EC 742: Public .Econ II Handout 4: Environmental Political economy

I. Introduction to Environmental Political Economy

1. Environmental economics is often thought of as a rather narrow applied area of public economics. However, I think of it in much broader terms than most economist do.
2. Environmental political economy concerns all matters which directly or indirectly affect the manner and the extent to which human society makes use of non-human resources.
3. There are three main areas of analysis in mainstream environmental economics.
   A. First, there is the pure logic of externalities and commons problems.
      - Mankind can not sustain itself without relying on nature for fundamental necessities, and any use of natural resources, naturally, alters the environmental balance in discernible ways.

   B. Second, there is the logic of environmental laws and regulation.
      - The positive strand of this sub area studies how particular environmental laws and regulations affect economic and environmental outcomes.
      - The normative strand of this sub area attempts to identify ideal environmental laws and regulations, as with Pigovian taxes and effluent markets (cap and trade).

   C. Third there is environmental politics/public choice, which attempts to explain why the environmental laws that we see around us are there.
      i. Political decisions largely determine the feasible uses of natural resources by defining and enforcing fundamental property rights and entitlements over matters with environmental consequences.
      ii. Political decisions largely determine the feasible uses of natural resources by defining and enforcing fundamental property rights and entitlements over matters with environmental consequences.
      - Government policies affect population magnitudes and densities through affects on birth rates, mortality rates, land use and patterns of migration.
      - Government policies affect the environment through policies and expenditures which affect the rate of return and thereby the accumulation of new knowledge and technologies.

      iii. To this may be added a variety of transactions costs and information problems that must be solved to recognize and address new environmental problems and regulatory failures.
4. Not all "environmental laws" are environmental in their direct intent.
   A. Many laws, regulations and policies have "environmental effects" in the sense that they address or directly affect man's relationship with nature, but many other laws and regulations have indirect effects on nature and environmental quality.
      i. For example, as we will see, a good deal of property law--especially that which deals with land and water--can be regarded as addressing environmental concerns, namely commons problems. Indeed, it can be argued that private property (at least rights to use and exclude) emerged to solve commons problems--as we will see in this part of the course.

ii. Legal systems have a variety of environmental impacts. Property rights which encourage mining and manufacturing imply that some minerals become less common and others more so. Rules which allow or promote hunting and farming imply that some fauna and flora become more common and others less so.

B. Environmental "law" properly understood, thus, includes many new the rules and regulations adopted by environmental agencies, but also a good deal of civic law that stretches back for thousands of years.

- It is essentially impossible for communities of humans to assemble and be self sustaining without dealing with environmental problems such as those associated with potable water and trash disposal.

5. All this implies that environmental policy was not invented in the 1960s or 70s, but has been **a long standing concer**n for all civilizations.

A. An important part of economic development has always been environmental laws of various kinds.

B. For example, North American environmental rules (in the narrow sense) have a long history.

i. As early as 1626, the Plymouth Colony passed ordinances regulating the cutting and sale of timber on colony lands (Meyer, 1966).

ii. In 1652, the first public water supply was constructed in Boston.

iii. In 1657, the burgomasters of New Amsterdam issued an ordinance prescribing that the streets be kept clean, and that all rubbish and filth be deposited at certain designated places (Sopper, 1966).

iv. In 1681, William Penn required that new land owners leave an acre of forest standing for every five acres cleared in his ordinance for the disposal of lands(Meyer. 1966).

C. Some "Old" Pronouncements on Environmental Quality:

"We are in a position more and more completely to say how far the waste and destruction of natural resources are to be allowed to go on and where they are to stop. It is curious that the effort to stop waste, like the effort to stop forest fires has often been considered as a matter controlled wholly by economic law. I think there could be no greater mistake."

Gifford Pinchot (1910, *The Fight for Conservation,* reprinted in Nash (1967)).

Aristotle's (330 B. C. / 1969 p. 278) discusses, in passing, several policies concerning water and air quality in his characterization of the ideal community.

"I mention situation and water supply in particular because air and water, being just those things that we make most frequent and constant use of, have the greatest effect on our bodily condition. Hence in a state which has [the] welfare [of its citizens] at heart, water for human consumption should be separated from water for all other purposes."

6. Economic development and environmental policies thus emerged simultaneously, because the latter was necessary for the former.

   A. People have always used natural resources to advance their own private interests.

      i. Food and shelter are obviously important, and efforts to obtain these necessities has obvious effects on the population of plants and animals that exists in a given area.

      ii. As knowledge of what is possible has increased through time, more and more natural resources become "economic resources."

   A. Economic development, in this sense, tends to increase the extent to which persons understand use natural resources advance private ends.

      i. Economic development by definition implies that natural resources are used more intensively and more extensively.

      - That is to say, more and more animals, plants, and minerals are determined to be useful, and this often implies that those "resources" become scarce.

      ii. As a consequence, externality problems tend to multiply, many of which are life or growth threatening.

   B. Neither increases in capital nor improved knowledge generate economic development automatically or by themselves

      i. Environmental rules are often necessary to make efficient use of natural resources.

      ii. In many cases, improved knowledge leads to less usage of resources in the short run.

      iii. For example, fishermen may realize that if they fish "too much" they will have fewer fish to eat in the future, or farmers realize that if they grow particular crops "too often" their fields will produce less food in the long run.

7. In addition to allow more fruitful uses of natural resources, scientific advances also allow us to recognize many externalities and commons problems that were "invisible" or "entirely mysterious" to persons in previous periods of history.

   A. This can be said to have begun with efforts to provide "clean" drinking water supplies for urban settlements. These efforts greatly improved as modern theories of disease (germs) were developed in the late nineteenth century.

   B. Another relatively early example includes many of the various wildlife and bird refugees established during the late 19th century as preserves that allow many species of wildlife to survive that might otherwise have perished. In the case of the bird preserves, a good deal of knowledge about the migratory paths of various types of birds was required to develop a series of preserves that birds could fly between on their normal routes north and south, or east and west.

   C. It can also be said to be the case regarding many subtle types of air and pollution, that have only recently been targets of environmental regulation.

D. However, improvements in our understanding of soil depletion, salinization, and sanitation clearly play roles in the development of sustainable farming and urban centers.

E. Many environmental problems that are addressed today are **very** subtle.

i. This does not necessarily mean that they are necessarily less important.

ii. But, it does mean that it is easier to make policy mistakes, because subtle processes can easily be misunderstood by regulators, politicians, and voters.

- In some cases, regulations are mistaken attempts to address "problems" that do not exist, because the risks are misunderstood by voters and policy makers.

8. It also bears noting that the politics of regulation imply that some "environmental regulations" are not actually solving environmental problems but simply shifting wealth from one group to another.

- From the public choice perspective, voters, elected representatives and bureaucrats are assumed to be **self-interested** in the same sense that consumers and firms are in the private sector.
- That is to say, given the opportunities before them, they are assumed to maximize their own net advantages (utility) given the constraints and risks that they face.
- That government decision makers are self-interested implies that one can not simply assume that environmental policies are made by an all knowing environmental agency that attempts to maximize social net benefits, as sometimes seems to be suggested in ordinary environmental text books.

9. This section of Public Economics II attempts to apply tools and concepts from public economics to environmental policy.

A. The aim of this block is not to persuade you to favor specific environmental policies, but to induce you to think systematically and carefully about environmental issues using the tools from economics, game theory, and public choice.

B. Sensible persons can disagree about what "good environmental policy" looks like at the margin, but all such persons should take account of effects that become clear using rational-choice based models of the economics and politics of environmental regulation.

II. Commons Problems and Solutions

1. An especially important externality problem for environmental economics is the "tragedy of the commons."

A. The tragedy of the commons involves the excess use of a resource that is freely available to all who wish to use it.

i. For example, in medieval Europe there were often common pasture lands or forests that could be used by the peasants for their own cattle or firewood.

ii. Note that air and water supplies are often used as commons these days. They are freely available to all that wish to use them.

iii. The oceans largely remain "commons" for fishing firms and carbon sinks.

iv. (Environmental laws have begun to regulate access to these common resources and reduce the many environmental commons problems to some extent.)

