Environment economics and policies

EC 506

Chapter 6: Pollution analysis and policy

Introduction: where marginal cost of cleanup is higher

Introduction: where marginal cost of cleanup is higher

Introduction: stock and flow pollutants

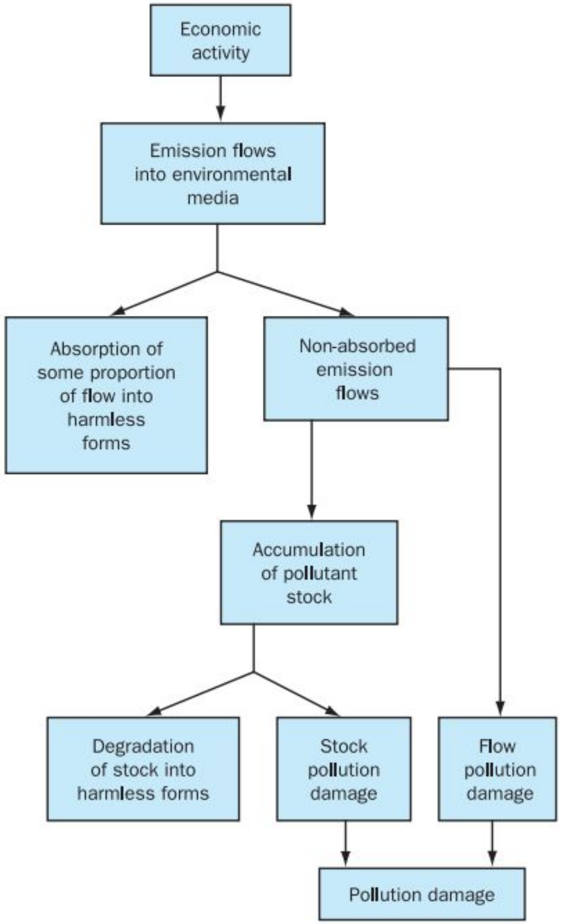
Introduction: stock and flow pollutants

Stock pollutants (deforestation, CO2 concentration) are those that accumulate in the environment over time because they do not degrade or degrade very slowly. This means their concentration increases as more is emitted unless active measures are taken to remove them. Management strategies often focus on long-term solutions, such as reducing emissions through technological innovations, implementing stricter regulations, promoting alternative energy sources, and engaging in activities like reforestation to absorb CO_2. Cleanup and remediation efforts may also be necessary for contaminants that have already accumulated.

Flow pollutants (industry waste, vehicle emissions), in contrast, do not accumulate in the environment because they degrade or disperse relatively quickly. Their impact is more dependent on the rate of emission rather than the cumulative amount. Management typically involves controlling the rate of emission and ensuring that the pollutants do not reach harmful levels. This can include measures such as installing scrubbers on industrial smokestacks, enforcing emission standards for vehicles, and improving waste treatment facilities.

The optimal level of pollution

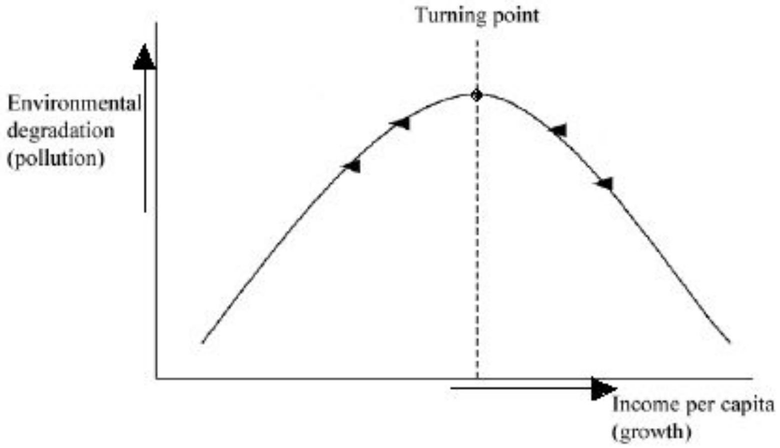
A zero level of pollution is desirable. But, zero pollution is not economically efficient.



How much pollution is too much?

Economic activity generates emissions (or ‘residual’) flows that impose loads upon environmental systems. The extent to which these waste loads generate impacts that are associated with subsequent damage depends upon several things, including:

- the assimilative (or absorptive) capacity of the receptor environmental media;
- the existing loads on the receptor environmental media;
- the location of the environmental receptor media, and so the number of people living there and the characteristics of the affected ecosystems;
- tastes and preferences of affected people.

