no gain over quotas if $D(x)$ is a step function.
- can have more than one kink. This will approximate the damage function more closely.

Finding the optimal pressure valve quota I

Steps:

1. Find firm's response to $P(x)$ After the firm learns ϕ, the firm solves

$$\begin{aligned} x(s,l,p,\phi) &= argmin\ \left(P(x;s,l,p) + C(x,\phi)\right) \\ &= argmin\ \left([sx + p\max(x-l,0)] + C(x,\phi)\right) \end{aligned}$$

2. Planner chooses s, l, p to minimize expected cost BEFORE learning ϕ,

$$\min E\left[D(x(s,l,p,\phi)) + C(x(s,l,p,\phi),\phi)\right]$$

Comments:

- This is just like the choice of price in 'prices vs. quantities'. (It's a 'Stackleberg game' or a 'Principal agent problem')
- What if damages are uncertain?

Finding the optimal pressure valve quota: example

- Finding the optimal pressure valve quota is difficult in general, but for simple cases, can be done graphically.
- Say $\phi = (0, 1; \frac{1}{2}, \frac{1}{2})$ and

$$C(x, \phi) = k + \phi x - \frac{1}{2}x^2$$
$$D(x) = \frac{1}{2}x + \frac{1}{4}x^2$$

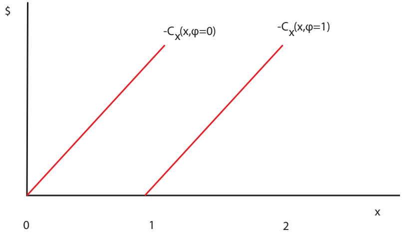
where *k* is an arbitrary constant – everything is decided by marginal conditions. We don't care about the level.

- The firm solves

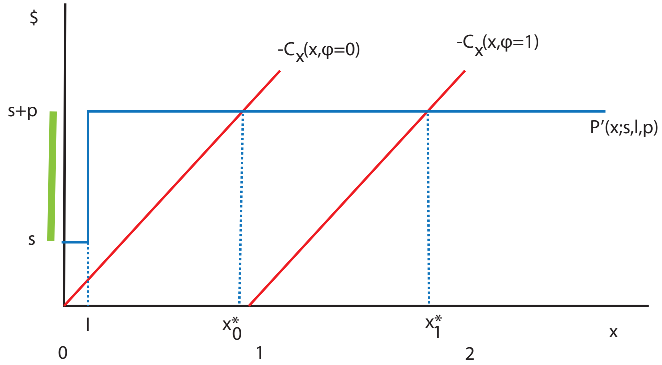
$$\min[sx + p\max(x - I, 0)] + C(x, \phi)$$

The firm's first order condition is $C_x = P'$ for whichever value of ϕ it draws.

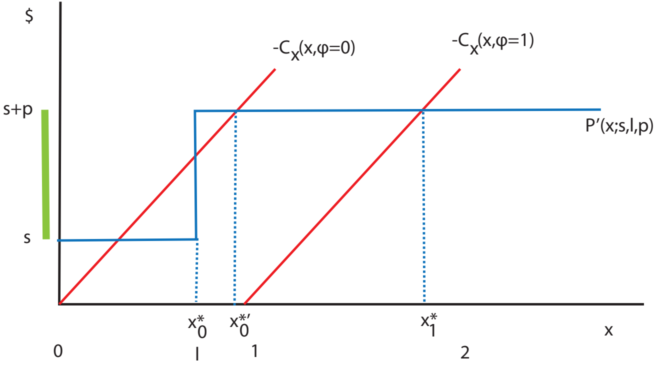
- Marginal cost curves look like this:



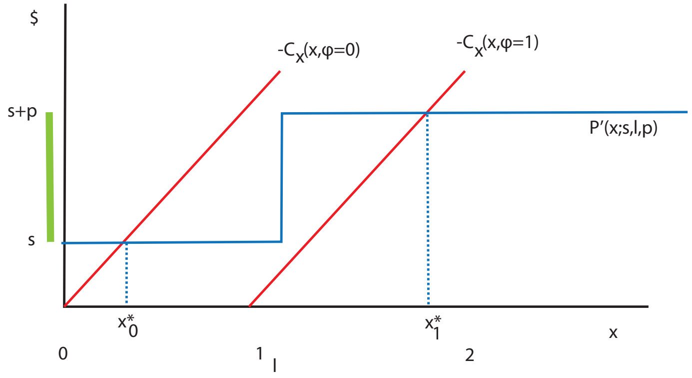
There are lots of ways to choose *s*, *l*, *p*. Following is a silly one. It's equivalent to a tax. We have the extra complexity of pressure valves, but no benefit.



