Environmental Economics

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Contents

Lecture 1: Introduction Lecture

Fri 02 Feb 15:50

[Lecture 1] [Reading]

1 Aims

1. Intro to environmental economic policy analysis. Overview, formal techniques, practical applications, case studies
2. Critique economic techniques that are used to support decision making in environmental policy context
3. Discussion of environmental policy through economic lens

4. Research proposal

- What is "good" environmental policy? How is this devised and implemented and especially in developing countries

Good economic policy satisfies

- Effectiveness - it contributes to improving the environment
- Efficiency - it improves the environment at least cost
- Equity - there is fairness shown in burden sharing

2 Framework

Difference between natural resource economics and environmental economics

Natural resource economics

- Inter-temporal allocation of **renewable and non-renewable resources**
- Uses dynamic control methods, fisheries, forests, energy, species, extinction etc
- Seminal work on non-renewable resources (1932)
- Pioneering work for renewable resources (1976)

Environmental Economics

- The valuation and regulation of **pollution** (*environmental bats*)
- The valuation and regulation of **environmental amenities** (*environmental goods*)

Shifts in focus over time on what are the most pressing issues in environmental economics

Direct risks to human health

- High risk
  - Pollinations in drinking water
  - Ambient air pollutants
  - Worker exposure to chemicals
  - Smoking
  - Pollution indoors
- Potential
  - Residues in/on food
  - Chemicals in consumer products

Risks to natural ecology and human welfare

- High Risk

  - Habitat destruction
  - Biodiversity loss
  - Global climate change
  - Ozone depletion
- Medium risk
  - Pesticide's
  - Nutrients
  - Toxics
  - Biochemical oxygen demand (BOD)
  - Turbidity in surface water (*acid deposition, airborne toxics*
- Lower risk
  - Groundwater pollution
  - Acid runoff to surface water
  - Thermal pollution
  - Oil spills

Example. Acid Rain one of the main issues in 1970-80 caused by SO_2 (from burning coal/ fossil fuels) causes

- Damage to buildings (corrosion)
- Damage to forests, croups, lakes, (change in acidity PH)
- *adverse health effects in lodger run* (smog : asthma, bronchitis etc)

Note. How to maintain or enhance human well-being in the long run?
Nature as an asset : making the value of nature readily apparent
Incorporating the value of nature in public sector projects and private sector decisions
Requires economic thinking
Appetite for information by decision-makers

Decision making and the policy process

1. Discovery Phase - preliminary stage, with no uncertainty. Prior to discovery almost
2. Political phase
   - Recognition - Political interest lowest but growing
   - Formulation - political interest increasing at flat rate
3. Management phase
   - Implementation - political interest has peaked, here it declines as uncertainty also decreases
   - Control - uncertainty completely diminished, poltiical interest reaches finite point as time progresses

Example. Recognition

1. Indoor air pollution Urban sprawl

Formulation

1. Global Warming
2. Nuclear wastes

Formulation-Implementation

1. Ozone depletion
2. Acid deposition
3. Toxic chemicals

Implementation

1. Municipal wastes
2. Air pollution

Control

1. Sewerage
2. Water treatment
3. Contagious diseases(?)

Stages in the policy life cycle

1. Problem recognition
2. Policy formulation/ design
   - Assessment of alternative solutions
   - Comparison and choice of an alternative
3. Implementation
4. Control
5. Evaluation
   - Does the implemented policy work?

For each stages we can discuss :

- What information is required to support decision making (and move it to the next stage of the policy life cycle)
- Economic theory and analytical methods are available, the analytical tools can be very similar for different environmental topics

- Applications : some countries experiences address specific environmental problems

Structure emphasises fact that

- Correct problem formulation is crucial
- Specific environmental issues can be in different life cycle state's
- *countries can be out of sync*, this is not helpful in setting up international agreements
- Shift in focus over time as to what are the main environmental problems.

Lecture 2: Causes of environmental problems

Wed 07 Feb 09:12

[Lecture 2] [Reading]

3 Market Failure

Environmental economists model market failures using *either* the theory of public goods or the theory of externalities

If the market is defined as 'environmental quality' then the source of the market failure is that environmental quality is a **public good**

If the market is defined as the good whose production or consumption generates environmental damage (benefits) then the market failure is due to negative (positive) externalities

Recall that economists don't simply view any polluting as an environmental problem, environmental problems must reflect an inefficiency whereby the costs of pollution are exceeded by the benefits.

3.1 The theory of public goods

The type of good depends on

1. Excludability : it is possible to prevent people who have not paid for the good from consuming it
2. Rivalness : when the good is consumed by one individual, another perosn is prevented form consuming it at the same time

It is important to note that for a pure public good (non-excludable, non rival) such as clean air or a lighthouse, in practice there is some rivalry or congestion.

Why do public goods lead to market failure

- Market demand for a private good is found by horizontally summing the demands of individual consumers
- In contrast, once a public good is produced it is available at the same quantity to all consumers (since it is non rival)
  - This implies we have to *vertically sum* each consumer's demand (marginal benefit) to find market demand
  - But how can this be represented graphically?
- However, marginal benefits are not revealed by the private market because public goods are non-excludable (consumers become free riders)
  - This is known as the "non-revelation of preferences" and leads to market failure due to under supply of public goods

How to obtain demand for a public good?

- Use valuation methods to calculate willingness to pay (WTP) of consumers:
  1. Stated preference methods (eg contingent valuation and choice experiments)
  2. Revealed preference methods (eg hedonic pricing methods, travel cost method)
- However, imperfect information can provide an added complication :
  - Consumers themselves may not be fully aware of the full benefits of consumptino, and so their WTP may underestimate the true value of the good

3.2 The theory of externalities

- If the production or consumption of a good or service generates environmental damage outside the market transaction, then the market failure is due to a **negative externally**
- The damage that occurs outside the market transaction is not captured by the price of the commodity
- How can we represent a negative (or positive) externally graphically?

What is the relationship between public goods and externalities?

- Externalities affect air, water, or land, all of which have public goods characteristics
- If the externality affects a broad segment of society and its effects are non-rival and nonexcludable, the externally is itself a public good
- If external effects are only felt by a narrow range of individuals or firms, then those effects are more appropriately modelled as an externality

How to adress the market failure?

Coase

Starting from the public good idea

Bargaining : the source of the environmental problem in private markets is that property rights are not defined. Ronald Coase (1960) demonstrated that proper assignment of property rights to any good, even in the presence of externalities, will allow *bargaining* between the affected parties that will obtain an efficient solution, no matter which party holds the rights. Thus : Negotiation will overcome market failure! *but how useful is this in practice?*

Pigou

Starting from the control of externalities

Regulation : Taxes, tradable permits, information nudges etc

Coase Theorem

How relevant and useful is the Coase Theorem to pollution problems *in practice*?

- Key assumptions underlying the theorem include
  - No transaction costs
  - Perfect information

- Vittel watter in North-eastern France provides an example of the Coase theorem

Example. In the 80s Vittel initiated a program to reduce agricultural water pollution in locality of the source of its bottled water

Vittel paid 26 local farmers, offered technical assistance and equipment to reduce pollution (ie switch to organic pesticides)

As a result, vittel water benefits from improved water quality

In summ,

- From an economic perspective environmental problems exist because they are market failures
- There are two basic explanations for environmental problems as market failures:
  - Environmental quality as a public good
  - Environmental externalities from the production or consumption of polluting generating goods
- Solution to market failure will typically involve government intervention

4 Government or Regulatory Failure

- Government policies can create market inefficiencies
- Further, government policies can lead to unintended environmental consequences
  - Negative externalities are created or intensified
  - Common example is a production subsidy to reduce price of market goods with negative environmental effects (fossil fuel)

Example (Case Study : US Ethanol Policy)**.** Ethanol is an oxygenate that is used as an additive to reformulated gasoline

Ethanol production has long been supported in the US

- Tariffs and subsidies were in place 2004-12
- Grants, loan guarantees, cost shares, tax credits, technical fuel standards and ethanol mandates remain in place. Of the petrol sold in the US, 95-95 % is sold within concentrations of E10
- The intended consequences to supporting ethanol production are :
  1. Enhance energy security by reducing dependence on imported oil and reduce gasoline prices
  2. Reduce net greenhouse emissions
  3. Rural development

