Lecture 3

ECON 4910, Environmental Economics

Spring 2008

From last time: Consumers' purcase of emission reductions

- Condition for Pareto efficiency:
  $\sum_i (u'_{iE} / u'_{ix}) z' = f_k'$ (and $f_k' = f_l'$)
- If individual consumers can pay firms to reduce emissions (no transaction costs), consumer i's first order condition for utility max is:
  $(u'_{iE} / u'_{ix}) z' = f'_k$
- Note: This may correspond to *very small* contributions compared to the PO, or none at all (contributions *do not* sum up to PO!).
- Assume (for a moment) that individuals are identical.
  - Then $(u'_{iE} / u'_{ix}) z' = MWTP$ for every *i.*
  - Individual utility max: MWTP= f'_k where *i* considers f'_k fixed.
  - Consider the case where one person "moves first" and increases his contribution until this holds.
  - Then, no-one else will act!

Bargaining & consumers' contributions

- The Coase Theorem:
  - If property rights are clearly assigned, and there are no transaction costs, private bargaining yields Pareto efficiency.
  - This holds regardless of whether the polluter or the victim holds the property right
  - See Perman Ch. 5.10.3
- External effects between two parties:
  - Define ”transaction costs” as the costs of establishing a binding contract -> the Coase theorem holds
- Public goods:
  - For the Coase theorem to hold: ”Transaction costs” must be defined to include all costs of establishing a binding agreement between all consumers (and firms), including all problems related to free-riding
  - The result becomes almost tautological: If there are no problems, there will be no problems….

Policy instruments

- Assume (will be relaxed later):
  - No uncertainty
  - no asymmetric information
  - costless lump-sum transfers are feasible
  - The number of firms, *K*, is fixed.

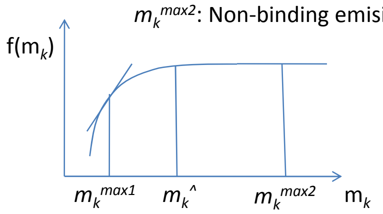
Command and control

- Prohibitions, required actions/procedures
- In our model: Emission caps (non-tradeable quotas) or abatement requirement
  - Binding if $m_k^{max} < m_k^{\wedge}$ (m_k^{max} = firm k's emission cap)
  - or if $a_k^{min} > 0$ ($a_k^{min} = m_k^{\wedge} - m_k$ = firm k's abatement)
- Other measures used in practice:
  - Required technology ("best practice")
  - Required waste handling procedures
  - Required internal environmental reviews, skill requirements, safety procedures

Profit maximization with emission caps

- No explicit emission price ($\tau = 0$)
- Max $\pi_k = f_k(m_k) - b_k$ with respect to m_k, s.t. $m_k \leq m_k^{max}$
- Lagrangian: $L = f_k(m_k) - b_k - \lambda_k (m_k - m_k^{max})$
- Kuhn-Tucker: Either
  - a) $\partial L/\partial m_k = f'_k - \lambda_k = 0$ -> $f'_k = \lambda_k$ or
  - b) $\lambda_k = 0$
- λ_k is called the *shadow price* of the restriction ($m_k \leq m_k^{max}$): It reflects the marginal value of changing the restriction (its marginal cost)
- These two cases correspond to
  - a) The emission cap is binding ($m_k = m_k^{max}$)
  - b) The cap is not binding ($m_k < m_k^{max}$)

m_k^{max1}: Binding emission cap
m_k^{max2}: Non-binding emisison cap

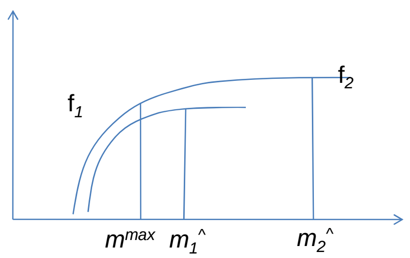


Emission caps, cont.

- Non-binding restrictions:
  - Firm behaves as if no emission cap, i.e. f'_k=0 and $m_k = m_k^\wedge < m_k^{max}$
- Binding restriction:
  - Firm behaves as if there were a price on emissions λ_k
  - i.e. $f'_k = \lambda_k$ and $m_k < m_k^{max} < m_k^\wedge$
- If caps are set such that $\lambda_k \neq \lambda_l$:
  - Shadow prices differ between firms
  - Profit max: Marginal abatement cost differ between firms
  - The same amount of x could then have been provided with less emissions, by changing caps such that $f_k' = f_l'$ for all firms.
- Pareto efficiency
  - Recall criteria for Pareto optimality: $f_k' = f_l'$ and $\sum_i(u'_{iE}/u'_{ix})z' = f_k'$
  - Emission caps are Pareto efficient if caps are set such that $\lambda_k = \lambda_l = \sum_i(u'_{iE}/u'_{ix})z' = D'$ for all firms $1,\ldots,K$