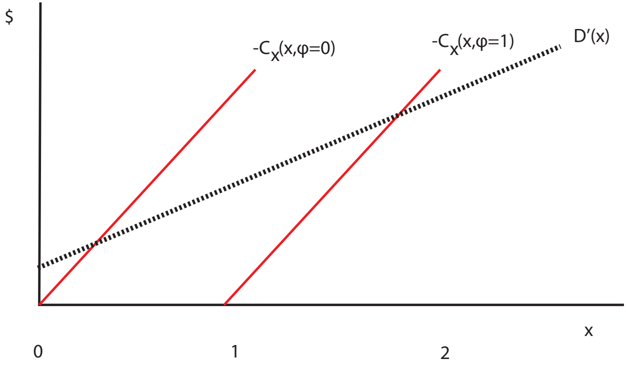
This one may also not be too good. We have to evaluate which of two local max is best for $\phi = 0$ to see what happens.



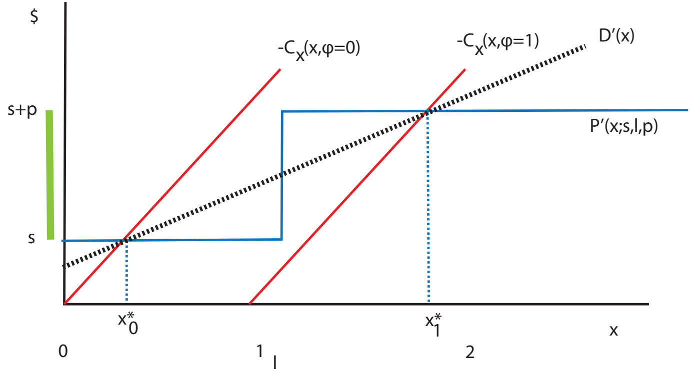
This is the obvious way to use this tool. We get to pick the firm's abatement in each of the different states of the world.



The planner wants $D'(x) = C_x$ for both draws of ϕ



If we're clever, pressure valve quotas give us the optimal outcome in both states of the world, even though the planner never sees ϕ!



Analytic solution to example

- $$D(x) = \frac{1}{2}x + \frac{1}{4}x^2$$
  $$\Longrightarrow D' = \frac{1}{2} + \frac{1}{2}x$$
- When $\phi = 0$, $-C_x = D'$ gives
  $$x = \frac{1}{2} + \frac{1}{2}x$$
  $$\Longrightarrow x^*(\phi = 0) = 1$$
- Similarly, when $\phi = 1$, we have
  $$x = \frac{1}{2} + \frac{1}{2}x - 1$$
  $$\frac{3}{2} = \frac{x}{2} \Longrightarrow \qquad x^*(\phi = 1) = 3$$

- Now we want to choose s, l, p so that firm wants $x^*(\phi)$.
- If we choose $l = 2, s = 1, p = 1$ then this works out.
- Note though that for this penalty function, $x^*(\phi = 0) = x^*(\phi = 1) = 2$ also satisfy first order conditions, so we have to evaluate $P + C$ for both extrema to be sure about what the firm does.

Tax interaction effects

- So far we have concerned ourselves exclusively with the effects of regulation on the regulated sector and ignored its effect on the rest of the economy. That is, we have been concerned with a 'partial' rather than 'general' equilibrium analysis of regulation.
- We are now going to consider the general equilibrium effect of regulation. These effects are almost surely relevant when we consider the regulation of CO_2, though we can probably ignore them if we are worried about fisheries or other 'smaller' environmental problems.
- 'Small' here means that regulation will affect only the prices of the regulated output, e.g., fish not labor.

- This will let us think about the idea of the ‘double dividend’. That is, if taxing smoke generates revenue and this revenue is used to reduce distortionary labor taxes, then environmental taxes are doubly good.
- This suggests that we should set them higher than the marginal social value of pollution.
- This intuition seems not to be correct, although this conclusion hinges on uncertain empirical quantities.

