Class notes Energy Economics 399 Spring, 2009

Lecture #1 Wednesday, January 14

Go over syllabus. Stress important points:

- Late HW is bad. No HW is terrible. (Easiest way to fail)
- All information is available on the web site: http://www.holycross.edu/departments/economics/vmatheso/
- As economics is the study of the allocation of scarce resources and your time is a scarce resource, in the interest of optimal economic efficiency, attendance is optional, but you will not do well without attendance.

Show price of oil over past 2 years. Record price of $147 in July but down to $40 today.

Does this affect a typical consumer?

Every $10 increase in a barrel of oil is about

Lecture #2   Friday, January 16

Measuring Energy

Energy can be measured in terms of kinetic energy (movement) or heat energy.

Energy is measured in metric and English and “common” equivalents.

Differentiation must also be be measured in terms of flows (power) and stocks (energy).

Kinetic energy:
newton = force required to accelerate 1 kg by 1 m/s^2
Gravity = 9.8 m/s^2
joule = work done by 1n traveling 1 meter
(raising 102 g 1 meter = 1 joule)
1 watt for 1 second = 1 joule
1 watt-hour = 3600 joules, 1 KWH = 3,600,000 joules

foot-pound = energy required to lift 1 pound 1 foot = 1.36 joules
1 horsepower = 33,000 foot-pounds/minute = roughly 750 watts
(Example of a “common” measure. Standard gauge railroad is another example at 4 foot, 8 ½ inches, the size of two horses.)

Heat energy:
calorie = energy required to heat one ml of water 1 degree C
K-calorie = food calories = 1000 calories
BTU = energy required to heat one pint or lb water 1 degree F
1 BTU = 252 (little) calories = 1055 joules = 0.293 wH

1 cu. ft natural gas has about 1030 BTU of heating power

Several more measures:

Q = 1 quadrillion BTU. Useful with “big” measures. U.S. uses about

Look over use patterns for energy in the U.S. EIA document

Note periods of falling energy use: 1973, 1979, little bit in 1991, probably large in 2008-09.

Note lack of increase in energy production over past 30 years.

Note only small increase in energy usage over past 30 years.

Note steady or falling energy use per person over past 30 years.

Lecture #3   Wednesday, January 21

First subject, evaluation of the energy projects. Before we can even get into answering questions about pollution, development and resource, we must figure out how to evaluate projects.

With this in mind, how do we find valuation of different goods and services?

True value for an economist is willingness to pay or willingness to accept payment. WTP/WTA. Easiest way is what are you willing to pay (if something is not yours) or what are you willing to accept as payment (if you own something). How do we decide if someone is willing to pay $20.00 or accept $10.00. Take maximum?

How can you find WTP and WTA? Good place to start is look at market prices. If McDonalds sells 5 billion Extra Value meals per year at $2.99, then WTP is at least $2.99 for at least 5 billion consumers, etc. However this doesn't tell the whole story since you may be willing to pay more than you are required to pay. We need consumer surplus. CS: the amount you would be willing to pay over the amount you have to pay. Similarly with WTA, PS: is the amount more than you were willing to accept that you received. For many goods a good first step in value determination is to observe the market. From there demand and supply curves can be determined and we can find WTA/WTP through consumer and producer surplus.

Two problems with using price.

- Water - Diamond Paradox
- Unobservable prices (will deal with this next week)

What is more valuable, water or diamonds? Water has a high value, but a low price.

Do graphs of diamonds and water. Water has high demand but high supply. Price near zero.

Diamonds have low supply (hard to find, impossible to make, cartel restricts supply), and some demand (but rather low).

Cost-Benefit Analysis

At its most basic level, it is simply what the name implies, a methodology for analyzing costs and benefits associated with some sort of action. Crucial that it is only a tool, but still good for helping in decision making.

If B>C then the project is good.
Or, if B/C >1 then the project is good. (Benefit/Cost ratio.)

