Lecture 1. What is Environmental Economics?

Economics is concerned with decision making by agents, which include consumers, firms, government agencies, and non-profit organizations like environmental advocacy groups.

One goal of economics is to understand what motivates particular decisions. This knowledge is used to anticipate (or predict) what decisions agents will make in particular contexts.

Want to be able to predict behavior in order to use agents' incentives and motivations to achieve social goals -- to conduct public policy when we think it is appropriate.

Environmental economics is the study of agent's decisions that have environmental consequences and how to affect these decisions to achieve environmental quality goals.

Three fundamental issues:

1. What is environmental degradation and why do we have it?
2. What level of environmental quality should we strive for?
3. How do we design institutions to improve and/or protect environmental quality?

Institutions refer to the basic organizational structure of society like laws, social customs, markets, firms, governments (at all levels), etc.

Why do we have environmental pollution?

Some common but incomplete explanations:

a) Environmental degradation is the result of immoral or unethical behavior.
-- If this is true then we all act immorally.
-- Environmental economics (and economics in general) does not pass judgment on people. We only seek to understand their behavior

b) Environmental degradation is the result of the profit motive. Firms only care about the bottom line, and hence, do not care at all about the impacts their decisions have on environmental quality.

Probably true, but can't be enough

1) Consumers pollute too.
2) Some of the worst polluters are government agencies and they aren't motivated by profit. Perhaps the worst polluter in the U.S. has been the Department of Defense.
3) Globally, significant environmental destruction has occurred under the old communist regimes, under which there wasn't supposed to be any profits.

c) Environmental degradation is the result of the lack of information. "If we only knew how our actions affect the environment we would change our behavior."

This has occurred to a certain extent and better information is probably a good thing, but it's not enough of an explanation. Even if we had perfect information about the consequences of our actions we would still pollute.

Again, why do we have pollution?

The simple answer is that **we must!** Waste products are an inevitable consequence of consumption and production activities. This is a straightforward consequence of the fundamental laws of thermodynamics.

First law: Energy and matter cannot be created nor destroyed, only transformed. The second law is the entropy law, which limits our ability to recycle.

Once we accept that waste products are inevitable we have a very practical problem: How to dispose of the waste that is generated by consumption and production activities?

And, agents will *look for the cheapest way to get rid of the waste.*

Example: When I was young we simply *burned our household waste*. That was the cheapest way to get rid of it.

And, it didn't hurt anyone. This is typical. Individual decisions about waste disposal usually do not change the environment at all. However, when lots of people burn their household trash it becomes a problem.

The Design of Environmental Policy

Suppose we are faced with a pollution problem. What can society do to mitigate the problem?

As a matter of public policy, we would change the <u>institutions</u> that people operate under in order to change the <u>incentives</u> they face.

Now think about a *coal-fired power plant*. And suppose we want to make sure that its emissions into the air are limited. How do we do this? First, we have to decide how much emissions we are going to allow. Then we have lots of options

a) Tell its managers, "If this plant emits more than __ tons of sulfur dioxide a year, you'll face fines or jail terms."

b) Require the managers of the plant to install a particular device that "scrubs" the emissions as they leave the smokestack.

c) Tell the plant managers, "You can emit as much as you want but you must pay a tax for every ton of emissions."

Each of these policies changes the incentives that managers face, and if implemented properly will result in lower emissions. But, how do we choose among these options?

Economic Criteria for Policy Evaluation

(1) Efficiency -- the social benefit minus the social cost of a regulation is as large as possible.

(2) Cost-effectiveness -- an environmental target is reached at least cost.

If a policy is efficient it must also be cost-effective. Sometimes it is not possible to determine an efficient policy, but we can almost always design one that is a cost-effective.

(3) Fairness -- How are the costs and benefits of a policy distributed among income classes, races, geographical locations, industries, etc.?

In general, efficient or cost-effective policies are not necessarily fair.

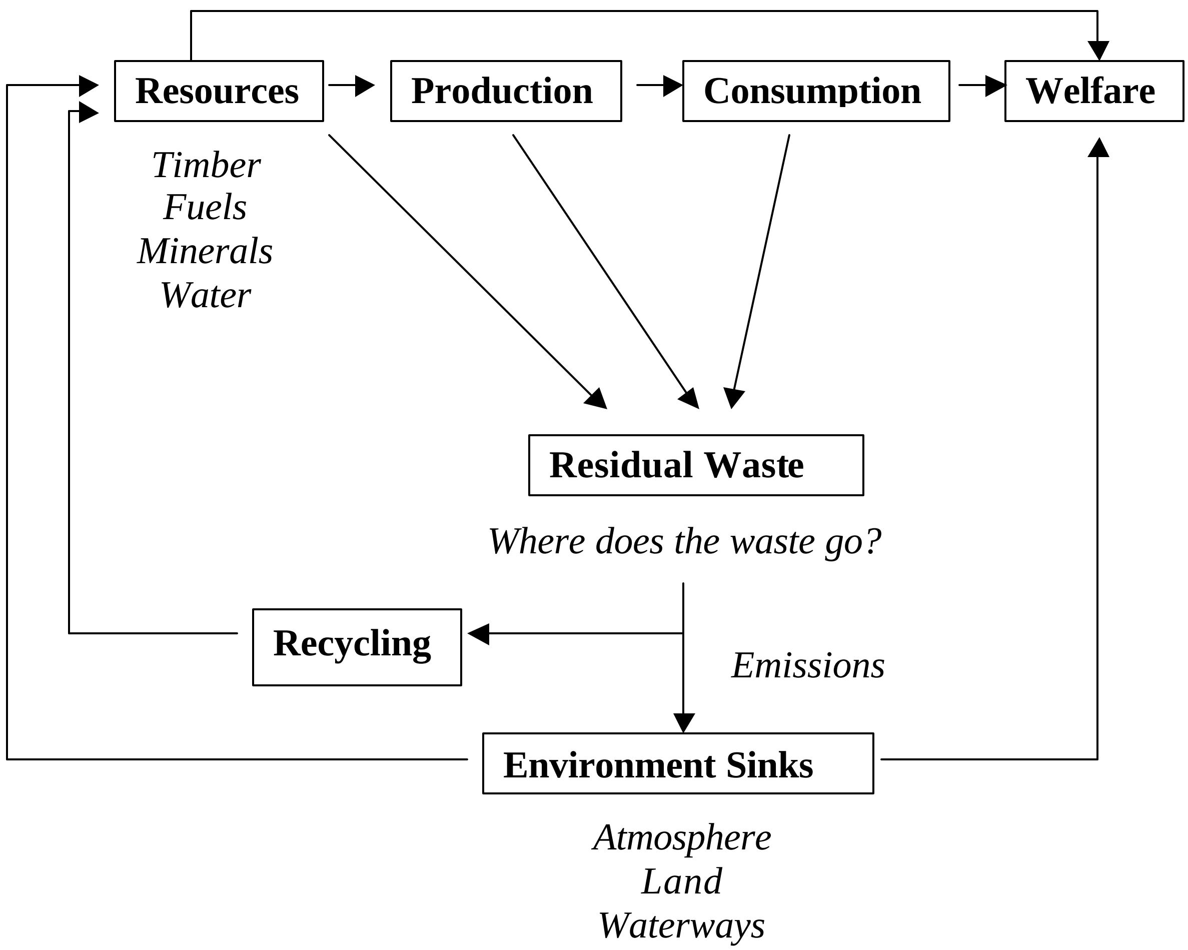
(4) Incentives for innovation -- we would like environmental policies to motivate sources of pollution to look for better (cheaper) ways to control emissions and to motivate victims to look for ways to protect themselves.

(5) Enforceability -- Everything else equal, policies that are easier to enforce are preferred.

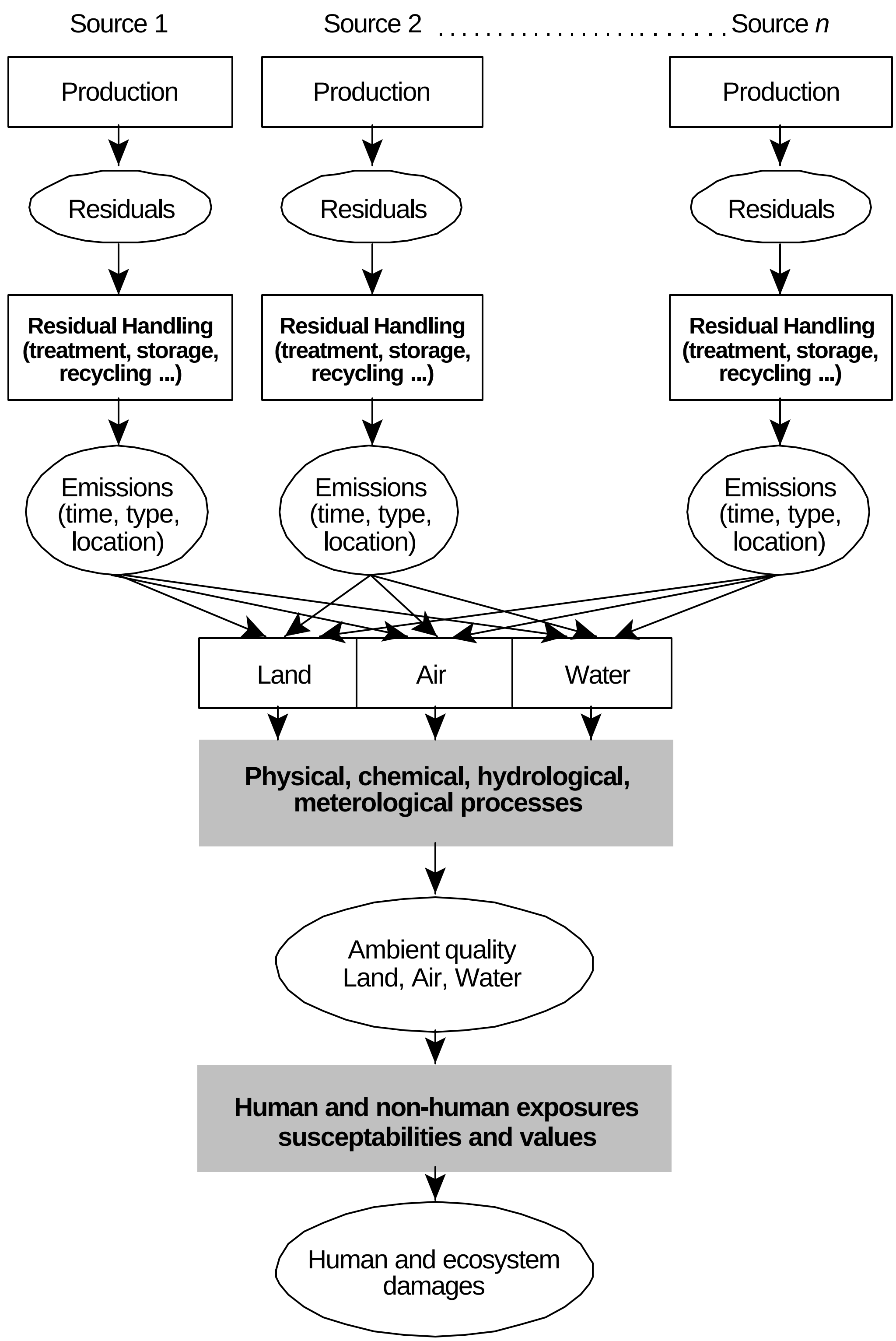
We will focus on (1), (2), *and* (4).

Lecture 2: The Economy and the Environment

An illustration of the primary linkages among economic activity, human welfare, and the environment.



More detail about the flows from emissions to human welfare



Types of Pollutants

Uniformly and non-uniformly mixed pollutants

Uniformly Mixed The damage caused does not depend on where the pollutant is released. (e.g. CFCs and ozone depletion; CO_2 and global climate change).

Non-Uniformly Mixed Damage depends in part on where sources are located. In fact, a singly source may cause different amounts of damage at different geographical locations.

Cumulative and non-cumulative pollutants

Some pollutants tend to accumulate in the environment (radioactive waste, lead)

Others tend to disperse, degrade, or dilute rather quickly (noise, nitrogen and sulfur oxides, particulate matter).

Some pollutants do not accumulate at first, but then start to accumulate once the assimilative capacity of a sink is reached. For example, the upper atmosphere can absorb and degrade CO_2 up to a certain point. However, the problem of global warming is due to the fact that we have, since the industrial revolution, emitted more CO_2 than can be absorbed or degraded.

Point source and non-point source pollutants

Point Source It is easy to identify where a pollutant is released and in principle measure emissions leaving the point of discharge (SO_2 emissions from power plants).

Non-point source Specific release points are hard to identify (pesticide and fertilizer chemicals that end up in waterways), or measuring emissions is impractical (mobile source emissions).

Localized and regional or global pollutants

Localized pollutants cause damage in a confined area—they do not ‘travel’ across political or geographical boundaries (auto emissions in a particular air basin).

Others travel to cause damage across local, state, and international boundaries (SO_2 and acid rain, chlorofluorocarbons and ozone depletion).

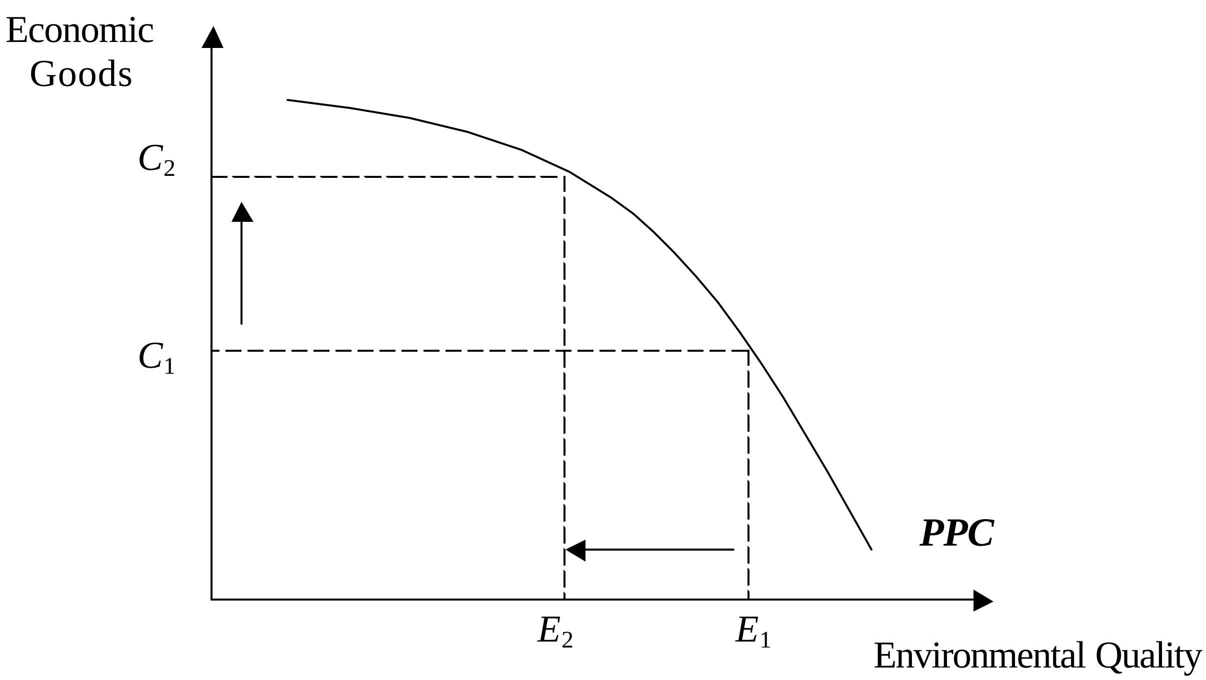
Continuous and episodic pollutants

Emissions from power plants, automobiles, and households occur on a roughly continuous basis. Other pollutants are released only once in awhile, often because of some sort of accident (oil or chemical spills).