  Griffin (2013) assesses the three intended benefits, finding

1. Benefits to motorists are insignificant
2. Benefits to oil security is small and ill-suited to dealing with supply disruptions

3. Minimal reduction in $C0_2$ emissions which could in fact increase due to changing land use

Also finding a negative unintended consequence on world food prices

- Corn is diverted from food to ethanol use, and other crop land is diverted to corn production
- Although it is difficult to measure precisely, even conservative estimates suggest mandates lead to a substation al increase in world food prices
- World's poor are particularly impacted due to a lack of substituting possibilities
- The unintended consequence far outweighs any intended benefits

Chen, Huang, Khanna, Onal (2014) consider the welfare effect and GHG emissions of two policies to induce biofuel production in the US

- Renewable Fuel standard (RFS) established in 2007, which sets targets for blending of specigic types of biofuels with fossil fuels
- A low carbon fuel standard (LCFS) aims to reduce the GHG intensity of transportation fuel
- In contrast to these polciies, a **carbon price** policy could be used to directly target a reduction in GHG

In sum,

- Government or regulatory failure refers to the situation where market inefficiencies are created by government policies
- Governments use policy tool to reduce prices of market goods, these incentives are justified if there are (net) positive externalities. If this is not the case the right hand of government undoes what the left hand has just accomplished

Exercise 1 (Microecinomics and the environment revision exercise). Application
Case Studies of 18 countries in Central and Eastern Europe

- CIS countries (Belarus, Estonia, Lithuania, Latvia, Moldova, Ukraine)
- CE countries (Poland, czech republic, slovakia, hungaria)

Trade off of ecosystem services showing non convexities. Non convexity in practice does hold up
Z axis agricultural output. So would expect this shape, but we don't see it here at all, we see that if you have.
If want to do research in ecosystem servcies, have to look at shape of PPF. In order to base regulation off of this.

Lecture 3: Designing Environmental Policy

Fri 16 Feb 11:30

[Lecture 3] [C4] [C5]

4.1 How to set a pollution abatement target

Tradeoff - Stricter abatement targets generates a benefit in the sense of to the environment and human health, but this is at a larger cost. The Tradeoff is optimal at the abatement level where the marginal benefits from further abatement fall to the level equal to the marginal costs of abatement.

Flow Pollutant such as water or air pollution

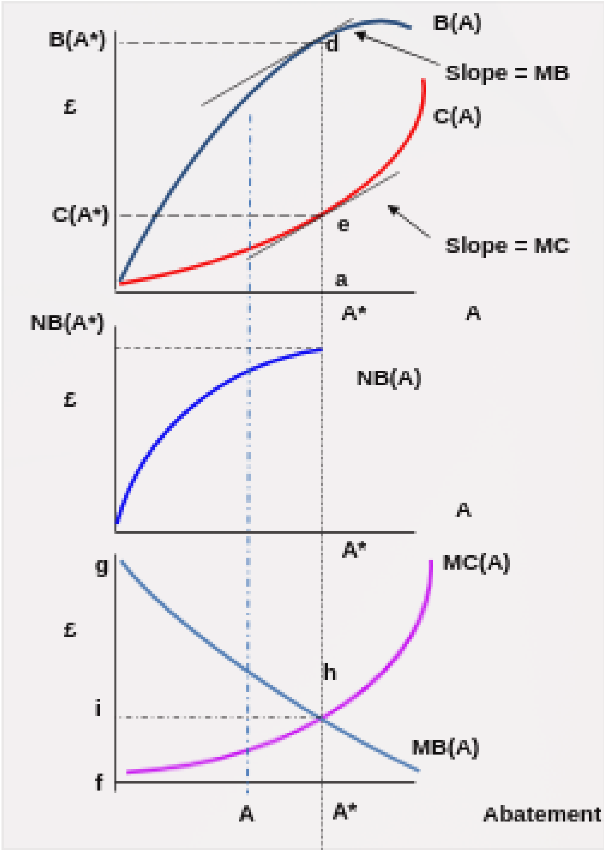

Figure 1: Optimal Level of Pollution Abatement

In the top panel the x axis is level of abatement, y is total benefits and total costs (red). We aim to maximise net benefit from abatement, this is second panel at a star where net benefits are maximised, where total distance from total abatement and total benefits curves are maximised. Similarly marginal benefits and marginal costs are equalised, in top tangent lines indicate marginal benefit and marginal cost equal.

The distance *de* is the cost measure of the optimal level of pollution abatement A* compared to the situation where none is generated.

Second panel, beyond a star is not efficient. In top panel distance de is identical to gfh which indicates the total net benefits from abatement activities. From net benefit perspective (alternatively costs).

Area under marginal abatement costs and marginal benefit abatement minimised in bottom panel.

de is equal to *gfh* since the area under a marginal function over some range gives the value of the change in the total function for a move over that range

An efficient allocation maximises total net benefit from generating A*, that is *gfh*

- CS : ghi
- PS : ihf

First Best Solution

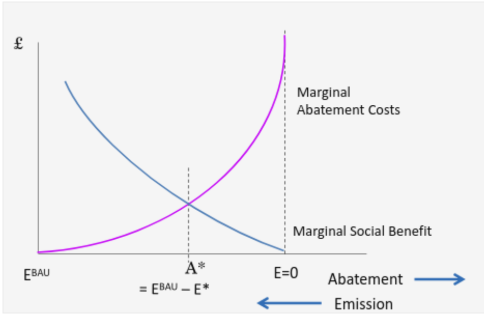

Figure 2: Abatement and Emissions

Abatement from left to right and optimal abatement at A*. Without any abatement there is no regulation at all and marginal abatement costs is 0 but this is business as usual. Moving to the right this is the optimal level of remaining emissions too, abatement goes from left to right and emissions go from right to left. Marginal social benefit 0 where no further abatement where emissions are 0.

The benefit from abatement activities is area between marginal social benefit and marginal abatement costs at A*. Area under marginal social benefit beyond A* is remaining costs from emissions

How clean should the environment be?

First Best solution

- The economically efficient level of pollution is where *marginal social abatement costs* and *marginal social benefits* of abatement are equalised. Thus indicating where the greatest possible net benefits to abatement are achieved
- This gives the first best solution (textbook case) and implies that *each* producer's abatement level consider the benefit to society of the associated abatement

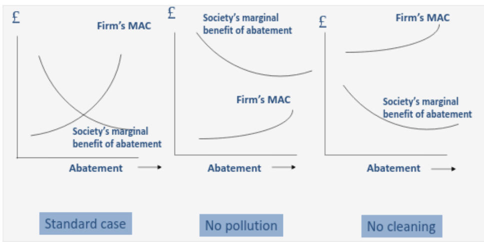

Figure 3

Efficient level may mean no abatement or no pollution LHS - standard case, where pollution refers to harmful residuals, less is prefers to more, it may not be possible to reduce pollution at cost of growth so in practice there is some pollution left in economically efficient situation.

It may also be economically efficient to have no pollution at all, the marginal benefit from abatement is above marginal cost of cleaning up the firm, so here we would suggest no pollution is optimal economic outcome.

Or, if the marginal cost is higher than marginal benefit, then from an economic perspective the suggestion would be no cleaning as the solution.

Summary In the textbook situation we aim for the

1. Economically efficient level of abatement and
2. We have full information

This results in the *first best solution* : that each producer must bear the marginal external cost of their emission and should abate upto where marginal benefits and marginal costs from abatement are equalised

In Practice

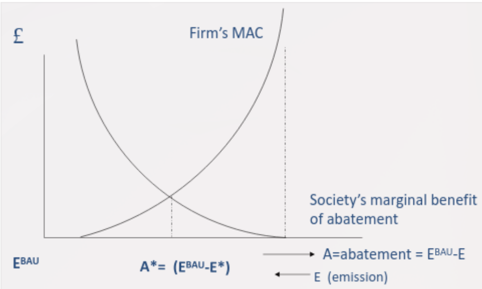

Figure 4

Efficient level abatement Where A is the level of abatement and A* is society's optimal level of abatement. For the efficient (first best) it is assumed we have perfect information, so the first best solution assumes the MSB and MSC can be identified, that the government has the marginal abatement cost for each firms to estimate the marginal social costs for each firm. In practice, this is not regelated by the markets due to the non-revelation of preferences.