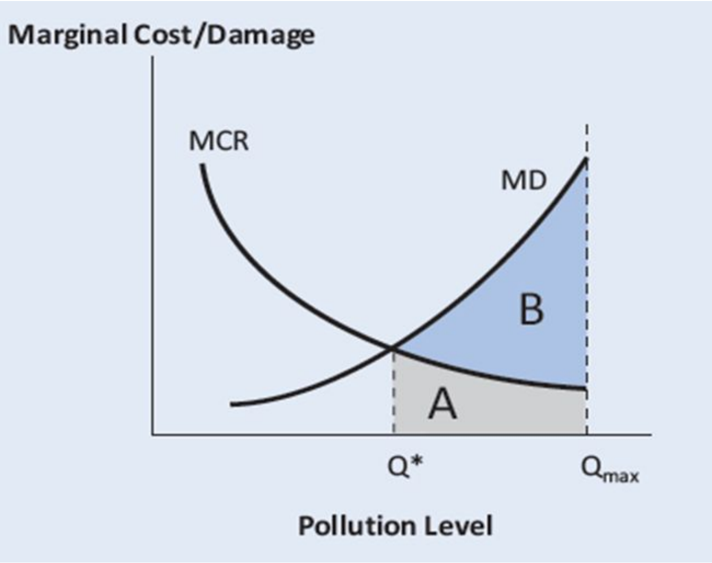


The Environmental Kuznets Curve (EKC) hypothesis: environmental degradation increases in the early stages of economic growth, reaches a peak, and then declines as a country becomes more economically developed. The EKC is named after economist Simon Kuznets, who initially proposed a similar curve to describe the relationship between income inequality and economic development.

How much pollution is too much?

- Pollution cannot be intrinsically beneficial; pollution refers to flows or stocks of harmful residuals. So, other things being equal, less pollution is preferred to more. But it may not be possible to keep ‘other things equal’ as the level of pollution is altered. If producers of goods and services act rationally, they will select private cost-minimising techniques of production. Those techniques will often be ones that generate harmful emissions as joint products.
- With both benefits and costs, economic decisions about the appropriate level of pollution involve the evaluation of a trade-off. Stricter pollution targets will generate benefits but will also generate costs; the trade off-is **optimised at the point where the marginal benefits arising from reduced pollution damage fall to a level equal to the marginal benefit from avoided control costs**.
- **The “optimal” level of production occurs when the externality is fully internalized, resulting in a lower level of production and a lower level of pollution.**
- If the pollutant is unregulated, then firms essentially have no incentive to take steps to reduce their emissions.

Economics of pollution control: unregulated pollution

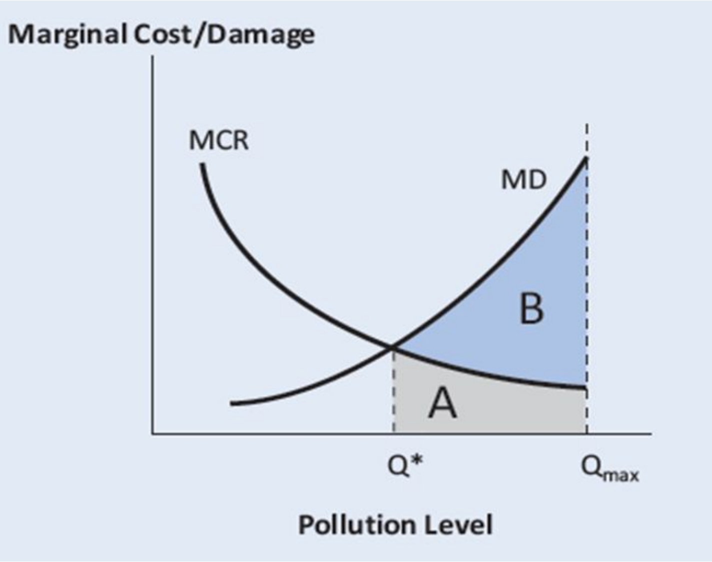


Unregulated level of pollution as *Qmax*

Firms can reduce pollution below Qmax, but it will involve costs such as installing pollution control equipment or substituting low-polluting materials.