Which is better project?
B = 1000, C = 800   Total net benefit = 200, B/C ratio = 1.25
B = 500, C = 350   Total net benefit = 150, B/C ratio = 1.42

Some crucial decisions to be made. How are cost and benefits from different time periods counted? Use discount rate. At what rate are you willing to trade current consumption for later consumption?

Discount rates. Accounting for costs and benefits in the future.

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

where r is the discount rate, B_t are the benefits in period t, and C_t are the costs in period t.

r > 0. We are all anxious. Think of eating pizza.

What is value of 500 in two years at a discount rate of 10% = 500/(1.1)^2 = roughly 415.

Can calculate this by hand or using Excel.

Now assume 100 cost today and 40 in benefits over next three years. (Need a discount rate.)

Set up problem: C = 100/1.1^ 0 = 100
B = 400/1.1 + 400/1.1^2 + 400/1.1^3 = 36 + 33 + 30 = 99 (99.47 precise)

B = 99 < C = 100 so bad project
B/C = 99/100 = .99 so bad project

Other methods of using costs benefit analysis to determine whether to do a project:

- Standard is B>C
- Also, what interest rate/discount rate is required to make the project have positive benefits. (Also called internal rate of return). Really only works with projects with upront costs and spread out benefits.
- Payback period. How many years before net benefits are greater than zero.

For our project: r = infinity leads to NPV = -100
r = 0 leads to NPV = 20
r = 10% leads to NPV = -0.53

So, IRR is between 0 and 10% and is likely very close to 10%. IRR can't be solved analytically (with algebra) but can be solved quantitatively (trying every possible r).

Using "goal seek" on Excel, IRR = 9.70%

For payback period with r = 10%, project is negative for n = 3, but if one more year of benefits, then it would be positive so payback period is 4 years (integer) or just over 3 years (if non-whole numbers of years are allowed).

Lecture #4 Friday, January 23

Discount rates. Accounting for costs and benefits in the future.

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

where r is the discount rate, B_t are the benefits in period t, and C_t are the costs in period t.

Can calculate this by hand or using Excel.

Short cut for NPV when net benefits are fixed over time.

An annuity paying P starting in year one and paying that same amount forever

- NPV = P / r

An annuity paying P starting in year zero and paying that same amount forever

- NPV = P + P / r

An annuity paying P starting in year one and paying that same amount for t years

- $NPV = P / r - (P / r) / (1+r)^t = P [1 - (1+r)^{-t}] / r$

Example: in March of 2007, the Big Game Lotto advertised a jackpot of $390 million.
The $390 million is actually 26 annual payments of $15 million. The first payment is made immediately so the $NPV = 15 + 15 [1 - (1+r)^{-25}] / r$

At a 7% discount rate, the NPV is $189.8 million.

Of you have to pay taxes as well which would take away about 40% more. We're now at $114 million. Finally if more than one ticket matches the winning numbers, the jackpot is split evenly between the tickets. There were three winning tickets for this jackpot meaning after taxes each winner only took home about $38 million in NPV after taxes.

Did examples of using Excel efficiently.

Spreadsheets are one of the 3 or 4 "killer apps" for small computers and led to their widespread adoption in business and the home (the other being word processing, the internet, and maybe media.)

What is the right discount rate to use?

What is your own discount rate? Tradeoff between $100 now and $x in 1 year.

Can solve NPV equation for r.

Most estimates will be too high.

- May have assumed that you wouldn't really get that amount in a year. Need to use risk free interest rate when examining social costs and benefits.
- May have suffered from hypothetical bias. Best estimates come revealed preference from observable interest rates. (Example of Nielsen ratings)
- Young persons have high discount rates. Young and poor.

Best to use a short-term, U.S. government T-Bills. Low risk, observable.

When assessing private returns, use actual rates that the private individual would receive or pay.

Also must account for after-tax issues.

Nominal vs. real discount rates. Nominal rates are simply those reported in paper. Real interest rates subtract out inflation.

Use nominal discount rates if costs and benefits are assumed to increase with inflation.
Use real discount rates if costs and benefits are held fixed.