The Trade-off Between "Economic Goods" and Environmental Quality

Often imagine a negative (or inverse) relationship between regular economics goods and environmental quality. To get more economic production we usually need to degrade the environment some. To get better economic quality we need to forego some economic production.

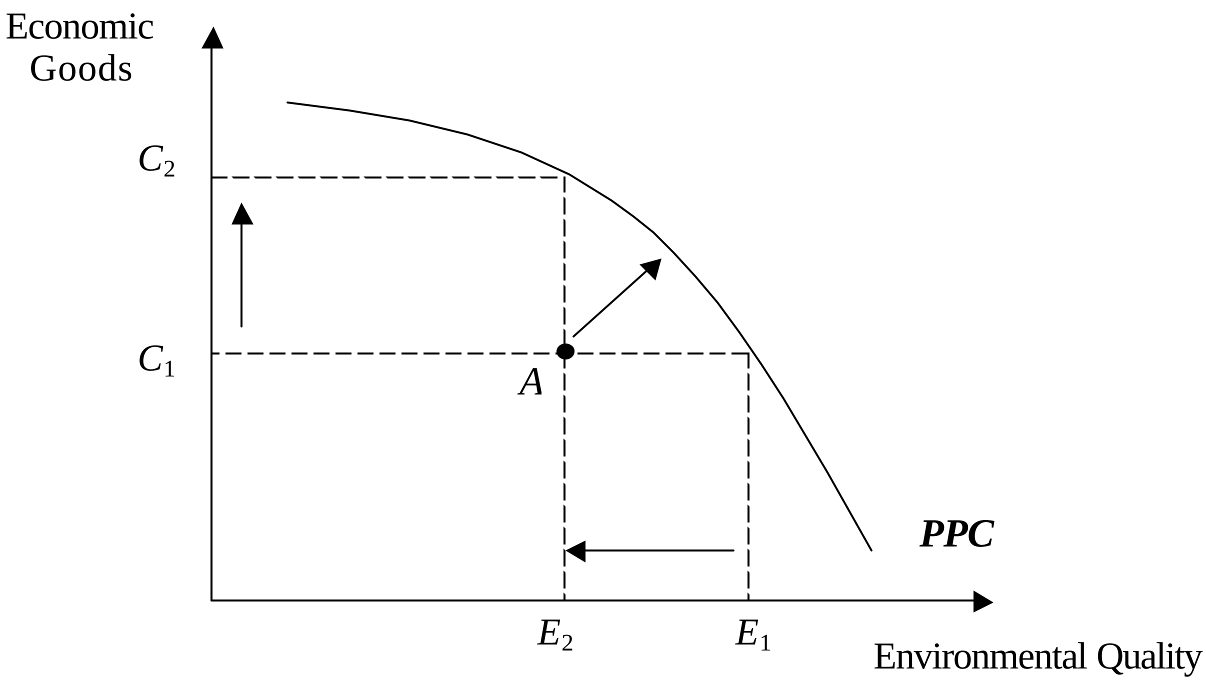
Illustrate this relationship with a Production Possibilities Curve between economics goods and environmental quality.



The *PPC* gives us combinations of some index of economic goods consumption (e.g., Net National Product) and environmental quality that are feasible.

Feasibility refers to technological capabilities for production and how production affects environmental quality at a point in time.

If we want economic output to be C_1 we can achieve *at best* environmental quality level E_1.



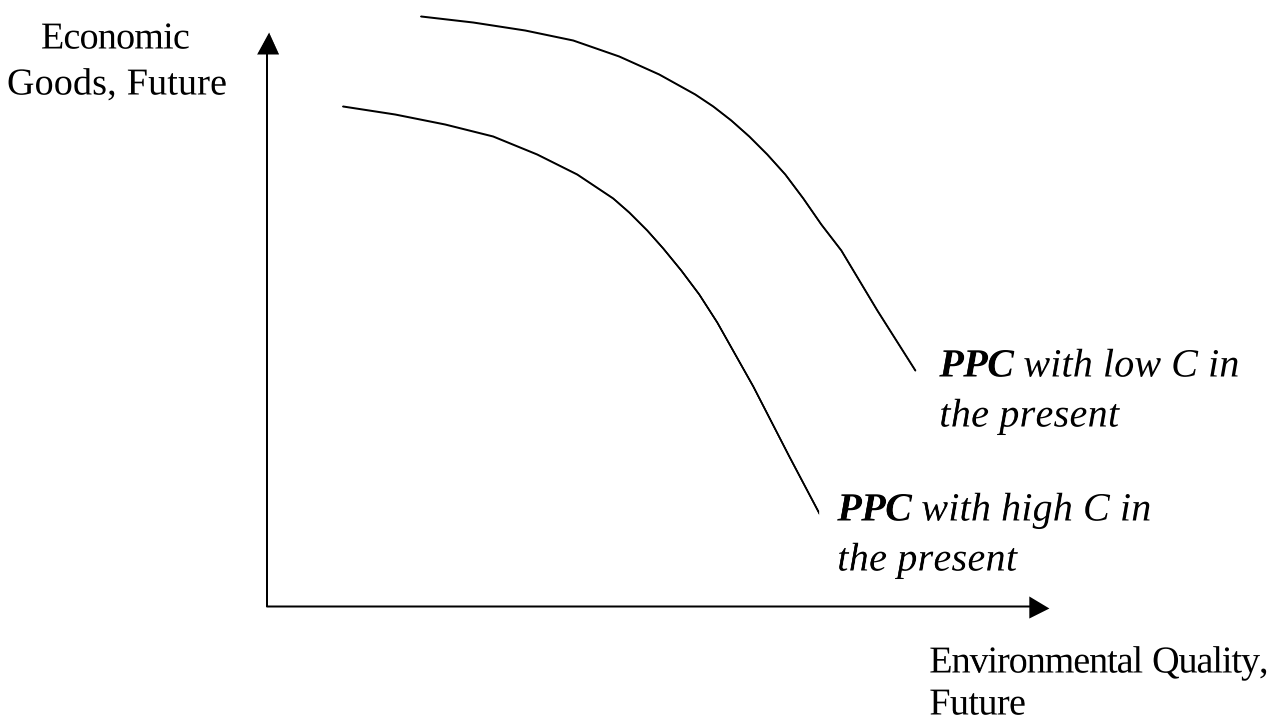
Although the *PPC* is determined by the state of technology, availability of raw materials, and environmental process, the location on the *PPC* is a matter of social choice.

If society wants more economic output—say an increase from C_1 to C_2—the environment must degrade from E_1 to E_2. This is what we mean by a trade-off between economic production and environmental quality.

Note that if an economy is operating at an inefficient point, say point *A*, then we can rearrange production and consumption choices to have more economic goods and environmental quality

A particular *PPC* is drawn for a specific group of people in a specific time period. However, the choices of the present generation often affect the opportunities available for future generations.

Suppose that to have more economic output now, we have to consume more fossil fuels. Opportunities for economic goods consumption and environmental quality may be less in the future because 1) less fossil fuel available in the future, 2) global climate change.



ECON 460
Environmental Economics

1 Market failure: Public Bads and Externalities

1. two characteristics of a good or bad are the degree of rivalry in consumption and the ability of producers to exclude consumers, preventing consumption

2. excludability is determined by the availability of a technology of exclusion. furthermore, the costs of exclusion must be low enough that the benefits of exclusion exceed the costs.

3. rivalry is a more fundamental characteristic of consumption of a good or a bad. A good or bad is nonrival if its consumption involves no opportunity costs for others. In other words, one person's consumption does not change the amount of the good or bad available for others to consume

4. A good or bad that is both rival and excludable is a private good or bad. A good or bad that is both nonrival and nonexcludable is a public good or bad.

5. Aggregate demand for rival goods is determined by summing individual demand curves horizontally; aggregate demand for nonrival goods is obtained by summing individual demands vertically.

6. Public gods may be privately provided by individuals in the market. In such a case, the market provision will be lower than is efficient. for public bads, market provision will be higher than is efficient.

7. Nonrival goods or bads should have a price of zero, which makes it difficult for revenues to equal costs. This also implies that no compensation be paid to victims of pollution in general..

8. An externality exists when the consumption or production choices of one person or firm enter the utility or production function of another person or firm without permission or compensation.

9. A pecuniary externality occurs when one person's actions affect the prices paid by another person. Since prices do not enter into utility or production functions, this is not a conventional externality and in fact does not involve an inefficiency.

10. the fact that a public bad is nonrival means that everyone consumes the same quantity of the public bad. This is equivalent to the amount of consumption being chosen by someone else, the generator of the public bad. this is an externality. thus there is an intimate connection, and in fact some redundancy, between the concepts of public bad and externality.

2 Property Rights

1. Property rights are important to a well-functioning market. Without property rights, even the most ordinary transactions are difficult.

2. Transaction costs are those costs associated with consummating a trade, over and above the trade itself (i.e., the money exchanged for the good). A simple example is the commission paid to an agent to sell a house. Transaction costs can involve non-monetary costs such as the difficulty in striking a bargain.

3. The Coase Theorem has two parts: one with transaction costs and one without. In achieving the efficient level of an externality (such as pollution), the initial assignment of property rights (right to pollute, right to clean air) is irrelevant if there are no transaction costs. With transaction costs, the initial assignment matters.

4. when transaction costs are present it is important for the government to distribute property rights in an efficient way and to try to reduce transaction costs associated with trading rights.

5. With public bads, where there are a few generators of pollution and many consumers, bargaining implicitly involves costs. Thus the Coase Theorem states that the free trade of property rights cannot be relied on for efficiency

Lecture 9: Overview of the Theory of Environmental Policy

Types of Environmental Policies

There are a wide variety of types of regulations that are employed to control pollution. A non-exhaustive list includes:

1. Liability rules—make polluters responsible for the damage they cause.

   i) Strict liability—polluter is responsible for all damage
   ii) Negligence—polluter is responsible for damage if it did not exercise due care in preventing damage.

2. Property rights approach—defines and allocates rights to use the environment and allows affected parties to trade these rights.

3. Command-and-control standards—simply mandate limits and methods of emission control.

   i) Emissions standards
   ii) Input standards
   iii) Technology standards

4. Incentive-based policies—create the proper incentive (financial) for sources to control emissions. Implies the creation of a ‘price’ for releasing pollution.

   i) Emissions taxes—allow sources to emit as much they want, but charge a tax for every unit emitted.
   ii) Emissions subsidies—pay sources to reduce emissions.
   iii) Transferable emissions permits—allocate ‘rights’ to emit and allow sources to trade these rights.
   iv) Auctioned emissions permits—allocate rights to emit via a centralized auction.
   v) Ambient taxes, subsidies, and transferable permits—tie policy to contributions to ambient levels of pollution instead of emissions.

5. Voluntary environmental agreements—the result of negotiations between environmental regulators and pollution sources over the control of pollution.

Criteria for choosing among types of policies

But how do we choose which policy is best for a particular setting?

1. Cost-effectiveness

   Does a policy achieve its environmental objective in the cheapest manner possible?

2. Efficiency

   Are the benefits minus the costs of the policy maximized?

   Recall: If a policy is efficient it must also be cost-effective, but the reverse need not be true. For example, a policy may be designed to reach some environmental quality goal in a cost-effective way, but the goal may be inefficient.

3. Incentives for innovation

   The type of innovation that we usually focus on is the development of new and cheaper ways to control emissions. The incentive to do so is greater under some policies than under others.

4. Enforceability

Everything else equal we should prefer policies that can be enforced effectively and cost-effectively.

Fundamental enforcement activities are:

Monitoring to see if sources are complying with a regulation.

Sanctions, usually financial, for punishing noncompliance. The purpose of sanctions is to return noncompliant firms to compliance, and to deter others from noncompliance.

5. Information requirements

Some policies require more information to implement and maintain than others. Since information gathering and dealing with the lack of information are costly, everything else equal, policies that require less information are preferred.

6. Fairness

How are the costs and benefits of a policy distributed across income classes, race, geographical locations, etc., and is this distribution acceptable from an equity perspective?

7. Morality

Does a policy conform to our moral sense of what is right and wrong, our duty to the environment, and to each other?

For example, under some circumstances subsidizing firms to reduce their emissions can be efficient. But we may object to paying polluters not to pollute.

In international environmental law, the Polluter-Pays-Principle is a guiding concept.

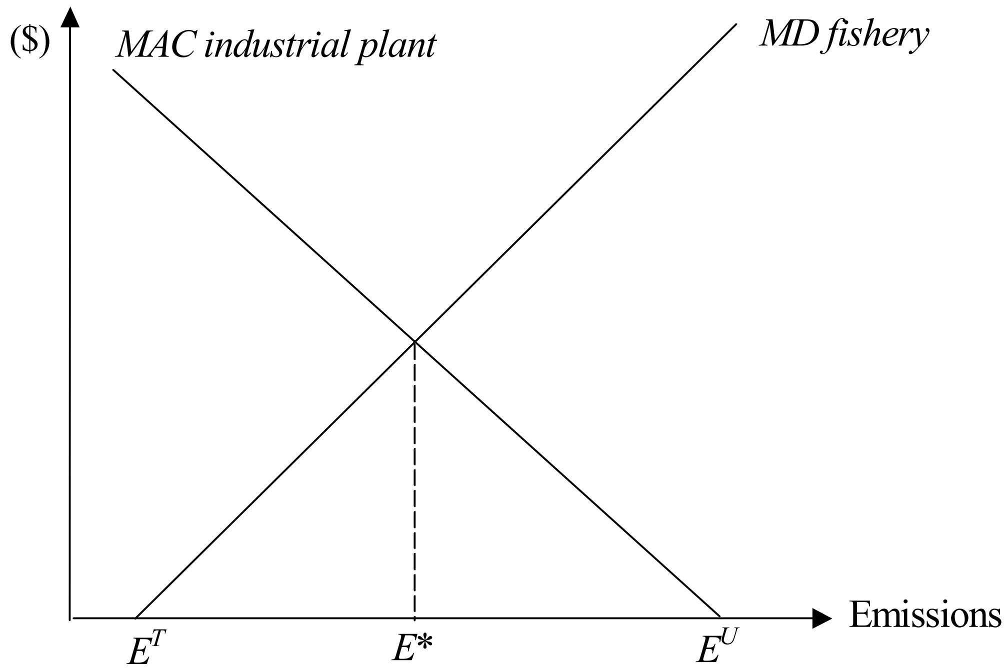
Lecture 10: Decentralized Environmental Policies

Decentralized environmental policies are those in which the role of government is limited to providing the institutional structure so that parties to an environmental conflict can reach resolution, without the government imposing a solution.

Under these policies the government is responsible for the establishment and enforcement of property rights, and to provide a court system to hear complaints and determine remedies.

Throughout this lecture we will consider a simple hypothetical example of an environmental conflict. Imagine just two firms that use a lake. One is a fishing concern, while the other is an industrial plant that uses the lake to dump residuals from production.