Cost efficiency

- Cost efficiency: Reaching a given goal at least possible cost
  - Emission level: If production functions differ, an equal emission cap m^{max} for all is generally not cost efficient
  - Abatement level: If firms have different abatement cost functions, a common abatement requirement a^{min} is generally not cost efficient
  - Note: If $m_k^\wedge$ differs, these may not be equivalent



Ex.: m^{max} implies larger abatement for 2 than 1

Information and efficiency

- We have assumed: Perfect information
  - the regulator knows all firms' abatement costs perfectly
  - and the value of marginal damage
  - Then, command and control can be made Pareto and cost efficient simply by choosing the right levels for each firm
- If information about marginal damages is unavailable:
  - the regulator is unable to ensure PO
  - can still ensure *cost efficiency*, by setting caps such that $\lambda_k = \lambda_l$ for all k
- If information about individual cost functions is unavailable:
  - The regulator is unable to ensure, by setting emission caps/abatement requrements suitably, that $\lambda_k = \lambda_l$
  - Cannot ensure cost efficiency through emission caps/abatement req.

Emission taxes

- If there is a common unit price on emissions τ, we know (from lect.1) that for each firm k={1,...,K}, profit max. gives
  $$f'_k(m_k) = \tau$$
- An emission tax is precisely that: A unit price on emissions
- Let t be a uniform emission tax (same for all emitters)
  - In practice, taxes are often not uniform (e.g. Norwegian CO_2 tax)!
- Then, profit max. gives $f'_k = f'_l = t$ for all k={1,...,K}
- If $t = t^* = D' = \sum_i (u'_{iE} / u'_{ix}) z'$: Pareto efficiency
- t* is called a **Pigou tax** (or Pigouvian tax): All externalities are internalized
- If $t \neq D'$: Cost efficiency ($f'_k = f'_l$ for all emitters), not PO
- Note: A tax is a cost for the firm, but no real cost for society.

Uniform versus differentiated taxes

- Uniformly mixing flow pollutant
  - If taxes differ between emitters there is NOT cost efficiency
  - Marginal trade-offs by firms: Like situation with CAC and different shadow prices
  - Effects of CAC and diff. taxes may still differ: Exit/entry
- If emissions are not uniformly mixing
  - noise; local particle or NO_x pollution
  - marginal damages are greater for some sources
  - differentiated taxes may be efficient
  - More generally: instrument use should be differentiated
  - Read: Perman 6.7 and 7.5

Abatement subsidies

- Abatement subsidy *s*: For every emission unit abated, the firm receives *s*
- Max $\pi_k = f_k(m_k) - b_k + sa_k$ (where $a_k = m_k^{\wedge} - m_k$)
- Differentiate wrt. m_k -> first order condition for interior max: $f'_k = s$
- If *s* is the same for all firms: Cost efficiency
- If, in addition, $s = D' = \sum_i (u'_{iE} / u'_{ix}) z'$: Pareto efficiency
- Recall Coase (1960):
  - Think of the regulator as a representative of the consumers (victims), demanding the compensation they would have demanded if (costlessly) coordinated.
  - It does not matter whether the ”property right” to the air is given to the firm (subsidy) or to the regulator (tax); outcome is efficient anyhow.

Entry and exit

- Assume now: The number of firms is endogenous
- Potential entrants:
  - Assume that production functions $f_k(m_k)$ can be mimicked by newcomers, but newcomers may have higher fixed costs
- Entry: If $\pi_k > 0$ for at least one firm, new firms mimicking firm k will enter the market, unless their fixed costs are too high
- Exit: If $\pi_k < 0$ for a firm, it closes down
- In equilibrium: The marginal firm's profit = 0

Subsidies, entry and exit

- Consider the introduction of a subsidy s>0 per unit abatement $a_k = m_k^{\wedge} - m_k$.
- Assume that firm A is a marginal firm: $\pi_A = 0$ initially.
- Before the subsidy (no regulation), $\pi_A = f_A(m_A^{\wedge}) - b_A = 0$.
- Consider a potential entrant B, mimicking A's production function f_A, but with slightly higher fixed cost:

  $b_B = b_A + \varepsilon$ where $\varepsilon > 0$.
- Firm B will not produce initially: $\pi_B = f_A(m_A^{\wedge}) - (b_A + \varepsilon) < 0$.
  - Corner solution: $m_B = 0$
- When $s > 0$ is introduced, then by cleaning one unit, firm B can get profits

  $\pi_B = f_A(m_A^{\wedge}-1) - (b_A + \varepsilon) + s > 0$ whenever $\varepsilon < s$.
  - Recall: at $m_k^{\wedge}$, $f'_k = 0$.
- b will move to interior solution: $f'_A = s$ -> pollutes a lot more!