Could observe interest rate to find rates of time preference, but inflation messes thing up.
In reality, social rate of time preference is 1-5%. (That is the after inflation return on risk-free debt.) Nominal returns are 5-8%. From a theory point of view, discount rate should be the growth rate of productivity which has been 2-3% over time.

One source of inefficiency is that the federal government mandates use of 7%. (inflation included) This clearly does not match real rates of time preference by not allowing discount rates to adjust with rates of inflation.

Two other reasons why private and social time preference may not match.

- Extreme poverty drives up discount rate due to declining MUI. As current income approaches minimum subsistence levels, private discount rate approaches infinity.
- The tax wedge. Assume a personal income tax of 40% and a corporate tax of 33%.
  To take home 3% after taxes an individual needs to earn 5%.
  To pay 5% after taxes the firm needs to earn 7.5% on their investments.
  Thus, society says that we should invest anytime there is a payoff of at least 3%, but
  firms only invest if there is a payoff of 7.5%.

Lecture #5 Monday, January 26

One source of inefficiency is that the federal government mandates use of 7%. (inflation included) This clearly does not match real rates of time preference by not allowing discount rates to adjust with rates of inflation.

Two other reasons why private and social time preference may not match.

- Extreme poverty drives up discount rate due to declining MUI. As current income approaches minimum subsistence levels, private discount rate approaches infinity.
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  To pay 5% after taxes the firm needs to earn 7.5% on their investments.
  Thus, society says that we should invest anytime there is a payoff of at least 3%, but firms only invest if there is a payoff of 7.5%.

Is the choice of discount rates important?

In a current law case in which I am preparing expert testimony, a little girl was injured by lead paint in her homes. Due to lead poisoning and the associated brain damage, she is likely to be unable to finish even high school schooling or obtain a high paying job. My job is to determine the potential earnings losses for this girl.

The plaintiff's economic expert has chosen a real discount rate of zero. His contention is that wages grow at roughly the same rate as short-term T-Bills.

Under the assumption of a zero discount rate, the girl stands to lose $2.81 million in earnings compared with lifetime earnings that would be expected under an assumption that the she would have gotten a college education.

My contention is that based on observing the Employment Cost Index, total compensation has risen slower than the interest rate on bonds.

Average ECI gain 1980 to 2007 = 4.31%
Average 1-year bond yield 1980 to 2007 = 6.39% (meaning a real discount rate of 2.08%)
Average 10-year bond yield 1980 to 2007 = 7.51% (meaning a real discount rate of 3.20%)
Average Aaa corporate bond yield 1980 to 2007 = 8.55% (meaning a real discount rate of 4.25%)

1-year bond is probably best but Aaa corporate bond is used to promote a starting point bias. I can be as guilty of this as the other guy.

NPV (0%) = $2.812 million
NPV (2.08%) = $1.270 million
NPV (3.20%) = $0.858 million

NPV (4.25%) = $0.605 million

This case is as much about the proper discount rate as it is about guilt or negligence.

Revealed Preference ways to measure value

Direct revealed methods:
- Markets (be careful to include both price and consumer surplus)
- Experimental methods: lab experiments (Tversky and Kahneman, Nobel prize in 2004?)
  Also created markets: pollution trading, Iowa experimental markets

Indirect revealed methods:

Find value of non-marketed component of a good through differences in marketed values of similar goods. (House with good view.) Wage and consumer premiums.

- Hedonic property values (how much lower price are houses near toxic waste dumps)
- Hedonic good/service values (speeding, airbags, smoke detectors, example in HW)
- Hedonic wage premiums (combat pay- a healthy 20-year old white male has slightly less than a .1% of dying in any given year while a male soldier in Iraq has about a .6% chance of dying, mining vs. construction or manufacturing)
- Travel Cost Estimation. Use WTP for travel as a proxy for WTP for the non-marketed good.
- Averting or defensive expenditures. How much to install water purifier.

Hypothetical methods to measure value:

Direct hypothetical methods
- Contingent Valuation. Use of surveys to determine value.