The pollution source is the industrial plant, and the victim of pollution is the fishery. Graphically,



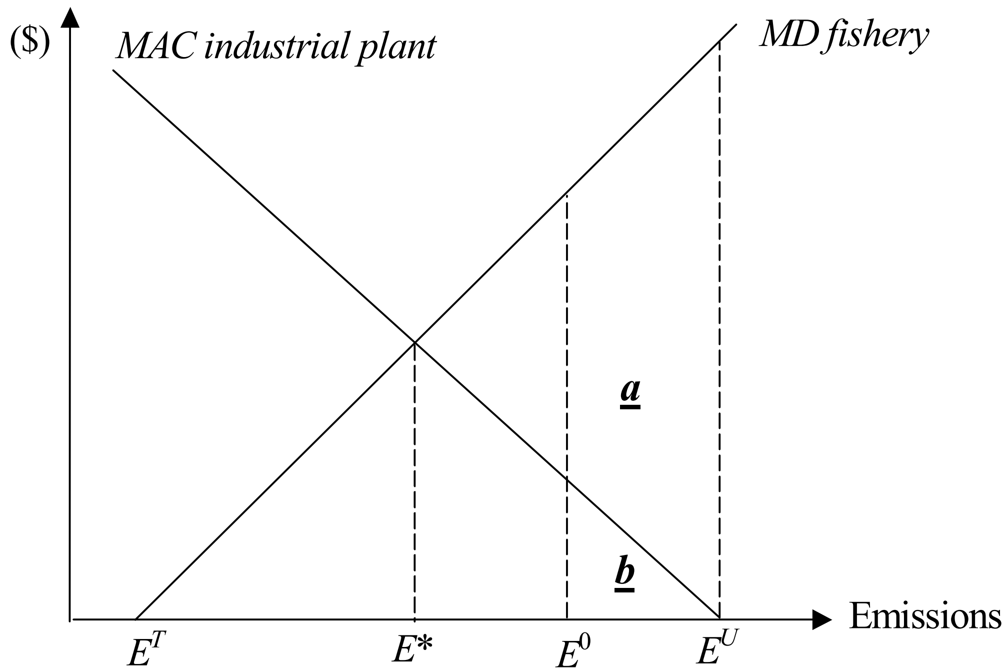
We will consider two types of decentralized policies, and judge them on their ability to induce the efficient level of emissions *E**.

Liability rules
A strict liability rule makes polluters liable for the damage they cause by forcing them to compensate the victims of their pollution.

The most important feature of strict liability is that polluters are forced to *internalize* the costs they impose on others.

For our example, suppose that the industrial plant is required to compensate the fishery for the damage it causes.

What level of emissions would the plant choose if it faced a strict liability rule??



Start with the unregulated level of emissions, E^U.

Will the plant reduce its emissions to say E^0?

- Benefit to the plant is that it avoids paying area ***a*** + ***b*** to the fishery.
- The cost is its abatement costs, area ***b***.

Since the payment it avoids is greater than the abatement cost it incurs, the plant would be willing to reduce its emissions to E^0.

Will it reduce its emissions further, say all the way to the efficient level? The answer is yes. As long as MD > MAC the reduction in the plant's payment to the fishery from decreasing emissions a bit more is greater than the increase in its abatement costs.

Therefore, under a strict liability rule the plant will emit at the efficient level E^*.

We think of liability rules as decentralized policies, because the government does not come in and mandate a solution.

You may be wondering how the compensation is to be determined. Typically, the victim would bring a suit before a court, which then makes a finding of liability.

Problems

Will liability rules work in every situation? Probably not.

1. Burden and standards of proof

In civil cases the burden of proof lies with the plaintiff—the victim in this case. The victim has to establish direct causal links between:

a. his/her damage and exposure to a particular pollutant
b. the pollutant and a particular source (or sources).

Establishing these links will be very difficult in many cases. For example, consider a case of groundwater contamination by a carcinogen.

a. Victims of cancer must establish that their disease was caused by the contaminant. This may be difficult, because 1) Cancer is a random event—exposure does not always result in the disease. Exposure only increases the probability that an individual will contract the disease. 2) Cancer often takes a long time to appear. Both of these characteristics make it more difficult to establish a link between a contaminant and the cancer.
b. Victims have to identify the source of the contaminant. This may be very difficult if there are many potential sources.

2. <u>Transaction costs</u>

In general, transaction costs are the costs of reaching and enforcing agreements. In cases involving liability rules, transaction costs include the costs of gathering evidence, presenting a case, awarding and collecting damages, etc. The costs are likely to be high if:

a. The causal links between source and damage are difficult to establish.
b. The number of parties on either side of the conflict is large.

<u>General conclusion about liability rules</u>

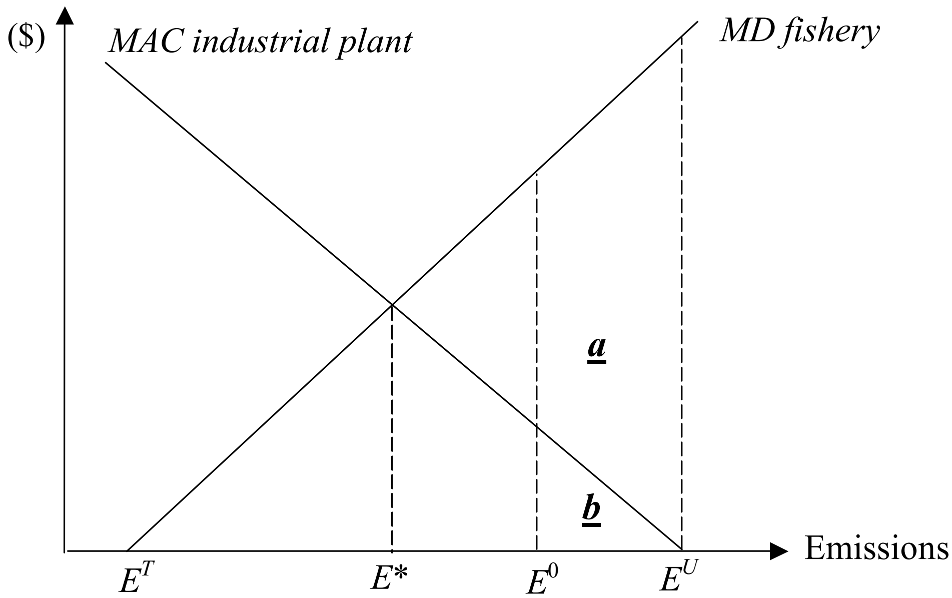
Liability rules may be an efficient policy in cases in which there are a small number of parties involved, the causal links between sources and damage are clear, and damages are easily measured.

Property Rights
One way to view our conflict on the lake is that it is not clear who has the right to do what with the lake. The fisher may think that he has a right to a clean lake, while the plant may think it has the right to use the lake as a residual dump.

The property rights approach to environmental policy would (1) specify clearly who has the rights to the lake, (2) allow these rights to be traded, and (3) use government authority to enforce these rights, including any trades that take place.

The conceptual justification for this approach is due to Ronald Coase.

The Coase Theorem
Regardless of the initial assignment of property rights, if agents are allowed to trade with each other they will trade to an efficient outcome if property rights are well-defined, enforceable, and transferable and transaction costs are negligible. All that is affected by the initial assignment of property rights is the distribution of welfare.



Suppose at first that the plant has the initial right to pollute as much as it wants. The status quo is then E^U.

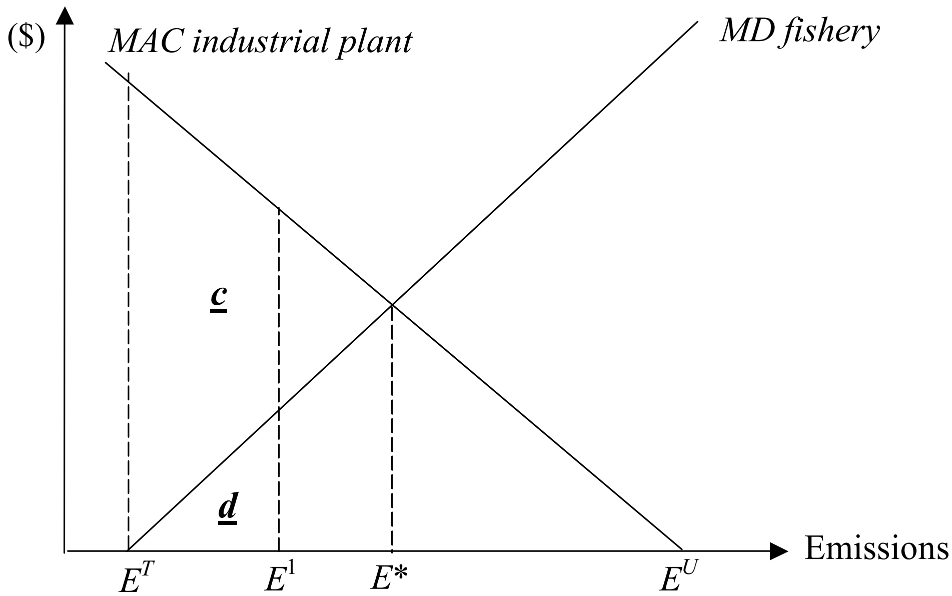
Is a trade possible to reduce emissions, say to E^0? Note that the fisher has to pay the plant to get it to reduce its emissions.

How much will the fisher be willing to pay? Up to the amount of damage avoided, area ***a*** + ***b***.

How much compensation would the plant require to reduce its emissions? It must at least be compensated for its abatement costs, area ***b***.

Since the maximum that the fisher is willing to pay is greater than the minimum that the plant is willing to accept, a trade between them will take place.

Will they trade to reduce emissions further? Yes! As long as MD is greater than MAC, the fisher is willing to pay more for further reductions than the plant requires in compensation. Therefore, trade between them will end up at the efficient level E^*.



Suppose now that the <u>fisher has the right to a perfectly clean lake</u>. The status quo is then E^T.

Is a trade between to increase emissions, say to E^1? Note that the plant has to pay the fisher for the right to increase emissions.

How much will the plant be willing to pay? Up to the amount of abatement costs avoided, area ***c*** + ***d***.

How much compensation would the fisher require? It must be at least be compensated for the damage it would suffer, area ***d***.

Since the maximum that the plant is willing to pay is greater than the minimum that the fisher is willing to accept, a trade between them will take place.

Will they trade to reduce emissions further? Yes! As long as MAC is greater than MD, the plant is willing to pay more for the right to increase emissions than the fisher requires in compensation. Therefore, trade between them will end up at the efficient level E^*.

Note that we have just illustrated the elements of the Coase Theorem.

- Trade between the two parties results in the efficient level of emissions.
- Doesn't matter who has the initial property right, as long as the initial assignment of the right is clear to both them.
- The initial assignment of rights does affect the distribution of welfare, because it determines who pays and who gets paid.

The appeal of the property rights approach is:

- The efficient level of emissions results.
- It does not rely on the government to interfere with some sort of regulation.
- Decisions are made by the parties themselves.

However, there are several problems with this approach that limit its applicability.

Problems with the property rights approach

The conditions of the Coase Theorem are critical if this approach is to work.

- Property rights are well-defined, enforceable, and transferable.

If property rights are not well-defined in the first place, there is no possibility that agents will be able to trade with each other.

Who owns the atmosphere? The open ocean? Rivers, lakes, and subsurface water supplies?

Ownership of rights must be enforceable. If the fishery owns the right to a clean lake, but can't keep the plant from polluting they won't be able to bargain with each other.

Obviously, rights must be transferable, otherwise no trade can take place.

- Transaction costs must be small.

In the this context the important transaction costs are:

1. Bargaining costs—the costs of actually reaching an agreement.
2. Enforcement costs—include the costs of monitoring and enforcing the contract, as well as the costs of settling disputes once the contract is in place.
3. Costs of identifying parties to a conflict—In many cases, sources of pollution are not easily identified. In other cases, the victims of pollution may not be easily identified.

Transaction costs will be small only when:

a. The number of parties to a conflict are easily identified and small in number.
b. Contracts are easily enforced.

- All the affected parties are present.

For some important pollution problems, damage falls on future generations (ozone depletion, CO_2 emissions leading to climate change, etc). Obviously, future people cannot bargain with present people.

<u>General conclusion about the property rights approach</u>
The property rights approach may be an effective policy option when: (1) Property rights can be clearly defined, can be transferred, and are easily enforced; (2) The affected parties are present, easily identified, and are small in number; (3) The costs of negotiating and enforcing contracts are small.

Lecture 11: Command and Control Standards

Under command and control policies, authorities simply mandate a certain standard of behavior and then use some sort of enforcement strategy to enforce compliance to the mandate.

<u>Several Types of Environmental Standards</u>

Ambient standards—set an upper limit on the concentration of a pollutant in the environment.
-National Ambient Air Quality Standards

Emissions standards—set an upper limit on emissions from a pollution source.

Performance standards—set an upper limit on emissions per unit of some activity.
-per unit of output
-per unit of outflow

Technology standard—specify the technology sources must adopt to control emissions.
-catalytic converters
-stack-gas scrubbers for power plants

Technology-based emissions standard—set an emissions standard based on the use of a particular control technology.
-1972 Water Pollution Control Act Amendments

Ambient Standards

The National Ambient Air Quality Standards (NAAQS) of the Clean Air Act sets limits on ambient concentrations of the six *criteria* pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_x). ozone, particulate matter, carbon monoxide, and lead.

NAAQS as of 2000 (Table 15-4)

Polllutant	**Primary Standard**
Particulate matter (PM_{10})	
Annual mean	50 $\mu g/m^3$
Daily mean	150 $\mu g/m^3$
Particulate matter ($PM_{2.5}$), Proposed in 1997	
Annual mean	15 $\mu g/m^3$
Daily mean	65 $\mu g/m^3$
Carbon monoxide	
8-hour mean	9 ppm
1-hour mean	35 ppm
Nitrogen oxide	
Annual mean	0.053 ppm
Ozone	
1-hour mean	0.12 ppm
8-hour mean (proposed in 1997)	0.08 ppm
Lead	
Quarterly mean	1.5 $\mu g/m^3$
Sulfur dioxide	
Annual mean	0.03 ppm
24-hour mean	0.14 ppm

Notes

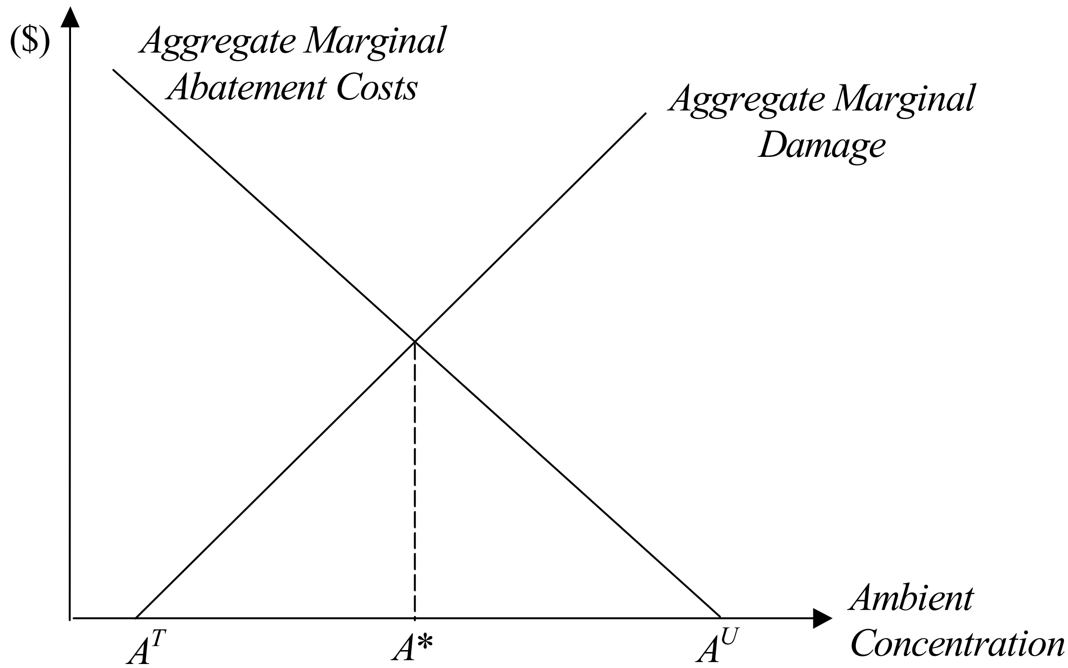
- $\mu g/m^3$ means micro-grams per cubic meter, ppm means parts per million.
- Note that these standards are expressed as averages over a some time frame
- For example, particulate matter should not exceed some level averaged over an entire year. That is, we can have some bad days as long as these are balanced by good days. For particulate matter there is also an upper limit for any 24-hour period to make sure that bad days are not too bad.

