Environmental Economics

Sol Yates

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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

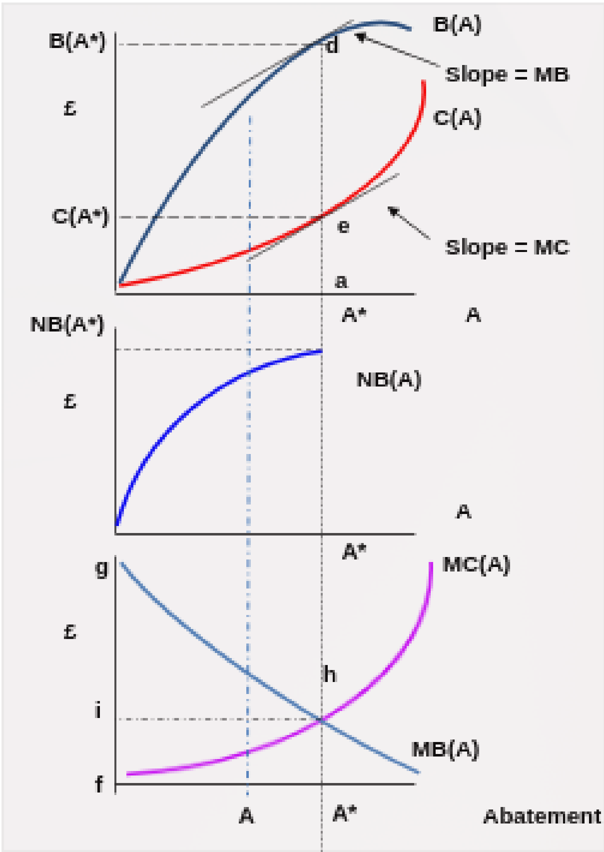


Figure 1: Optimal Level of Pollution Abatement

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

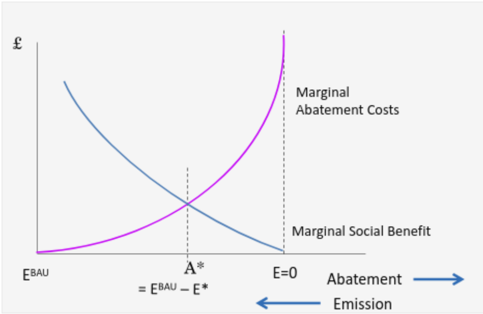


Figure 2: Abatement and Emissions

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

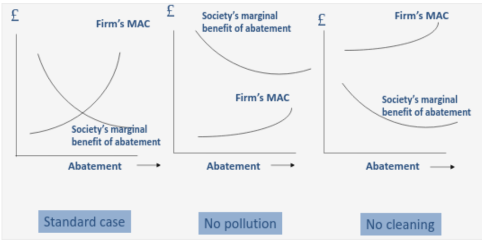


Figure 3

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

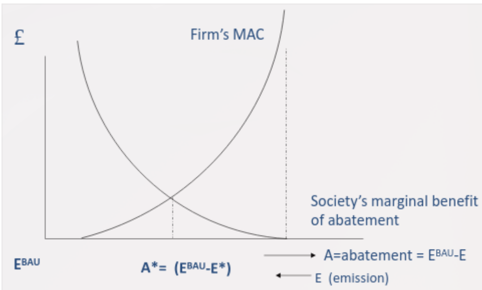


Figure 4

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.

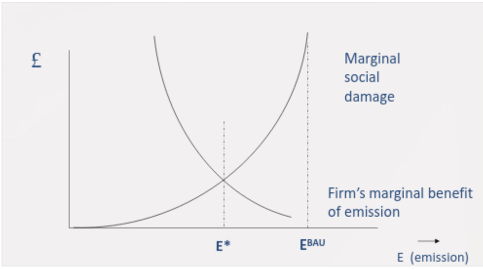


Figure 5

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)

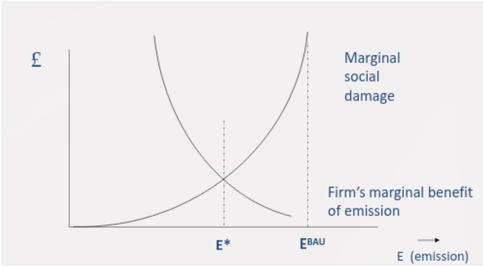


Figure 6

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)

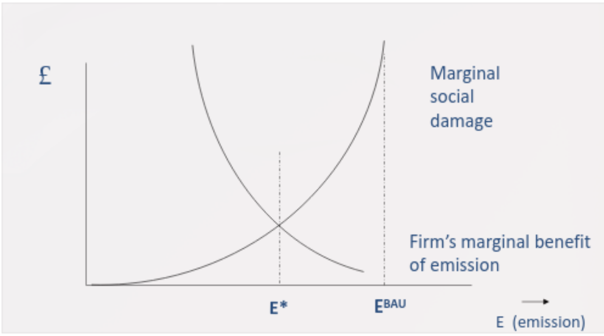


Figure 7

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* → A* abatement (price) and vice versa with quantity, allow E* emissions

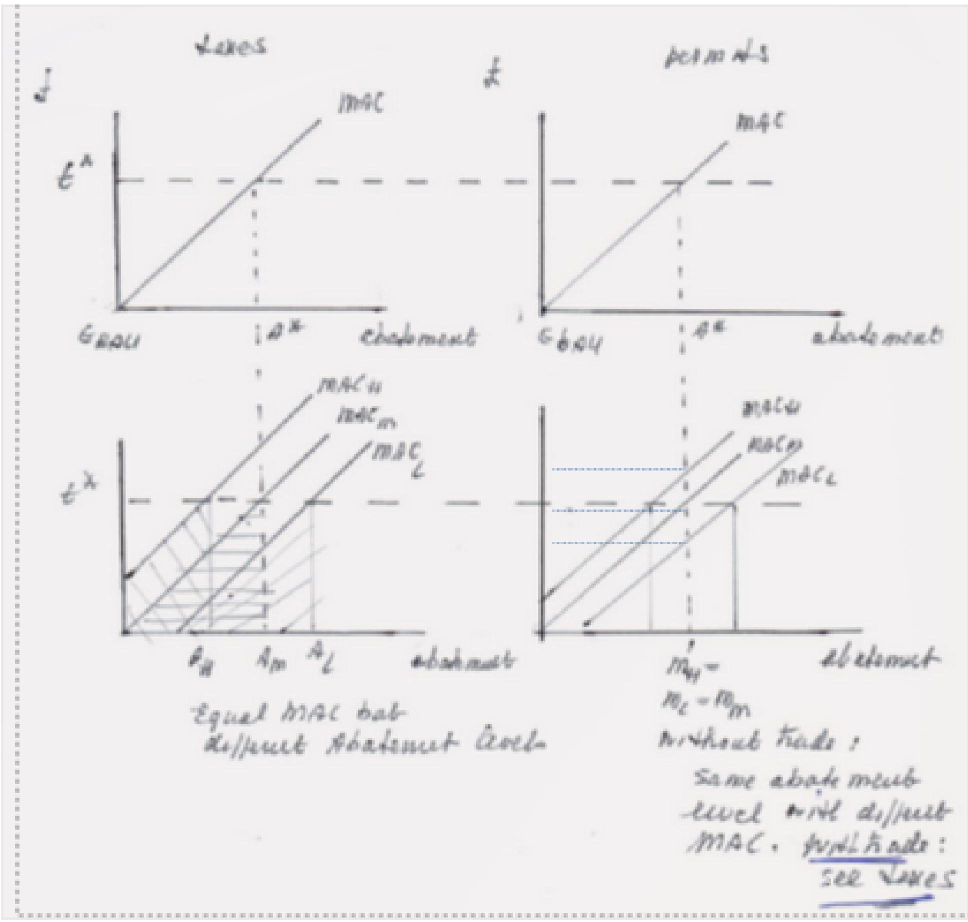


Figure 8

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.