B. The **commons problem** arises when a common resource begins to be *over* utilized, that is used at a rate that diminishes its overall output.

i. This excess usage tends to happen because individual users bear only part of the cost of using the common.

ii. The reduced access, or remaining productivity, that each person's use imposes on others can be ignored by all users when they make their decisions.

iii. That is to say, an ordinary externality problem occurs, and the result is over usage.

2. A Very Simple Game Theoretic Illustration:

A. The commons problem begins with a production function. The commons is assumed to hold inputs that can be used to produce outputs, but exhibit diminishing marginal product over at least part of the range of interest.

i. A common pastureland can be used to add weight to cattle.

ii. A common fishing area can be a source of fish, when combined with labor (fishermen) and capital (fishing nets and poles).

iii. A common hunting ground can similarly be a source of food.

iv. A common stream may be a source of water, fish, and waste disposal services.

B. In the standard game theoretic illustration of a commons problem, each persons use of the commons diminishes somewhat the output realized by other users of the commons.

The Tragedy of the Commons

Herd Size	**Bob: Small Herd**	**Bob: Large Herd**
Al: Small Herd	**A, B** **3, 3**	**A, B** **1, 4**
Al: Large Herd	**4, 1**	**2, 2**

i. Note that regardless of what Bob does, Al has an incentive to place a large herd on the commons. Note that 4>3 and 2>1. (Use vertical comparisons for Al)

ii. Similarly, regardless of what Al does, Bob has an incentive to place a large herd on the commons. Again 4>3 and 2>1. (Use horizontal comparisons for Bob's payoffs.)

iii. Thus both Bob and Al will graze large herds and the pastures output of beef falls to 4 (2+2) from 6 (3+3).

iv. [The commons problem, thus, can be considered to be a special case of the "Prisoners Dilemma Game."]

v. Note that there are potential gains to trade that both Al and Bob could realize if they could each agree to restrain themselves from placing larger herd sizes on the commons.

C. On the other hand, if they agree to place small herds on the commons, each may cheat--note that there remain incentives for each to graze large herds on the commons.

- [Illustrate this with a more sophisticated version of the game derived from a production function with a peak output from the commons.]

3. This 2x2 game matrix can be easily generalized.

- The class website includes links to a spreadsheet version of the discrete game, but with payoffs based on a production function.
- The tragedy of the commons can also be modeled with continuous strategy options as below.

A. Suppose that the output (Q) from a communal resource can be written as a function of the inputs (I) used to harvest the commons $Q = 20I - I^2$

- In this case the quantity of inputs (use rate) that maximize to total output is I=10.
- Differentiating $Q = 20I - I^2$ with respect to I yields $20 - 2I^* = 0$, or $I^* = 10$
- The maximum output is $Q^* = 20(10) - 10^2 = 100$

B. Now suppose that inputs are controlled by several persons, and that each input obtains the average product from the commons.

- Average product is Q/I = 20 - 2I
- The amount received by Commons User i is $Qi = Ii (20- \Sigma Ij)$
- Common User i's ideal use rate maximizes his or her output from the commons:
- Differentiating with respect to Ii yields $20 - Ii - \Sigma Ij = 0$
- Solving for Ii, and remember that one of the Ij's is Ii, yields $Ii^* = [20 - \Sigma_{j\neq i} Ij]/2$

C. At the symmetric Nash equilibrium, $Ii^{**} = Ij^{**}$

- In which case the above becomes $Ii^{**} = 10 - (N-1)Ii^{**}/2$
- which implies that $Ii^{**} = 20/(N+1)$

D. Since each user uses the commons at this rate, the total usage is Nii** or

- $I = 20 [N/(N+1)]$

i. Note that for N = 1, the use rate is 20 (1/2) = 10, the optimal total rate.

ii. Note that for N = 2, the use rate is 20 (2/3) = 13.333 which exceeds the optimal rate by 33%

- Output fall from 100 to $20(13,3) - (13,3)^2 = 88.89$, a decline of more than 10%.

iii. Note also that as the number of users increase, total usage approaches 20 in the limit.

- Output in this case asymptotically approaches zero!

E. This mathematical illustration captures the intuition of the tragedy of the commons quite well, although it bears noting that it somewhat overstates the problem.

- Many commons do not have such large diminishing returns from use over the entire range of possible uses.
- In such cases, the commons problem may emerge after the number of users exceeds a number significantly greater than 1, but still finite.
- (This partially explains why communal resources continue to exist today, even in Western economies.)

4. In the case of communal lands, the tragedy of the commons has largely been addressed around the world by privatizing the commons.

A. That **is to say, given single user exclusive control over the use of an area of land (the right to use and/or exclude others from using that piece of land).**

- To see how this solves the problem, suppose that the commons is divided in half.
- In this case the new production functions must add up to the original one so the new production functions are $Q = 10I - .I^2$
- (Note that this is not just half of the original function, why? The outputs have to add to the original function. Just halving the function yields much more output than can be produced.)
- Each user will maximize his or her output, so $10 - 2I^* = 0$ which implies that $I^* = 5$ and output from each half of the commons is maximized, as total output from the original commons.
- Each "owner" will maximize their output. Differentiating by I yields: $10 - I = 0$

B. Privatizing gives complete control over a parcel of land, or other resource, to a single individual, group, or firm.

i. This individual or firm will want to maximize output from his/her assets and will place the herd size on the pasture that maximizes output.

ii. The above mathematical illustration shows that one gets the efficient level of output when there is a a single owner.

iii. Dividing the commons into several pieces also allows would eliminate the usage externality in the example, although its not entirely clear what the individual production functions look like for this particular commons problem.

- Show that it is not simply Q/N as might be thought. Explain why this is the case.
- What properties should the correct functions have?
- ["Privatizing" to solve commons problems does not require the right to sell. Why?]
- If commons cause problems, why are there so many commons left in modern life?
- [Are there cases where privatization will not work? Explain Why? A few of these are developed below.]
-

C. Elinor Ostrom won the 2009 Nobel Prize in economics for her work on alternative solutions to commons problems. See her famous 1990 book on *Governing the Commons.*

- Here 1990 book shows that a wide range of alternative solutions to the commons management problem exist.
- These include privatization and various forms of cooperative management, with, for example, user fees or use limits.
- Many of these solutions have remained in existence for decades or centuries at a time.
-

5. **ECONOMIC DEVELOPMENT AND ENVIRONMENTAL PROBLEMS.**

A. Both the standard environmental external cost problem (pollution) and the tragedy of the commons problem (over use) imply tend to arise as a common resource becomes more intensively used. That us to say, as the aggregate use rate increases, one become more and more likely to reach the range where total output falls,

i. Holding technology and the legal setting constant, it is clear that as market output increases there tend to be more wastes to be discarded, and many of these will use the "free" disposal available from the **circulating** water and air systems.

ii. Holding technology and the legal setting constant, it is also clear that the more intensive the use of a common resource, the more likely it is to be over utilized. As a body of water is fished by more and more fisher-man and women, eventually the harvest reduces the number of fish left to reproduce to the point where the fish population **declines from season to season**.

iii. That is to say, holding technology and the legal environment constant, **environmental problems increase with economic development**.

- Note that this suggests that air and water pollution problems are instances of commons problems. [Explain why]

B. Fortunately, however, both technology and the legal environment also change through time. And, many of these changes may reduce the magnitude of externality and commons problems.

i. Technological change may allow producers to reduce their costs (and consumers to save money) by using new production methods that have smaller flows of wastes.

ii. ("Waste outputs" of production "sell" with negative prices--that is to say, firms and consumers have to "pay" people to carry their "waste products" away.)

iii. Technological change may also create production processes that reduce waste flows or trans-form wastes into valued products. (Sawdust into composition board, scrap metal into new metal products, used paper into new paper products.)

iv. Note that economic development may also create political pressures for solutions to commons problems to be adopted.

C. Generally, the material used to produced goods and services have been **falling** through time as technology increases.

- **i.** Thus a modern house has far less wood in its structure than a log cabin.
- **ii.** A modern plastic bag has far less plastic, an automobile less steel, and a modern aluminum can less aluminum, than similar products of twenty or thirty years ago.
- **iii.** It is literally true that **"they don't build them like the used to."**
- **iv.** Of course, technological change can also worsen environmental problems as when it becomes profitable to extract valuable metals such as gold or copper from low grade ores that used to be ignored by miners, because they were unprofitable.