The Clean Air Act requires the EPA to set these standards "requisite to protect the public health" with "an adequate margin of safety." This has been referred to as a **zero-risk standard.** The thinking at the time was that thresholds existed for these pollutants below which the pollutants had no adverse affect on humans.

These standards are **uniform across the country**, except for "prevention of significant deterioration."

Aside: Of course, ambient quality cannot be controlled directly. Have to control emissions in order to affect ambient quality. Therefore, a link between emissions and ambient quality must be determined.

Some Economics of NAAQS



<u>Zero-risk standard</u>

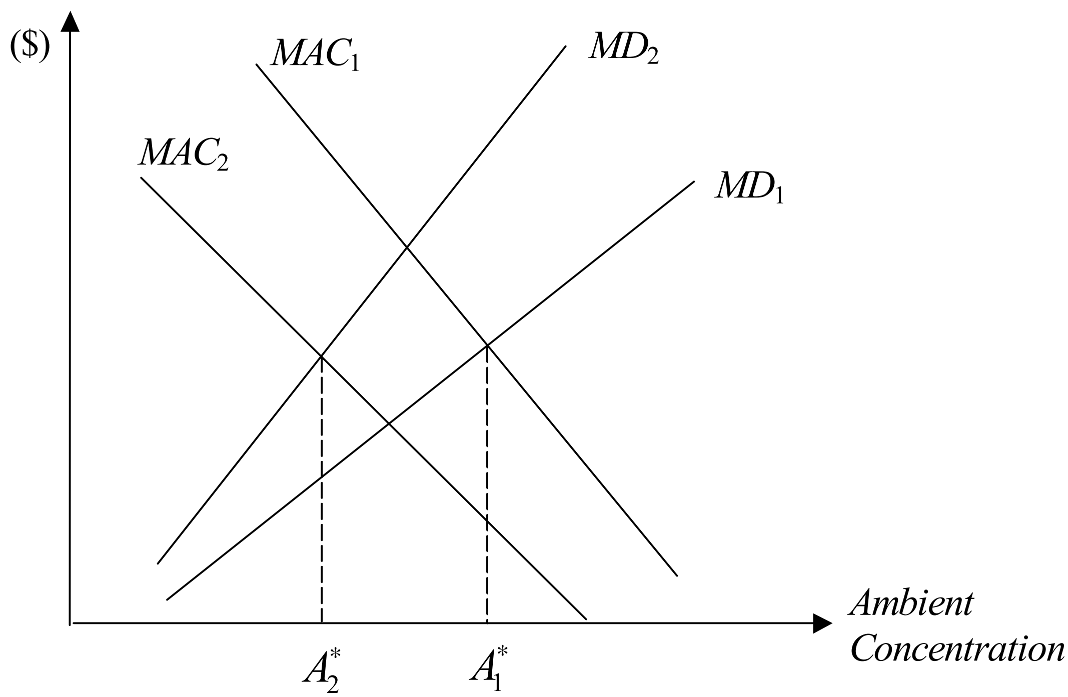
The efficient ambient quality standard is, of course, A^*. But a zero-risk standard with an "adequate margin for safety" would require that the standard be set below A^T.

Clearly, setting a zero-risk standard is inefficient because the costs of reaching the standard are ignored.

Threshold levels may not even exist. Some research suggests that for some of the criteria pollutants even very low concentrations have adverse health affects.

Uniform across the country

Uniform standards cannot be efficient if difference regions of the country have different damage and abatement cost functions. To see why, imagine two areas of the country, 1 and 2, with different marginal damage and marginal abatement cost functions graphed below.



Notice that efficiency requires two standards: one for region 1 where $MD_1 = MAC_1$, and one for region 2 where $MD_2 = MAC_2$.

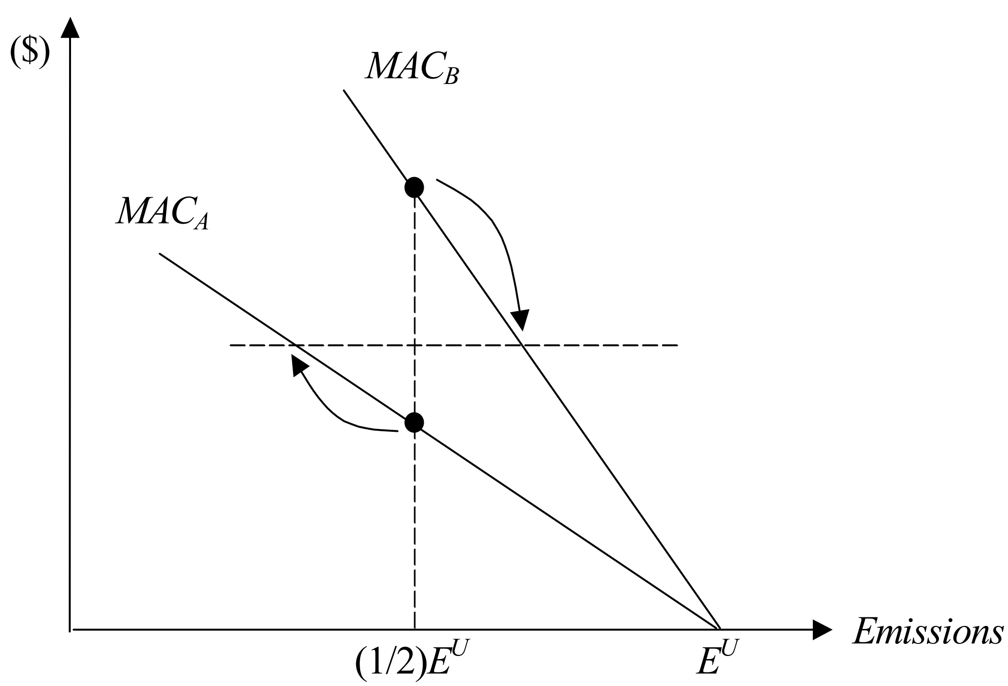
Emissions Standards

Uniform emissions standards are not cost-effective

There is also tendency to impose uniform standards on sources of pollution. Doing so will usually not be cost-effective, because differences in sources' abatement costs are not accounted for.

Suppose we have two sources of emissions, A and B, with marginal abatement costs graphed below. Each firm has E^U uncontrolled emissions, so total uncontrolled emissions are $2E^U$. Suppose the regulatory goal is to cut total emissions in half by requiring uniform reductions in emissions so that each source faces an emissions standard $(1/2)E^U$.

This policy will not satisfy the equi-marginal principle, so we could achieve the same total emissions reduction at lower cost. This would require imposing a stricter standard on firm A and a less strict standard on firm B.



If uniform ambient or emissions standards are inefficient or cost-ineffective, why are they so common?

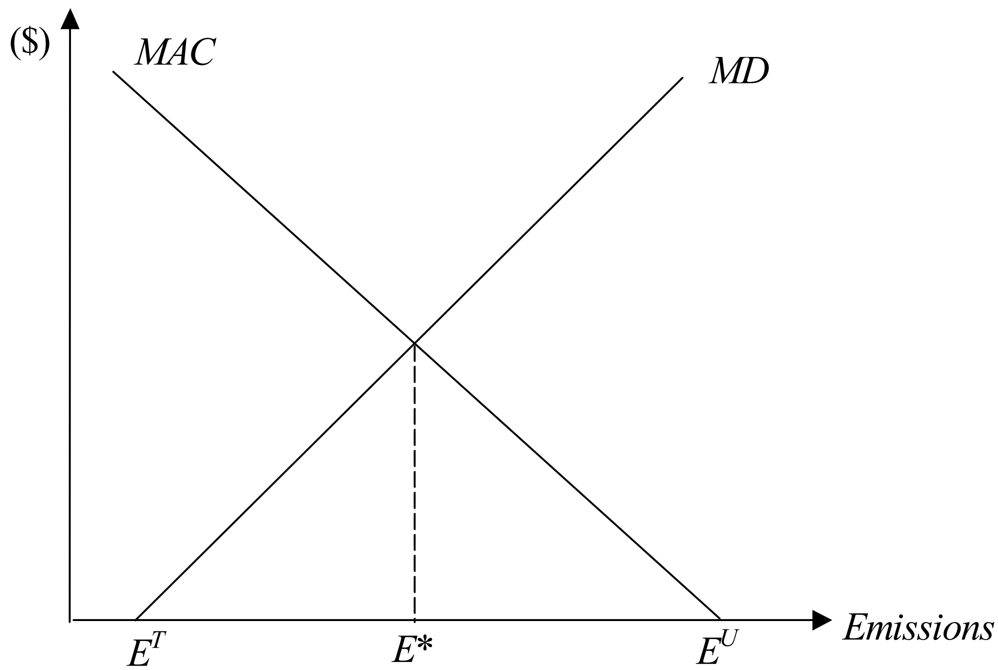
1. Simplicity It may be easier to implement and enforce uniform standards.

2. Low information requirements For example, to set cost-effective emissions standards by applying the equi-marginal principle the environmental regulator must have perfect knowledge of each source's marginal abatement costs. In most cases this information will be very costly or impossible to obtain.

3. Fairness Uniform standards may appear to be equitable.

Efficient Emissions Standards

To keep things simple suppose we have one source of pollution and one victim of pollution. The efficient emissions standard is E^*.

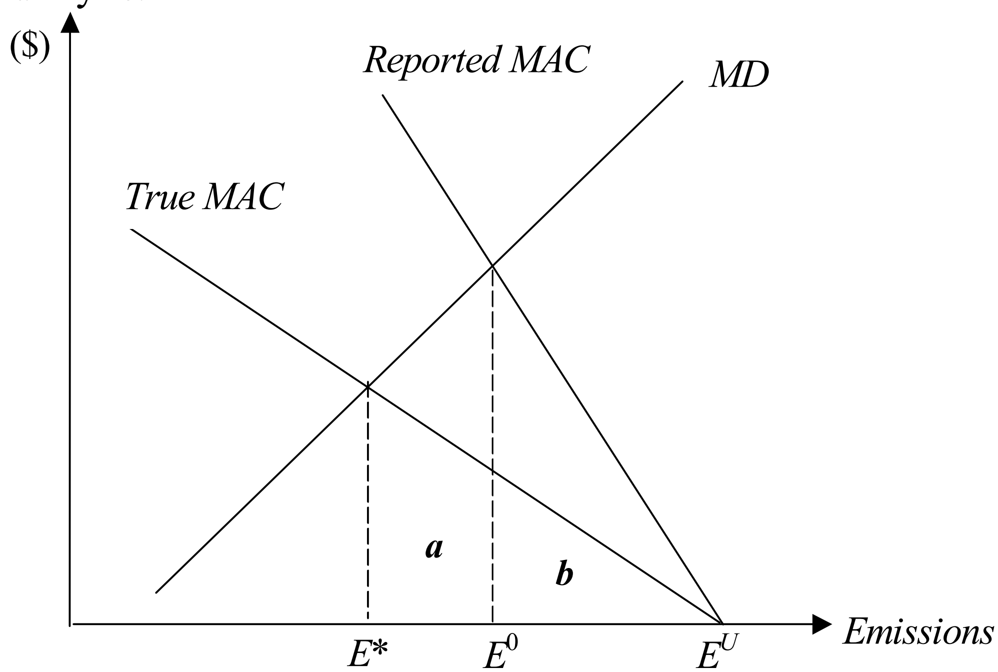


Let's use this simple model to investigate two features of setting the efficient standard. These have to do with the kind of information required to set standards, and the incentives that emissions standards provide to sources to find innovative ways to control their emissions.

<u>What information is required?</u>
To set that efficient standard the authority has to have all the information in the graph. It has to know the marginal abatement cost function and the marginal damage function. In real policy settings these pieces of information won't be readily available. Indeed, the quality of information will be asymmetric.

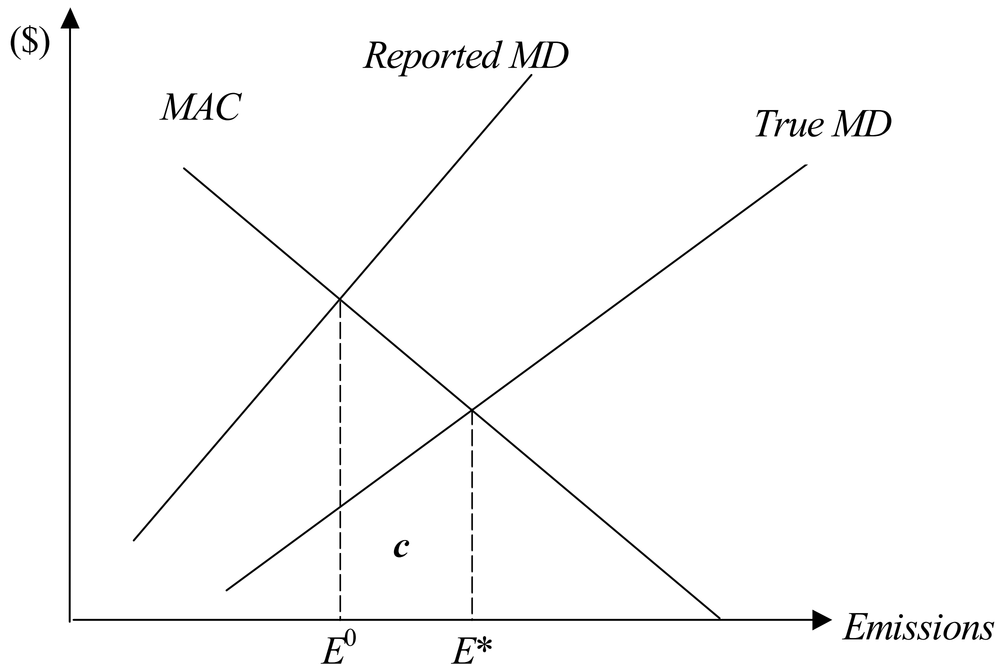
Asymmetric information
It is likely that the source will have better information about its abatement costs than the regulator, and the victim may have better information about its damages. Because they are better informed than the regulator, they may be able to use this asymmetry of information to their advantage.

Imagine that the source knows its true MAC, but the regulator does not. Suppose that the regulator asks the source to report its MAC and will use this report to set an emissions standard. Will the source provide a truthful report of its MAC? The answer is no. In fact, it will try to convince the regulator that its MAC is higher than it actually is.