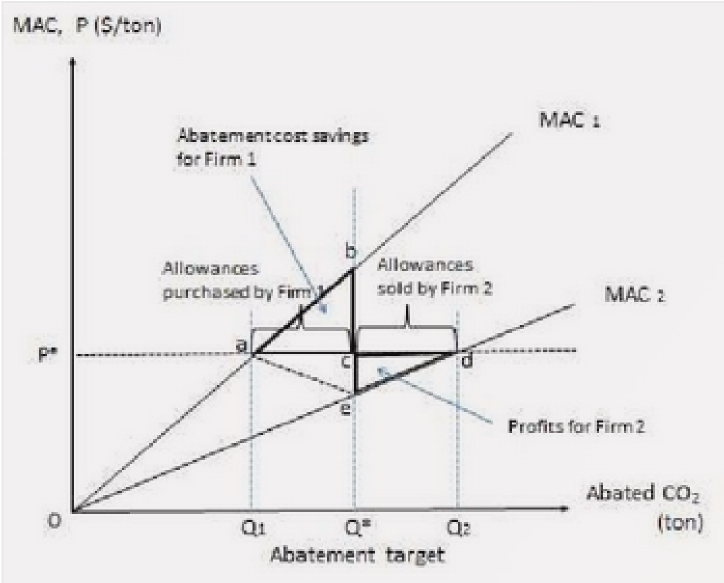


Figure 9

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

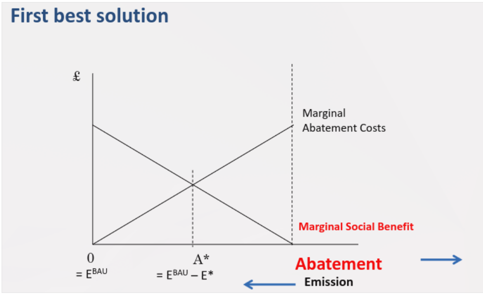


Figure 10

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

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

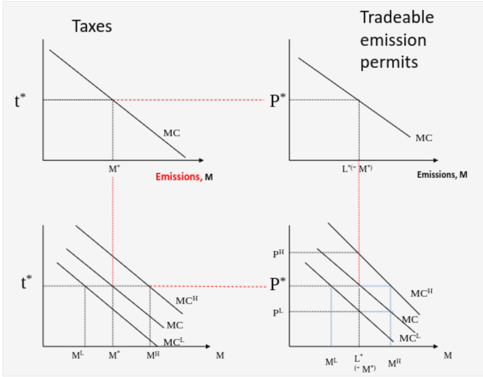


Figure 11

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

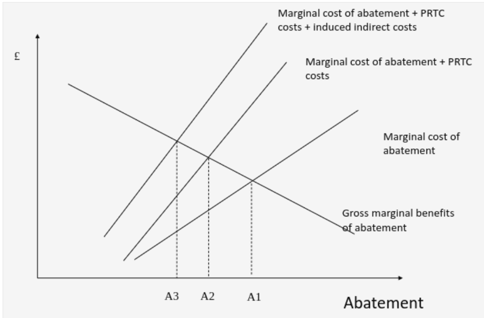


Figure 12

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

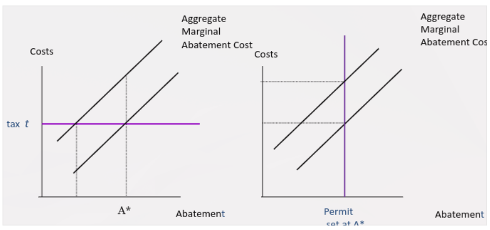


Figure 13

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

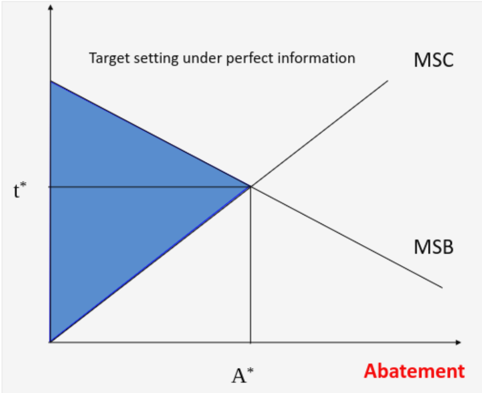


Figure 14

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**

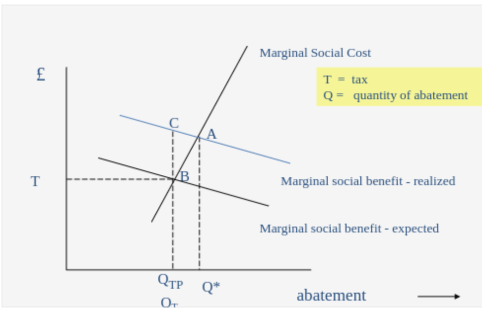


Figure 15

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**

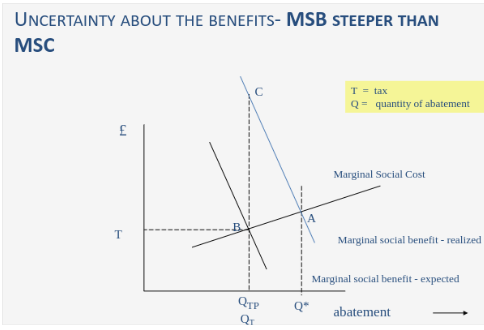


Figure 16

Uncertainty about benefits, but doesn't help

Scenario 3 - uncertainty about cost - MSC steeper than MSB

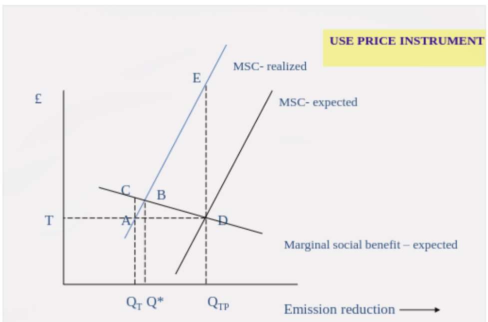


Figure 17

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

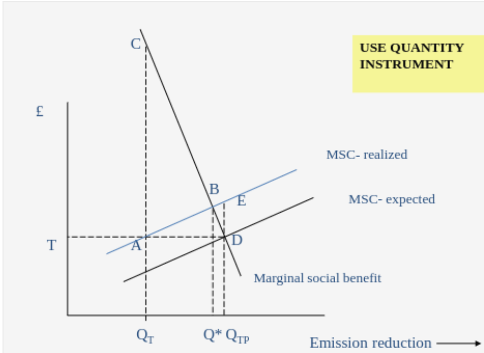


Figure 18

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.