As pollution levels are reduced closer to zero, the cost of additional pollution reduction will rise . The marginal cost of pollution reduction (curve MCR) rises as we move from *Qmax to lower levels of pollution.*

Economics of pollution control: unregulated pollution



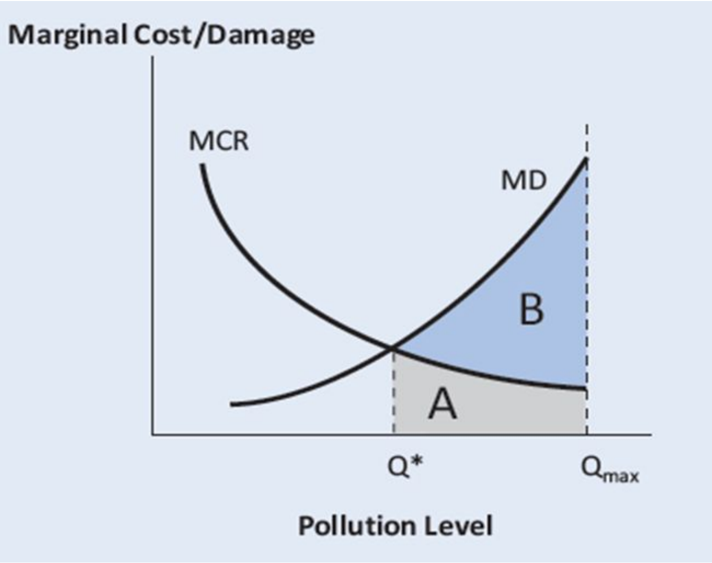
The marginal damage associated with pollution

The marginal damage of pollution starts off small and grows as the level of pollution rises . This is represented by curve MD

The MD curve can also be viewed as **the marginal benefits of pollution reduction**, or the avoided damage.

Starting at Qmax and moving from right to left on the graph, there are very great benefits from the first units of pollution reduced (since the damages caused by these units were very high), and the marginal benefit declines as cleanup proceeds.

Economics of pollution control: unregulated pollution



The optimal level of pollution

At Qmax the marginal damage of pollution is high, while the costs to reduce pollution are relatively low. Social welfare would increase if pollution were reduced below Qmax. This is true for every unit of pollution above Q*, which is the optimal level of pollution.

At Q*, the marginal benefits of pollution reduction just equal the marginal costs. This balancing of marginal costs and marginal benefits is known as the **equimarginal principle.**

The total cost to firms of reducing pollution from Qmax to Q* is area A. The total social benefits of reducing pollution to Q* are represented by areas (A + B). Thus the net increase in social welfare from reducing pollution is area B **.**

Economics of pollution control: instruments

Instrument	Description	Examples
Institutional approaches to facilitate internalisation of externalities		
Facilitation of bargaining	Cost of, or impediments to, bargaining are reduced	Polluter information placed in the public domain
Specification of liability	Codification of liability for environmental damage	Used to compensate for respiratory damage in Japan
Development of social responsibility	Education and socialisation programmes promoting 'citizenship'	Energy-conservation media campaigns; Environmental labelling
Command and control instruments		
Input controls over quantity and/or mix of inputs	Requirements to use particular inputs, or prohibitions/restrictions on use of others	Bans on use of toxic cleansing agents
Technology controls	Requirements to use particular methods or standards	Requirement to install catalytic converters in exhausts. BAT, BATNEEC (3)
Output quotas or prohibitions	Non-transferable ceilings on product outputs	Ban on use of DDT Vehicle quotas. Effluent discharge licences
Emissions licences	Non-transferable ceilings on emission quantities	
Location controls (zoning, planning controls, relocation)	Regulations relating to admissible location of activities	Heavy industry zoning regulations

Economics of pollution control: instruments

Instrument	Description	Examples
Economic incentive (market-based) instruments		
Emissions charges/taxes	Direct charges based on quantity and/or quality of a pollutant	Air pollution charges (e.g. on NO_X and SO_2) Carbon/energy taxes Water effluent charges Noise pollution charges Fertiliser and pesticide taxes
User charges/fees/natural resource taxes	Payment for cost of collective services (charges), or for use of a natural resource (fees or resource taxes)	User charges on municipal waste collection, treatment or disposal Hazardous waste charges Wastewater charges Aircraft noise charges Water extraction charges Congestion pricing
Product charges/taxes	Applied to polluting products	Taxes or charges on vehicle tyres, nuclear waste, plastic bags, other disposables
Emissions abatement and resource management subsidies	Financial payments designed to reduce damaging emissions or conserve scarce resources	Subsidy for energy generated from waste Grants to ecological farming
Marketable (transferable, marketable) emissions permits	Two systems: those based on emissions reduction credits (ERCs) or cap-and-trade	CO_2 emissions from power plants
Deposit-refund systems	A fully or partially reimbursable payment incurred at purchase of a product	Refillable plastic bottles Charges on one-way beer and soft-drink bottles
Non-compliance fees	Payments made by polluters or resource users for non-compliance, usually proportional to damage or to profit gains	Sea dumping of oil from ships
Performance bonds	A deposit paid, repayable on achieving compliance	Australia: mine sites US: open pits
Liability payments	Payments in compensation for damage	Restoration of sites polluted by illegal dumping