- To proceed, introduce the following notation:
  - $E =$ emissions, social cost is $C^E(E) = C_0 E + \frac{C_1}{2} E^2$
  - $L =$ labor, private cost (disutility) of labor is $C^L(L) = B_0 L + \frac{B_1}{2} L^2$
  - $Y =$ output

$$Y = A_0 E - \frac{1}{2} A_1 E^2 + A_2 L + \frac{1}{2} A_3 L^2 + A_4 EL$$

  - $p = 1$ is price of output
  - τ tax on labor (to fund schools etc.)
  - τ_E tax on emissions

- We want to solve

$$\max_{E,L} Y - C^E(E) - C^L(L)$$
$$\Longrightarrow MRP(E) = MC(E)$$
$$MRP(L) = MC(L)$$

where

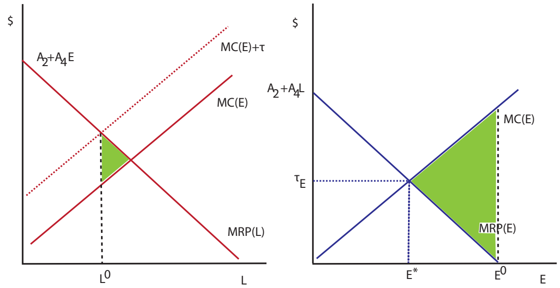
$$MRP(E) = A_0 - A_1 E + A_4 L$$
$$MRP(L) = A_2 + A_3 L + A_4 E$$
$$MC(E) = C_0 + C_1 E$$
$$MC(L) = B_0 + B_1 L$$

...and we are constrained to also collect some amount tax revenue.

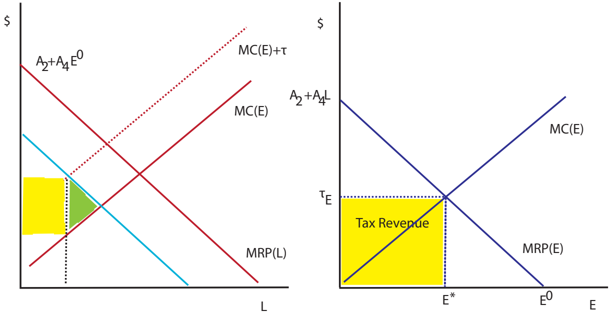
- Without regulation or a price of emissions, we won't solve this problem. In the equilibrium where labor is taxed and CO_2 is not, we'll have

$$MRP(E) = 0$$

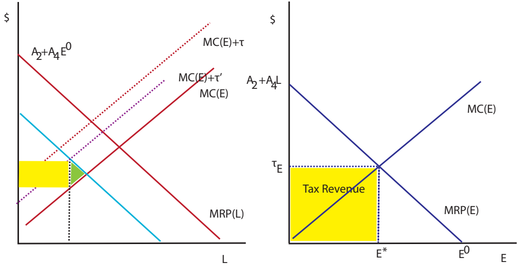
- This leads to an equilibrium like this:



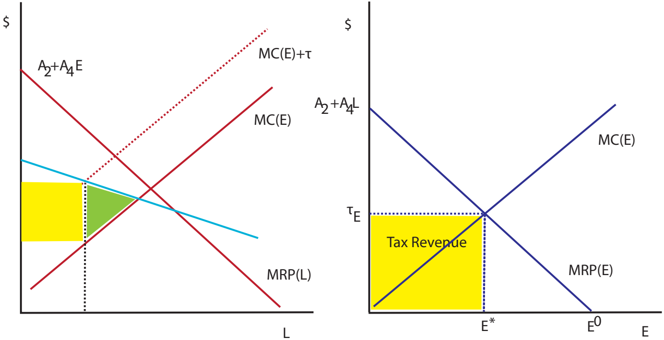
- If we choose τ_E so that $MPR(E) = MC(E)$ then we get this



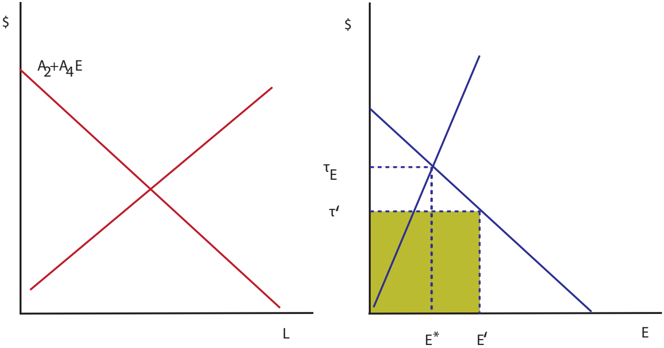
- As drawn, deadweight loss from emissions goes down, from the labor tax is unchanged, and tax revenue increases.



- We do better if we use emissions tax revenue to reduce the labor tax. This is the ‘double dividend’. Maybe we should choose a tax on emissions bigger than τ_E?
- Implicitly scale of two figures is not the same. Area of CO_2 tax revenue should equal change in labor tax revenue.



- The double dividend need not occur. If the reduction in E reduces the MRP of L, then τ_E we might increase the deadweight loss in the labor market.