Problems include
- Information bias. (People may not have adequate experience to answer the question correctly.)
- Starting point bias. Giving people a starting point (more or less than $200? How much more or less?) changes answers. Trial lawyers give huge figures for bogus lawsuits so that people think that they are doing the right thing when they reduce the claims by 90%.
- Hypothetical bias. People claim higher amounts than they reall would be willing to pay. Big problem in airline question.
- Strategic bias. If I love a resource, I have an incentive to overbid.
- Status quo bias. People holding an event ticket wouldn’t sell it for $100 but would buy one for $100 either.

Indirect hypothetical methods:

- Contingent ranking. Make people rank a bunch of different things in order of preference. As long as at least some of the ranked items have measurable prices, you can infer value of other items based on their ranks. Rank iPod or ½ grade higher on final grade in class.

Lecture #6 Wednesday, January 28

Direct hypothetical methods

- Contingent Valuation. Use of surveys to determine value.

Problems include

- Information bias. (People may not have adequate experience to answer the question correctly.) Conflating one thing with another.
- Starting point bias. Giving people a starting point (more or less than $200? How much more or less?) changes answers. Trial lawyers give huge figures for bogus lawsuits so that people think that they are doing the right thing when they reduce the claims by 90%.
- Hypothetical bias. People claim higher amounts than they really would be willing to pay. Big problem in airline question. New Year's resolutions.
- Strategic bias. If I love a resource, I have an incentive to overbid. Nielsen ratings example.
- Status quo bias. People holding an event ticket wouldn't sell it for $100 but would buy one for $100 either. Health care example from state of the union. (Non-starter.) This is a problem for any type of evaluation method.

Indirect hypothetical methods:

- Contingent ranking. Make people rank a bunch of different things in order of preference. As long as at least some of the ranked items have measurable prices, you can infer value of other items based on their ranks. Rank iPod or ½ grade higher on final grade in class.

Types of total economic value:

- Use value. Value from fisheries, forestry, recreation, etc.
- Option value. Value from the option to use things in the future. I want to make sure Machu Pichu or Kilimanjaro are preserved for future generations because I want to visit. Coral reefs and global warming. The rarer or more unique something is, the more likely it is to have option value. Option value. Much more esoteric. Amount a value changes by leaving it alone. For example if you gain knowledge, the resource may be more valuable. My bottle of Pinch Scotch. Especially important when irreversibility is an issue. Option value can be positive or negative. CFC's were more valuable years ago than today. Many people say that genetic diversity may have a tremendous option value. Wild plants may have little value now but may contain important genetic information. For example, when the Yellow Dwarf virus hit the California Soybean Crop, researchers looked through 6,500 known barley varieties to find a single Ethiopian barley plant that protects this $160 million crop.
- Non-use value. Value for something they will never use. I may not want tigers or panda to go extinct in the wild even though I will never see a wild tiger.

Killington: huge use value, some option value (but there are good substitutes)

Smithsonian: huge use value and huge option value.
ANWR: almost all non-use value.

Wage and consumer premiums:

A final common method of valuation is foregone earnings as a measure of life.

A variety of studies use wage/consumer premiums, contingent valuation, cigarette information studies, etc., roughly give a value of life between $1.5 and 3.5 million. 37/57 in one study had cost per life saved of over $6 million. We may be over regulated. On other hand, less death is only part of the benefits. Less sickness is also helpful. Bush and arsenic regulations.

Iraq example: Hedonic wage premiums (combat pay- a healthy 20-year old white male has slightly less than a .1% of dying in any given year while a male soldier in Iraq has about a .6% chance of dying, mining vs. construction or manufacturing)

So, signing up to work as a soldier in Iraq "costs" .5% of your life. What would they have to pay you above and beyond what you could make elsewhere. .5%L = $20,000 (Of course, there are other costs and benefits here.)

Typical value of life come out at $3 to $7 million.

Is it moral putting a value on life? For an individual life, probably not. Are we willing to spend more that $5 million to find the guys on Hood?