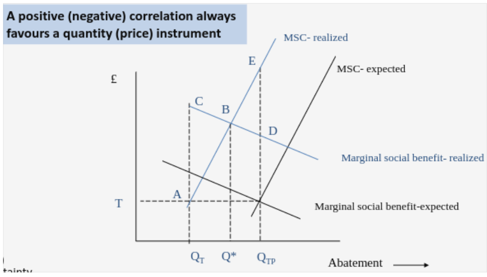


Figure 19

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.

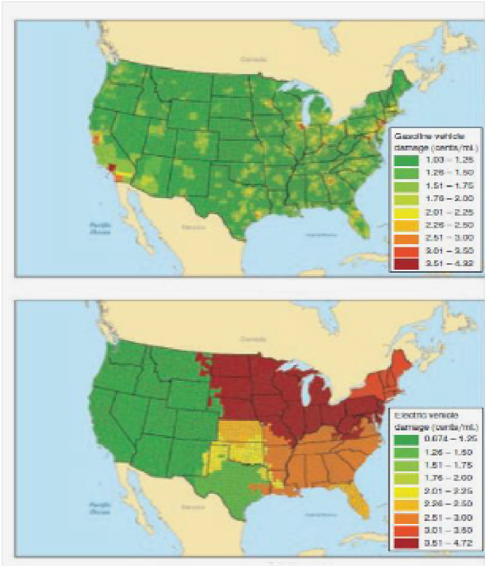


Figure 21: Differences in fossil fuels use by power plant for EVs vs FF Cars

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

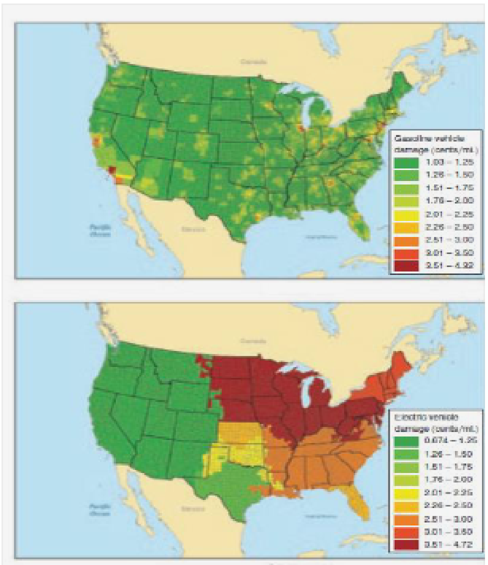


Figure 22: Second Best EV subsidy by County

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

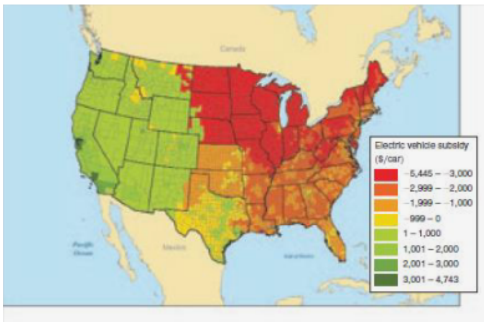


Figure 23

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

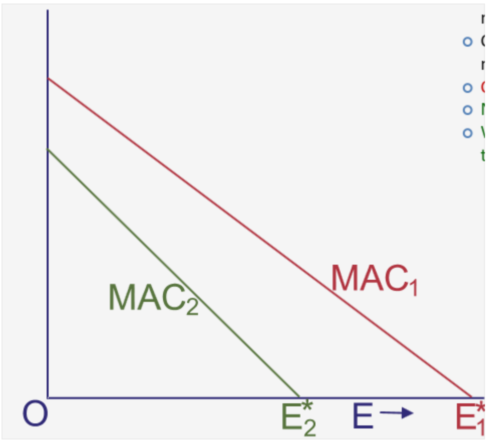


Figure 24

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

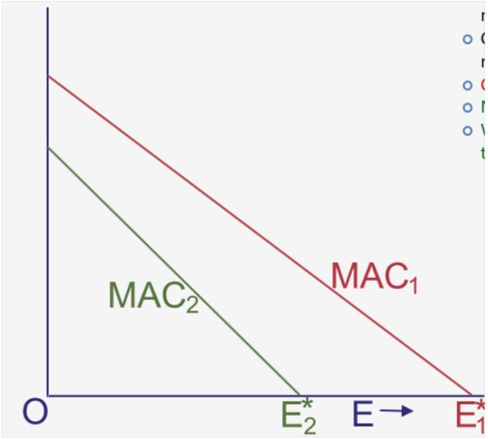


Figure 25

Grand parented permits

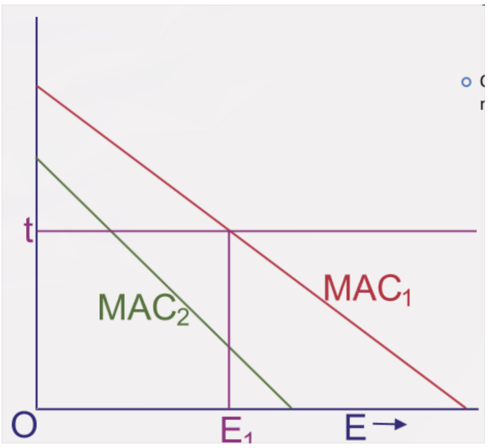


Figure 26

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

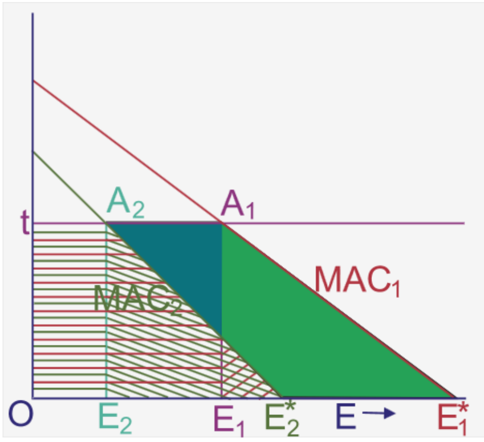


Figure 27

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

Wed 28 Feb 09:04

[LECTURE 5] [Reading]

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 → 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)
- $\Delta SW(j) = SW(U_{10}, U_{20}, \dots, U_{i0}, U_{N0}) - SW(U_{11}, U_{21}, \dots, U_{i1}$

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

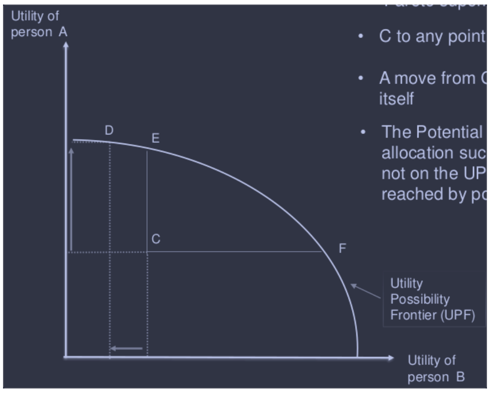


Figure 28: Potential Pareto Criterion

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.