6. The laws that frame economic decision may also change in a manner that reduces or increases the magnitude of environmental externality and commons problems.
   A. Polluting activities may be subsidized or encouraged as with agricultural policies and zoning laws
   B. Or increases in the magnitude of externality and commons problems lead to new laws that reduce environmental problems.
      - For example, some commons problems can be solved by simply "privatizing" or regulating acces to the resource exhibiting usage externalities.
   C. Democracies have generally done a better job of addressing new externalit problems than dictatorships.
      - There is much literature on this, especially with respect to treaties, beginning with Congleton [1992].
      - Not all studies find the same result, but most do and those that do not are often measuring environmental quality or treaties in somewhat odd ways.
      - [The Congleton comparative environmental policy model may be developed in class.]

III. Solutions to Externality and Commons Problems

1. **Privatization**: the transformation of communal resources into private resources
2. **Coasian Contracts**: bargaining among "polluters" and "pollutees" can lead to contractual solutions that internalize externalities.
3. **Collective Management** of Access: Use Rights and Use Fees can reduce incentives to engage in pollution generating activities.
4. **Pigovian Taxes**: taxes and fines on pollution itself creates incentives for firms (and consumers) to reduce pollution by a combination of changes in consumption, reduced consumption of pollution generating goods, and the adoption of less polluting production technologies.
5. **Direct Regulation**
6. [If so many solutions are possible, why is it that so few "ideal" policies are observed? We will analyze the politics of environmental policy later in the course.]

A. Coasian Contracts (Tradable Pollution Rights)

A. In other settings, privatization may not be sufficient, but it may be possible for the affected parties to develop contracts that solve the problem.

B. For example those affected by pollution may pay the polluter not to pollute.

C. Or alternatively, those wishing to pollute may pay those who will be affected by that pollution for the privilege.

D. The Coase theorem says that (a) as long as property rights are well defined (and tradable or contracts enforced) and (b) transactions costs are negligible, then voluntary exchange can solve all externality problems. More over if (c) there are not significant income (original endowment) effects, then the final result tends to be the same regardless of the original assignment of property rights.

E. Intuitive Example.

i. Suppose a factory, Acme, uses a production process that produces smoke along with its market-able output. The wind mostly comes out of the West so that the smoke fall mostly on homeowners who live East of the factory .

ii. The *weak form* of the Coase theorem (a and b) suggests that voluntary exchange can be used to solve the externality problem. The home owners can band together and attempt to pay the firm to reduce its emissions either by reducing output or by using pollution control devices.

iii. Gains to trade exist because at the margin, the firm realizes no profits from the last unit sold, but the home owners association is willing to pay a positive sum to get the firm to produce less.

iv. Notice that similar gains to trade would exist if the home owners initially had veto power over the firm's output. In this case, the firm would be willing to pay the home owner association for the privilege of producing its output and smoke.

v. Whenever transactions costs are small, contracts can be developed (trade can take place) that completely solves the externality problem in the sense that after the "Coasian contract" all gains from trade are realized, and net benefits are maximized.

F. The *strong form of the Coase theorem* holds if transactions costs are low and there are no important income effects that arise from the assignment of control over the resource or activity of interest.

i. In such cases, Coasian contracts will alway reach the same output level--if the Pareto efficient outcome is unique, as it often is in diagrams.

ii. And consequently, the final outcome is the same no matter who controls the resourcs after all gains from trade are realized!

iii. That is to say, in such cases, the gains to trade are exhausted at the same output level regardless of the initial assignment of control (property rights).

G. The Coasian approach to externalities implies that essentially all externalities are reciprocal in the sense that who "creates" the externality depends on the original assignment of control.

i. In the case where the home owners association control the resource, their decision imposed large costs on Acme!

ii. And vice versa. If Acme controls the output or activity level, then the home owners are made worse off.

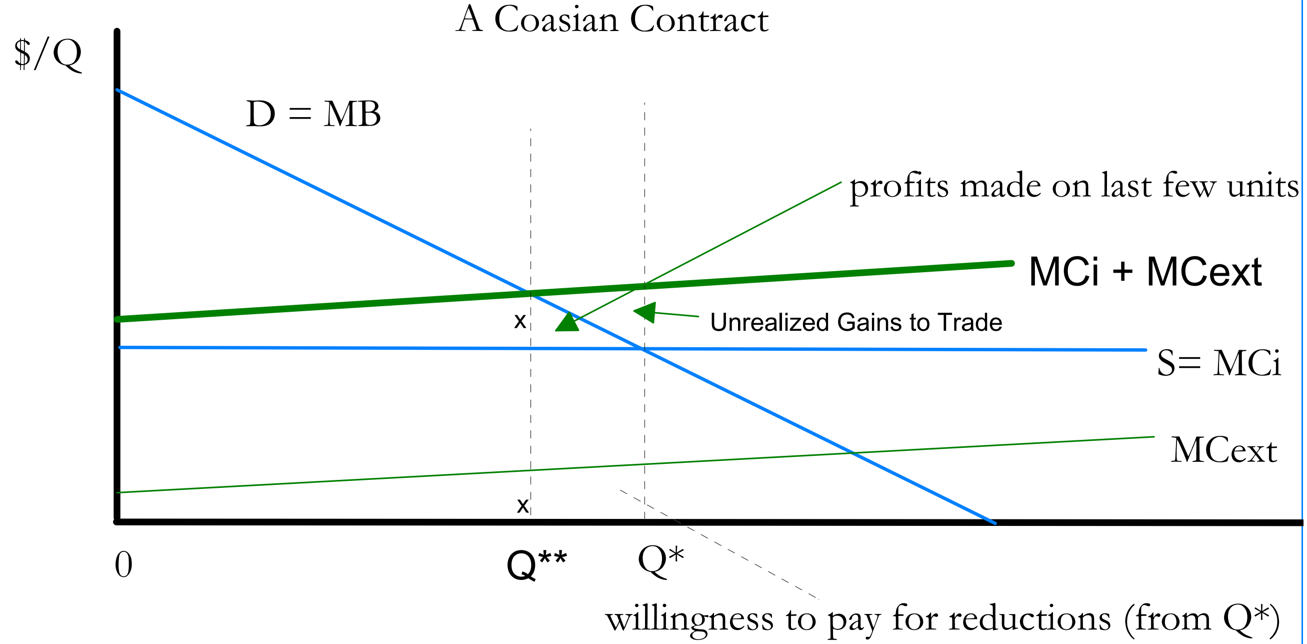
iii. However, the process of exchange always makes both parties better off, given their original circumstances.

iv. The orginal property rights assignment affects the direction of payments, although not the final output level in a Coasian world.

H. An Illustration of the geometry of the Coase Theorem

Figure 1

A Coasian Contract



i. Suppose that the firm, Acme, initially controls the output or emissions. In this case, in the absence of a Coasian Contract, the outcome will be an output that maximizes profits such as Q*.

ii. Note that unrealized gains to trade exist at Q*. The home owners are willing to pay more for reductions in output than the firm earns as profits.

iii. The last unit that the homeowners can afford to compensate the firm for "not to producing" is Q** where the marginal compensation required by the firm (the marginal profit labeled x) equals the willingness of the home owner association to pay for it (the marginal external cost labeled x).

iv. Note that the result is not changed by a reassignment of property rights. Had the homeowner association initially had veto power over the firm's activity, they will set output at 0 in the absence of a Coasian contract. ("0" minimizes cost imposed on them by the firm.)

v. Clearly, gains to trade also exist in this case. The distance from the MR curve to the firm's MC curve is much larger than the size of the marginal external cost borne by home owners at 0.

vi. The firm can, thus, compensate the homeowners for the costs imposed on them by its smoke on all units of output up to the point where Acme's willingness to pay for the privilege of producing more output exactly equals the amount required to compensate home owners at Q**.

vii. In the case depicted, the strong form of the Coase theorem holds. The same output level occurs regardless whether the firm or the home owners initially control the emission or output level. (This counter intuitive result is why Ronald Coase won the Nobel prize in economics in 1991.)

viii. (Of course, the flow of payments clearly differs! Acme prefer the first setting, and the homeowner's association prefer the second.)