Space heater regulations: For an annual cost of about 6 million, 63 lives could be saved from house fires. $100K/year. Easily worth it.

FAA regulations on floor emergency lighting, cabin fire protection, seat cushion flammability. Also easily worth it.

On the other side of the coin, OSHA workplace formaldehyde regulations are costly and don't save many lives. Cost per life of $72 billion.

You might say that every life is sacred, but couldn't $72 billion have been spent on AIDS prevention, vaccinations, prenatal health care, better communication equipment for first responders. Remember, economics is the allocation of scarce resources.

Lecture #7   Friday, January 30

Income distribution and risk in CBA.

If people have diminishing marginal utility of income, you want equal spread of income both across people and across outcomes.

By 2007 Consumer Expenditure Survey, the poorest 20% of households average roughly \$20,471 in expenditures and \$10,531 in income. \$1,205 of this is spent on heat and electricity. Another \$1,046 is spent on gasoline. 11% of expenditures and 22% of income spent directly on energy.

The richest 20% earn \$158,000/year and spend \$96,752/year. \$2,847 on heat and electricity and \$3,696 on gasoline or 7% of expenditures and 4% of income on energy.

Full Compensation Criterion: Pareto Realized

Winner must actually compensate losers. Therefore, distribution problem largely disappears in decision to do a project. Still, can't compare projects with differing effects on income. Also may reject good projects if cost of redistribution is high. Certainly will always raise costs.

Also requires compensation of rich. SO???

New concept of equitable compensation. Full compensation only if losers are poor.

1) Do it if costs of compensation are small and if rich are significantly richer than poor.

Generally unwieldy, costly, causes rejection of good projects.

Kaldor-Hicks/Potential Pareto Criterion

Do it if winner's could potentially compensate losers. Assumes gains and losses weighted equally for all persons. Often costs of assessing and compensating for distributional losses outweigh any potential gains. Practical argument for generally using Kaldor-Hicks, unweighted CBA. Second argument is that you want to do what's best and let government take care of the rest. Almost a trickle-down argument. Development brings higher regard for income equality.

Identify Winners and Losers

Here you are simply an information gatherer with no policy role at all. Certainly important, but you should learn how to be decision makers not just presenters.

Willig-Bailey (No undesirable transfers)

Sum up gains and losses for each successive income group. As long as at each point net gains are positive, we are ok. Very restrictive. Even small losses early outweigh big gains later. Results depend on demarcation of groups. Can’t compare projects. Some good projects are rejected.

Distributional Weights

Simply weight gains and losses for different groups differently. $F(y) = (y/\text{avg. } y)^{-d}$ Good method except for two reasons. 1. Weights seem arbitrary. 2. Could be redistributing money inefficiently.

Harberger Opportunity Cost Rule

If the project distributes money more cheaply than the most efficient way to do it otherwise, then do the project even if there are small losses. As long as the losses are smaller than what it would cost to do otherwise, you go ahead with the project.

Dealing with risk.

First concept is expected value.

Second concept is risk-weighted expected value.

Imagine a lottery ticket with a positive expected value

Several ways one can account for risk.

Maximin: Maximize the worst you can do. Example of end of a football game leading by a 3 points.

Concave utility function: $U = I^d$ where d is an aversion to risk. If d = 1, then no aversion. If d <1 risk averse. If d>1 then risk loving.

$1 but has a 1 in 10 chance of winning 100.

Suppose I start with $1.
EX(if d=1) = .9(0) +.1(100) = 10 (if I play) and 1 (if I don't)
EX(if d=1/2) = .9(0) +.1(100^.5) = 1.
Maximin = 1 (don't play and keep the dollar).

St. Petersburg Paradox.

Lecture #8 Monday, February 2

How many horsepower can Larry Fitzgerald generate?

10 c per ft per 100 lbs of body weight

Fitzgerald weighs 220 lbs and can run a 4.4 40.