$$\sum_i \Delta y_i \geqslant 0$$

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

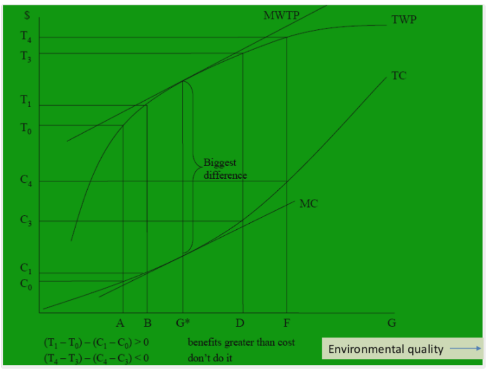


Figure 29

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

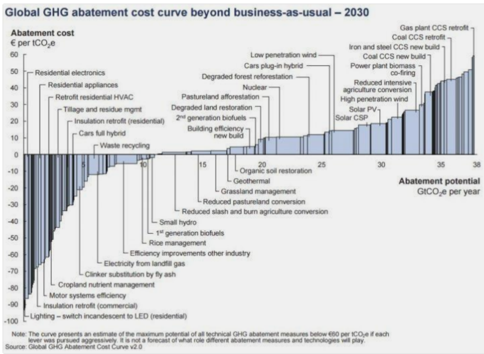


Figure 30: Mckinsey Curves

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

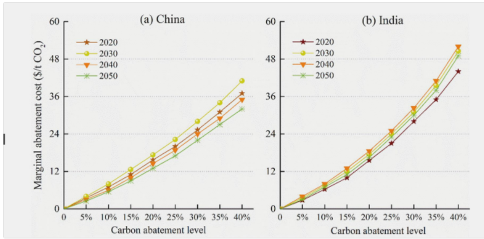


Figure 31: Typical marginal abatement cost curves

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

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

Then introduce

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

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

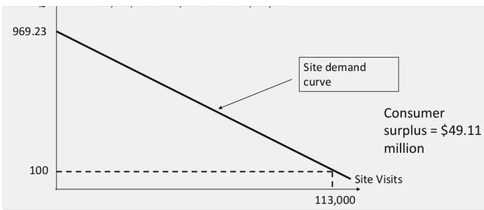


Figure 32: Linear demand function

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

Lecture 6: Environmental Cost Benefit Analysis (cpd) and alternative methods

Mon 06 May 20:20

Recap

- CBA is the identification, economic evaluation and qualitative comparison of the advantages and disadvantages of public policies and public sector projects based on their net contributing to society's overall well-being
- Conventional CBA incorporates the normally reasonable assumption that the project under examination is incremental in the sense that it will not significantly change relative prices
- A program is deemed to be efficient when the **present discounted value** of all benefits is greater than the discounted value of call costs. Thus, present discounted value of net benefits (NPV) > 0. If multiple projects, then ranking is based on the NPV
- For environmental projects, CBA implies a valuation of the expected environmental improvements using a variety of methods based on revealed preferences and stated preferences
- Four informational inputs needed for calculating NPV
  1. Cost schedule
  2. Benefit schedule
  3. Time horizon
  4. Discounting

How to compare costs and benefits that occur at different points in time We have discussed the impact of emissions in terms of social damages. And the cost of abatement

Many policies and public projects last many years. The cost may be now and the benefits (reduction of social damages far in the future

we need to compare future and present consumption

The economic solution concept involves :

- **Discounting** - describes the valuation in present day terms of future outcomes
- Discount factor d - value today of one unit in the future
- Discount rate r - gives the rate at which the future is discounted
- It holds that

$$d_t = \frac{1}{(1+r)^t}$$

Benefits minus Costs per year in billions				
Policy	Year 0	Year 1	Year 2	Year 3
A	-30	+20	+10	+10
B	-30	+10	+20	+20

Figure 33: NPV Example: two abatement policies

Using a social discount rate of 5% we get:

$$NPV(A) = \sum \frac{(B-C)t}{(1+r)^t} = -3 = +\frac{20}{1.05} + \frac{10}{(1.05)^2} + \frac{10}{(1.05)^3} = 6.76$$

Choice of discount rate There is also disagreement about the social discount rate that should be used in CBA. This is especially true where the project or policy lifetime is long, as it often is with projects with environmental consequences, such as energy generation and their externality products, or climate change policy.

Value today of £100 in the future

	Time horizon (Years)			
Discount rate %	**25**	**50**	**100**	**200**
0.5	88.28	77.93	60.73	36.88
2	60.95	37.15	13.80	1.91
3.5	42.32	17.91	3.21	1.03
7	18.43	3.40	0.12	0.0001

Figure 34

$$\sum_{0}^{\infty} \frac{1}{(1+r)^t} = \frac{1}{r}$$

	r					
t	**r=0.001**	**r=0.01**	**r=0.02**	**r=0.03**	**r=0.04**	
10	0.9901	0.9053	0.8204	0.7441	0.6756	
20	0.9802	0.8195	0.6730	0.5537	0.4564	
30	0.9705	0.7419	0.5521	0.4120	0.3083	Children
40	0.9608	0.6717	0.4529	0.3066	0.2083	
50	0.9513	0.6080	0.3715	0.2281	0.1407	
60	0.9418	0.5505	0.3048	0.1697	0.0951	Grandchildren
70	0.9324	0.4983	0.2500	0.1263	0.0642	
80	0.9232	0.4511	0.2051	0.0940	0.0434	
90	0.9140	0.4084	0.1683	0.0699	0.0293	
100	0.9049	0.3697	0.1380	0.0520	0.0198	

Figure 35: selected discount rates

Example : Climate Change

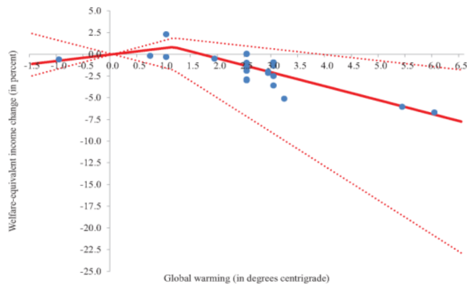


Figure 36: The global total annual impact of climate change according to Tol (2018)

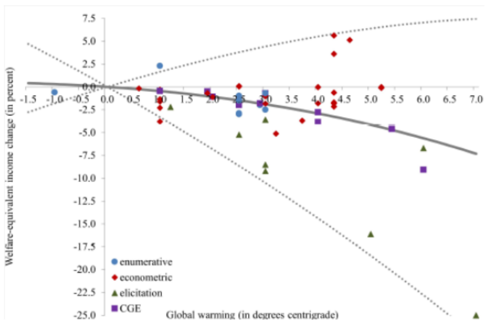


Figure 37: The global total annual impact of climate change according to Tol (2024)

Impact is expressed in welfare-equivalent income change as a function of the global annual mean surface air temperature since pre-industrial time

These diagrams show that the potential impacts from unchecked climate change (unchecked global emissions) are several percentage points of global economic output Whilst compelling for acting on climate change, they provide little guidance in comparing the benefits of differences in regulation or in assessing the benefits of more stringent policies.

We therefore need a measure of damages of much smaller changes in emissions, so we consider the damages from 1 t of carbon dioxide today.

The social cost of carbon (SCC) is the present value of all future social damages of carbon dioxide emission today (usually given in $ per ton of CO_2). Global per capita carbon dioxide emissions averaged 4.66 metric tons in 2022.