Or, it might be that we can increase tax revenue in the emissions market by REDUCING the emissions tax from τ_E to τ'.

- Environmental taxes pay a ‘double dividend’. They reduce deadweight loss in the pollution ‘market’ and allow us to reduce the distortions from other pre-existing taxes. The ‘double dividend hypothesis’ is that we should therefore tax pollution at a rate above marginal social cost.
- This hypothesis hinges on the effect of emissions reductions on the marginal productivity of labor and on whether an increase in emissions taxes actually increases revenue. These are empirical questions.

- The empirical literature on this issue typically considers much richer models than the one presented here. They allow for a ‘clean good’ and a ‘dirty good’ and think about all of the different types of substitution that can occur, e.g., dirty good for leisure, clean good for dirty good. This literature generally finds that the tax interaction effects lead to emissions taxes a bit below the social marginal cost of pollution.
- There is a lot of estimation here, so there is a lot of uncertainty about these estimates. I’m inclined to ignore this literature, though I’m not expert on it.
- The really important conclusion from this literature is on the importance of ‘revenue recycling’ if you tax emissions, it matters what you use the money for, and paying down labor taxes is a good thing to do.

Taxes vs Subsidies

People don't like paying taxes and don't mind getting subsidies, so it is common to see policies organized around subsidizing good behavior rather than taxing bad behavior. The Inflation Reduction Act of 2022 is a good example. It has lots of subsidies for green energy, but no carbon tax.

To understand how taxes and subsidies are related, let's consider a simple case.

An economy consists of many small, identical households, $i = 1, ...N$, who use fossil energy, x_{fi} and green energy, x_{gi} and have income Y. Without regulation each household solves,

$$\begin{aligned} \max & u(x_{gi}, x_{fi}) \\ \text{s.t.} & p_g x_{gi} + p_f x_{fi} = Y \end{aligned}$$

Suppose that this problem results in the optimal bundle (x_{gi}^0, x_{fi}^0) for all households.

The planner wants to discourage use of x_f and implements a tax τ. The planner is constrained to balance the budget, and returns tax revenue to households as a lump sum, T.

With this tax, the household problem becomes,

$$\begin{aligned} &\max u(x_{gi}, x_{fi}) \\ &\text{s.t.} p_g x_{gi} + (p_f + \tau) x_{fi} = Y + T \end{aligned}$$

Let (x^*_{gi}, x^*_{fi}) be households' optimizing response to this tax.

Comments:

- With budget balancing,

$$\begin{aligned} T &= \frac{1}{N} \sum_{k=1}^{N} \tau x^*_{fk} \\ &= \frac{1}{N} \tau x^*_{fi} + \frac{1}{N} \sum_{k \neq i} \tau x^*_{fk} \end{aligned}$$

  For N large, $\frac{1}{N} \tau x^*_{fi} \to 0$, so each household ignores the effect of its own actions on T.

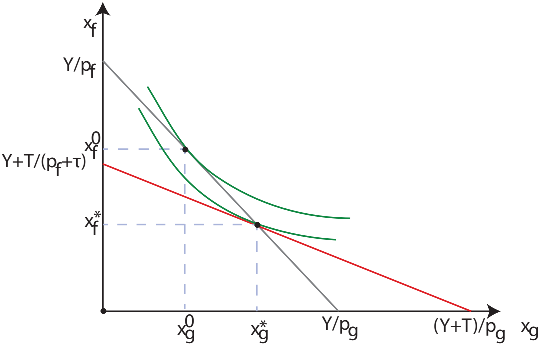
- We need to evaluate T at x^*_{fi} to get the government budget to balance.
- We have that

$$\begin{aligned} p_g x^*_{gi} + (p_f + \tau) x^*_{fi} &= Y + T \\ \implies p_g x^*_{gi} + p_f x^*_{fi} &= Y \end{aligned}$$

because, with identical households,

$$\begin{aligned} T &= \frac{1}{N} \sum_{k=1}^{N} \tau x^*_{fk} \\ &= \frac{1}{N} (N \tau x^*_{fk}) \\ &= \tau x^*_{fk} \end{aligned}$$

So the household is on the same budget line before and after the tax, and because (x^*_{gi}, x^*_{fi}) is feasible under the untaxed budget, we must have $u(x^*_{gi}, x^*_{fi}) < u(x^0_{gi}, x^0_{fi})$.



- The tax must decrease consumption of x_f if the household is optimizing under the new budget.