If the source reports its true MAC, the regulator will set the efficient emissions standard E^*, and the firm's total abatement costs are ***a*** + ***b***. If the source reports a higher MAC, then the regulator sets the emissions standard at E^0, and the firm's total abatement costs are only area ***b***. Therefore the source is motivated to try to convince the regulator that its MAC is higher than it really so that the regulator will set a less strict standard.

What about the victim? Suppose that it has better information about its damages than the regulator (in many real cases this will not be true). Suppose that the regulator asks the victim for a report of its damages and will use this report to set the emissions standard. Will the victim provide a truthful report of its MD function? No. In fact it will try to convince the regulator that its damages are higher than they really are.



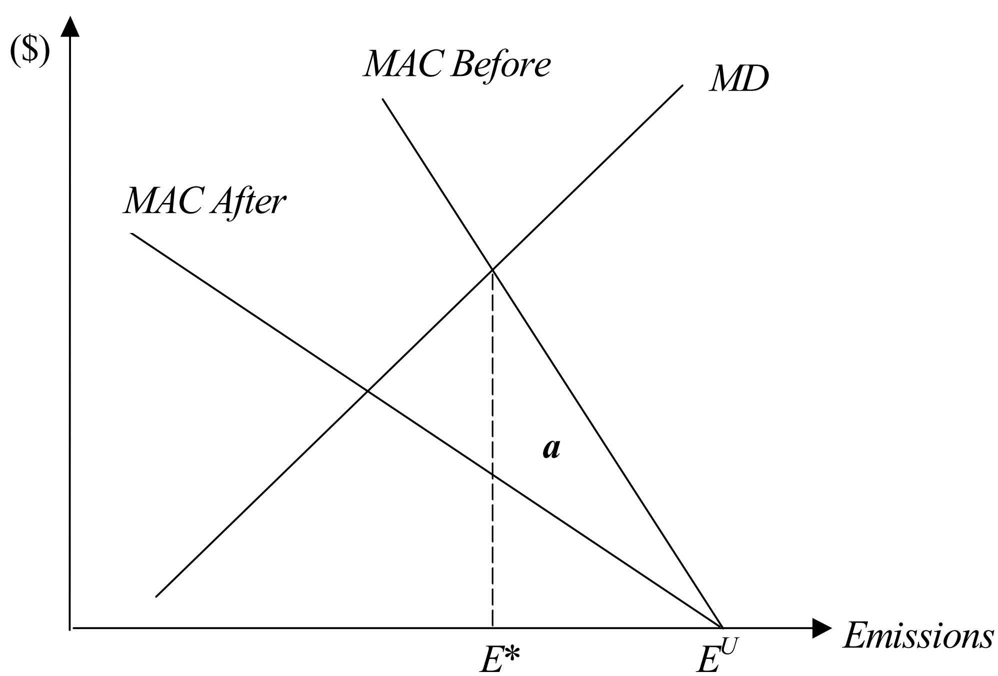
If the victim convinces the regulator that its MD is higher than it really is, then the regulator will set an emissions standard that is stricter (lower) than the efficient standard. The victim then avoids damage in the amount of area ***c***.

Emissions Standards and Incentives for Innovation

Different policies yield different incentives for sources of pollution to find and adopt new abatement technologies that reduce the costs of complying with regulations.

We will investigate incentives to adopt new cost-reducing abatement technologies by examining a source's cost-savings from adopting a new technology.

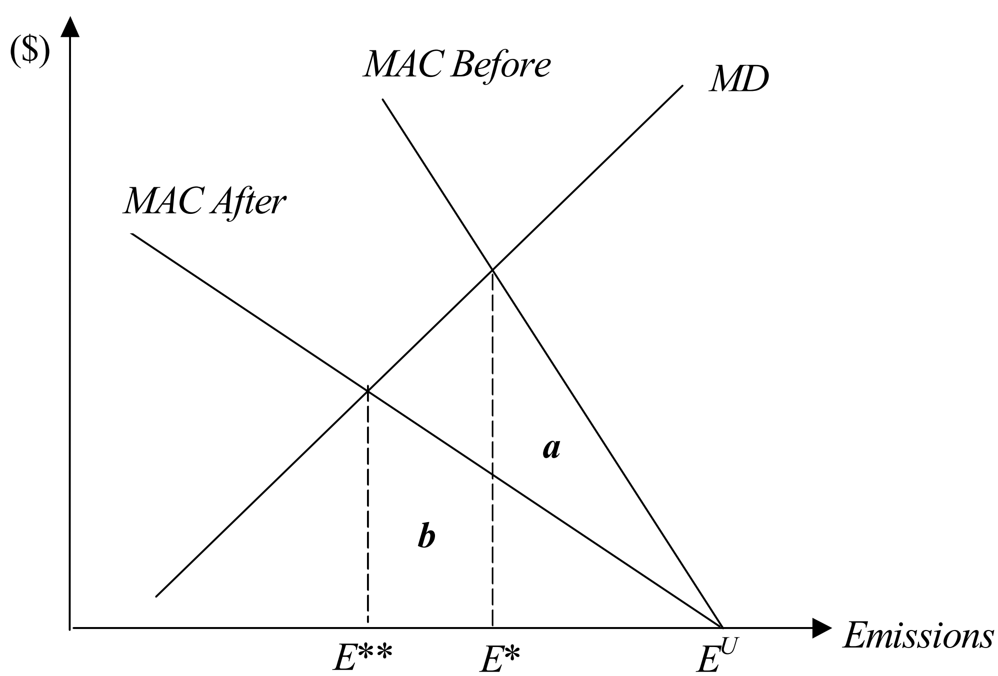
The graph below is of a single source of emissions with marginal abatement costs before and after adopting a cost-reducing technology. Before the firm adopts the new technology the regulator sets the efficient standard E^*. If the regulator leaves the standard alone after the firm adopts the new technology, the firm's cost of complying with the standard is reduced by area ***a***. This is the firm's incentive to adopt the new technology.



But leaving the standard unchanged after the firm adopts the new technology will not be efficient. In the graph below the regulator reduces the standard to its new efficient level after the firms adopts the new technology. In this case the firm's total abatement costs change by area ***a* – *b*.**

Area ***a*** represents the reduction in the firm's total abatement costs that is due solely to adopting a cheaper way to control emissions. Area ***b*** represents an <u>increase</u> in the firm's total abatement costs because the regulator makes the emissions standard stricter.

The conclusion is that if the regulator responds to technical innovation by tightening emissions standards, then firms' incentives to adopt cost-saving technologies are reduced.

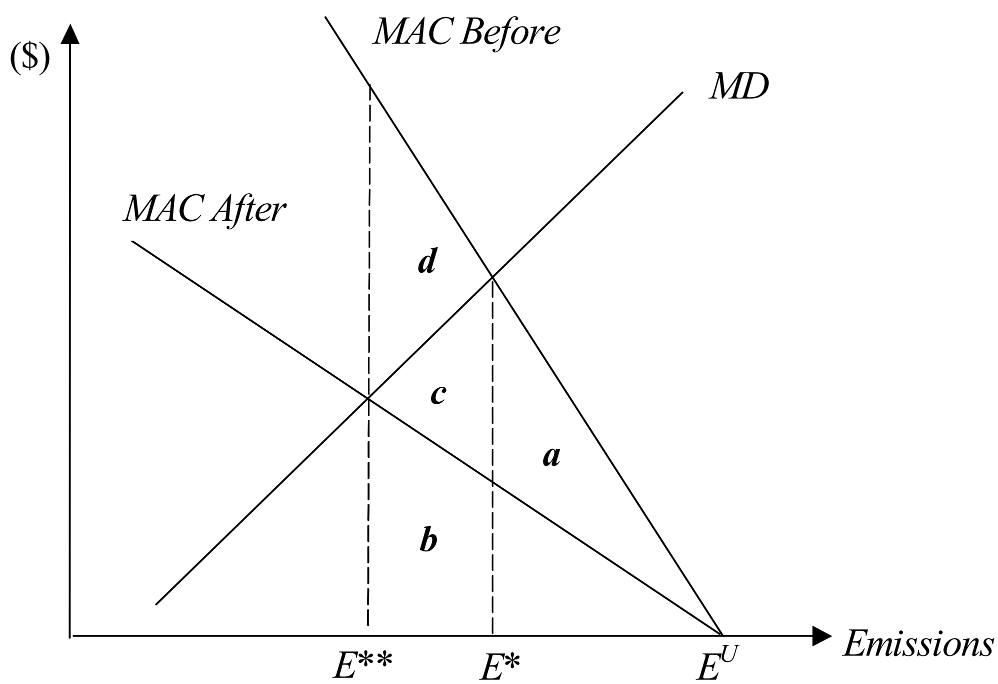


Technology forcing

Because technological change is so important for making progress on improving environmental performance, a regulator may wish to increase the incentive to adopt new technologies by imposing a stricter-than-efficient standard in anticipation of technological innovation.

In the graph below the regulator sets the emissions standard at *E*** before the firm adopts the new technology. Note that the standard is inefficiently strict before the firms adopts the new technology, but is efficient after.

The reduction in the firm's total abatement costs from adopting the new technology is now area ***a* + *c* + *d*.** This implies a substantial increase in the firm's incentive to adopt the new technology.



Lecture 12: Incentive-based Policies: Emissions Taxes

We now turn away from command-and-control policies to what are called incentive-based policies. The simplest form of these policies is an emissions tax, whereby sources of pollution pay a fee for every unit of pollution they emit.

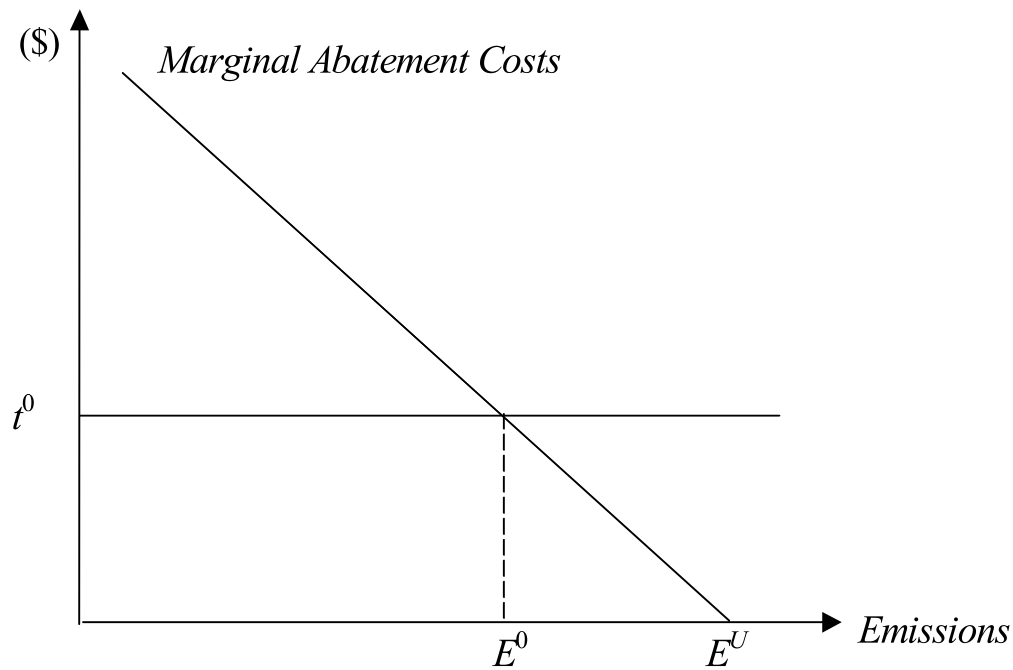
Under an emissions tax a polluting source is not required to reduce its emissions with certain methods or devices, or even reduce its emissions at all. It can do whatever its wants, but it must pay a 'price' for each unit of emissions it releases.

The main appeal of emissions taxes is that it allows firms to find the most cost-effective way to reduce emissions and it establishes a price for them to use the environment as a waste dump.

Note at the outset that we have a monitoring problem that is the same as emissions standards—we must be able to obtain a continuous measure of emissions to assess tax liabilities.

The Basic Economics of Emissions Taxes

In the graph below is the marginal abatement costs of a single firm. The firm can emit as much as it wants, but it must pay t^0 for every unit that it releases.



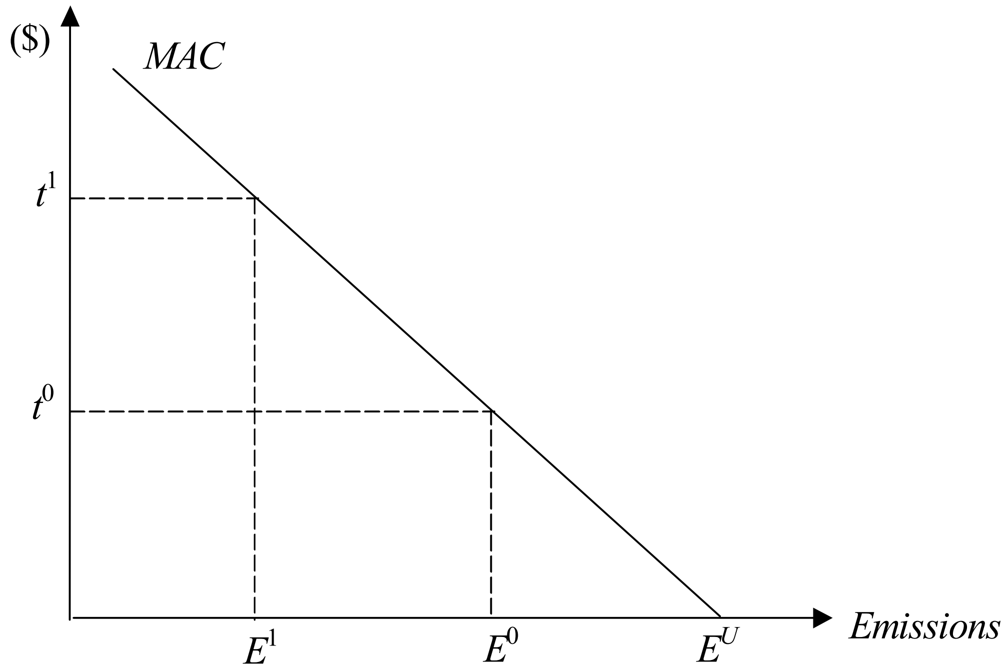
If the firm faces an emissions tax of t^0 per unit it is motivated to reduce its emissions from the unregulated level to E^0.

To understand why, note that for each unit of emissions the firm can choose to emit and pay the tax, or not release it and bear the abatement costs. It will do whatever is cheapest.

As long as MAC is lower than the tax—emissions to the right of E^0 –the firm will reduce its emissions. It is cheaper for the firm the bear the additional abatement costs of reducing emissions than to pay the tax.

As long as MAC is higher than the tax—emissions to the left of E^0 – the firm will not control its emissions, because it is cheaper to pay the tax than to control its emissions.

Now suppose that we choose a higher tax rate t^1. The firm will respond to this by reducing its emissions to E^1.