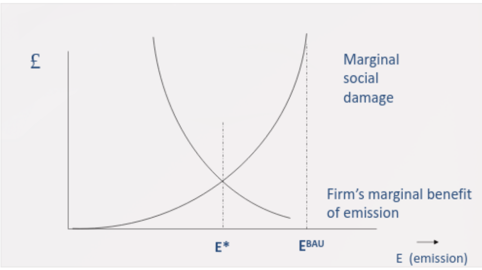

Figure 5

Efficient level of pollution

Environmental Policy in Practice In theory, first best level of pollution abatement A* can be achieved by setting appropriate abatement requirements for each firm

However in practice, this can be very difficult for the government to achieve because of

1. Legislative constraints
2. AND, imperfect information - we do not have this in practice since we do not have full information (about the marginal social benefits of abatement or the marginal abatement costs of each firm)

Thus, the *second best criterion* is to achieve a (likely suboptimal) abatement target using the least amount of resources since this involves setting a minimum level of abatement that is needed and then evaluating the cost of implementing this.

The **Second best criterion** can be achieved by an environmental policy instrument that leads to **cost effective abatement**. That is, allocation of abatement across pollution sources such that MACS are equalised across firms, and as such environmental objectives are met at minimum costs.

Essentially, we drop the idea of efficient level of pollution and turn to minimum cost abatement.

Cost of pollution abatement

- Polluting firms will select the least cost method of polluting abatement
- This is reflected by the firm level marginal abatement cost function
- Each polluter may face a unique MAC curve
- Each firm's total abatement costs will typically increase at an increasing rate with abatement, e, marginal abatement costs rise
- This general pattern is ubiquitous for emission control

As abatement continues and environment becomes cleaner, the costs to added abatement rise at an increasing rate

Deriving market level marginal abatement cost

- MAC_{mrkt} represent the least cost methods of pollution abatement and so at each point on the aggregate MAC_{mrkt}, the MAC of individual firms are equalised
- Aggregation of all individual firms' MACs represents the market-level marginal abatement cost (e, $MAC_{MRKT} = \sum MAC_i$ for all I firms)
- MAC_{mrkt} is defined by horizontal summation
- If there are no costs to monitoring and enforcing pollution regulation, then MAC_{mrkt} = marginal social cost of pollution abatement (MSC)

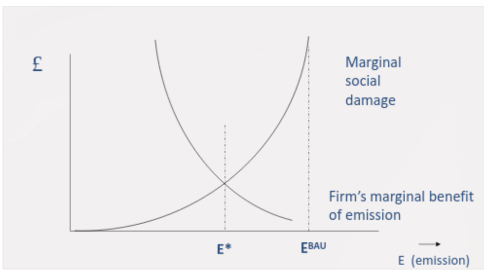

Figure 6

Policy instrument to minimise total abatement costs, here 2 firms with information on market level MAC and target of abatement at 150 Tans of this specific pollutant. Natural approach would be to split abatement equally, reduce by 75 with total abatement costs would be area under marginal abatement cost of respective firm upto 75.

Starting from uniform allocation, we can shrink total abatement by assigning more abatement to firm with lower marginal cost. That is marginal abatement costs equalised, abate upto here, the intersection with horizontal brown line

Thus the cost effective allocation is achieved when the asst unit of pollution control is the same, other wise there is a way to reallocate and reduce total abatement costs. Now we need to find policy instrument to enforce this, but without knowing each individuals firms marginal abatement cost.

What environmental policy instruments should be used Most environmental policies fall into two broad categories

- Direct regulation - 'command and control' : use technology or performance standard to prescribe how emission reduction take places
- Market based (Economic) instruments : use incentives to motivate abatement through market forces

Other approaches include voluntary agreements and the dissemination of information

Direct Regulation Technology Standards

- Designate the equipment or method used to achieve some abatement level - preventing from being least cost method (some operate above marginal abatement cost curves, thus not very suitable from economic perspective)
- **Advantage** being that it has low monitoring costs
- **Disadvantage** being that it is no cost-effective, there is no incentive to develop new technologies

Performance Standards

But does not say how to achieve, each polluter would follow its self interest and choose the least cost abatement method. But still isn't cost effective since abatement costs differ among polluters

- Uniform (emission or ambient standard) is not cost effective
- Non-uniform standard can be CE (cost effective) in theory but in practice, imperfect information and legislative constraints make this difficult to achieve

In second case regulator would need to know firm's MAC, but this again runs into the problem of imperfect information, there is no incentive to provide this

Market Based Instruments Pigouvian Tax

- A unit charge on a market good whose production generates a negative externality. The tax should equal the marginal external cost at efficient output level
- This can be an attractive option when it is difficult to monitor emissions directly
- Internalises negative externalities, which can be difficult to measure in the real world, it differs on the suitability however, say whole range of consumer goods
- Regressive tax - burdens lower income population disproportionately more

Emission Tax

- A fee placed directly on every unit of pollution emitted (removed below baseline)
- A **Price Instrument** establishing the price of emissions
- *Firms need to decide how much emission to abate and then pay the tax on their remaining emission*
- Firm chooses cost minimising response - firm has incentive to reduce all or part of emissions

Emission trading scheme (permit / cap and trade)

- Establishes a market for rights to pollute by issuing traceable permits to polluters
- *Quantity instrument* : placing a limit on total quantity of emissions (determined by number of permits issued)
- Within this overall limit, companies can boy and sell emission allowances as needed
- The regulator either grandfathers the permits (distributes for free) or sells them at auction, with a combination also possible

Direct Controls vs Market Based Instruments

- Economic theory suggests that market instruments are the least costly way of achieving a given environmental objective
    1. Firms can decide whether they would prefer to control their output of emissions or change their inputs or change production techniques
    2. Firms with the lowest abatement costs will be the ones to abate more
- In contrast, direct controls force all polluters to meet the standards regardless of their opportunity costs
- Other Advantages
    1. Economic instruments provide dynamic incentives to develop new and cleaner technologies
    2. Economic instruments can generate revenue, which can be used for environmental or other purposes
- However, the cost advantage of market based instruments decreases if marginal abatement costs are similar across firms
- If there is a narrow range of technology options available to achieve the environmental target (for ie)

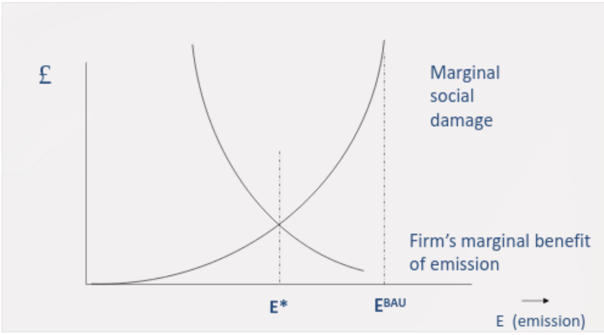

Figure 7

Price vs Quantity Instrument 1 : emission tax (price insturment) set tax at P*, resulting in abatement A* 2 : Emission trading scheme (quality) set abatement at A*, resulting in price P*

Shows why price instrument gives same result as quantity instrument Fi there is no uncertainty, marginal social cost and marginal abatement costs across all firm s are important. P* $\rightarrow$ A* abatement (price) and vice versa with quantity, allow E* emissions