Issues in discounting

Choice of social discount rate

Option 1 : take the market rate Or, the real interest paid on certain investments, representing the productivity of capital in the market equilibrium

Comes with difficulties, namely that in the context of environmental policy evaluation and long time horizons, the market rate might not reflect preferences of society correctly because of :

- Market failures and market imperfections
- Super-reasonability of government: Government has to represent future generations as well as current generations (while only current generations are represented on the market)
- Dual role of individuals: in their role as a citizen, individuals are more concerned about future generations in their day-to-day activities as a consumer or producer (which are reflected in the market)

Option 2 : Social Discount rate Find the determinants of the discount rate from economic (or ethical) considerations

Reasons to discount

- Pure rate of time preference (time discounting or utility discounting) IE, pure impatience - rather consuming now (and getting utility) than later, we let ρ denote pure time preference
- Economic growth - if you are richer in the future, £1 today is worth more now to you than in 10 years under a concave utility function, so let g denote economic growth
- Uncertainty (more later)

Determinants of the Social Discount Rate On the formalisation of reasons for social discounting

Starting from the two periods case and a situation where markets function optimally:

$$
\begin{aligned}
U(c_1, c_2) = U(c_1) + \frac{1}{1+p}U(c_2) \\
W = c_1 + s \\
c_2 = (1+r)s
\end{aligned}
$$

Where consumption c in $t = 1$ and $t = 2$ can include environmental damages and benefits. W is per capita income, s is savings, the utility function is the same for all periods, corresponds to stationary assumption and ρ characterises pure time preference (impatience) and r denotes productivity of capital.

Going back the old necessary conditions for an economic equilibrium:

- The marginal rate of substitution **MRS** of two goods has to equal the **price ratio** of these two goods which in turn has to be equal to the
- Marginal rate of transformation

However, this time we take the first good to be consumption in $t = 1$ and the second good consumption in $t = 2$

On the consumption side,

$$\text{With} U(c_1, c_2) = U(c_1) + \frac{1}{1+p} U(c_2) \text{we get}$$

$$MRS = -\frac{\frac{\partial U}{\partial C_1}}{\frac{\partial U}{\partial C_2}}$$

For example $U(c) = \ln(c)$

$$MRS = -(1+p)\frac{\partial U'(c_1)}{\partial U'(c_2)} = -(1+p)\frac{U'(c_1)}{U'(c_1 + gc_1)}$$

$$-(1+p)\frac{\partial U'(c_1)}{\partial U'(c_1) + U''(c_2)gc_1} \quad \text{assumes } \gamma \text{ is small}$$

$$= -(1+p)\left[\frac{1 + U''(c_1)c_1}{U'(c_1)g}\right]^{-1}$$

Then define

$$\theta = \frac{-U''(c_1)c_1}{U(c_1)} = -\frac{\frac{dU'(c_1)}{U'(c_1)}}{\frac{dc_1}{dc_1}}$$

Then θ is the percentage change in marginal utility of one percent change in consumption (the consumption elasticity of marginal utility)

Consumption side: With the definition of θ we have

$$MRS = -(1+p)\left[1 + \frac{U''(c_1)c_1}{U'(c_1)}\right]^{-1} = -(1-p)(1-\theta g)^{-1}$$

From the production side, we have $c_2 = (1+r)s$ with r the return on investment, we get

$$MRT = -(1+r)$$

So with MRT = MRS we have

$$-(1-p)(1-\theta g)^{-1} = -(1+r) \equiv r = p + \theta\gamma + r\theta\gamma \approx \rho + \theta\gamma$$

Then, in the optimal inter temporal allocation

$$r = p + \theta g$$

Which is the **Ramsey Equation** Where

- r is the productivity capital (return on investment) or the consumption discount rate
- p is the utility discount rate - a characteristic of individual preferences
- θ is the elasticity of marginal utility for the instanter nous utility function - defining the extent to which marginal utility changes as consumption grows
- g is the growth rate of consumption / income

And note that $g > 0 \rightarrow r > p$ so r would be positive for $p = 0$ and $g = 0 \rightarrow r = p$

We also need to take into account **uncertainty of the economy**, where

- The main argument can be illustrated using the Ramsey equation

$$r = p + \theta g$$

- Two types of uncertainty matter
  - One that relates to the growth rate of consumption g
  - One that relates to the utility from this consumption θ
- This leads to an extended Ramsey equation

$$r = p + \theta + \breve{g} - 0.5\theta(\theta + 1)\sigma^2 \quad \text{extended ramsey equation}$$

  where $\breve{g}$ denotes the mean growth rate and σ^2 its variance

Recent developments **Normative perspective** : consider environmental good and produced good and the fact these aren't perfect substitutes (Baumgartner et al, 2015)

Environmental goods have to be discounted at a lower-than-average rate and produced goods at a higher than average rate

This reasoning is equivalent to arguing that due to increasing relative scarcity, the monetary value of the environmental good increases in the future

The Social discounting rate

- Descriptive approach $r = \rho + \theta g$ where we use the market rate for r. We derive p and θg by reverse engineering; p of the order 0.03, p = 3%
- The prescriptive approach. Decide on p and θ. The growth rate $g(t)$ then determines the corresponding real interest rate $r(t)$. arguments for deciding on p and θ generally rely on ethical reasoning. the prescriptive approach : p of the order 0.001, p = 0.1%
- Prescriptive approach with uncertainty $r = p + \theta\breve{g} - 0.5\theta(\theta + 1)\sigma^2$ the prescriptive approach under uncertainty means that the social discount rate is declining with time

Just as economic fundamentals (interest rate, growth, risk) vary from country to country, so do the social and individual preferences over them, as a consequence the SDR varies across countries in its level and specific theoretical approach

Whilst there are many ways to determine the SDR, in practice governments and supranational organisations tend to rely on the social opportunity cost of capital approach to determine the appropriate discount rate or not he social rate of time preference approach.

5 HOW DO ENVIRONMENTAL POLICIES AFFECT ECONOMIC PERFORMANCE?

Over the last 2 decades, there has been a general shift toward using lower SDRs under both of these 2 approaches. These lower SDRs contribute to more weight being placed on future well-being in th appraisal of public policy, programs and projects.

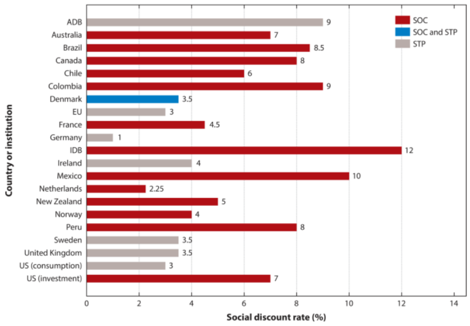
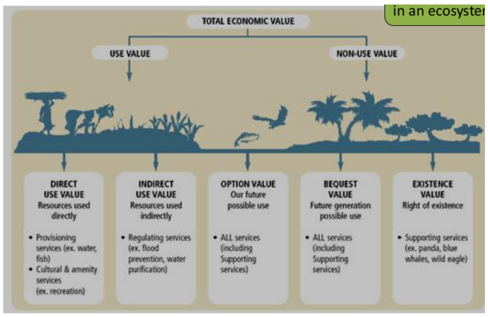


Figure 38: a review of social discounting, groom et al (2020)

SOC is primary a production side approach, whilst STP is primarily a consumption side approach.



Example : Valuation of ecosystem services Where TEV is the net value of a change in ecosystem to humans When looking at gross increases in ecosystem benefits, we should assess WTP (a constant valuation). When looking at reduced extraction of forest product, we should use TC methods, and when looking at cost of conservation measure, we should use the conventional market approach.]