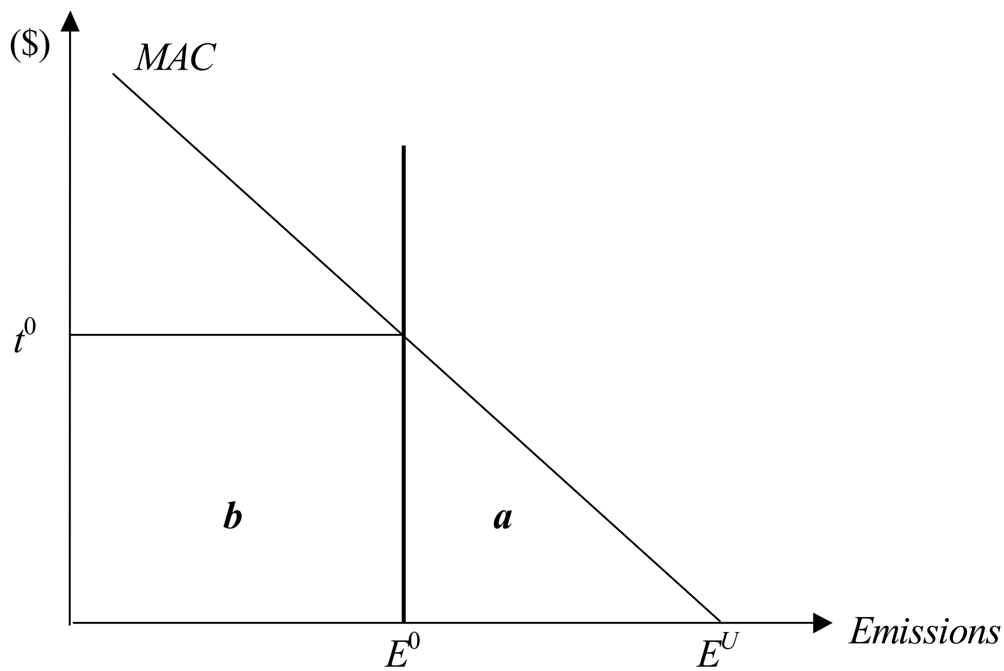
Note two things:

1. The higher the 'price' the firm has to pay to release its pollution into the environment, the less it will emit.

2. If the environmental authority knows the firm's MAC it can induce any level of emissions it wants by choosing the appropriate tax.

Firm's costs: emissions tax vs. emissions standard

Impose an emissions standard E^0 or an emissions tax t^0. Both result in the same level of emissions, so they are equivalent in terms of controlling pollution. However, the firm's costs of compliance are different under the two policies.



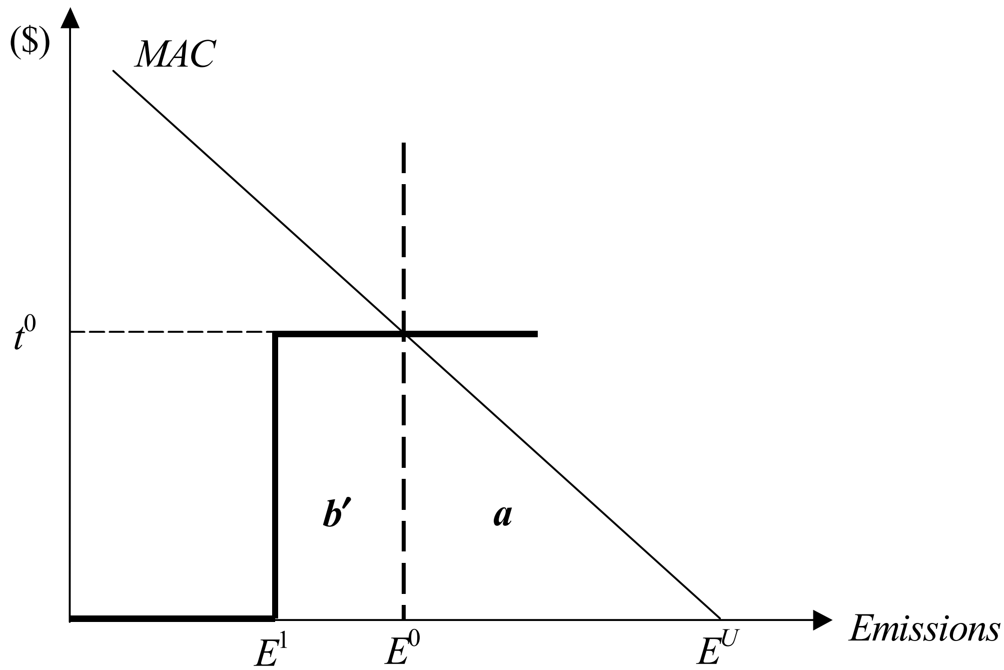
Under the emissions standard E^0, the firm's costs are just its total abatement costs, area ***a***.

Under the emissions tax t^0, the firm's compliance costs consist of its total abatement costs (area ***a***) plus its tax bill. Since it pays t^0 per unit of emissions and emits E^0, its tax bill is $t^0 \times E^0$, which is area ***b***. Its total compliance costs under the emissions tax is area ***a*** + ***b***.

Clearly the firm would prefer the emissions standard to the tax.

Although the tax bill ***b*** is a cost for the firm, it may not be from society's perspective. We often think of the tax bill as a simple transfer from the firm to another segment of society.

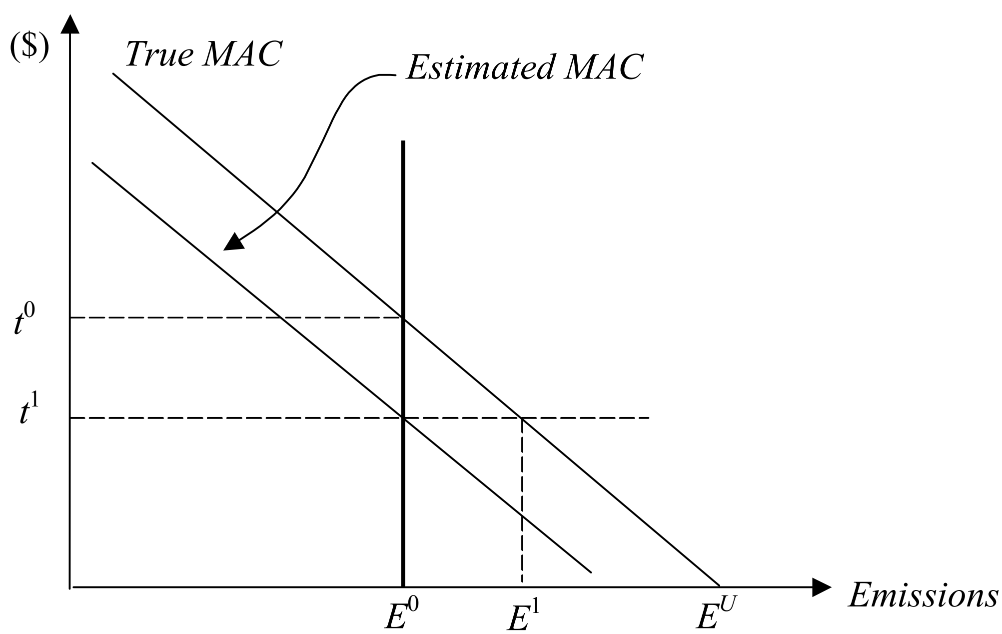
It would be relatively easy to reduce the tax burden of emissions taxes. Suppose that we allowed the firm to emit up to $E^1 < E^0$ for free, and then imposed the tax t^0 for emissions above E^1. The firm would choose the same level of emissions, E^0, but its tax liability would be reduced to ***b′***.



Uncertainty about MAC

Recall that if the environmental authority knows the firm's MAC it can induce any level of emissions it wants by choosing the appropriate tax. However, if it is uncertain about the firm's MAC, then it will not be able to guarantee that the firm will choose the level of emissions that it wants.

Suppose that the regulator wants the firm to reduce its emissions to E^0, as before. It doesn't have perfect information about the firm's MAC, so it generates an estimate. In the graph below imagine that the estimated MAC is lower than the true MAC.



With its estimated MAC the regulator will impose the tax t^1, hoping that the firm will respond by choosing E^0. But the firm doesn't do this. It equates t^1 to its true MAC and chooses $E^1 > E^0$ emissions.

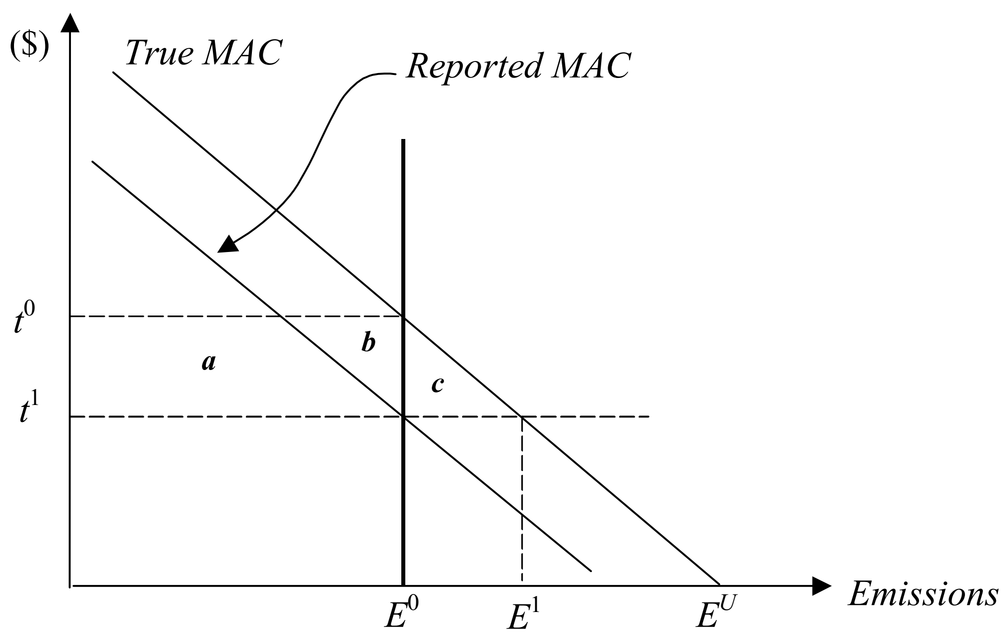
Thus if the regulator underestimates MAC, emissions will be higher than the target. If the regulator over-estimates MAC, the firm's emissions will be lower than the target. The basic conclusion is that if the regulator is uncertain about MAC, it will have a difficult time inducing a particular level of emissions. Note that this is not a problem with emissions standards.

Asymmetric information

When we looked at emissions standards, we found that a firm has an incentive to try and convince a regulator that its abatement costs are higher than they actually are. In this case the firm is motivated to do this so that the regulator will set a less strict standard.

In the case of emissions tax, however, a firm will have the incentive to convince the regulator that its abatement costs are lower than in reality.

Suppose that the regulator wants the firm to reduce its emissions to E^0, as before. Because it does not know the firm's MAC, it asks the firm to provide a report of its MAC so that it can use this report to set the tax.

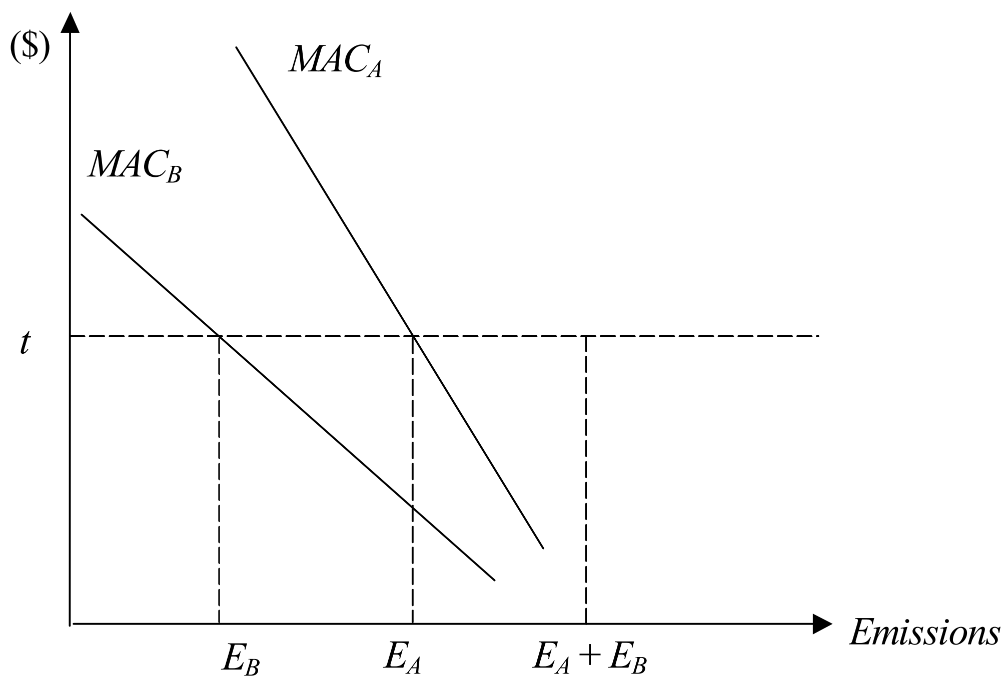


In the graph note that if the firm under-reports is MAC, the regulator will set the tax at t^1, and the firm will respond by choosing E^1 emissions. Relative to its total costs if it had truthfully reported its MAC, its costs are reduced by area $\boldsymbol{a} + \boldsymbol{b} + \boldsymbol{c}$.

Cost-effectiveness and emissions taxes

Economists often favor emissions taxes over emissions standards, because taxes have a very attractive feature. Whatever level of aggregate emissions results with the use of an emissions tax, the level will be achieved at lowest aggregate abatement costs.

In the graph are two firms, A and B, with different MACs. Faced with an emissions tax t, A chooses E_A emissions and B chooses E_B emissions. Since both firms choose their emissions so that MAC is equal to the tax and they face the same tax rate, $MAC_A = MAC_B$—their marginal abatement costs are equal. Thus, the equi-marginal principle for minimizing aggregate abatement costs is satisfied; that is, the aggregate abatement costs of the total level of emissions, $E_A + E_B$, are minimized.



Cost-effectiveness: Standards vs. taxes

A regulator could set cost-effective emissions standards if it had perfect knowledge of the firms' abatement costs, but it can't without this knowledge. However, it would be easy to meet an aggregate emissions target—just make sure that the individual standards add up to the aggregate emissions target.