Economics of pollution control: instruments

Pigovian (pollution) tax

A per-unit tax set equal to the external damage caused by an activity, such as a tax per ton of pollution emitted equal to the external damage of a ton of pollution, e.g., **Carbon tax**

Danish Carbon Tax on farmers

The main issue with milk production is the methane emitted by cows and their digestive systems, and that is generally a difficult thing to limit. Danish farmers will have to pay taxes for climate-polluting agricultural activities, apply a carbon dioxide tax of 750 Danish kroner (about $100) per ton emitted for all farmers.

Economics of pollution control: instruments

Transferable (tradable) pollution *permits*

Cap-and-trade in Carbon market

Permits allow firms to emit only the level of pollution for which they have permits. Tradability implies that firms can buy and sell these permits, with low-emitting firms able to sell extra permits and high-emitting firms able to purchase additional permits, e.g., **Emission Trading Systems**.

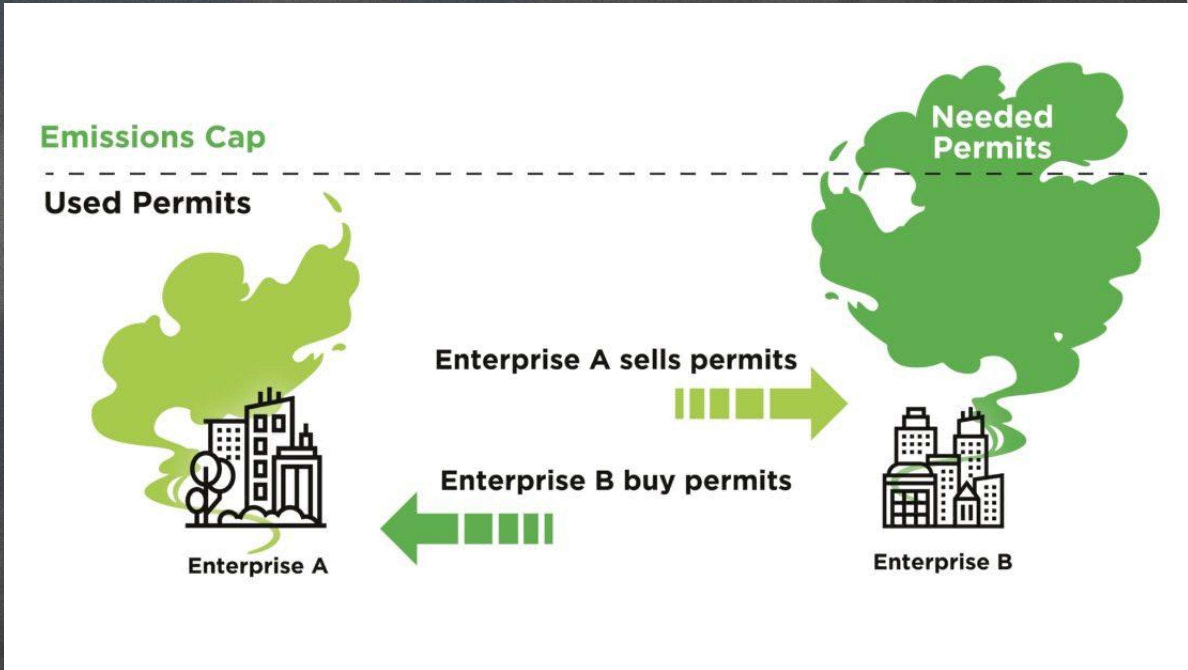
EU ETS system

The EU ETS is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one. The EU sets a cap on the total amount of certain greenhouse gases (GHGs) that can be emitted by the industries covered by the system. The cap is reduced over time to decrease total emissions.

Emission permits, also known as European Union Allowances (EUAs), are distributed to companies. These can be allocated for free, auctioned, or a combination of both. Each EUA permits the holder to emit one ton of CO_2 equivalent.

A cap-and-trade programme lessens the burden for companies trying to meet emissions targets in the short term, and adds market incentives to reduce carbon emissions faster.

When companies meet their emissions "cap," they look towards the regulatory market to "trade" so that they can stay under that cap.



Economics of pollution control: instruments

Pollution (or emissions) standards

Standards require all firms to pollute below maximum allowable levels or reduce pollution to a certain percentage below a baseline level. These standards can also specify a given level of efficiency for products such as appliances and motor vehicles.