But, can we really place a monetary value on the flow of ecosystem goods and services

- Complexity and interdependence - social and ecological systems may be too complex and inter-dependent to quantify comprehensively through benefit / cost analysis, and it may be possible to adequately measure impacts only when an element of a larger ecosystem is under analysis
- Commensurability - using CBA as the single deciding factor in setting policy assumes implicitly that the values of all object and states of affairs are commensurable, meaning that they can be ranked based on a single characteristic of value such as money or utility.
- Future vs Current Generations : what discount rate is appropriate when bring future impacts into present discounted value?

- Marginal utility of money : when we monetise benefits and costs without regard to who receives them, we are implicitly assuming that a dollar generates the same incremental gain in pleasure or marginal utility to all people

[slides]

actual use of CBA in policy practice

Alternatives to CBA

Lecture 7: Environmental Cost-Benefit Analysis and Alternative Methods

Mon 06 May 20:21

5.3 Alternative Evaluation methods

Cost effective analysis

Multi criteria methods were developed to reach a decision in the fact of multiple different and incommensurable, going back to Pareto Efficiency. Cost effectiveness analysis is the simplest version.

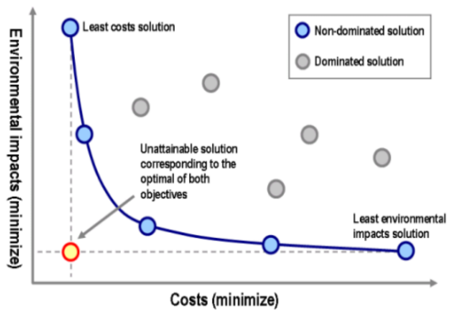


Figure 39

If we cannot capture the benefits in monetary terms, Pareto came up with the concept of MCDA. Cost effectiveness is particularly appropriate when we cannot capture the effect in monetary terms. Say effect of biodiversity or reducing pollution to certain level.

In the diagram we want to minimise cost of achieving this

An example of cost effectiveness analysis is capturing urban water runoff So with urban drainage, increased urbanisation leads to problems with water quality (flood control) and water quality (pollution control). We would need to adapt to extreme events, if it rains two feet or it didn't rain at all. Traditional policy options are centralised large scale practices (constructed wetlands, retention pounds). Where economies of scale are in place but impinge on the re-development and or / on private land

So the question is what practices to use?

The method would be to look at:

- The total costs of each practice to control urban storm water (rain garden, constructed wetland, sand filter etc)

$$\text{total construction cost} + \text{maintenance costs} + \text{land opportunity costs}$$

- Assume practice functional for x years minimum

- Assessment by location : are to be covered and imperviousness (CNN = curve number)
- Calculate present value of costs, assuming discount rate of r %
- Assess removal effectiveness of practices
- Calculate annualised cost per acre treated and per percent of pollutant removed

Wossink and Hull 2003 - finding the size of the watershed, the soil type, the imperviousness of the watershed as described by CNN range, the pollutant of main concern, and the amount and price of land for the structure all influence practice selection.

Conservation Planning The problem is the failure to consider both cost and ecological benefits, which is common in many conservation initiatives. For example, those working in conservation may focus solely on the ecological benefits that each parcel contributes toward the policy objective, while governmental agencies often focus on acquiring parcels as cheaply as possible (emphasising maximum land acquisition with a given budget)

Considering the costs and ecological benefits simultaneously would lead to, by definition, a more cost efficient environmental policy outcomes

Therefore, whilst benefits of intervention may only be expressed in biophysical / ecological units (ie biodiversity), the costing of measures is usually feasible. In those cases, CEA is the appropriate method to compare alternative measures. And if there are multiple objectives, CEA can be applied if those objectives can be added up, if not then MCDA should be used.

Multi Criteria Methods

Beginning following dissatisfaction with decision supporting techniques that rely on single features of merit, EG NPV (CBA), B/C ratio. Today it is consistent with deliberative analytical methods.

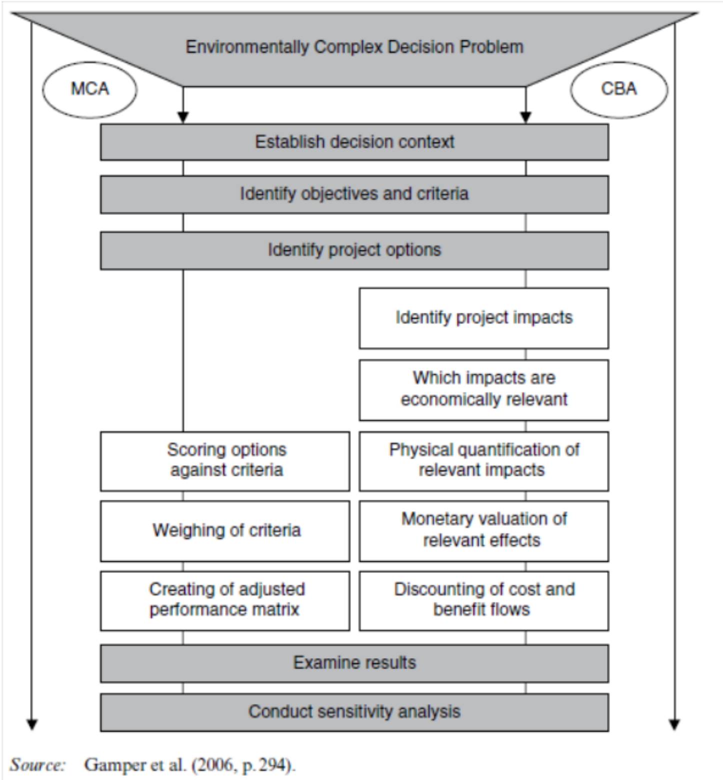


Figure 40: Comparison MCA vs CBA of the steps involved

Figure shows similarities and differences. Initially, steps are similar, CBA identifies positive and negative with single evaluation criteria quite differently in monetary terms. Making input elements straightforward to compare, in monetary terms. But this demands a high degree of rigour to retain validity and reduce biases, so a price on biodiversity may be impractical in monetary terms, thus leaving some values out of the equation altogether (and technically invalid) MCDA reflects the multiplicity, especially useful when soft or intangible factors. Putting pacts in monetary terms may be very difficult or contentious.

MCDA MCDA encompasses a multitude of methods, with 4 common steps

1. What is the issue and what are the options to be considered
2. What are the criteria - what is expected from the project / intervention
3. Weight - what is the weight of each criterion
4. Comparison and ranking - evaluate the options against criteria, do sensitivity analysis, and establish ranking among alternatives

MCDA provides a framework for breaking down a complex decision into more manageable components: defining and understanding the relationship between these components, addressing each component, and then combining them to indenter solutions