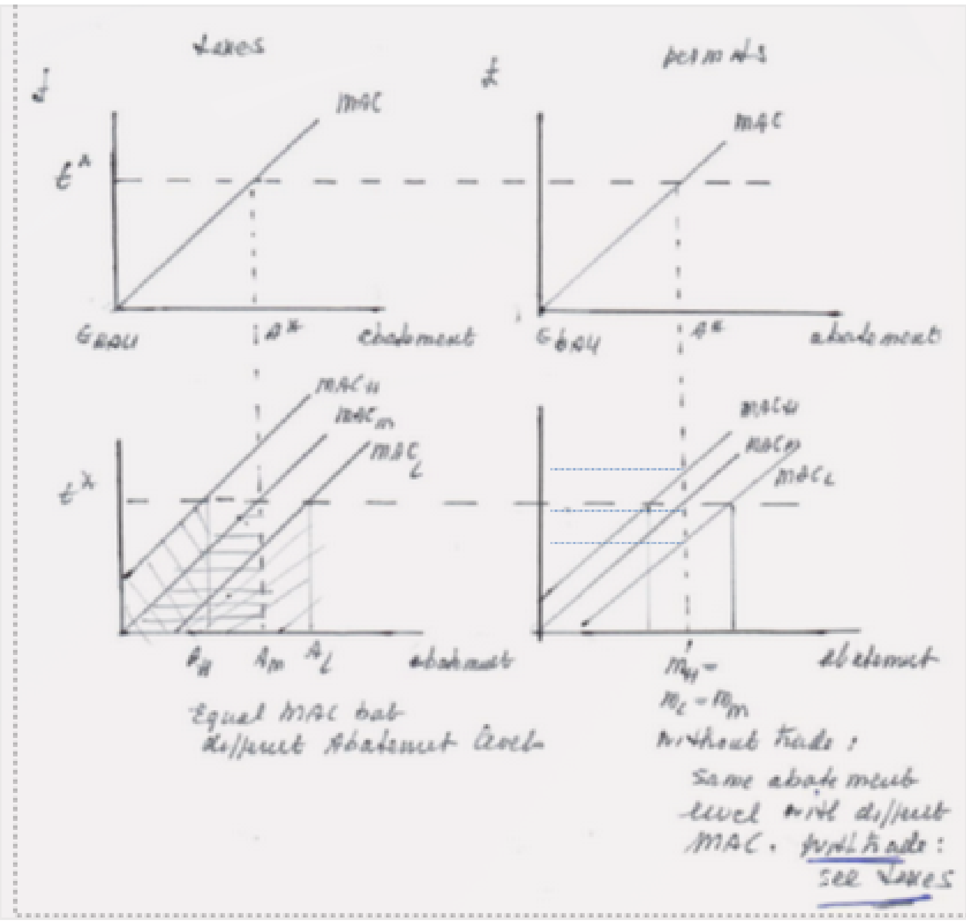

Figure 8

Cap and trade and carbon tax are both CE Four panels, if we are interested in certain level of abatement we could use either instrument to shift and get at same cost. To achieve A* set tax at t* or introduce permit to allocate firms allowances and to abate upto A*. In bottom panel 3 firms, different abatement costs, each 3 firms abate upto level where abatement costs meets tax, shaded area indicates total abatement costs for each of 3 firms, techy have equal marginal abatement costs but different levels of abatement. For remaining emissions, the firms pay the tax.

Initially M allowances, they have same abatement level but with different marginal abatement costs, if allow trade, the high cost producer buts more permits to avoid marginal abatement costs.

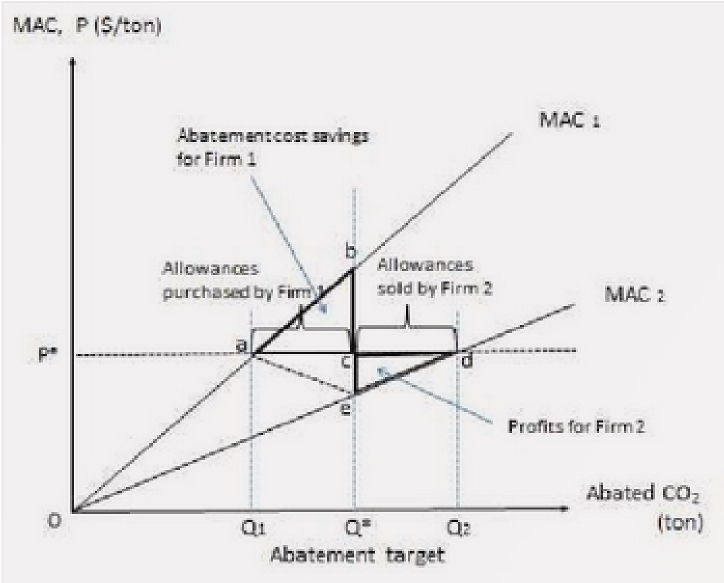

Figure 9

Why price and quantity are both CE and give same result. For Co2 abatement, 2 polluters,

1 high cost, introduce tax, firms abate upto marginal abatement cost s meet tax, q1, q2. Total abatement is sum of these, marginal cost per last unit of abatement is equalised for 2 firms, without needing to know marginal abatement costs (market instrument system - market takes care of that)

cap and trade - set an abatement target, q*. Tell each firms to abate upto q* and we see high cost polluter has significant abatement costs to get to same level of abatement, if tradeable then firm 1 will buy permits from firm 2so that it would not need to abate q1 - q* and thus cost saving for firm 1 of ABC. Firm 2 interested in selling permits, marginal abatement cost are below price of permits,

In equilibrium, firm 1 abate upto q1 and firm 2 to q2 - the same as the tax

Emissions taxes and trading schemes are both cost-effective

- Both equalise MACs across firms
- Which holds regardless of whether permits are distributed through auction or by free allocation
- If we know where the aggregate MSC and aggregate MSB are with **certainty**, then two policies will lead to the same (optimal) outcome

However, there are differences between these instruments in practice

- In practice, we are usually uncertain about the MSC of abatement ($\sum MAC$) and about the MSB of abatement
- Trade in permits is needed for the tradeable permit system to be cost effective but there might be transaction costs that prevent this
- Tradeable permits don't have to be adjusted for inflation or economic growth

Summary Economic theory suggests that market instruments (carbon tax and cap and trade) are the least costly way of achieving a given environmental objective :

- Firms can decide whether they would prefer to control their output of emissions, change their inputs, or change production techniques
- Firms with the lowest abatement costs will be the ones to abate more

In contrast, direct controls force all polluters to meet the standards regardless of their opportunity costs $\sum_{i=0}^{n}$

Lecture 4: Designing Environmental Policy: Complications in practice and voluntary approaches

Wed 21 Feb 09:04

[Lecture 4] **[Reading]**

4.2 First best solution

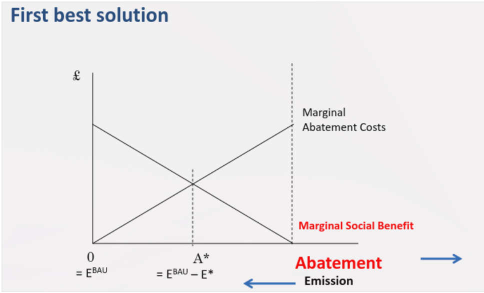

Figure 10

$$\frac{\partial D}{\partial e} = -\frac{\partial D}{\partial e} \cdot \frac{\partial E}{\partial z} \cdot \frac{\partial z}{\partial \delta}$$

Where E is people, z is residual environment and δ is abatement

In the textbook situation, to achieve optimal abatement:

- Direct regulation (compulsory installation of scrubber (filter))
- A tax t per unit of pollution
- Allocation of tradeable permits would restrict pollution associated with the quantity E^*. After trade the permit per unit would be the same as t

4.3 Recap

- In practice there are many polluters with different MACS
- WEE have found that economic instrument schemas are cost effective, while direct regulation usually isn't
- And that pollution taxation and cap-and-trade are interchangeable

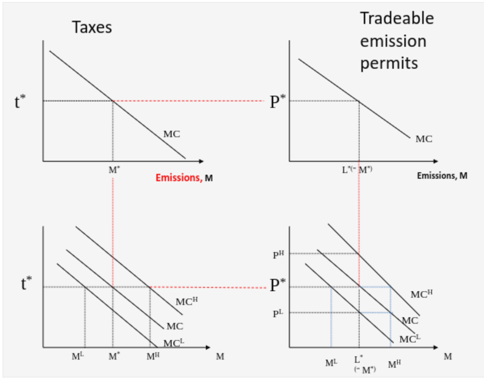

Figure 11

Right, assume we don't have complete information so allocate L. Then compare emissions to abatement costs, MAC^H has higher abatement costs

4.4 Considerations in practice

We have found that economic instruments are cost effective, while direct regulation usually isn't (second best solution). Also, pollution taxation and cap-and-trade are **interchangeable**

Although, *in practice* there may be complication that change this

Considerations in practice when using environmental policy instruments

1. Policy related transaction costs (may vary by instrument)
2. Incomplete information: non-point source of pollution
3. Incomplete information : uncertainty in marginal costs and benefits of pollution control
4. Non-uniform pollutants - pollutants located closer to an exposed population or ecosystem will cause more damage
5. Dynamic analysis : which policy instruments are dynamically efficient?
6. Other considerations : legal issues political economy etc.