IV. APPENDIX: on the Technological and Legal Solutions to Common Access Resource Problems

A. Natural resource management issues can be divided into two areas: those regarding the management of stationary resources and those regarding the management of freely circulating resources.

i. Both these areas have long been subjects of government regulation, and both exhibit similar problems insofar as free access to either sort of natural resources tends toward excessive use: what Hardin (1968) termed the tragedy of the commons.

ii. However, the cost, effectiveness and feasibility of alternative management methods differs substantially across these two types of resources. Regulating access to stationary resources is generally easier than regulating access to freely circulating resources because monitoring costs are lower and the problems associated with mismanagement are more obvious.

B. **Stationary Resources**

i. Historically, a variety of management methods have been used to limit access to stationary resources in order to promote their productive and sustained use. One broad class of methods widely used for centuries involves the assignment of "use rights" for particular stationary resources, such as grazing lands, gardens, or lodging sites. Here political authorities do not directly regulate the use of natural resources, but rather define and protect the use rights of lawful "owners" or lawful "users." [6]

---

[6] Ostrom (1990, ch. 3) analyzes a variety of long standing methods of managing access to common property resources including: grazing lands in the Swiss Alps, communal forest land in Japan, and canal systems in Spain. **She concludes (p. 90) that enduring methods for resolving commons problems share eight characteristics**: (i) clearly defined boundaries, (ii) congruence between appropriation and provision rules and local conditions, (iii) collective choice arrangements, (iv) monitoring for appropriate behavior, (v) graduated sanctions, (vi) conflict resolution methods, (vii) minimal rights to organize locally, and for larger commons problems, (viii) organization of monitoring, enforcement, and conflict resolution as "nested" enterprises.

ii. In cases where "use rights" are exclusive *and* tradable, markets for "use rights" give owners incentives to consider both the current and future productivity of the resource over which they have control. The current income and resale value of a well managed site tends to be higher than one that is poorly managed. Exclusive and marketable "use rights" also create a low cost method whereby resources may be shifted from more talented resource managers. Better managers are naturally willing to pay a higher price for use rights than poor managers because they anticipate greater output from the same resources.

iii. The property rights solution to the management of stationary resources is relatively permanent and unobtrusive, and requires little political oversight on a day to day basis.[7] Monitoring the unauthorized use of privately owned resources is largely undertaken by property owners themselves, which further reduces the cost of the this solution to the commons problem. Privatization may not solve all the problems of managing stationary resources, but the efficiency of the property rights solution as a method of encouraging the production of valued services for humankind is attested to by the fact that formal chains of title to real estate in Western Europe and in the Eastern United States generally predate current governments, often by several centuries.[8]

C. **Circulating Resources**

i. Management of freely circulating resources is more difficult, and it is, partly for this reason of greater modern policy interest.

ii. Circulation and diffusion give air and water systems a substantial capacity for dissipating and neutralizing many of the undesired byproducts of farming, manufacturing, and transport. Circulation and diffusion also imply that access to these resources is largely unimpeded by inconvenient distances, no trespassing signs, or fences. These properties have long been relied on (at least implicitly) as inputs in the production process. It is, after all, what makes fire, farming, and indeed breathing, possible. Unregulated free access to these systems eventually leads to over exploitation of their productive capacities in much the same manner as was true for stationary resources. New users gain average net benefits from use rather than marginal net benefits. Marginal net benefits are below average benefits (and may even be negative) because a large proportion of productivity losses are borne by other users in the form of reduced air or water quality.

iii. The same properties of the air and water systems which make them valuable inputs for production and convenient vehicles for waste disposal also make them difficult to regulate and/or to privatize.

---

[7] The above argument is not meant to imply that privatization has very often been adopted with the conscious intent of solving commons problems. Rather, it is likely that regions of the world which adopted ownership rights avoided commons problems that others societies using more politicized methods had to cope with. Through time, as legal institutions evolved, better assignments of use rights tend to supplant management methods which yielded significantly inferior outputs.

It may be argued that there has been a gradual restriction of private use rights through time. Often these restrictions do not substantially restrict the uses of the stationary resource, but rather access to *circulating* resources which pass under, over, or through the stationary resource. For example, modern rules governing solid waste disposal attempt to ensure that "disposal" is undertaken in a manner which does not affect local water or air quality.

[8] See Macfarlane (1978) for an overview of English property law during the medieval period.

- Communities can not assign use rights to *particular units* of freely circulating air and water in the same manner that they can for land and mineral resources.[9] Air and water are unlike railroad box cars and cattle in that particular "pieces" of air or water can not be readily identified, isolated, or therefore assigned to particular "owners."
- This contrasts with, for example, homogeneous acreage in a featureless desert or plain which can be assigned to owner/users on the basis of geometric coordinates.

iv. Tradable rights to ***use*** air and water can be established, but such rights are *user rights to a common property resource* rather than ownership in the usual sense.[10]

D. Political conflict over the management of circulating resources is nearly unavoidable because common ownership implies that decisions to curtail, maintain and/or increase "use rights" directly affects the interests of all other users of the common property resource.

i. The physical properties of circulating natural resources imply that a relatively large number of affected parties will disagree over the importance of controlling particular point sources of effluent emissions.

ii. Diffusion generally diminish the impact of effluents as distance from the point of origin increases.

iii. Consequently, even if there were no other disagreement regarding acceptable emission rates, diffusion provides a physical basis for political controversy at all levels of government with authority over the affected parties.

V. Environmental Politics: the Median Voter and Public Policy

1. At the level of domestic (national or state) politics there are both election driven and interest group driven models of public policy.

A. The most widely used electoral model is the median voter model.

B. The most widely used interest group models are Peltzman like in that a variety of groups compete for net benefits (rents) that can be generated via public policy.

2. For most empirical purposes, the median voter is the VOTER with MEDIAN characteristics.

A. That is to say he or she is a voter of median age with median income, median education, median family size, median political ideas and so forth..

B. The median voter is not usually be the same as the median member of the community because not all persons are equally likely to vote!

---

[9] One can own bottles of air or water. But, generally bottled air and water are only temporarily partitioned from the common circulating air and water systems. "Purchase" of a bottle of water is more analogous to renting than owning an asset.

[10] See Block (1990) for several extended discussions of the merits of market based environmental regulation. These discussions generally neglect the fact that determining the optimal quantity of use permits, and/or the range of uses (permissible effluent rates) allowed are bound to remain ongoing political/regulatory issues.

i. In the US it turns out that the median voter is a bit older, richer, and better educated than the median member of the group of persons eligible to vote.

ii. Poor, young, and less educated person vote less frequently than older, richer, and more educated persons.

3. To the extent that the Median Voter gets what he or she wants, anything that changes the median voter's preferred policy will affect government policy.

   A. [This neglects possible "agency problems."

   B. Candidates may say one thing to get elected and do something else once in office.

   C. Moreover, elected representatives may not be able to fully control the bureaucracy.

   D. However, candidates that are known to have cheated and done poorly at overseeing the bureaucracy will be more likely to lose the next election than those that have not since the median voter will not have gotten what he or she wants. So this is not a crazy assumption.]

4. To the extent that government services are normal goods, Government services will tend to increase as the median voter becomes wealthier, as their tax-cost relative to private services decreases, and as their perceived value increases.

VI. Elections and Environmental Regulation

1. The standard model of electoral equilibrium is the median voter model.

   A. Modeling the median voters optimal degree of regulation requires a bit different approach than modeling demands for government services paid for via taxes, because the cost of regulation is always indirect.

   B. There is no "direct" tax bill for regulations, instead regulations indirectly increase the cost of other valued goods and services.

2. Consider the case of environmental regulation.

   A. Here there are direct benefits from increasingly stringent environmental regulation: cleaner air, improved health, more pleasant environment, more attractive outdoor life styles and so forth.

   B. However, the cost of environmental regulation is very indirect. Pollution control devices (usual) increase the cost of manufactured goods. Thus, the price of clean air and water generally shows up as an increase in the price of manufactured goods relative to environmental "amenities."