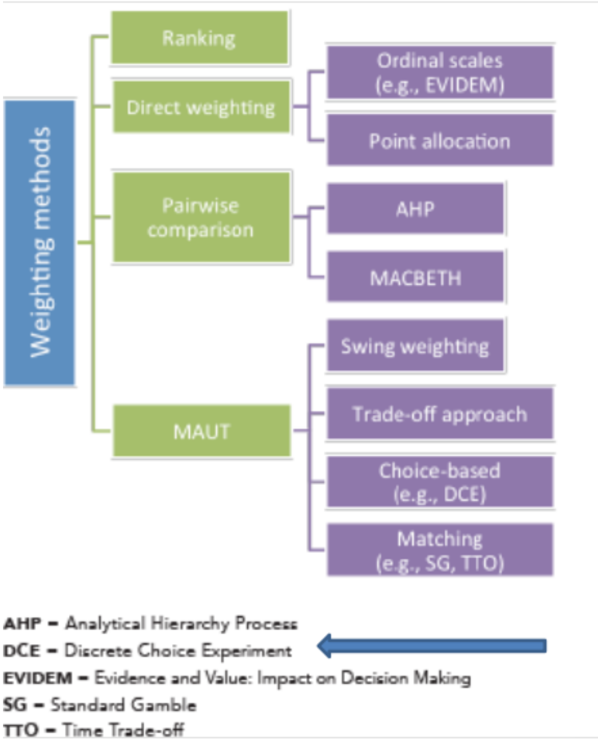


Figure 41: How weights are generated (different across methods):

Weighting

1. Ranking : stakeholders are asked to rank criteria, and assumptions are made to translate ranks into weights
2. Direct weighting : stakeholders provide their assessment of the importance of criteria by, for instance, giving each criteria a weight between 1 and 5, or by allocating 1000 points across the criteria
3. Pairwise comparison : stakeholders compare pairs of criteria, indicating their relative importance. IE the analytical hierarchy process asked stakeholders to rate pairs of criteria on a 9-point scale, where 1 indicates the criteria are equally important and 9 indicates that one criteria is extremely more important than the other
4. Multi attribute utility theory : Stakeholders' preferences are elicited in a Discrete Choice Experiment (DCE) or a best worst scaling experiment that provides respondents with choices between hypothetical interventions, from which weights are inferred

Usefulness The primary aim of MCDA is to develop models of decision-maker objectives and their value trade-offs so that alternatives under consideration can be compared in a consistent and transparent manner. The process is often more important than numbers. MCDA enables decision makers to think systematically.

This elicits several benefits

- Ensuing that all relevant criteria are considered by decision makers

- Providing a transparent synthesis of both quantitative and qualitative evidence on performance of options against criteria

Thus, helping with value focused thinking and value clarification.

Outlook MCDA is consistent with deliberative-analytical methods

- Identifying key stakeholders that should be involved and agree on a shared definition of the problem
- Quantifying stakeholders' priorities and preferences, an element of decision problems that if often not addressed systematically
- Fosters a shared understanding of the problem, identifying areas of important disagreement
- Forms a transparent link between judgements and decisions

However, MCDA is **not suitable for situations of large preference heterogeneity**. To find areas of common ground there is a need for a deeper understanding of the value plurality underlying the different position and their relations to affected ecosystem services. In these situations, Q-method might be useful, which identifies groups of people with similar or diverging perspectives and is increasingly used for analysing resouce conflicts.

Lecture 8: International Environmental Issues : trans boundary pollution, pollution havens, trade and the environment

Mon 06 May 20:21

5.4 Trans boundary Pollution / International Environmental Externalities

Trans boundary Pollution

- International externalities are the unintended and uncompensated by-product of a country's consumption and production on another country's welfare
- natural and environmental resources do not respect administrative borders
- such as climate change, ozone depletion, overfishing of oceans, biodiversity

Can use a simple example to show why these are different from economic point of view, country X and country Y, emissions indicated by m, helps to think of air pollution created by fossil fuels.

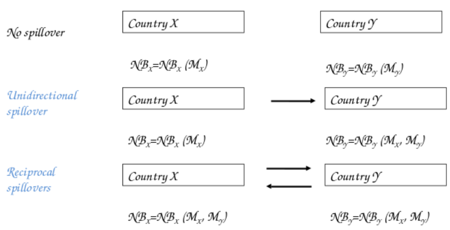


Figure 42: Trans boundary Pollution

In country Y, situation is different, emission from country X also affects the total amount of emissions by both its own and X

In the bottom row, reciprocal spillovers, emissions from country affect both countries

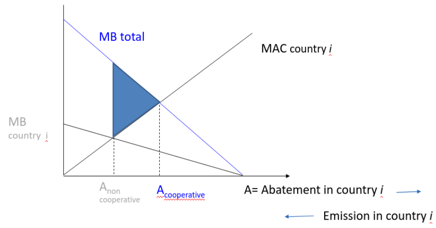


Figure 43: Comparison of the non-cooperative and full cooperative solution to a transboundary pollution problem

Or, in diagram form. Showing us what determines the amount by which abatement exceeds cooperative and non-cooperative And magnitude of efficiency gain is the blue triangle

Depends on relative slope of MB curve and slope of MB curve, and also on the number of countries affected by emissions in country I

co-op vs none co-op **non Co-op** For each country, the optimal level of emissions is such that the marginal benefit of emitting equals the marginal cost to the country itself The necessary conditions is $dNB_i\,(M_i) = 0$ And the spillover effects will be ignored and these don't influence the chic of emission level

Co-op For each country, the optimal emissions are such that the marginal benefits of emitting equal the sum of the marginal costs of its emission to all countries. This would be welfare maximising overall, but there is no international institution that can force this on sovereign countries

International Externalities These are different since typically negative externalities are internalised at the national level by government intervention. However, this doesn't work for international externalities, as for any public good, too little is provided in the 'private solution' Thus, there is a disparity between developed and less developed countries which becomes particularly important in the context of international externalities. These issues require international action, and thus it is natural to ask how to design a self-enforcing international agreement in that case

International Environmental Agreements

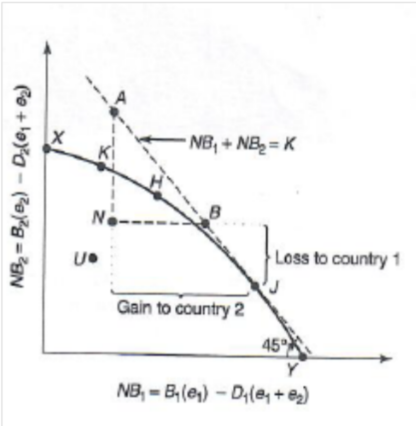
1. the agreement should be self enforcing
2. each country should be better off as part of the agreement than not
3. pollution levels obtained under the agreement should be a pareto improvement over the status quo, and ideally, pareto optimum

Self Enforcing International Environmental Agreements Two countries, i = 1,2 emitting pollution e_i

- damage to each country $D_i(e)$ where $E = e_1 + e_2$
- Benefits to each country i from being able to emit $B_i(e_i)$
- net benefit to each country i : $NB_i = B_i(e_i) - D_i(E)$ depends on $E = e_1 + e_2$

Two non-cooperative emission levels

1. **U** - no regulation at all (unregulated amount of pollution)
2. **N** - regulation as far as damages within same country are concerned



In figure above there is ‘gain to country 1’ and ‘loss to country 2’

Figure 44: Self-enforcing International Environmental Agreements

This figure presents the net benefits to each of the two countries at an emissions level from an international agreement where N is the non cooperative regulation and U is the absence of cooperation.