Policy related transaction costs In carrying out its responsibilities, an environmental protection agency necessarily incurs transaction costs. This is a generic term for a variety of costs that include "ex ante costs of establishing environmental policy and the ex post costs of administrating, monitoring, and enforcing them" (Krutila and Krause, 2010)

- Transaction costs *do include* the costs of personnel

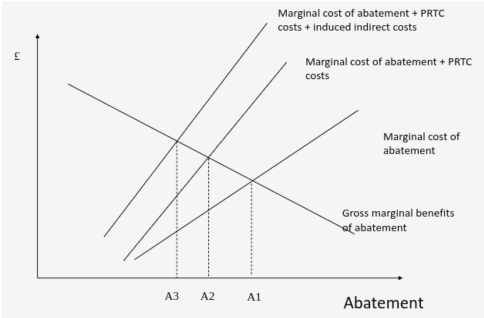

Figure 12

Incomplete information

Non-point sources of pollution

- Point source of pollution : discharge of pollution comes from a single easily identifiable locating
- Non-point source of pollution : pollution discharge of emissions comes from a carnage of activities and so the specific point of discharge cannot be easily identified Egg
    1. Fertiliser and pesticides from lawns or farms
    2. Organic wastes - from minuter and sewage
    3. Sediment from erosion of bare soils
    4. Toxins - airborne chemicals, oils and metals
- For non-point sources of pollution, pollution abatement from individual firms is difficult to monitor (and costly) to measure. This can significantly raise the policy related transaction costs

Example. Fishery Shellfish, very sensitive to chemicals, particularly nitrogen and phosphorus Have a couple of big cities with waste water treatment site on the river? If we regulate these to make sure they reduce, we know exactly where this comes from. This is point source

But if we have many farmers around this river, then this is non-point source of pollution

4.5 Uncertainty in benefits and costs of pollution control

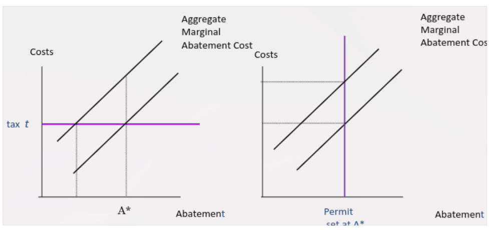

Figure 13

Weitzman (1974) **When there is uncertainty about the benefits and the costs of pollution control, are 'prices' (taxes) better than 'quantities (tradeable permits)**

Taxes - set the marginal cost of abatement whereas tradeable permits set the total quantity of abatement

Thus, in a situation of uncertainty we have that

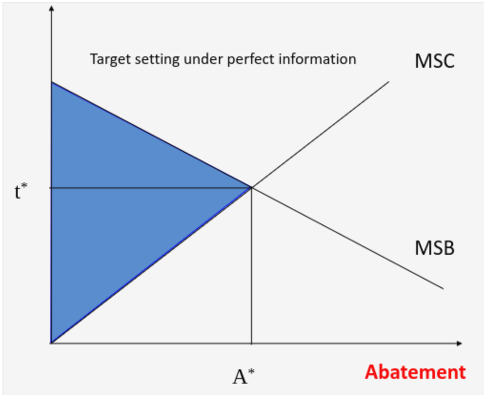

Figure 14

If we are not so sure about either the MSC or MSB, we don't get the triangle, this is under perfect information

The efficient target A* is the level of emissions which equates the marginal social cost of emissions abatement (MSC) and the marginal (social) benefits of emissions reduction (MSB). MSC = aggregating of marginal abatement costs actors the firms to be regulated.

Weitman (1974) : Uncertainty about *either*

1. The benefits
2. Or, the costs of abatement

That is, either the MSC is steeper than the MSB. Or, the MSB is steeper than the MSC

Scenario 2 **MSC steeper than MSB**

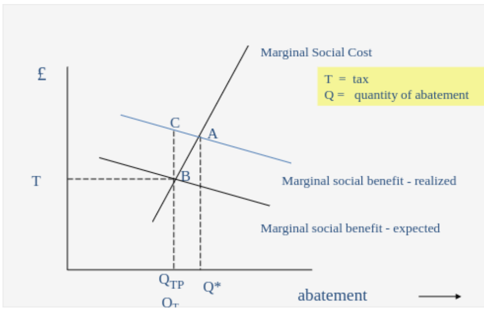

Figure 15

Can't wait for better information, have to act now. Tax scheme gives Q_t amount of abatement, as does tradeable permit.

Some time later we get information that MSB is higher than originally thought (shift up). In this situation, we should have abated upto Q*.

Then we have underabated, where the benefits are higher than the costs and we lose the triangle ABC. Since with the new information, we have fixed the permit scheme we are fixed at Q_{TP}

For the tax scheme, tax scheme where emits marginal costs, so we are still here as well, this is the first scenario, essentially it is more expensive to clean up, we lose efficiency but it is the same for both.

Scenario 2 **MSB steeper than MSC**

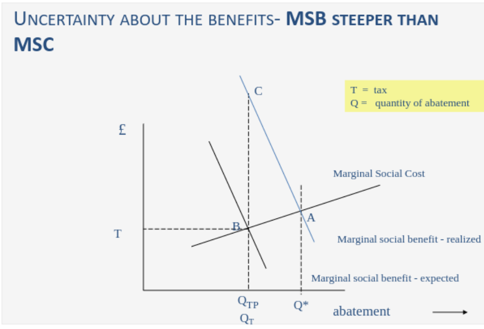

Figure 16

Uncertainty about benefits, but doesn't help

Scenario 3 - uncertainty about cost - MSC steeper than MSB

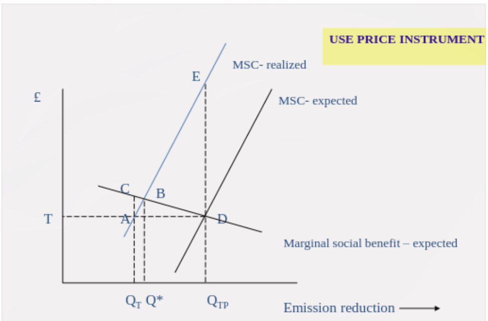

Figure 17

Here we have overabated under TP, meaning that TP for distance $Q_{TP} - Q*$ the cost is higher than the benefits. Even tax scheme has under-abated. If uncertain about cost of abatement but MSC steep, then it is better to have taxation in terms of social loss.

Scenario 4 Uncertainty about cost - MSB steeper than MSC

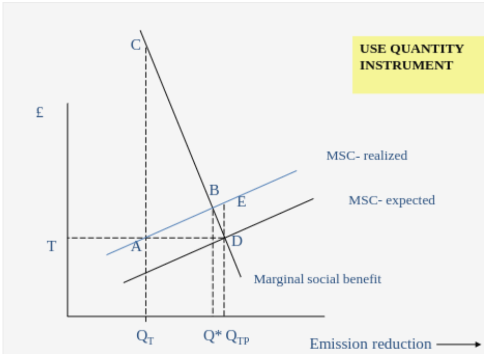

Figure 18

With tax scheme we have under-abated by $Q* - Q_T$ the benefits are higher than the cost. Later, people have elaborated upon this - in practice we might have uncertainty on both.

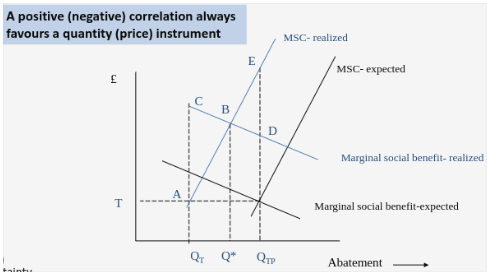

Figure 19

Triangle ABC increases, now it is bigger, we have moved away. If we have both uncertainty, and both move the same way (higher than original - positive correlation) - then the final result could switch if the effect is strong enough

Relative slope of curves *	Uncertainty in:		
	MSB	MSC	Both
|MSC|> |MSB |	Indifferent	Taxes	Taxes but a positive correlation favours** permits
|MSB|> |MSC |	Indifferent	Permits	Permits but a negative correlation favours** taxes

Figure 20: Effect of uncertainty on 'prices vs quantities'

It is the slope of the curves that decides the result for the case where there is uncertainty wrt to either the MSB or the MSC. The level of the new curves also plays a role in the case where we have uncertainty in both MSB and MSC.