Likewise, with perfect information about firms' abatement costs a regulator could choose the appropriate tax rate to induce an aggregate emissions target, and the firms' emissions choices would be cost-effective. Without perfect information about firms' marginal abatement costs the regulator will not be able to induce a specific aggregate emissions target. Whatever level of aggregate emissions results, however, will be reached at least aggregate abatement costs. To summarize:

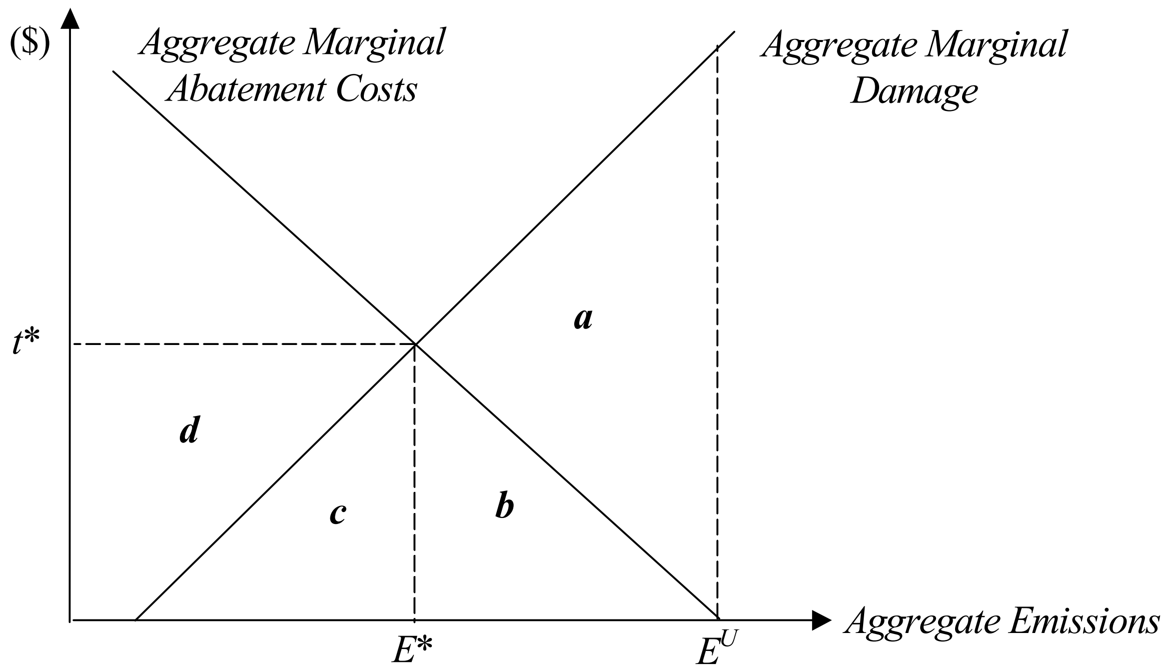
Uncertainty about abatement costs: Standard vs. Taxes

	Achieve Emissions Target	*Minimize Aggregate Abatement Costs*
Standards	**Easy**	**Hard**
Taxes	**Hard**	**Easy**

Note the trade-off of choosing standards vs. taxes. It is easier to meet an aggregate target with emissions standards, but easier to minimize aggregate abatement costs with emissions taxes.

Efficient Emissions Taxes

Suppose that a regulator has perfect information about the abatement costs of every source of emissions, as well as aggregate damages from emissions. In the graph the efficient level of aggregate emissions is *E**. To induce this level with an emissions tax, the regulator sets the tax at *t**.



The benefit of the policy is the amount of damage reduced, area ***a*** + ***b***.

The costs of the policy are the firms' aggregate abatement costs, area ***b***.

Area ***c*** + ***d*** represent the aggregate amount of taxes paid to the government. Do these tax receipts involve a cost, a benefit, or neither, beyond simple emissions control?

Is there a double-dividend?

More often than not, we simply treat the revenues from emissions taxes as a mere transfer from one part of an economy (polluters) to another (the government and the public). If this is true then these revenues generate neither social benefits nor costs.

However, for many years economists have speculated about the possibility of a double-dividend from emissions taxes. The double dividend is that an emissions tax will reduce pollution and the tax revenue from emissions taxes can be used to reduce other taxes in an economy like income taxes (labor and capital).

It turns out that it is not as easy as that, but the most recent consensus is that emissions taxes (and other revenue-generating environmental policies) are more efficient than emissions standards (and other policies that don't generate public revenue), simply because the tax revenue can be used to reduce other taxes.

Because there is still much controversy about the double-dividend hypothesis, we will treat emissions tax revenue as a simple transfer that does not involve costs or provide a benefit. The only benefits and costs that come from emissions taxes have to do with the reduction in emissions.

Emissions Taxes and Incentives for Innovation
Recall that in the last lecture we studied the incentives that emissions standards provided to firms to find and adopt new abatement technologies that reduce the costs of complying with regulations. Let's do the same for emissions taxes.

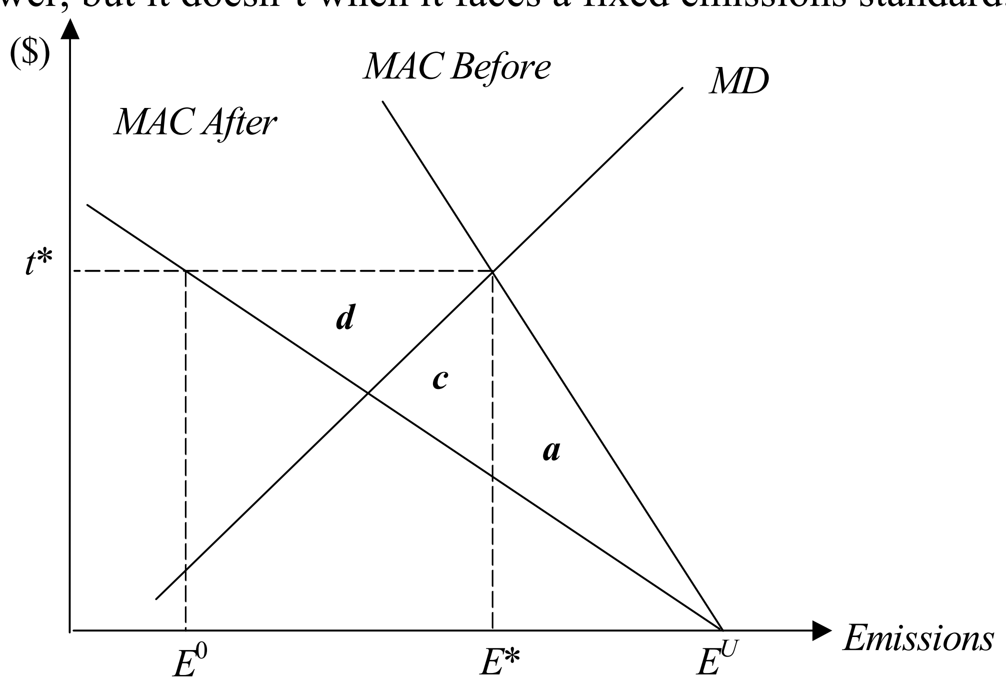
As before suppose we have only one source of emissions. We will see that if the firm faces an emissions tax, its incentive to adopt a new cost-saving abatement technology is much greater than when it faces an emissions standard. This is one of the reasons that economists tend to favor emissions taxes over standards.

The graph below illustrates the firm's marginal abatement costs before and after adopting a cost-reducing technology. Before the firm adopts the new technology the regulator sets the efficient tax t^* and the firm emits E^*.

If the regulator leaves the tax alone after the firm adopts the new technology, the firm will reduce its emissions to E^0. Its costs of compliance (abatement costs plus the tax payment) fall by area ***a*** + ***c*** + ***d***. [You'll see why we skipped ***b*** in a second].

Compare this to its cost-savings of adopting the new technology if it faced a fixed emissions standard E^*. This would be only area ***a*** in the graph. We conclude that a fixed emissions tax provides a greater incentive for the firm to adopt a new technology than a fixed emissions standard.

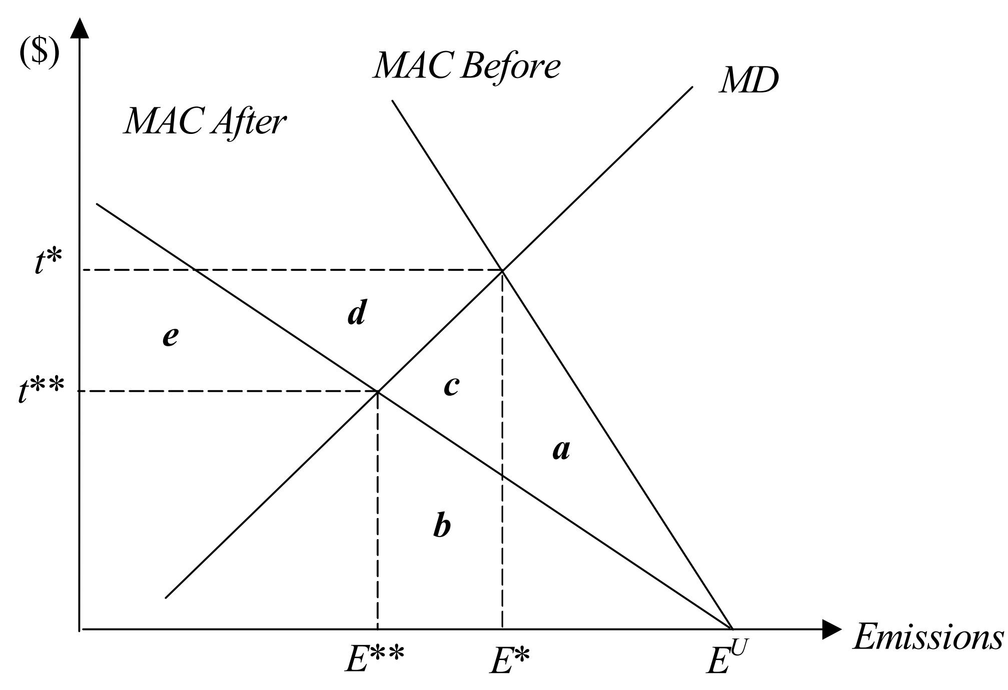
The main reason for this conclusion is that the firm has an incentive to reduce its emissions under a tax when its abatement costs are lower, but it doesn't when it faces a fixed emissions standard.



Note that leaving the tax unchanged after the firm adopts the new technology will not be efficient. In the graph below the regulator reduces the tax to its new efficient level, t^{**}, after the firm adopts the new technology. The firm responds by choosing emissions, E^{**}. Note that the firm's cost-savings from adopting the new technology is increased to ***a*** + ***c*** + ***d*** + ***e*** when the regulator reacts to the adoption of the new technology with a lower tax.

Go back to this section of the last lecture to remind yourself of the cost-savings from adopting the new technology when the firm faced efficient emissions standards. This is area ***a* – *b***, and we concluded that the firm may not have an incentive to adopt the new technology.

The primary point here is that a firm's incentive to adopt a new technology is greater under an emissions tax than under an emissions standard. This is one of the reasons that economists tend to favor emissions taxes over standards.



Lecture 13: Transferable Discharge Permits

This is another incentive-based policy.

Components of a simple transferable discharge permit policy:

1. Regulator chooses a level of aggregate emissions that it wants to achieve.

2. Constructs permits to emit that is consistent with this target. Every permit conveys the legal right to emit one unit of pollution. The number of permits should equal to the aggregate emissions target.

3. Distribute these permits to the pollution sources covered by the policy.

4. Allow sources to trade these permit among themselves.

Sources comply with the policy by holding enough permits to cover their emissions.

Transferable discharge permit policies (TDPs) are also called emissions trading, marketable emissions permits, and cap-and-trade policies.

<u>Examples of a few Transferable Discharge Permit programs</u>

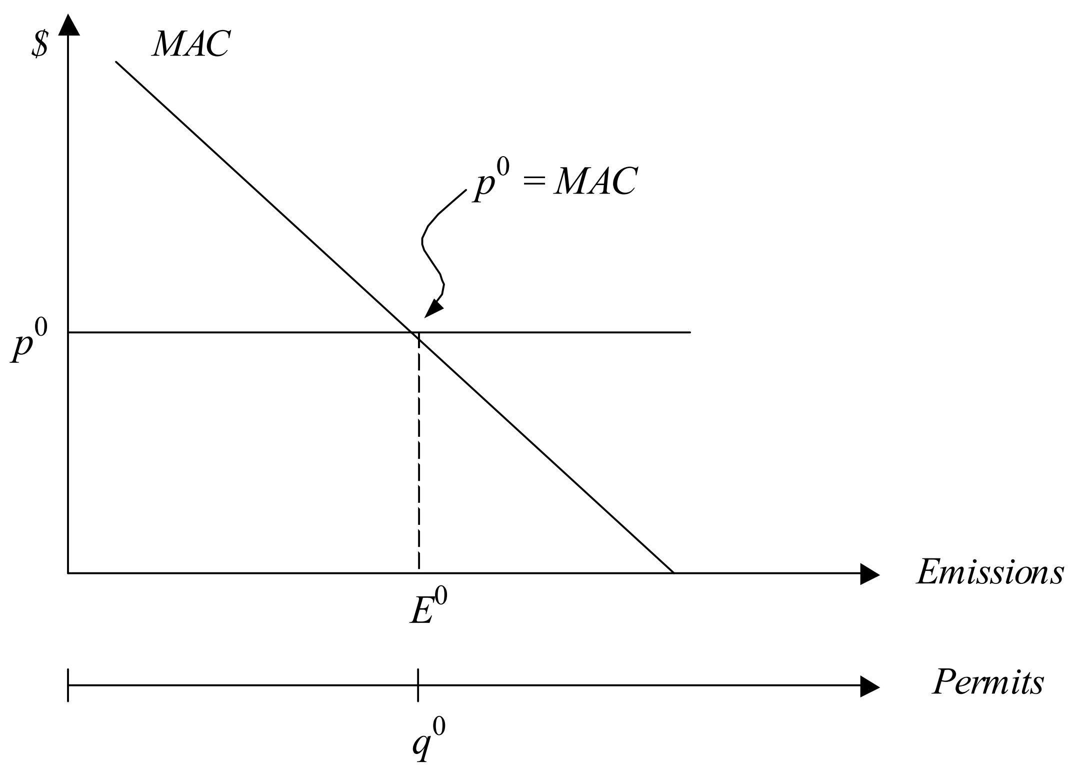
Sulfur Dioxide Allowance Trading
Ozone Transport Commission NO_X Budget Program
The Regional Clean Air Incentives Market (RECLAIM) of Southern California
Total Suspended Particulates in Santiago, Chile
Carbon Dioxide Trading under the Kyoto Protocol

How Does a TDP Policy Work?

The key to a TDP policy is that sources of emissions are able to trade permits (i.e., the rights to release pollution).

Under reasonable conditions trade among the sources will establish a competitive permit price.

Each source treats the going permit price as constant when it makes it choice of how much to emit and how many permits to hold.

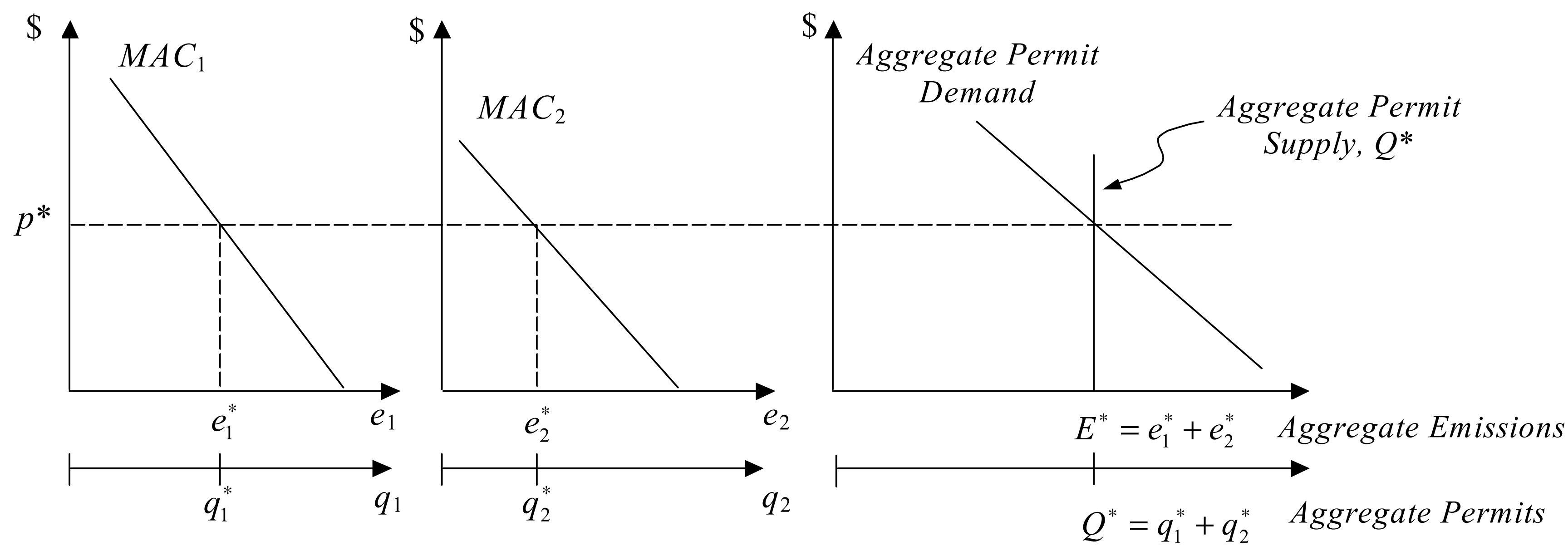


The graph is of a single firm and we suppose that the prevailing permit price is p^0. The firm chooses emissions E^0 and holds q^0 permits so that its marginal abatement cost is equal to the permit price.