3. A Geometric Illustration:

   A. Assume that three voters have different tastes for environmental quality but have similar tastes for non-environmental goods.

      i. This allows the figure below to be used to characterize the MC for environmental regulation with the same curve,

      ii. and the MB from environmental regulation to be characterized by their individual curves

B. Note that Bob is the median voter. (Why?)

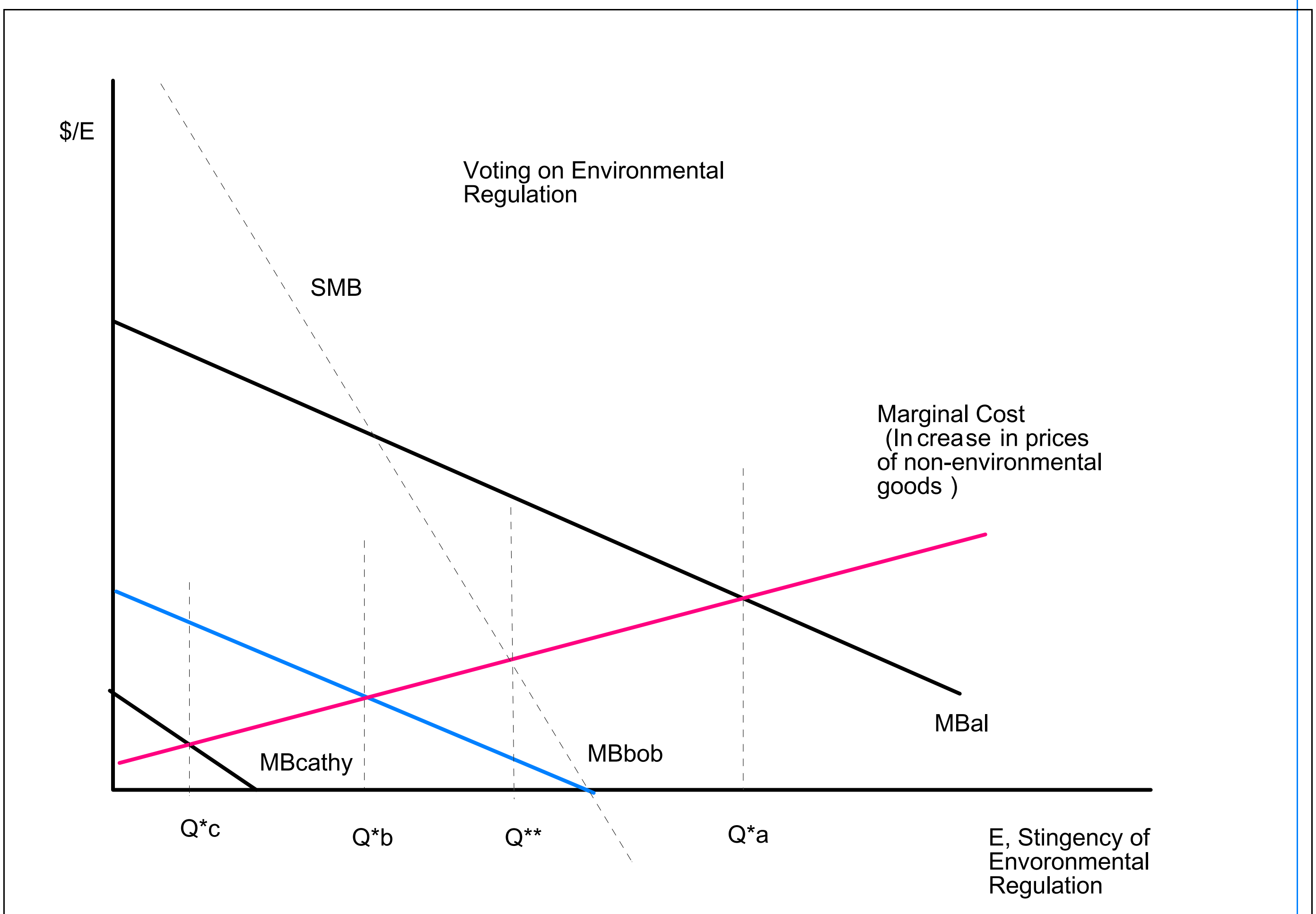
i. Thus the predicted result of democratic politics is policy Q*b.

ii. However, Bob's ideal point is not the same as the Pareto efficient level of regulation because Bob has no reason to take account of the benefits and costs imposed on other voters. (Remember we assuming self-interested voting.)

iii. Note that Q** will lose to Q*b under majority rule!

- This implies that environmental regulations are *under supplied* in this case (because Q** > Q*b).
- (Of course it is also possible that Q** < Q*b and the regulations will be over supplied. Draw such a case.)

C. What does this imply about environmental regulation in a democracy?



- Of course, voters are not perfectly informed about environmental matters or environmental policies, they consequently **may also make mistakes** about environmental regulations or be ignorant of problems that exist in the law

D. An illustrative mathematical representation of a voter's ideal level of regulation is also easy to develop.

i. .Suppose that environmental quality, E, increases as regulatory stringency, R, increases: $E = e(R)$

ii. Suppose that regulatory stringency also increases the price of some good of interest, $P = p(R)$

iii. Suppose that the consumer normally spends Y dollars on the good (as would be the case if the good is generalized consumption expenditures and Y is personal income). $C = Y/p(R)$

- If the voter values both personal consumption and environmental quality, his or her utility function can be written as $U = u(C, E)$.

iv. Using the substitution method one can write U in terms of regulatory stringency:

$$U = u(Y/p(R), e(R)$$

v. Differentiating with respect to R and setting the result equal to 0 allows us to characterize the voter's ideal level of environmental regulation.

- R^* is such that $U_C(-Y/P^2)(P_R) + U_E E_R = 0$
- The first term can be regarded as the marginal cost of regulation and the second as its marginal benefit.

vi. The implicit function theorem implies that $R^* = r(Y)$ in this case.

vii. The implicit function differentiation rule implies that

$$R^*_Y = \{(U_{CC} (1/P) (-Y/P^2)(P_R) - U_C(1/P^2)(P_R) + U_{ER}(1/P)E_R \} / -(SOC)$$

- The second order condition is simply the second derivative of the indirect utility function with respect to R, which must be negative if the first order conditions characterize a maximum. So, the sign of this partial derivative is determined by the numerator.
- The first and last terms of the numerator are positive under the usual assumptions about utility functions. The middle term, however, is negative, so the relative size of the middle term relative to the others determines the relationship between voter income and their demand for regulatory stringency.
- If there was no diminishing marginal utility from consumption and no complementarity between environmental quality and consumption, then the first and last term would equal zero ($U_{CC} = 0$ and $U_{ER}=0$). In this case, there would be a negative relationship between income and optimal regulatory stringency.
- Contrariwise, if diminishing marginal utility of consumption is substantial and if there is significant complementarity between environmental quality and the marginal utility of consumption, then the sign of the numerator would be positive. In this case, there would be a positive relationship between income and desired environmental regulation.

viii. Note that if either of these cases holds (for all voters), then the person of median income would be the median voter.

- (E.g. voter demands for regulation would be a monotone function of their income.)
-
-
-
-

VII. Regulatory Externalities, Federalism, and Treaties

1. There are many cases where even if a local democratic government attempted to achieve Pareto efficient outcomes locally, they can not because part of the problem is generated by persons or companies outside their jurisdiction.

   A. In such cases, regulation itself can be an externality generating activity. That is to say regulations in one state may impose benefits or costs on resident of other adjacent jurisdictions.

   B. Consequently, there may be unrealized gains to trade between governments regarding appropriate regulation.

   C. In a median voter model, in effect the median voters would have reasons to coordinate their policy choices.

2. There are basically two common methods for dealing with such externality problems.

   A. First, the affected parties may attempt to negotiate a "Coasian" contract that "internalizes" the externality. That is to say, the governments may negotiate a treaty where the countries "trade regulations."

      i. For example, in the various international environmental treaties, countries agree to strengthen various environmental regulations to deal with an international externality.

      ii. State and local governments may negotiate with each other and sign agreements to coordinate policies or to create a "special use district" of the same "size" as the externality. (Examples include airport and transit authorities (NY, NJ and CN) and water commissions (US and Canada, Sweden and Denmark) etc.

   B. Another second possible within a country is to "ask" higher levels of government to regulate the matter of concern. Adjacent counties may ask states to regulate "county externalities," states may ask the federal government to regulate "inter state externalities."