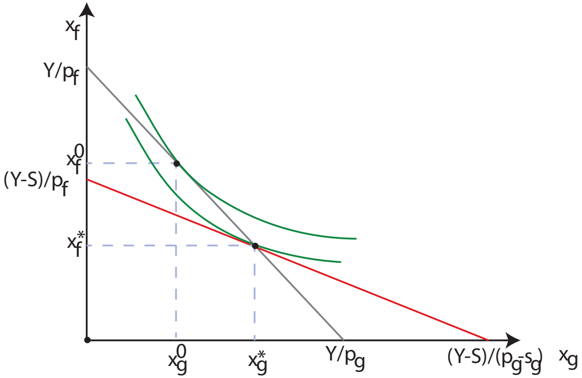
It turns out that we can accomplish exactly the same thing by subsiding x_g. We can get the same relative prices by taxing fossil energy or by subsiding green energy. Since we require that the government budget balance, this forces the intercept of the budget set to move so that both policies give the same budget set. Faced with the same budget set, households do the same thing.

A household facing a subsidy s_g on green energy and a lump sum tax to finance it, solves,

$$\begin{aligned}
&\max u(x_{gi}, x_{fi}) \\
&\text{s.t.}(p_g - s_g)x_{gi} + p_f x_{fi} = Y - S
\end{aligned}$$

for $S = \frac{1}{N}\sum_{k=1}^{N} s_g x^*_{gk}$.

Let $(x^{**}_{gi}, x^{**}_{fi})$ be households' optimizing response to this tax.


x_f
Y/p_f
x_f^0
$(Y\text{-}S)/p_f$
x_f^*
x_g^0
x_g^*
Y/p_g
$(Y\text{-}S)/(p_g\text{-}s_g)$
x_g

To match the taxed outcome we just need to get the slope of the budget line under taxes to match the slope under subsidies.

$$\frac{p_g}{p_f + \tau} = \frac{p_g - s_g}{p_f}$$
$$\implies s_g = p_g(1 - \frac{p_f}{p_f + \tau})$$

The 2022 'Inflation Reduction Act' is the most important piece of US climate change regulation ever. It contains lots of subsidies for green energy, but no carbon tax.

We've just shown that this might be OK. It might be that the energy subsidies and tax increases have more-or-less the same effect as a carbon tax.

... But probably not.

In practice, we don't have lump sum rebates. Some people probably won't be affected by the tax very much. These people will just see a subsidy for green energy. For these people, we might well see an increase in both types of energy use. Other people will see a big tax increase.

How will this all balance out? It's hard to say. It will probably not work out so that everyone has the same marginal disutility from carbon abatement. This means that there are unexploited gains from trade, something that probably would not happen under a carbon tax.

More generally, complicated policies have complicated unintended consequences. To see this consider how and Electric vehicle subsidy (EV) is going to interact with the Corporate Average Fuel Economy Standards (CAFE).

CAFE is one of the main ways of regulating fuel economy in the US. Companies have to hit targets for the vehicle weighted mean fuel economy of the vehicles they sell each year, or pay a penalty.

To understand how an EV subsidy makes trouble for CAFE, think of a simple example (example due to Metcalf, Brookings 2019).

- Suppose the CAFE standard is 20 mpg and the penalty for going over is very large.
- Before the EV subsidy, the firm sells 10 conventional cars per year at 20 mpg each, and exactly hits the 20mpg fleet average.
- After the EV subsidy, suppose the firm sells its same 9 20mpg cars, and one EV at 100mpg. Then their fleet average fuel economy is $(9 \times 20 + 100)/10 = 28$.

- So the EV subsidy creates a lot of room for the firm in their CAFE budget. After the EV, they could decrease the fuel economy of their gas cars to 11.1 mpg and still hit their CAFE target; $(9 \times 11.1 + 100)/10 = 20$.
- In fact, CAFE lets firms count EVs double, so producing one EV would mean that the firms fleet fuel economy was $(9 \times 20 + 2 \times 100)/10 = 38$, so the firm in our example could reduce the fuel efficiency of its gas cars to 4mpg and still hit its CAFE target.
- Again, this is probably not going to lead to a situation where everyone has the same marginal disutility from carbon mitigation. Something we could hope for with a broadly based tax.
- Is this happening? To my knowledge, nobody has been able to check yet.

Summing up, in theory, we can duplicate the effects of a carbon tax with subsidies. In practice, complicated policies are going to interact in complicated ways and have lots of unintended consequences. Carbon taxes are simpler, and we can at least hope that they lead to a situation where the marginal disutility of mitigation is the same across households.

This naturally leads to the question of why we get these sorts of policies instead of a carbon tax.