Figure gives possible benefits from particular emissions level

The maximum attainable level of net benefits us the curve XY, the pareto frontier Where each point on frontier XY is the solution to

$$\underset{e_1,e_2}{max} B_2(e_2) - D_2(e_1 + e_2) \quad \text{such that } B_1(e_1) - D_1(e_1 + e_2) \geqslant \tilde{\mathbf{N}}$$

Where $\tilde{\mathbf{N}}$ is the level of net benefits

Net benefits are better for N, than for U (as expected). But also we see, we can do better than N, since each point is a solution where we guarantee net benefits to country 2 and ask how large can we make the benefits for country 2? Thus it would be desirable for the agreement to be on the frontier

We should try to find largest total gain, here at point J, where joint net benefit is maximum, but without possibility of compensation, country 2 would veto any movement like this. Compensation is politically very difficult, but allows us to differentiate between perfectly and imperfectly

Thus leading us to the five conditions in developing and maintain an effective international environmental agreement

1. to locate the pareto frontier
2. to choose a point on this frontier
3. to detect cheating
4. to deter cheating

5. to discourage countries outside the agreement from exploiting it

Negotiations proceed in stages where Stage 1 : the N countries involved decide simultaneously and independently whether to sign an agreement (with an overall target and to form a coalition) Stage 2 : all signatories individually decide on ratification (consent to be bound to a treaty, meaning their national governments have to approve this). And the agreement becomes active once certain number of signatories have ratified (and this covers certain % of total mission) as specified in the agreement

Literature

- extend the two country example to many countries, where each country has a unilateral incentive to pollute and cooperative abatement is optimal
- when countries differ in cost and benefits, it becomes harder to establish a coalition
- coalition is smaller than maximum size, since the more countries join, the larger the incentive not to join
- the coalition will be large (small) when the difference in global net benefits between the cooperative and non-cooperative solution is small (large)
- **transfers** make it easier to forma coalition (side payments). But another way to do this is through trade linkages

Typically, negative externalities are internalised at the national level by governmental intervention. This does not work for international externalities. As for any public good, too little is provided in the 'private' solution. Thus, for an international environmental agreement to work it must provide net benefits for all potential participants, the parties must agree on the design by consensus and also enforce the treaty by themselves

5.5 Relationship between international economics and the environment

Environmental regulation and industry location

Pollution haven hypothesis That the production of pollution intensive goods will locate in countries with weak environmental regulations

Two approaches :

1. **Trade Flows -** do countries with weak environmental regulations hold a comparative advantage in the production of pollution intensive goods, and consequently specialise in their production?
2. FDI flows - do firms relocate their production to countries with weak environmental regulations?

In both cases, empirical tests of the PHH focus on identifying the "pollution haven effect". That is, whether tighter pollution regulation (at the margin) has had a negative effect on the decision of a plant to operate in that county (ceteris paribus) Which is sometimes called the "environmental regulation effect".

However, despite being intuitively plausible, empirical studies have traditionally been unable to identify convincing evidence for the PHH (data issues, estimation issues (endogeneity) and mistaking pollution haven effects for PHH).

Factor endowment hypothesis Pollution intensive industry is often capital intensive and so will locate in countries which are capital abundant. However, countries which are capital abundant are generally industrialised countries with stringer environmental regulations.

Hence, the factor endowment hypothesis will work against the pollution haven hypothesis. Empirical studies of these competing forces find evidence they both determine a country's comparative advantage and tend to cancel each other out.

Testing competing forces Differential stringency of environmental regulation is only one of several motives for firms' location choices. These can also be explained by a country's factor endowments as derived from Hecksher-Ohlin models (which can be extended with cross-country differences in the stringency of environmental regulation). Or, further country characteristics such as market access and upstream and down stream linkages (possibly leading to clustering (New Economic Geography literature))

Mulatu et al (2010) Combines two strands of literature on location motives, HO model of comparative advantages (factor endowments and the laxity of environmental regulation). And the New Economic Geography (NEG), on the importance of market access and upstream and downstream linkages. Using a multiplicative interaction trade model, to weigh the relative strength of these motives

Where the determinant of the share of country i in the total manufacturing production of industry k,

$$S_{ik} = z_{i,k}/\Sigma_i z_{i,k}$$

$$\ln(s_{i,k} = c + \alpha \ln(pop_i) + \Sigma_j \beta^j (x_i^j - \S^j)(y_k^j - \gamma^j) + \varepsilon_{i,k}$$

Where j is the potential interaction channels, x is the country characteristics, y is the associated industry attributes, § is the neutral country characteristic level, cut off point and γ is the neutral industry attribute, cut off point

The key interest for the PHH debate is the effect of a country's characteristic on firm location

$$\frac{\partial \ln(s_{i,k})}{\partial x_i^j} = \beta^j (y_k^j - \gamma^j) = \beta^j y_k^j - \gamma^j$$

Other explanations for weak PHH evidence Kelenberg (2009) considers the fact that environmental regulations and trade policy are often determined by countries competing strategically. They estimate a model using data over 1999-2004 that account for the **endogeneity** of environmental and trade policy (policy in one country depends on policy in another). Finding a substantial pollution haven effect for US multi nations in foreign countries. Where, of the destination countries in the top 20th percentile in terms of US multinational production growth, 8.6% of that growth can be attributed to falling relative environmental stringency and enforcement levels.

International trade and the environment

Answering questions such as what are the effects of trade liberalisation on the Environment, whether this is the direct composition effect where a country specialises according to comparative advantage. Or, the indirect growth effect where trade liberalisation leads to economic growth. To answer whether free trade is good for the environment, we must also ask **if economic growth is good for the environment**.

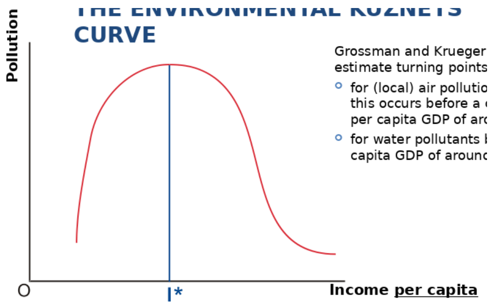


Figure 45: Environmental Kuznets Curve

Grossman and Krueger (1993, 1995) estimate turning points. For local air pollution, they find this occurs before a country reaches \$6000 per capita GDP. For water pollutants before per capita GDP of \$8000

Following Grossman and Krueger, a substantial literature developed on the environmental kuznets curve. Finding that local pollutants tend to support Grossman and Kruegers findings, however with less or no support for the EKC when looking at global pollutants such as CO_2. There is also a lack of a consensus about the turning point. Leading to a number of important criticisms of the EKC literature, whether econometric issues on the functional form, data quality, role of other covariates of pollution beside income levels.

Although Grossman and Kruegers work lacks explicit theoretical foundations, they identified three underlying forces at work

1. Scale effect - more production means more pollution (holding constant industry composition and production techniques)
2. Composition effect - industry composition changes as countries develop in 3 stages
   (a) Agriculture (clean)
   (b) Industry, physical capital (dirty)
   (c) Services, human capital (clean)

   As rich countries develop and proceed to stage 3, dirty industries may move to poorer countries. However, developing countries cannot keep repeating this
3. Technique effect - as income grows, production methods become cleaner. Environmental quality is a normal good, and so, as income increase the population demands a cleaner environment, leading to a more stringent regulation.

Grossman and Krueger find support for the scale effect, so more production means more pollution. However, an ambiguous effect of the composition effect on pollution. And the possibility of lower pollution levels with economic growth for the technique effect.

Summary

- The relationship between international trade and the environment has been viewed largely through the lens of comparative advantage
- Today's perspective differs little; what is changing is the set of econometric tools and data available

- There has been shift towards examining firm level adjustments to more trade which enables novel decomposition linking changes in emissions to changes in productive activity at the plant, firm, industry and national levels.