      - In Europe the regulation of many international externalities is coordinated by the European Community.

3. One expects the results of these two general methods are highly imperfect (relative to Pareto optimality) for several reasons. Discuss some of these.

4. [We will analyze the demand for treaties, treaty organizations, and their effectiveness later in the course.]

   -
   -
   -
   -

VIII.Global Warming

1. Some Background from Climate Science

   A. The global warming debate concerns a variety of disagreements about climate science, economics, and politics.

   i. One the one hand, there are physical science debates concerning the exact relationship between green house gases and the average temperature of the earth.

   ii. On the other hand, there are economic predictions about the long run time path of human emissions of green houses gases (which are necessary to make long term climate predictions) and economic estimates of the damages associated with changes in the earth's average temperature.

   iii. These economic effects, in turn, depend in large part on future regulatory decisions by national, state, and local governments, as well as technological advance.

   B. There is a body of climate science based on elementary physics that is largely uncontroversial.

   i. If the earth has a stable temperature, or has had one, then it must be the case that the energy absorbed from the Sun and produced by the earth itself (via radioactive decay and friction within its core) must be essentially equal to that radiated into space.

   - Otherwise the earth would be warming or cooling through time.

   ii. Climate models have become increasingly sophisticated in their treatment of radiation and absorption as more complete consideration of air and water circulation have been added to the models.

   - There as also been a more sophisticated accounting of the paths through which carbon dioxide is added and subtracted from the atmosphere.
   - The circulation of the air and water systems tend to moderate temperature variations on the Earth.
   - The circulation of air and water tend to even out the temperatures on earth, although there is still quite a bit of variation around the planet and from decade to decade.
   - (For example, the moon is much warmer during the day and colder at night than the earth is.)
   - The atmosphere, however, also traps additional heat because of the "green house" effect.

   iii. The transfer of energy from the Earth to outer space is affected by a number of variables including the composition of the atmosphere and various air and water currents.

   - Some of these factors affect the absorption of the earth.
   - Examples include clouds and sulfur dioxide, both of which increase the reflectivity of the atmosphere, and the ice cover which affects the reflectivity of the ground.
   - Others affect the rate at which heat is **radiat**ed back into space.
   - Examples include vertical winds and, of course, the density of greenhouse gases.

- The most important green house gases is water vapor (by the far the most important), followed by CO_2, Methane, and CFCs.
- See your class notes for discussion of a series of climate models with drawings, arrows, and analysis.

C. It bears noting that naturally occurring green house gases--chiefly water vapor (H_2O), carbon dioxide (CO_2), and Methane (CH4)--cause the earth to be substantially warmer than it would have been without them.

i. Estimates of climate scientists suggest that the average temperature would have been -18^o Celsius rather than + 14^o Celsius without the greenhouse gases that are presently in the atmosphere.

- (The earth is about 58^o Fahrenheit rather than 0^o Fahrenheit because of the green house effect, about 58 degrees F warmer than it would be without it!)

ii. The greenhouse effect has long been present and fortunately so.

- This effect is what makes most of the earth habitable, at our present distance from the Sun.
- When people claim that all climate scientists acknowledge the existence of a greenhouse effect, this is essentially what they mean.
- (It does not mean that all climate scientists believe that human contributions to global warming are about to generate a catastrophe.)
- The United Nation's Intergovernmental Panel on Climate Change (IPCC) has predicted an average global rise in temperature of 1.4°C (2.5°F) to 5.8°C (10.4°F) between 1990 and 2100, based on the assumption that CO_2 densities will double in that period.

D. Water vapor (H_2O)) is by far the most important of the green house gases and accounts for about 90% of the natural green house effect.

i. Nonetheless, CO_2 gets the most press attention.

ii. This is largely because CO2 is the most important of the green house gases emitted by human activities.

- It accounts for about 70% of the relatively small human impact on the density of green house gases.
- Most of the human induced increase in CO_2 density is from burning fossil fuels.
- This is not because they are carbon-based, but because prior to burning they were buried deep in the ground and so had little or no effect on the density of CO_2 in the air.
- Although densities of other green house gases (methane and CFCs) are also affected by human activity, most of the human induced increases in the density of green house gases are generated by decisions to mine and burn fossil fuels

iii. The estimated effect of increased CO_2 densities on the earth's average temperature varies according to the climate models used.

- Models that assume relatively high positive feed back effects, predict the largest change in temperature from a given change in CO_2 densities. (In such models, increases in CO_2 density are magnified by increases in water vapor density generated by higher temperatures.)

- Models with moderate or no feed back effects yield predictions that are approximately the same as those of the average IPSS panel of climate scientists.
- Models with negative feedback predict the smallest increases in temperatures for a given increase in CO_2 densities. (In these models increases in cloud cover reduce heat gain and increases in vertical winds increase heat transmission back into outer space.)

iv. There is a far wider range of predictions than you would think based on newspaper accounts and coverage of environmentalists.

E. The physics of heat transfer in gases implies that changes in the density of **any** green house gas can change the equilibrium temperature of the earth--other things being equal--by affecting the radiation of energy back into space (the green house effect).

- Changes in the density of greenhouse gases **also occur through natural processes** such as plant decay and volcano eruptions.

F. Less CO_2 tends to be added to the atmosphere from burning fossil fuels than scientists at first predicted, because there are a variety of **carbon sinks** that remove CO_2 from the air and store it.

- For example, plants such as plankton and trees take CO_2 from the air and turn it into plant material (cells).
- Much CO_2 is also dissolved in the planet's oceans.

G. There are also variety of factors (negative feedbacks) that tend to moderate the effect of increases in the density of green house gases.

i. For example, increases in vertical air currents tend to increase the rate at which energy is radiated back into space, reducing the green house effect.

- Water vapor in the form of clouds reflects energy back into space, reducing heat gain.
- (The form that water vapor takes is, thus, critical to the forecasts of climate models.)

ii. These factors imply that the earth maintains a more constant temperature than predicted by many of climate models. (See Lindzen.)

H. There are also a variety of factors that can increase the warming generated through increases in CO2 density.

- Higher temperatures tend to increase evaporation and increase water vapor densities in the atmosphere.
- Higher temperature changes tend to reduce the extent to which the tundra and oceans serve as carbon sinks.

I. Overall, in spite of the relatively small **direct** effect of CO_2 densities and the various offsetting effects (clouds and vertical winds) there is a surprisingly high correlation between CO_2 densities and average global temperatures in the long run according to data assembled from ice cores.

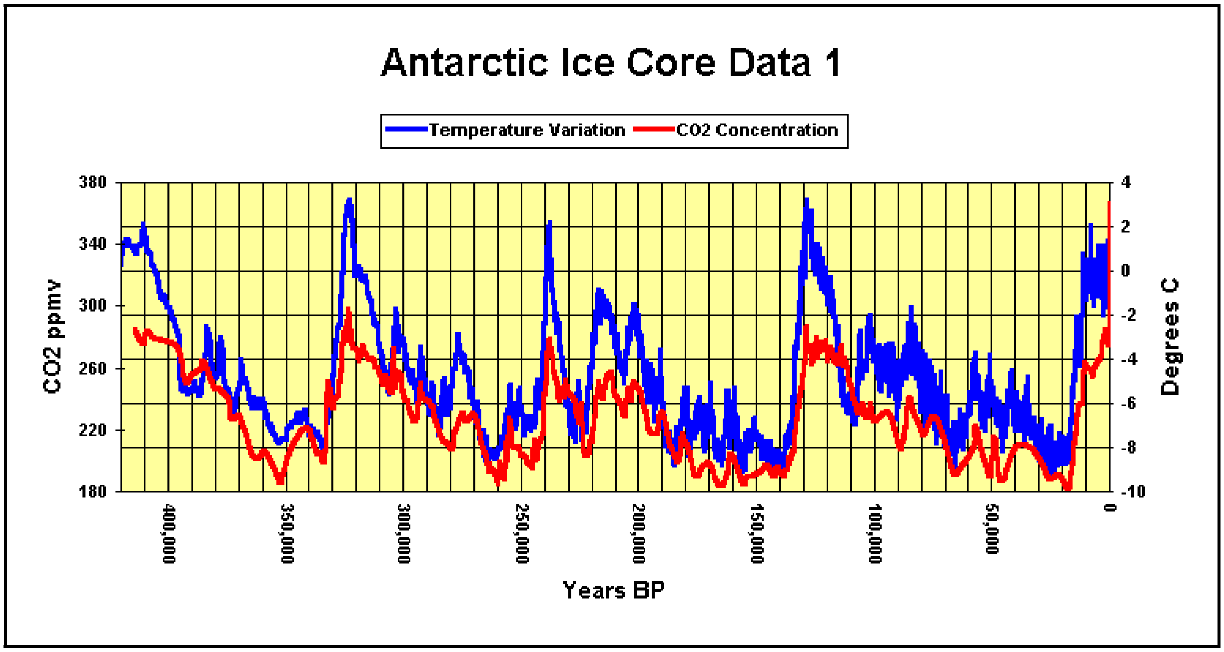
- (See the ice core data plot below.)

i. Ice core data is the most extensive record of gas densities and temperature estimates that we have.