The U.S. Clean Air Act and Vehicle Emission Standards

The Clean Air Act of 1990 establishes tighter pollution standards for emissions from automobiles and trucks. These standards will reduce tailpipe emissions of hydrocarbons, carbon monoxide, and nitrogen oxides on a phased-in basis beginning in model year 1994. Automobile manufacturers will also be required to reduce vehicle emissions resulting from the evaporation of gasoline during refueling.

California Zero Emission Vehicle Program

Zero-emission vehicle requirements within ACC II are designed for new vehicles to reach 100% zero-emission and clean plug-in hybrid-electric in California by the 2035 model year. At present, zero-emission vehicle technologies are battery electric vehicles and hydrogen fuel cell electric vehicles.

Economics of pollution control: instruments

Technology-based regulations

These include requirements that all firms use a certain type of technology or install specific equipment

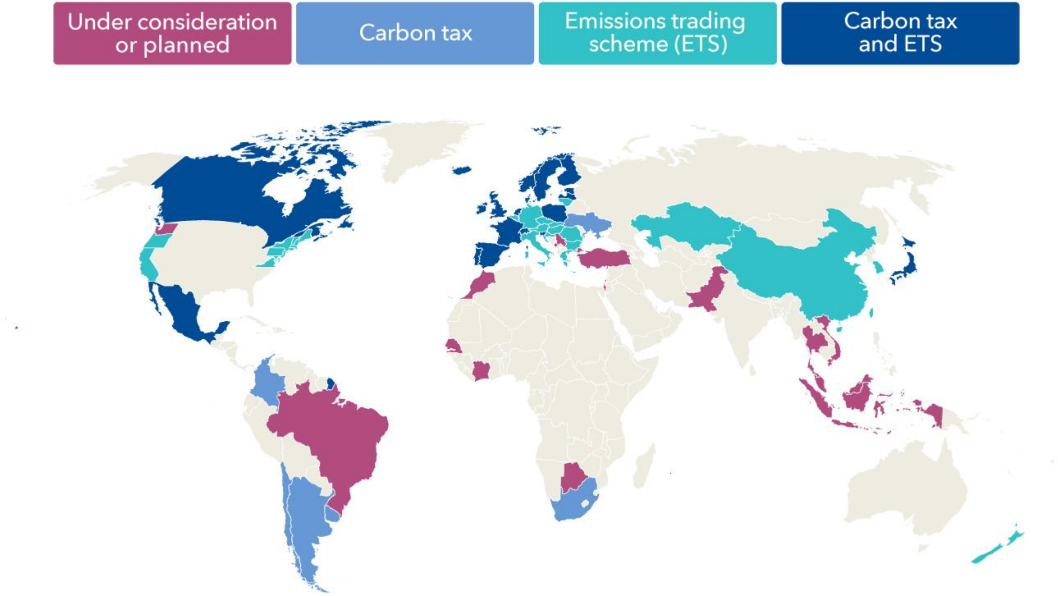
Best Practicable Control Technology, Best Available Control Technology

Wastewater Treatment Plants: BPT may require secondary treatment processes, such as activated sludge systems, to reduce organic pollutants in wastewater. BAT standards may necessitate additional advanced treatment processes, like membrane filtration or chemical precipitation, to remove heavy metals and other toxic substances.

For existing direct dischargers, effluent guidelines are referred to as best available technology economically achievable (BAT).

Carbon price choices

Countries and states are choosing different approaches to carbon pricing based on their own circumstances and objectives.



To keep global warming to no more than 1.5°C – as called for in the Paris Agreement –
emissions need to be reduced by 45% by 2030 and reach net zero by 2050.