Theoretically, the effect can overwhelm the usual relative slope recommendation. The correlation refers to the uncertainties. A positive correlation means that the MSC realised is higher than the MSC expected and the MSB realised is also higher than the MSB expected. A negative correlation means that one of the two realised curves is higher than expected but the other one is lower than expected.

4.6 Non-uniformity of pollutants

Uniformly mixing pollutants - physical processes operate so that the pollutant quickly becomes dispersed to the point where its concentration does not vary from place to place - eg greenhouse gases

Non-uniformly mixing pollutants

For non-uniform pollutants, polluters located closer to an exposed population or ecosystem will cause more damage. Polluters are then facing different MSB of abatement. While efficient outcomes require MAC to be equalised with MSB for each individual polluting firms.

Different MSBs across space (or + time) may be problematic when the policy instrument is an economic instrument (permit trading, emission tax) - these policies allow pollution from individual sources with high MACs to increase (even as overall emissions fall). Such emissions may cause a higher level of damage locally ('hot spots')

Different MSBs across space (or+time) can also be problematic when the policy instrument is a subsidy scheme on new technology such as electric vehicles

Mullen and Manderson 2009, power plants in USA SO_2 handling scheme, but damages from SO_2 depend on technology at each plant, but this is not factored into the scheme.

Further on the example by holland et al 2016, geal zivin on emission damages from EVs vs gasoline cars.

Environmental benefits from driving electric vehicles Despite being treated as zero-emission vehicles, the use of electric vehicles is not necessarily emission free. It depends on how the electricity for charging the vehicle is produced. Since many location in the US, the comparison between a gasoline vehicle and an electric one is really a comparison between burning gasoline and mix of coal and natural gas.

However, average emissions of regional power plants can be a misleading indicator of the environmental impact of electric cars because emissions from different power pants have different environmental impacts. By locating and technology but also by how they respond to an increase in demand.

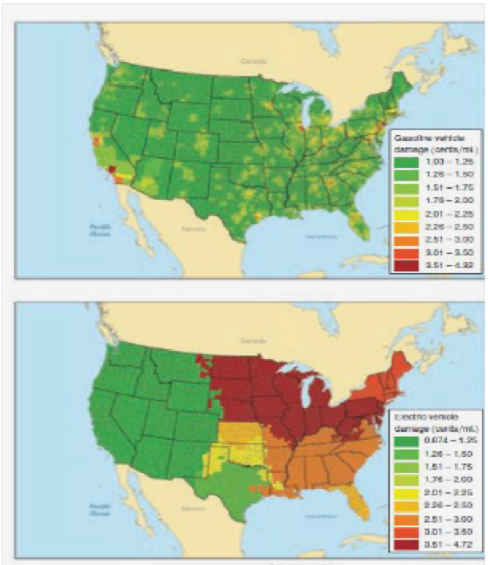

Figure 21: Differences in fossil fuels use by power plant for EVs vs FF Cars

Differences depend on damages between 2 types of car. We can see there is very big differences across the country. Comparing 11 types of EVs, comparing with

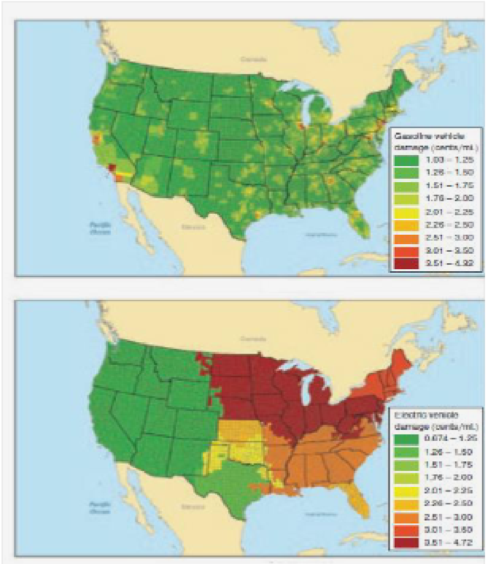

Figure 22: Second Best EV subsidy by County

4.7 Dynamic Efficiency of Policy Instruments

In practice, we live in a dynamic world. But how does this affect the performance of the policy instruments? So far we have considered a static analysis, we need to look into the adoption of abatement technology

Findings

- Emission taxation

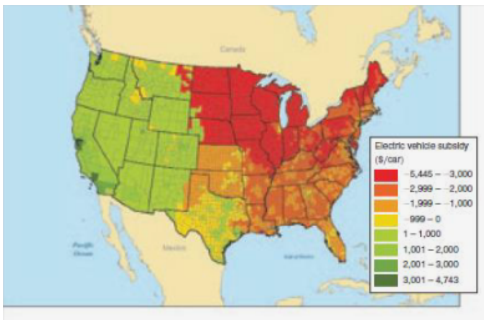

Figure 23

Without any regulation we are at E_1^* with MAC_1, we assume the firm emits E_1

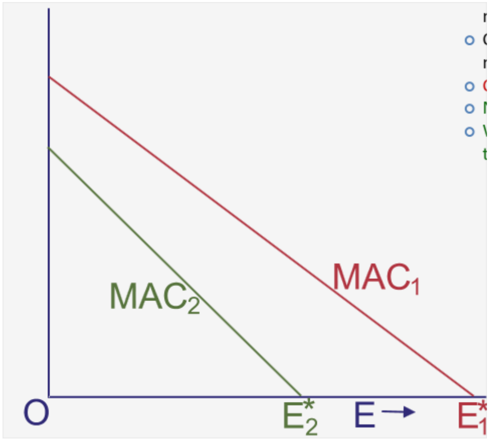

Figure 24

With new technology, how does the firms behaviour change? The firms abates E1, A1 E1*, and pays tax 0E1A1t

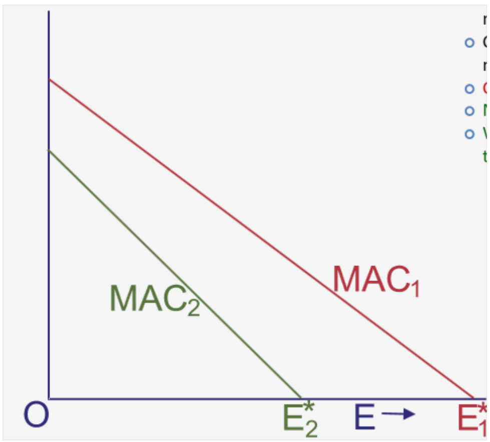

Figure 25

Grand parented permits

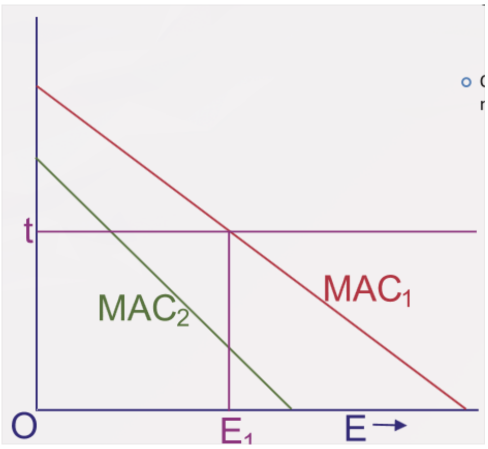

Figure 26

With a new technology, t is price of permits in market, we abate upto A_2 and sell the permits we don't need. Thus resulting in a gain from new technology instead of current technology

4.8 Other considerations

Public finance impacts and secondary impact

- Market based instruments can affect regulator's budget
- Costly to implement but also tax revenue from permits (if auctioned)
- Could use the tax revenue generated to fund research into environmentally friendly technologies (energy saving and CO_2 cutting) and to promote adoption thereof
- Could use the tax revenue generated to offset other distortionary taxes. The 'double-dividend' hypothesis suggests that increases taxes on polluting activities can provide two kinds of benefits.