- They allow global temperatures be estimated for several hundred thousand years, although it is not perfect.

ii. Estimated temperatures from ice cored data are highly with CO_2 densities (as shown below).

- ◆



J. Whether the CO_2 effect on average planet temperatures is large or small, it is clear that the human activities that change the density of green house gases can be regarded as an **externality problem.**

i. Note that to reach this conclusion, we need only assume that the density of CO_2 tends to increase as fossil fuels are burned and that higher temperatures, on net, are undesireable.

ii. However, to determine how **much should be done** about it requires cost benefit analysis of the sort that we have used in class during the semester.

- (a) This requires estimating the effect of higher $C0_2$ densities on global temperatures
- (b) the effects of higher global temperatures on plant, animals, humans, and geology (such as ocean depth).
    - ◆ (c) whether these effects increase, overall, net benefits or reduce them.
- (d) the extent to which CO_2 densities are increased by econonic growth.
- and (e) the extent to which the estimates can be trusted.

iii. The various estimation problems are very difficult to solve, and so a good deal of disagreement can occur among well-meaning scientists at essentially every step in the analysis.

- The fact that estimation is difficult does not mean that one should ignore all the estimates.

- One should, however, investigate the assumptions made and take into account that the estimates are uncertain.

2. Economic Development and Global Warming

A. The use of fossil fuels for energy sources is an essential part of contemporary production methods.

i. Clearly, burning fossil fuels puts more carbon dioxide into the atmosphere than has been there recently..

- CO_2 densities have risen from 280 ppm to about 370 ppm in the past two hundred years.

ii. Increased CO_2 densities along with simple physics implies that Earth's average temperature will increase insofar as it increases the greenhouse effect--other things being equal.

iii. How large the CO_2 effect is depends on climate feedbacks.

- The most dire predictions assume that higher densities of CO_2 **cause increases in water vapor** density. (CO_2 densities by themselves have a relatively small effect.)
- The most optimistic forecasts assume that higher densities of CO_2 are largely offset by offsetting feed backs of one kind or another.
- In general there are models with negative feedback, little or no feedback, and positive feedback.
- (The little or no feedback models are the mainstream models.)

B. The net effect on the earth's long run average temperature from using fossil fuels depends on a number of factors.

i. **Emissions of CO_2 is a nearly unavoidable consequence of combustion.**

ii. How much carbon dioxide (and other green house gases) are added by reliance on fossil fuels partly depends on the rate at which fossil fuels are used.

iii. The net increase in CO_2 densities also depends on the rates at which CO_2 is removed from the atmosphere by carbon sinks.

- The increase in CO_2 densities observed, is only about half of the total amount that should have been produced by the fossil fuels consumed.
- That is to say, **about half** of the CO_2 gas generated by burning fossil fuels has been removed by from the atmosphere by plant growth (trees and plankton) and by being dissolved in the oceans.

iv. The various places (and processes) at which carbon is removed from the atmosphere and stored are called **carbon sinks**.

- The most important carbon sink is the ocean--not rain forests.
- (See lecture notes on the carbon cycle.)

v. It bears noting that burning wood and other "bio mass" does not add significantly to CO_2 density levels in the same manner, because this part of the carbon supply has long been part of the surface "carbon system" of plant growth and decay.

- (This is why switching to biomass can be one way of reducing the effect of energy production on green house gas density.)

- (Wood remains the main source of biomass energy, although it is a relatively small portion of the energy used in the modern world.)

3. Assessing and Solving the Global Warming Problem

A. In general, **the extent to which global warming is a "problem" depends on a number of factors** as noted above.

i. There are costs and benefits associate with global warming.

ii. There are also costs and benefots associated with various policies that could reduce or eliminate the human component of global warming.

- For example, if only a bit of global warming is induced by increases in CO_2 densities, then there is not much of a problem, and not much should be done.
- If the problem is thought to be severe (catostrophic) then much more aggressive and costly steps can be justsified.

B. The main link between economic development and global warming is through the increased rate of use of fossil fuels that has until recently always been associated with industrialization.

i. Fossil fuels are used because they are relatively inexpensive and portable sources of energy.

- The technology for mining and using fossil fuels are relatively new ones.
- They emerged, for the most part, in the late eighteenth and early nineteenth century.

ii. The industrial age of the past 200 years, consequently, has greatly increased our use of fossil fuels as coal, oil, and natural gas.

- Fossil fuels are our main energy sources.
- They are used to help produce all kinds of things, including transportation, heating, and cooling of buildings, most electricity (world wide), etc.

iii. Other sources of energy do not add "carbon" to above ground carbon cycle, and so they have little or no effect on global warming.

- For example, hydro (dams), nuclear. solar, and wind generation of electricity do not add to green house gas densities.
- Several European countries use nuclear power to produce most of their electricity (as in France and the Netherlands).

iv. So, the link between global warming and economic development is mostly a matter of the relative price of alternative energy sources, rather than growth per se.

- It is **economics that induces "us" to use fossil fuels** rather than other technologies for energy production.
- Fossil fuels are simply "cheaper" and/or more convenient than other energy sources at present.

v. If these relative prices change, there connection between economic development and global warming, if any, may disappear.

C. The key scientific and **policy questions** involve how much warming will occur, where it will occur, and how soon?

i. **First** there is the question of the quantitative link between CO_2 densities and temperature.

- The quantitative evidence on CO_2 and heating, is a bit mixed at present, because temperature increases have not been perfectly correlated with industrialization and the use of fossil fuels.
- (Much of the warming is a bit too early, s**ee the temperature plots from class**.)
- Satellites, tree rings, and ice cores provide some evidence of **human induced** warming that is widely accepted by climate scientists.
- The planet does appear to warmer than it was a hundred and fifty years ago.
- However, there is significant disagreement over "how much" of the recent warming is due to human induced increases in greenhouse gases and how much of that is a consequence of other long term processes (such as solar variation).

ii. **Second, t**here is the economic question of how economic development over the next many decades will affect the emission of green house gases.

- Future emissions can not be known with certainty because technologies may change, because prices of energy sources may change, and because public policies may change.
- Economies have recently become somewhat less energy intensive through time (in terms of btu/$of GDP), partly because of environmental regulations, partly because of technological advance, and partly because of the relative scarcity of oil and natural gas.
- For much of the past 50 years, there has been a tendency to switch to cleaner energy sources--oil for coal, and natural gas for oil--which often reduce CO_2 emissions somewhat along with other more toxic forms of air pollution.
- (The substitution of nuclear power for fossil fuel has largely been blocked by regulations in the US and some Scandanavian countries, although it is extensively used in France and the Netherlands.)

iii. **Third**, there is the economic question of damages.

- How large are the damages associated with temperature changes.
- That is to say, how important is this externality problem?
- Some sense of the importance of the problem is necessary to appraise how much "we" should be willing to pay to reduce it.
- (To answer this question, we must have good reliable climate and economic models, plus a good senses of the distribution of benefits and costs around the world.)
- Most estimates (see for example, Nordhaus) find relatively **small** aggregate damages, **with gains** in the far north and south nearly offsetting losses elsewhere.