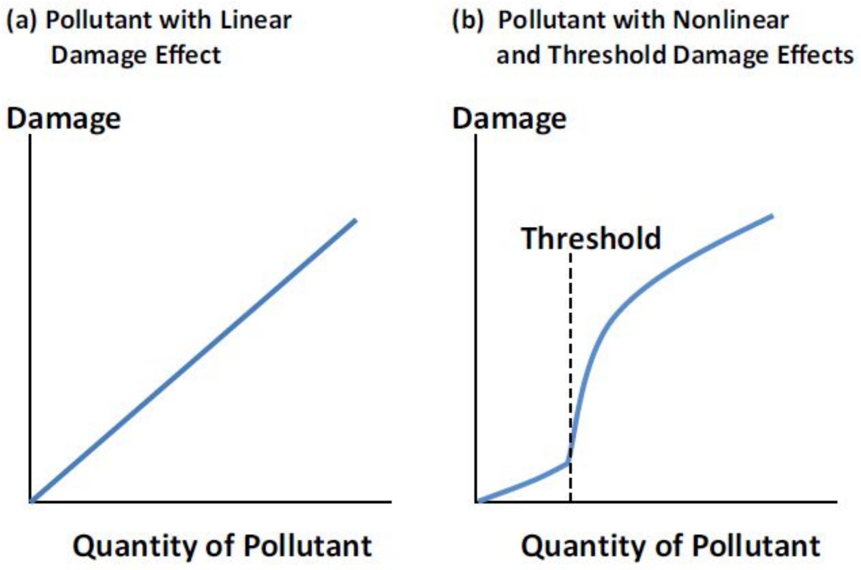
Scale of pollution impacts

One of the major questions in formulating effective pollution control policies is the nature of the pollution involved. Are its effects primarily local, regional, or global?

Do the effects increase linearly with the amount of pollutant, or are there nonlinear or threshold effects?

Fig (a) shows a case in which environmental damages increase linearly as the quantity of pollution increases, for example, the impact of moderate levels of air pollution.

Fig (b) shows a case of a heavy metal pollutant, e.g., lead, a small amount poses serious health risk, thus the threshold for acceptable level is low and damages can increase quite significantly as pollution exceeds this threshold.



Scale of pollution impacts

Local pollutants	Regional pollutants	Uniformly mixed pollutants	Non-uniformly mixed pollutants
Damages from any particular source are usually limited to relatively small groups of people in a circumscribed region Examples: Lead, noise Ineffective policies: market-based (pollution taxes, permits) Effective policies: emission standards, technology based approach	Pollutant that causes adverse impacts distant from where it is emitted, such as due to air transport by winds Example: Sulfur oxides (SOx), acid rain Effective policies: tax, permit scheme, market-based	Any pollutant emitted by many sources in a region resulting in relatively constant concentration levels across the region Example: GHGs Effective policies: tax, permit scheme, market-based	Pollutants that cause different impacts in different areas, depending on where they are emitted, they create hotspots. Example: lead and particulate matter Effective policies: technology based approach, standard set at a local level

Scale of pollution impacts

Flow pollutants

A pollutant that has a short-term impact and then dissipates or is absorbed harmlessly into the environment.

Example: industry waste, vehicle emissions, noise

Effective policies: emission standards, technology based approach

Stock or cumulative pollutants

A pollutant that does not dissipate or degrade significantly over time and can accumulate in the environment

Example: carbon dioxide, chlorofluorocarbons.

Effective policies: tax, permit scheme, market-based

Global pollutants

A pollutant that can cause global impacts

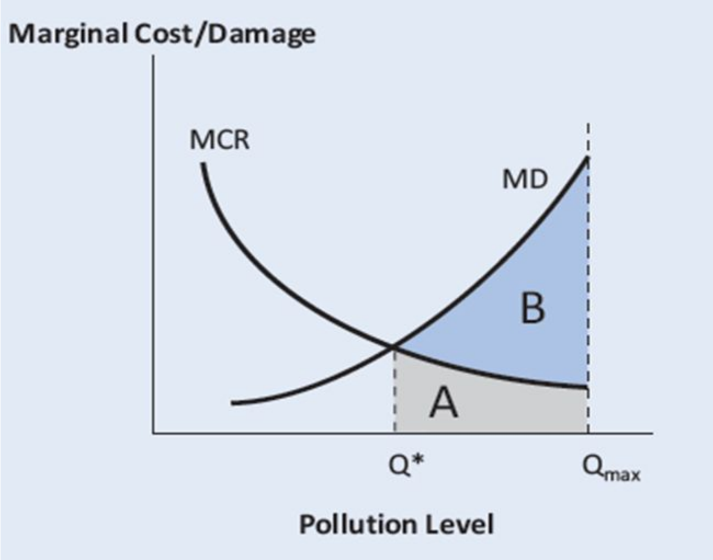
Example: carbon dioxide, chlorofluorocarbons.

Effective policies: tax, permit scheme, market-based

Policies under uncertainty

Normally we do not have enough information to fully plot out the marginal damage and marginal cost curves. In the case of a tax, we may set the tax at the wrong level, leading to a socially inefficient level of pollution, possibly too much but also potentially too little pollution. In the case of a permit system, we may allocate too many or too few permits, also leading to inefficiency.

In the likely case of uncertainty, the choice between a tax or permit system is partially dependent upon the shapes of the marginal cost of reduction (MCR) and marginal damage (MD) curves.