Note that the permit price acts just like an emissions tax. For emissions above E^0, it is cheaper for the firm to reduce its emissions than to purchase the right to pollute. Below E^0 it is cheaper to purchase the right to pollute that it is to control emissions.

How is the equilibrium permit price determined?

Note for the previous graph that a firm's marginal abatement cost schedule can be thought of as the firm's demand schedule for permits—if the permit price is p^0, the firm demands q^0 permits. As in any competitive market the equilibrium permit price is determined by equating aggregate demand for permits to the aggregate supply of permits.



In the graph we have two firms. Aggregate demand for permits is the horizontal summation of their individual demands (their marginal abatement costs). It is therefore the aggregate marginal abatement cost schedule. The regulator issues Q^* permits to achieve an aggregate emissions target of E^*. The intersection of *Aggregate Permit Demand* and *Supply* determines the equilibrium price p^*. Firm 1 chooses emissions and permits (e_1^*, q_1^*); firm 2 chooses emissions and permits (e_2^*, q_2^*).

Cost-effectiveness and transferable discharge permits

From the previous graph it is easy to see that a competitive TDP programs will be a cost-effective policy. Recall that cost-effectiveness requires that the firms' marginal abatement costs be equal. Since each firm chooses its emissions so that the prevailing permit price is equal to its marginal abatement cost ($p^*= MAC$) and each firm faces the same price, we have $p^*= MAC_1 = MAC_2$. Since their marginal abatement costs are equal, the aggregate emissions target E^* is achieved at lowest aggregate abatement costs.

If the goal is to achieve an aggregate emissions target at least cost, a TDP program may be preferred to an emissions tax or emissions standards. Note that to achieve a target with a TDP program, a regulator doesn't have to know anything about the firms' marginal abatement costs. The target is easily met by distributing the correct number of permits. Furthermore, the permit market leads to a cost-effective distribution of emissions control.

In contrast, recall that to achieve an aggregate emissions target with an emissions tax a regulator must have perfect information about abatement costs to set the correct tax.

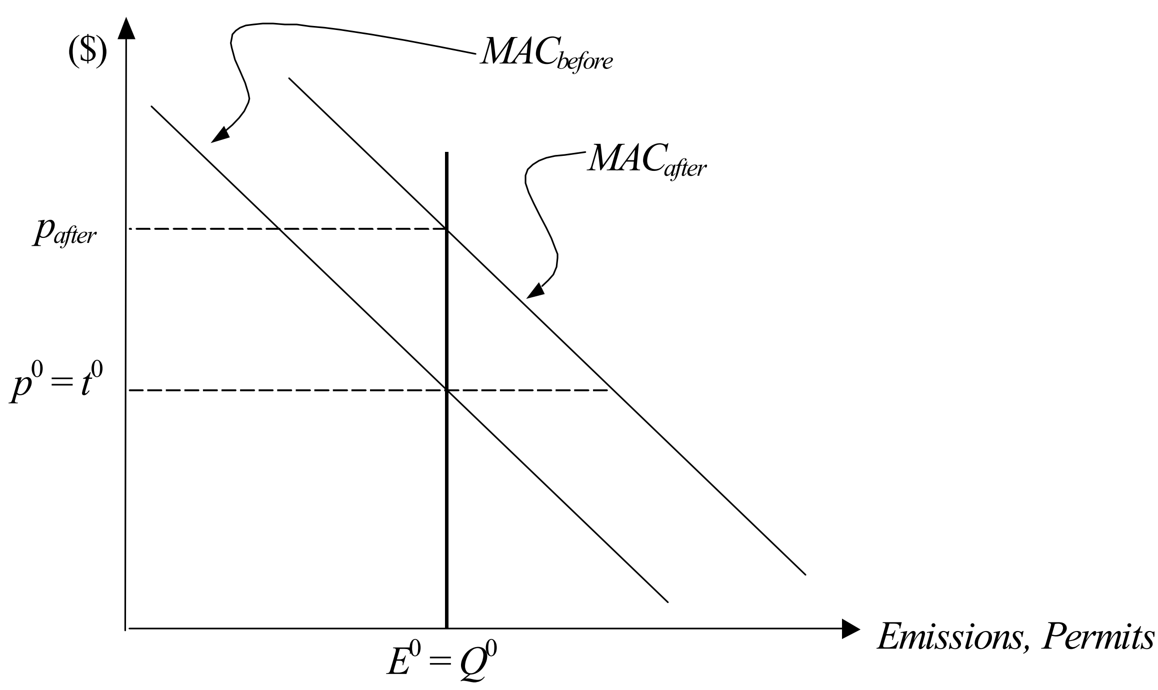
Under emissions standards a regulator must also have perfect information about abatement costs to set cost-effective standards.

TDP policies adjust automatically to changes in the economic environment, while emissions taxes do not.

If the goal is to reach a fixed aggregate emissions target cost-effectively, then an attractive feature of a TDP program is that it will adjust automatically to changes in the economic environment like industrial growth, inflation, and technological advance in abatement technologies.

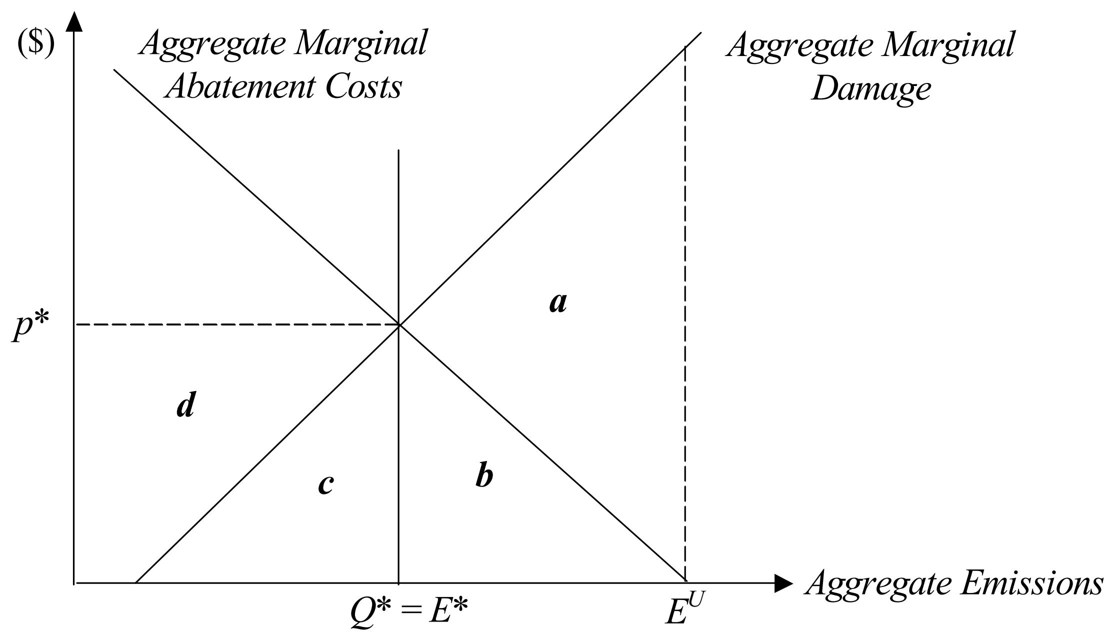
The graph illustrates the effects of industrial growth. MAC_{before} is the aggregate marginal abatement cost function at first, and MAC_{after} is the aggregate marginal abatement cost after the start-up of new sources of pollution. The goal is to hold aggregate emissions to E^0. This can be accomplished by putting Q^0 permits into circulation, which generates a permit price p^0. Alternatively, the regulator could set a tax t^0.

After industrial growth the level of emissions doesn't change under a TDP policy because the number of permits in circulation stays the same. However, the permit price rises to p_{after} automatically because the demand for permits is higher. Under an emissions tax the government would have to increase the tax to p_{after} to hold emissions at E^0. If it doesn't increase the tax, aggregate emissions will increase beyond E^0.



Efficient TDP Programs

Suppose that a regulator has perfect information about the abatement costs of every source of emissions, as well as aggregate damages from emissions. In the graph the efficient level of aggregate emissions is *E**. To induce this level with an emissions tax the regulator issues *Q** permits. Competitive trade of permits establishes the equilibrium permit price *p**. Notice that this price is equal to the efficient emissions tax.



The benefit of the policy is the reduction in damage, area ***a*** + ***b***.

The costs of the policy are the aggregate abatement costs, area ***b***.

Area ***c*** + ***d*** represents the aggregate value of the permits in circulation. If the permits are given to the firms free-of-charge, then this area represents the total value of permits that the firms own.

Under an emissions tax, area ***c*** + ***d*** represents the aggregate amount of taxes paid to the government. Note that firms will always prefer a TDP program with permits distributed free-of-charge to an emissions tax.

The area ***c* + *d*** is important because it is represents part of the value that is created by controlling emissions. Under a TDP program in which the permits are simply given to sources, this value is given to the pollution sources. Under an emissions tax this value is retained by the government, and hence, the public at large.

If emissions tax revenues are used to reduce other taxes in an economy, economists have shown that emissions taxes are more efficient than freely-given transferable discharge permits.

An alternative to giving discharge away for free is for the government to auction the permits. A well-designed auction will lead to the same outcome as freely-given permits, but would generate public revenue that could be used to reduce other taxes.

Lecture 12 Continued: More on Transferable Discharge Permits

Non-uniformly mixed emissions

So far we've examined TDP programs with uniformly mixed pollutants. This allows us to focus on limiting aggregate emissions, not on where the sources are located. However, many pollutants are non-uniformly mixed, so that the damage caused by a source depends on where the source is located.

The figure below depicts a non-uniformly mixed air pollutant. The emissions of sources in zones A and B cause greater damage than those in zones C and D.

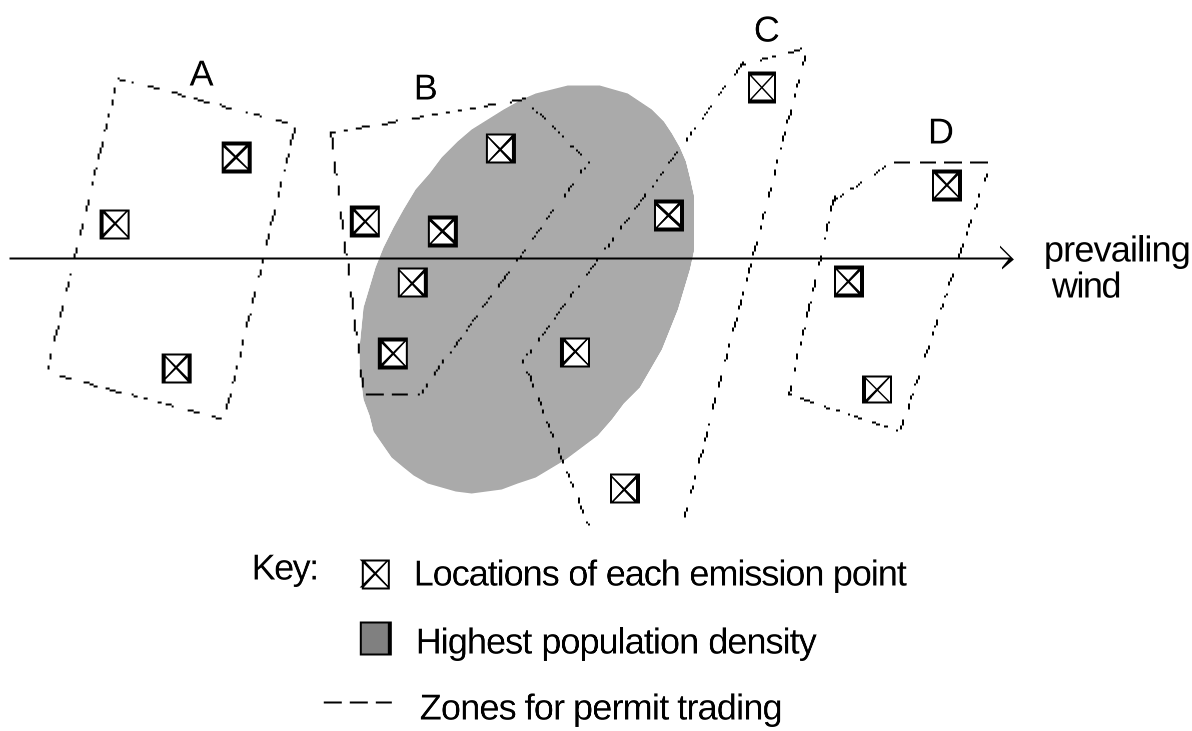


Figure 13-3: Non-uniform Emissions and TDP Programs.

The problem with controlling only aggregate emissions in this context is that a *hot spot* may develop. Suppose that sources in zones A and B buy a lot of permits from the sources in C and D, because they do not find it efficient to reduce their emissions. This will lead to more damage than if sources in zones C and D ended up with most of the permits.

One way to deal with this problem is to group the sources into zones as shown, and to specify exchange rates for trading permits across zones. The exchange rates should reflect the different impacts on damage from emissions from each zone. For example, suppose that a ton of emissions from a source in zone B causes twice as much damage as a ton of emissions from a source in zone D. Then, if a source in zone B wants to increase its emissions by one ton, it can do so by either purchasing one permit from a source in its own zone, or by purchasing two permits from a source in zone D. On other hand a source in zone D can increase its emissions by two tons with a zone B permit.

The problem of market power

It is crucial that TDP programs be designed so that there is perfect competition for discharge permits. Recall that perfect competition means that no individual source can affect the price of permits. If a source, or small group of sources, can influence (manipulate) the prevailing permit price, then a TDP program will not be cost-effective.

If a source that sells permits can influence the permit price, it will hold on to too many permits in order to keep the permit price high. If a source that buys permits can influence the permit price, it will not buy as many permits in order to keep the permit price low.

To limit the influence of market power, the number of sources in a TDP program should be relatively large so that no one source has any power.

Transaction costs

A TDP program will also not be cost-effective if there are significant costs associated with trading permits other than the permit price. In a TDP program there may be costs associated with seeking out trading partners, costs associated with negotiating and consummating trades, and costs associated with overcoming regulatory barriers to trading permits.

If transactions costs are high enough, then this will limit the development of a permit market.

TDP programs should be designed to keep these costs to a minimum. Allowing brokers to participate in TDP markets would reduce sources' costs of finding trading partners and consummating trades. Not requiring regulatory review and approval for permit trades would also decrease the costs of these trades.