D. Disagreement about the answers to these three issues are affected by both scientific uncertainty and ideological disagreements (priors).

i. Model errors tend to larger in the long run than in the short run, at least in economic and political models.

- This is certainly true of economic and political models.

ii. Using middle of the road projections on global warming, still leaves disagreements about the damages done (the magnitude of the externality problem).

- See overheads from the Nordhaus C/B estimates.
- (A significant minority of climate scientists and physicists have suggested that other factors such as variations in solar energy from the sun) are being neglected.)

iii. And, a few have pointed out that the earth has "recently" (past half million years) suffered from a long period of ice ages.

- See Muller's "Icebook".)
- (There are also **national security** reasons and other economic rationales for reducing our use of petroleum.)

E. If we accept the "middle of the road" forecasts, there may well be benefits from reducing the rate of global warming and/or the maximum temperature reached.

i. Note that some of these externality arguments are essentially independent of the size of the externality.

- However, the benefits of reductions in emissions will vary a lot according to the climate theory that one uses for the estimates.
- The costs of such programs tend to rise with reductions in fossil fuel use (more aggressive programs to reduce emissions), and are largely independent of the climate model used.
- The optimal level of emissions (E**) varies with the extent of the damages associate with global warming, which vary with both the climate and economic assumptions used, as in our previous analyses.

F. Within a given country, the emission of green house gases (and the associated global warming problem, however large or small) can be addressed using the same tools as we have already examined for other environmental problems.

- Pigovian taxes (e.g. Carbon taxes)
- Direct Regulation
- Subsidizing non fossil fuel energy sources and/or carbon sinks (e. g. Pigovian subsidies).
- Cap and Trade systems (CO_2 emission markets).
- *See previous lecture notes for illustrations with diagrams.*
- As an exercise, represent these problems and solutions with diagrams and game matrices.

i. To reduce US emissions by half requires us to emulate Europe's current policies, because these are about half of US emissions per capita.

- This is largely caused by higher energy taxes (6-8 dollars per gallon of gasoline, etc).

ii. However, it is also caused by a climate that is less variable than that in the US, a much higher population density with many persons living in smaller houses and apartments.

- Higher densities allows cost effective mass transit systems, which are largely already in place and substantially powered by electricity. Shorter distances, also tend to reduce their transportation costs.

- To reach European emission levels per capita will require a somewhat more aggresive policy in the US--e.g. higher gasoline taxes and greater support for non-fossil fuel sources of electricity.

G. If we take the upper range of estimates seriously, more stringent regulations tend to make sense, because the potential damages tend to be greater.

- To reduce net carbon emissions to zero requires either elimination of fossil fuels are a great increase in the capacity of carbon sinks.
- The former might be accomplished by replacing all transport, heating, and cooling with electricity based technologies and by producing electricity via nuclear, hydro, wind, and solar power plants.
- (Clever new artificial carbon sinks might be possible, as with engineered plants, seeding the oceans, or new techniques for increasing the reflectivity of the Earth.)

H. If we take the low end or moderate temperature change estimates seriously, or the low end damage assessments seriously, the externality problem is a relatively small one.

i. In this case, it is certainly possible that the "cure" could be worse than the disease.

ii. (Indeed, one might want to increase CO_2 emissions if one expected a new Ice Age was underway.)

- (Few of us carry umbrellas on bright sunny days, because the cost of carrying the umbrella is greater than the expected reduction in risk.)
- The cost of some regulatory systems can exceed their benefits.

iii. It bears noting, however, that even if today's moderately increasing temperature were entirely a natural phenomena, but could be "adjusted" through public policy, we might still want to attempt to regulate greenhouse gas (net) emissions in some way.

4. International Treaties as Part of the Solution to Human Induced Climate Change (Kyoto and Beyond)

A. In addition to the usual environmental externality problems, successful efforts to address human induced (anthropogenic) increases in the density of green house gases face a number of other problems associated with "regulatory externalities."

i. The problems are international ones analogous to the regulatory externality examples that we examined in recent weeks.

ii. Each country can rather easily "free ride" on the efforts of other countries to reduce their net greenhouse gas production.

- See the regulatory externality examples in previous lectures.

iii. International treaties will be required to coordinate the greenhouse regulations of all the major producers (and regulators) of green house gases.

- Consequently there will be a variety of enforcement problems.
- And, of course, the agreements themselves may not do very much.
- (See Bjorn Lomborg or Nordhaus on the costs and benefits of implementing the Kyoto accord.)

B. **International solutions** require Coasian contracts (such as the Kyoto treaty negotiated in Japan in 1997.)

i. **National sovereignty** implies that international solutions will be voluntary, and that domestic political and environmental considerations ultimately determine which nations sign and implement the treaties developed.

ii. All the usual problems of relations between governments will obtain.

iii. There will be collective choice problems (what temperature is best?), enforcement problems, free rider problems, and problems of designing institutions to advance international aims.

iv. *Should global temperatures be "selected" by the median voter? by bureaucrats? by new international agencies, through negotiations of national leaders, or by referendum?*

C. Implementing international treaties tends to be problematic, because environmental treaties lack penalties for non-performance.

i. The regulator's dilemma problem does not go away simply because a treaty is signed.

- Treaties may be cheated on in a number of ways--by interpreting them to be symbolic, by failing to adopt or enforce enabling domestic legislation.
- These may be insurmountable problems, if the high-damage estimates are correct, since a major shift away from fossil fuels is required in that case.
- (This makes some of the enhanced carbon sink ideas likely to be the only way to address severe global warming, because this can be implemented by fewer countries.)

ii. Illustration of the Implementation Game after signing a mutually beneficial treaty for pivotal governmental decision makers.

Implementation Dilemma for International treaties

country B country A	fully imp.	partly imp	don't imp.
fully implement	**4, 4**	**2, 5**	**0, 6**
partially implement	**5, 2**	**3, 3**	**1, 4**
don't implement	**6, 0**	**4, 1**	**2. 2**

iii. Note that the Nash Equilibrium will normally be "don't implement," because a country may hope to free ride on the tougher standards adopted by other countries.

iv. Treaties, evidently need some enforcement mechanism to avoid this problem.

- Show how an enforcement regime might avoid this problem with fines..
- (Environmental treaties, however, rarely include such provisions. In effect they believe that reputation effects [or good will] are sufficient to induce countries to "live up to" their agreements.)
- Show how "reputation effects" may produce similar incentive effects.

v. The free-rider problem tends to be more difficult to solve the more persons or more countries have to change their policies.

- The **politics** of implementing at treaty, however, are clearly significant when domestic costs are large relative to domestic benefits.

D. An important current example: the **Kyoto Protocol**

i. See lecture and web links for details of treaty (differences in constraints/targets)

- Signatories vs. Ratifiers
- Modifications -- are heat sink credits "hot air?"
- Cap and Trade system adopted
- http://en.wikipedia.org/wiki/Kyoto_Protocol

ii. Kyoto includes no explicit enforcement provisions, and there has been only small reduction in net carbon emissions among signatories so far that have been induced by the treaty.

iii. (See the international treaty handout for more details about Kyoto.)

E. Overall, it is clear that the global warming issue is interesting for many reasons even if it turns out not to threaten the end of life on earth as only a few very high end forecasts predict.

i. Evaluating the expected costs and benefits of global warming raises a number of interesting and important scientific, philosophical, and economic puzzles to be analyzed and resolved.

- Nearly all aspects are worth "a bit more thought" regardless of your intuitions about the magnitude of the effects are or the severity of the problem.

ii. At some point, however, policy decisions will have to be made, and these will have real effects--although not necessarily huge ones on the look of modern life.

- (Cap and trade systems have been on the Congressional agenda for several years now.)

iii. Fortunately, most of the climate models suggest that there is **no immediate crisis**.

- The global warming problem is anticipated to be around for a long time according to the models.
- The cost of addressing the problem increase with delay, but not enormously. (See Nordhaus)
- So, we have some time to figure out what to do and to try to determine how to do what we think should be done.
- As a thought experiment: discuss some of the consideration that would cause you to favor more stringent or less stringent regulations on CO2 emissions or carbon taxes in the US.
- Are any of our policy tools (Coasian contracts, Pigovian taxes, cap and trade, direct regulation, better than current proposals under consideration by the US Congress? Why or Why not?