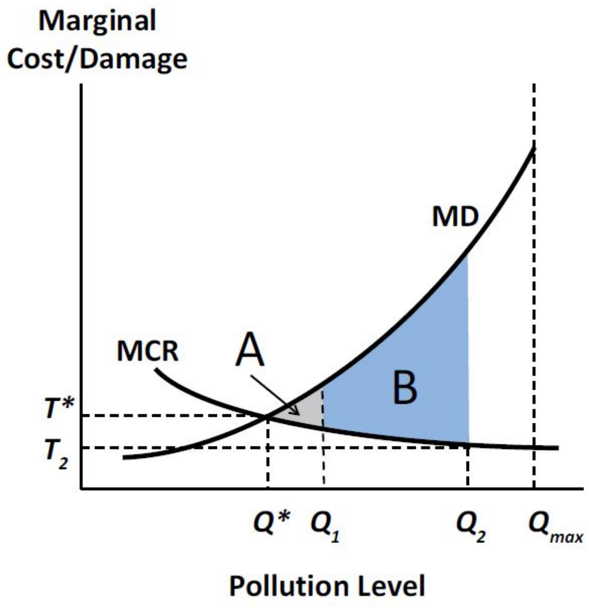
Policies under uncertainty

Suppose that for a particular pollutant the marginal damage curve is relatively **steep, meaning that marginal damage rises quickly as the level of pollution increases**.

At the same time, assume the per-unit costs of pollution reduction for this pollutant tend to be fairly stable, with marginal costs rising only slowly as pollution reduction increases.

We know the optimal level of pollution is Q*. We could achieve this by allocating a number of permits equal to Q* or by setting a pollution tax equal to T*. Now, suppose that we lack the information to determine either of these values accurately. So we allow too much pollution by setting the number of permits equal to Q1 instead of Q*.

For every unit of pollution between Q1 and Q*, the marginal damages exceed the marginal reduction costs, so Q1 is inefficient relative to the optimal level of pollution. The amount of the inefficiency is equal to area A in the graph. This represents a loss of potential benefits.



Pollution Regulation Under Uncertainty With Steep Marginal Damages

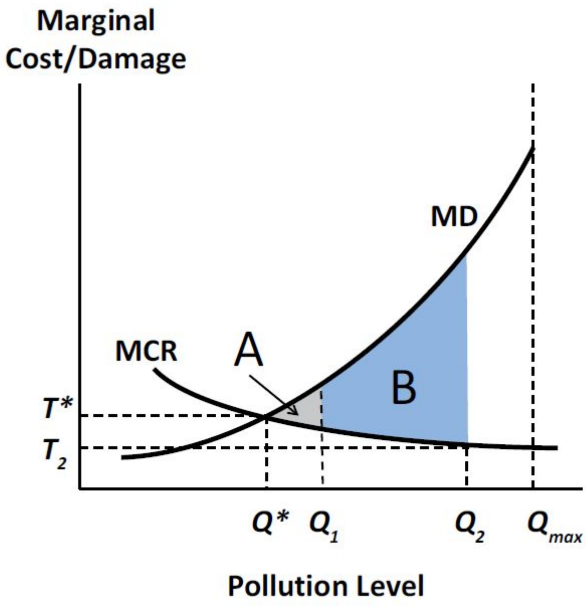
Policies under uncertainty

Now suppose instead that we institute a pollution tax but set the tax slightly too low, at T2 instead of T*. With a relatively flat MCR curve, a small error in the tax level results in a pollution level of Q2—significantly more pollution than optimal.

Now the unrealized benefits, relative to pollution at Q*, are areas (A + B). Getting the tax wrong has resulted in a much larger inefficiency than allocating too many permits.

This pattern of damage costs might be associated with a pollutant like **methyl mercury (accumulated in soil, water, plants, meat, bread)**, which can cause serious nerve damage above a low tolerance threshold.

In this case, a quantity-based control system would be a more effective policy. If we allocate slightly too few or too many permits, the inefficiency will be relatively small. However, a small error in a pollution tax could result in large inefficiency and a very high pollution level.