Effects of a subsidy

- Existing firms pollute less
  - with fixed # of firms: Uniform subsidy -> cost efficiency
- But: The industry is now more profitable than before
  - Total activity may increase
- In our example: There is now one more firm
- Which effect dominates?

Subsidies versus taxes

- Similar reasoning:
  - An emission tax will make the industry *less* profitable
  - An abatement subsidy makes the industry *more* profitable
- With fixed # of firms:
  - this difference is a pure transfer, no real cost
  - may matter for fairness; not for efficiency
- With endogenous # of firms:
  - subsidy gives higher activity before abatement
  - even if each pre-existing firm abates just as much with each instrument, there are more firms with the subsidy -> total emissions are higher.
- CAC: In-between-case; shadow price is just ”shadow”, not paid to/from the regulator.

Consumers: Taxes vs. subsidies

- Three consumption goods; two types of energy, and other
  - e^1: dirty energy (e.g. coal), producer price q^1, tax t
  - e^2: clean energy (e.g. windpower), prod. price q^2, subsidy s
  - c: all other consumer goods, producer price p
  - Consumer price = producer price + t – s.

Max $U = u(e^1, e^2, c, E)$ E is considered exogenous

s.t. $e^1(q^1+t) + e^2(q^2-s) + cp = F$ F = ex. income

- First order conditions:

$(u'_{e1}/u'_{e2}) = (q^1+t)/(q^2-s)$ The same rel.price through t or s

$(u'_{e1}/u'_c) = (q^1+t)/p$

$(u'_{e2}/u'_c) = (q^2-s)/p$

- Subsidy makes energy cheaper, relative to other consumption goods, than tax
- With subsidy, *total* energy demand is higher than with tax
  - If clean energy is not absolutely clean, emissions might increase

Tradable permits

- Total emission cap for society: M^{max}
- Initial allocation (initial emission cap) for each firm k: m_k^0, such that $\sum m_k^0 = M^{max}$
  - for the moment: consider # of firms fixed
- Firms can buy or sell permits
- If firms' abatment cost differ after initial permit allocation,
  - i.e. $f'_k(m_k^0) < f'_l(m_l^0)$ for some k, l

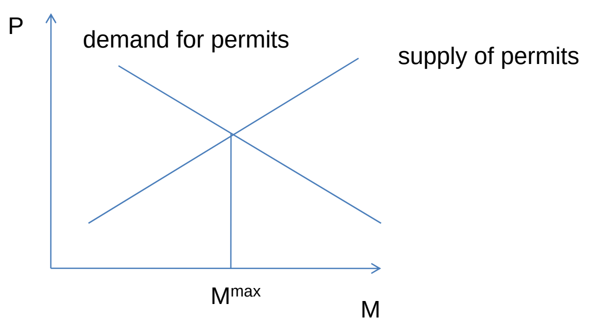
  there is room for "bargaining" between firms:
  - Firm k can abate cheaper than firm l -> k sells a permit to l, l pays a price P such that $f'_k(m_k^0) < P < f'_l(m_l^0)$ -> Both benefits
- A market for permits will arise
  - Demanders vs suppliers: determined by initial allocation and marginal costs
  - Trade occurs until every firm has the same abatement cost
  - In equilibrium, M^{max} is reached at least possible cost

Profit max with tradable permits

- Permit purchase: m_k - m_k^0
- Permit sale: $m_k^0 - m_k$ = negative purchase
- Assume perfect competition in the permit market, i.e. each firm considers the permit price P fixed
- Assume each firm considers m_k^0 exogenously fixed
- Max $\pi_k = f(m_k) - b_k - P(m_k - m_k^0)$ wrt m_k
- Differentiate, get first order condition for interior max:
  $f_k' = P$
- Market price for permits P: Similar to a uniform tax
- Note: This holds even if the firm is a permit seller. Reason: Alternative value of permits

Permit market

- Suppliers: Firms with $f_k' < P$
- Demanders: Firms with $f_k' > P$



- At M^{max}, all firms have $f_k' = P$ -> cost efficiency
- If goals are set such that M^{max} = M* (PO level), then the market will produce the equilibrium price P=D'= t* (Pigou tax)

Next time

- More on instrument choice:
  - Initial allocation of permits: Free or not?
  - Uncertainty: Price vs quantity regulation?
- Enforcement
  - Will rules be kept?
  - If not, what should the regulator do?