Legal and Political Constraints

- The most efficient policy based on compliance cost, PRC, and public finance impacts may not be feasible because of legal, political or social constraints
- Political constraints : choice must garner sufficient support from stakeholders (public acceptability, distributional impacts) and be consistent with other government policies

5 How do environmental policies affect economic performance?

The Porter Hypothesis

- The traditional view was that environmental regulations damage economic performance
- This was challenged in 1990s by Micheal porter
- He argued that well-designed environmental regulation may often enhance competitiveness

- Suggesting that market based incitements can 'trigger innovation . . . That may partially, or in some instances, more than fully offset the costs of complying with them
- *the porter hypothesis*

Why might environmental regulations increase environmental innovation? Porter and van der Linde (1995) offer various reasons, including :

1. "Regulation signals companies about likely *resource inefficiencies* and *potential technological improvements*"
2. "Regulation focused on information gathering can achieve major benefits by raising corporate awareness"
3. "Regulation reduces the uncertainty that investments to address the environment will be valuable"

Not empirical and not very precise, leading to three variants of the porter hypothesis

1. Strong version of the porter hypothesis - environmental regulation improves the economic performance of the firm
2. Narrow version - flexible environmental regulations give greater invectives to firms to innovate than command and control regulations
3. Weak version - properly designed environmental regulation may spur innovation

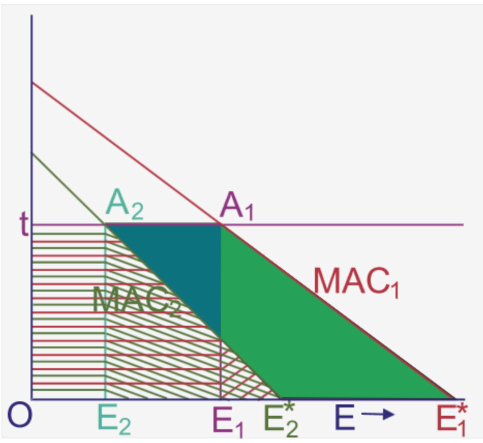

Figure 27

Say W_s is water quality standard, if introduce environmental regulation then W_1 starts figuring out how to change production. The curve bc would be of interest, it would improve water quality and have higher profit - the firms moves to the frontier and profit goes up

Over time, new technology becomes available, the firm A_1 new technology expands to F, with innovation and inefficiency offset. Firm A_3 over time, if these 3 types of firms describe the porter hypothesis, the gravity of the differences matter - but this requires empirical research.

Policy evaluation

EU ETS : Environmental and cost effectiveness
Dechezleprêtre et al 2018

- Analyses the impact on firm performance using firm level date for all countries covered by the EU ETS
- Uses a matching methodology to estimate the policy's causal impact on emissions and on firms' revenue, assets, profits and employment
- Finds that the EU ETS has induces carbon emission reductions in the order of -10% between 2005 and 2012, but had no negative impact on the economic performance of regulated firms

How do environmental regulations affect economic performance The porter hypothesis argues that well crafted and well-enforced regulation would benefit both the environment and the firm. The key mechanisms is that regulation promotes innovation aimed at lower the cost of compliances

5.1 Voluntary Approaches

Background : legislative threat and often also some positive incentive by government Conditions for voluntary actions : $P(A_M)C(A_M) > C(A_V) - S$ Where $P(A_M)$ is the probability of mandatory abatement A_m, $C(A_M)$ is the abatement cost of mandatory abatement A_M, $C(A_V)$ is the abatement costs of voluntary abatement and S is the fixed incentive supporting voluntary abatement

> **Exercise 2.** Agreement to reduce use of pesticides, if not taxation This was successful, there was some subsidy to support some training schools to learn about pesticides, and testing the equipment so it doesn't.

An agreement between a sector and firms

Self-Regulation

Building a green reputation through corporate social responsibility / public relations measures

- Reaction to change in consumer, investor and employee/executive preferences
- Reaction to pressure groups and to pre-empt costly regulation

> **Exercise 3.** Carbon Disclosure Project Climate disclosure score is annually calculated. In 2019 over 8400 companies disclosed through CDP

Advantages being that it enables establishment of long term comprehensive environmental strawy vat the firm level, instead of ad hoc reactive handling of urgent responses to targets set from above

Lecture 5: Environmental Cost Benefit Analysis

[LECTURE 5] [Reading]

Wed 28 Feb 09:04

5.2 Cost benefit analysis

Motivation

- Using tax payers money to build bridges, what is the best use of taxpayers money?
- For a certain location and bridge crossings, even though it is a public good, the willingness to pay (toll) implied that a bigger bridge results in a smaller return
- Thus the first idea of comparing costs and benefits

When environment was included was the US flood control act of 1936 - to build levy for the river, but you have to account for the whole river. Depending on the design, people would be affected in different ways. Fishing disrupting from levies etc.

- 1960s environmental economics - to use public funds more efficiently
- Thomas schilling - if controlling air pollution then there is an effect on mortality and morbidity $\rightarrow$ preventing this is a benefit (loosely he figured out)
- John krutilla -
- Next step - since 1981 it is compulsory federal regulation to perform a CAB

Cost benefit analysis is the *social appraisal* of marginal investment projects and policies, which have consequences over time, the purpose is to identify the best alternative from society's welfare perspective
Environmental CBA seeks to correct project appraisal for market failure

Ranking alternative outcomes

- Ideal situation according to their impact on social welfare (SW)
- $\Delta SW(j) = SW(U_{10}, U_{20}, \ldots, U_{i0}, U_{N0}) - SW(U_{11}, U_{21}, \ldots, U_{i1}$

Economists prefer to avoid specifying the SWF if possible, then step away from *normative* welfare perspective and toward an efficiency perspective

- The pareto improvement criterion implies a re allocation is desirable if it increases one's utility without reducing another's utility - avoiding the need to refer to the SWF to decide on whether to recommend that re-allocation

Though, there are two problems of principle with the pareto improvement criterion

- The recommendation that all re allocations satisfying this condition be undertaken does not identify a unique allocation
- Most re allocations that require analysis involve winners and losers and are therefore outside the terms of the pareto improvement criterion

Leading to the Potential Pareto Improvement Criterion

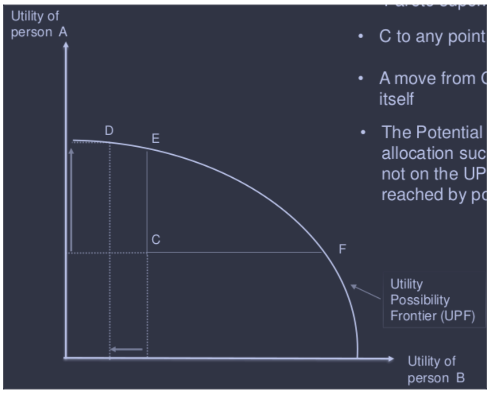

Figure 28: Potential Pareto Criterion

Instead of requiring that everybody is better off, if compensation is possible then we have potential pareto improvement.

- Assume currently at C, a move anywhere to EF would be pareto improvement
- Strict pareto implement criteria
- Potential pic

Kaldor Compensation test

- If allocation d superior to allocation c, then we should go ahead with it
- Doesn't require compensation but instead if overall benefits larger than loss

Hicks compensation test and Kaldor Hicks Scitovsky test

- Start from losers, they can compensate winners for not going ahead
- Then using the hicks test if the answer is yes, then the re allocation is not sanctioned, otherwise it is
- It is necessary to use both the kaldor and hicks criteria

In practice

Measure everything in money terms, disregarding SWF again.

$$\sum_i \Delta y_i \geq 0$$

Where Δy_i are income based changes in welfare as measured by compensating variation or surplus (kaldor-hicks)

- Calculate net benefit, in money terms
- Distribution effects - with this approach, you are not doing that, inherently cannot capture that - Nyborg K 2014 - Norway Oil money etc - had to explain that CBA couldn't explain issues of equity. This article explains what CBA does

- Efficiency issue -
- Equity issue - whether re allocation / compensation should take place

Operationalising CBA

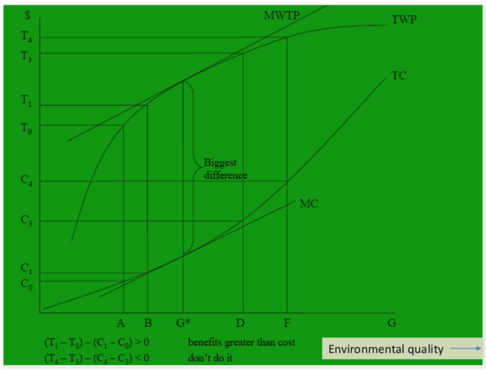

Figure 29

Issues with no market price since they are so important, we know we have to compare TC and TB.