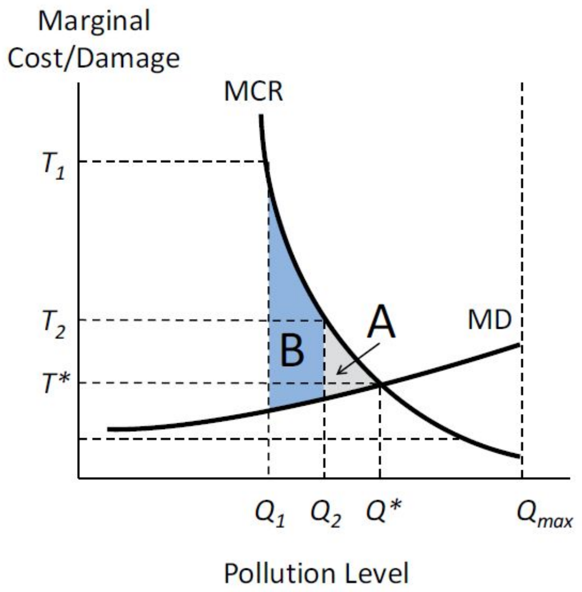
Pollution Regulation Under Uncertainty With Steep Marginal Damages

Policies under uncertainty

Here, the marginal damage curve is relatively flat, but the marginal reduction cost curve is **steep, pollution reduction costs rise rapidly, while per-unit damage is fairly stable**. A tax on fertilizer or pesticides could encourage farmers to seek more environmentally-friendly production techniques.

In this case, quantity controls pose the more serious risk of error. The ideal quantity control would be at Q*, but an excessively strict control at Q1 would cause a rapid rise in marginal control costs, to T1, with net social loss shown by areas (A + B).

A tax policy could deviate from the appropriate level of T* without having much negative effect either in excessive cost or excessive damage. For example, the impact of a tax policy with a tax level set too high at T2 causes only a small deviation from the Q* level, with net social losses equal to the small triangle of area A.



Pollution Regulation Under Uncertainty With Steep Marginal Reduction Costs

Policy effectiveness and technological change

When considering the effectiveness of different policies, we should also evaluate their relationship to technological progress in pollution control. The marginal reduction cost curves that we have used in our analysis are not fixed over time. With technological progress, control costs can be reduced.

This raises two issues. First, how will changing control costs affect the policies that we have discussed? Second, what incentives do these policies create for the development of improved pollution control technologies?

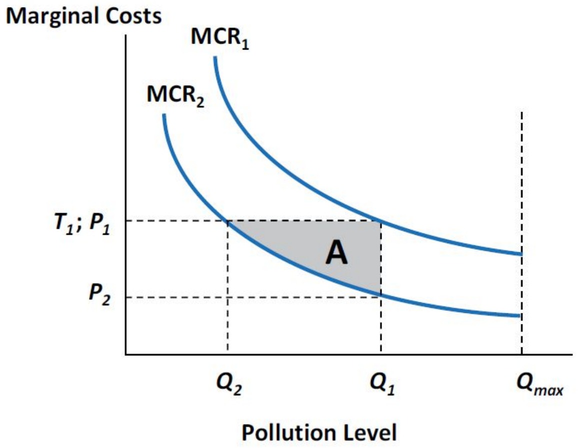
Policy effectiveness and technological change

This Figure shows how the level of pollution control will vary with different policies and technological change.

Suppose that we start with control costs of MCR1 and an initial pollution level of Qmax. A pollution tax at the level T1 will lead to reduction of pollution to the level Q1. A permit allocation of Q1 permits will have the same effect, with a market determined permit price of P1. Now suppose that technological progress lowers control costs to MCR2. How will firms react?

In the pollution tax case, firms will have an incentive to increase pollution control, reducing pollution levels to Q2. By doing so, they save area A (the difference between the new control costs and the pollution taxes that they were formerly paying on units Q1 to Q2).

With a permit system, however, the result will be different. Given the lower control costs, the permit price will fall to P2 (the equilibrium permit price is each firm's' marginal reduction costs). The total units of pollution reduced will remain the same at Q1—equal to the total number of permits issued.



The Impact of Technological Change

Summary of pollution policy approaches

	Pollution Standards	*Technology-Based Approaches*	*Pollution Taxes*	*Tradable Permit System*
Is policy economically efficient?	No	No	Yes	Yes
Does policy create an incentive for innovation?	Only for meeting the standard	Generally no	Yes, resulting in lower pollution	Yes, resulting in lower permit price
Does policy require monitoring?	Yes	Minimal	Yes	Yes
Does policy generate public revenues?	No	No	Yes	Yes, if permits are auctioned
Does policy provide direct control over pollution levels?	Yes	No	No	Yes
Can policy eliminate hotspots?	Yes, if localized standards	Yes	No	No
Other advantages of policy?	Allows for flexibility in meeting standards	Can lead to lower costs for the best available control technology	Revenues can be used to lower other taxes	Individuals or organizations can buy and retire permits
Other disadvantages of policy?	Possibly no incentive to go beyond the standard	Doesn't allow for flexibility	Taxes generally politically unpopular	Permit system can be difficult to understand