In CBA we consider rolling out some policy, say air quality in Manchester and we are already at some policy point, we want to improve further, say oxford road corridor - there are costs and benefits involved, we need to figure these out.

Taking this further from B to G* say the ULEZ in Manchester. Say going beyond this from economic point of view, it would not be a good idea. AB ok but G*D not.

Four informational inputs needed for calculating NPV

1. Cost schedule
2. Benefit schedule
3. Time horizon
4. Discount rate

Examples of abatement costs

- The cost of reducing waste water streams
- The additional costs to comply with more stringent particulate matter regulations

Mckinsey Curve - for different interventions

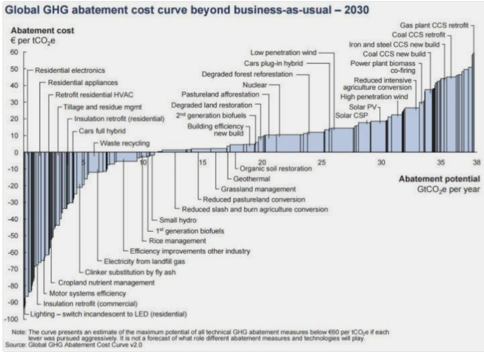

Figure 30: Mckinsey Curves

Nuclear energy.

Negative costs - they will pay for themselves. How do these abatement costs compare? How do these changes make other changes in the economy?

In 2022 the global emissions were . . . ?

Top down studies

- How much it costs taking into account how the economy changes, initially similar but more costly in India
- Can compare marginal abatement costs here
- 2020 red stars whereas 2050 is green cheaper - phase out of coal etc - whereas India different

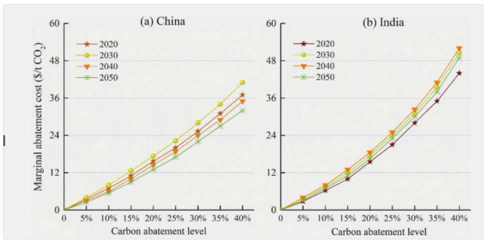

Figure 31: Typical marginal abatement cost curves

How to figure out the benefits

- Benefits are typically harder than costs to figure out
- Most past discussion has been on *direct health effects* - dying / becoming unwell due to environmental pollution
- Methods are not looking at effect on the natural ecology and on human welfare

Direct Impacts on Human Health Marginal benefit of reducing externalities

$$X = \text{ polluting input used by producer}$$
$$Z = \text{ emissions associated with production process}$$
$$E = \text{ environmental quality}$$

Then introduce

$$\frac{\partial z}{\partial x} = \text{ change in emissions with abatement effort}$$
$$\frac{\partial E}{\partial z} = \text{ change in environmental quality with change in emissions}$$
$$D = \text{ damage (recalling private price)}$$
$$\frac{\partial D}{\partial E} = \text{ change in damage with change in environmental quality}$$

Thus marginal benefit of abatement is

$$\frac{\partial D}{\partial x} = -(\frac{\partial d}{\partial x} \cdot (\frac{\partial E}{\partial z}) \cdot (\frac{\partial z}{\partial x}))$$

Where first is people, second is environmental media and third is abatement effort

The dominant approach is the value of statistical life (VSL) to capture say impact on dying prematurely and impact on being hospitalised from pollution (introduced shcelling 1968)

Impacts on natural ecology and human welfare Krutilla (1967)

- *use value* based on observable actions that associate behavior to environmental quality
- Non-use value - no observable action / behaviour that establishes individual concern for environmental amenities
- As with the direct effect of human health, here we need to consider the effect (say TEV) for *all* people that are affected by the incremental change
- Impact on natural environment - say a river
- Think about utlity and water quality in river, directly, we can assume we enjoy boating and fishing if the water quality is better we can assume this has a direct effect on utility. Say if we go to one part of the river where water quality is better
- Indirectly : soft drink or beer produced using this polluted water

Direct : $U = U(\ \mathbf{X}\ , Z, W)$
Indirect : $X_1 = F(L, K, W)$

Hedonic pricing for revealed preferences (surrogate market). Cost based methods for production or cost based methods (market based). CVM or choice experiments for stated preferences (simulated market)

Example. Great barrier reef study by oxford economics

- Loss in benefits of total and permanent bleaching of the GBR off the NE of Australia
- The analysis has been conducted using a TEV approach, the total loss in benefits from bleaching of the GBR and of the cairns area were calculated

- Report takes into account the
    1. Direct use values of the commercial, recreational, fishing and tourism industries (profitability)
    2. Direct use values by tourists and recreational fishers (how much the groups using the reef truly value it)
    3. The non use value of the Australians who may not visit the reef but are willing to pay for its continued existence
    4. Non use values for international residents

Sometimes, a portion of the benefits of an environmental improvement can be estimated using market prices But we can only capture things that have a market value

Revealed preferences : travel cost method

- But can only use for recreational use
- Say coral reefs off Columbia. Would have to to a survey, which and where and when, how can we do this - by interviewing etc, or how many people visiting and where from + secondary data on travel costs - these can be used to apply this method
- To obtain the demand curve by examining how participation varies with cost of getting there

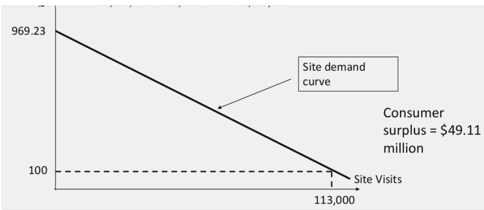

Figure 32: Linear demand function

Example. Water quality Europe There has been EU bathing water directive for water quality Travel cost method - travel cost to get to sites, value if water quality changes Finding the consumer surplus per visit and per person Then figured out what would happen if water quality changed by a unit Assessed benefits of improved water and compared to costs

Hedonic Pricing

Exercise 4. Property Pricing Rent depends on room, age quality, location, attributes - collecting information and running a regression to figure out how environmental attributes translate to Environmental issues America has limited vacations, and this area is affected by hurricanes - leading to serious damage and coastal erosion Gopalakrishnan et al, (2011) - estimates the value of beach width that is capitalised in property values Comparing to restoring the beaches - figured out the optimal beach nourishment Interval only 8 years for expensive property - depends on hedonic beach value

Climate Change

- Benefits of reducing carbon emissions today is less damages from carbon in the future

- For different degrees of warming we can expect different damages
- Change in crop yields, issues with infections disease, species extinction etc.
- Hedonic modelling also used to figure out future crop yield damages

two major economic approaches to study the interaction between climate and agriculture
The bottom up production function approach

- Uses data from carefully controlled experiments that measure damage on crop growth due to variation in T and water availability and sometimes also carbon dioxide
- Can direct phenomena (such as extreme weather events) that have not yet occurred in nature

Top down Hedonic pricing approach (ricardian)

- Relationship of T and agricultural returns per Ha is estimated directly through econometric regression and recent data
- Cross sectional method that examines farm performance (rather than crop performance) across climate zones
- Is used for countries, regions large enough to contain wide range of climate (India, USA, Brazil, China)
- Ricardian - diminishing returns

Ricardian Approach

Production function method leads to an overestimating of the economic effect of climate change, by estimating $y_i - F^i(x_i, T, D)$for each $i = 1, \ldots, k$ we are implicitly constraining farmers not to change crop or to change pasture or to urbane use of the land as climate changes
Mendelsohn, Nordhaus and Shaw (1994)

- Look at the effect of climate on agricultural land rent R
- Overall, severe climate impacts then everywhere in the world has negative effects.
- But heterogeneous climate effects of 4 degrees of warming
- South America affected as bas as Africa

Summary

- Economic valuation highlights benefits and costs and cost bearers and beneficiaries that in the past may have been ignored
- Economic valuation provides a set of tools with which to make better and more informed decisions

5 HOW DO ENVIRONMENTAL POLICIES AFFECT ECONOMIC PERFORMANCE?