In 4.4 seconds he can generate 10(2.2)(40)(3) = 2,640 c

1 wh = 859.8 c, so 2,640 c = 3.070 wh

4.4 seconds = .001222222 hours, so 3.070 wh in 4.4 seconds requires 2,511.8 watts

746 watts = 1 horsepower, so 2511.8 watts = 3.367 horsepower.

Dealing with risk.

St. Petersburg Paradox.

First concept is expected value.

Second concept is expected utility. Expected utility = Expected value if risk neutral.

Suppose a concave utility function: U = I^d where d is an aversion to risk. If d = 1, then no aversion. If d <1 risk averse. If d>1 then risk loving.

Third concept is Maximin: Maximize the worst you can do. Example of end of a football game leading by a 3 points.

Imagine flipping a coin. $0 if you lose, $3 if you win. ($1 if you don't play)

EV = .5(0) +.5(3) = 1.5 > 1
EU if d = 1 = .5(0) +.5(3) = 1.5 > 1
EU if d = .8, EU = .5(0) + .5(3^.5) = .866 < 1. (But this assumes your wealth = $1.)

Assume you have $1000000 in expected discounted lifetime earnings.
$1,000,000 and $1,000,003 vs. $1,000,001
= .5(1000000^.5) + .5(1000000^.5) = 500 + 500.00075 vs. (1000001^.5) = 100.0005

Now assume a $10,000,000 bet
$1,000,000 and $31,000,00 vs. $11,000,000
= .5(31,000,000^.5) + .5(1,000,000^.5) = 2784 + 500 = 3284 vs. (11,000,000^.5) = 3317

Maximin: min = 0 < 1, so don't play.

People are risk averse. Whether we should apply risk aversion to society as a whole is a different issue.

Suppose I flip the coin individually for each person. Makes sense to pool risk.

But what if everyone's risk is closely related. Mortgage meltdown and global warming.

Lecture #9 Wednesday, February 4

Types of fairness:

- Weak Sustainability: Resource use should not lead to a lower level of utility in the future. Total capital stock should not decline but you can make up for lost natural capital with physical capital.
- Strong sustainability. Natural capital should not decline over time. Assumes limited substitutability between natural and physical capital. Focuses on value of natural capital over time not absolute flow.
- Environmental sustainability: the physical flows from environmental goods should stay the same. It's not just that the value of wetlands remains but that the wetlands should maintain their ecological functions.

Start with simple $U = I^{.5}$

Concave utility function, will tell us something about both income issues and risk.

If $I = I1 + I2 = 100$, how to maximize joint utility.

Max $U(I1) + U(I2)$

Two ways to do this.

First, could substitute $I2 = 100 - I1$ and maximize. This can become mathematically difficult quite quickly.

Second is use a Lagrangian.

$I1^{.5} + I2^{.5} + L(100 - I1 - I2)$

$dU/dI1 = .5I1^{-.5} - L = 0$
$dU/dI2 = .5I2^{-.5} - L = 0$
$dU/dL = 100 - I1 - I2 = 0$

Solving, $.5I1^{-.5} = .5I2^{-.5} \Longrightarrow 1/I1^{.5} = 1/I2^{.5} \Longrightarrow I1^{.5} = I2^{.5} \Longrightarrow I1 = I2 = 50$

In terms of income, this is the reason economists care about income distribution.
In terms of risk, this is called income smoothing.

Now what if this is across time rather than across people or states of the world?

Intuitively, people are anxious, so they want stuff now, but also want to smoothing income over time, so want stuff later. If r = infinity, I1 = 100. (You can't take it with you.) If r = 0, the solution is like above.

Otherwise, $I1^{.5} + I2^{.5}/(1+r) + L(100 - I1 - I2)$

$dU/dI1 = .5I1^{-.5} - L = 0$
$dU/dI2 = .5I2^{-.5}/(1+r) - L = 0$
$dU/dL = 100 - I1 - I2 = 0$

Solving, $.5I1^{-.5} = .5I2^{-.5}/(1+r) \Longrightarrow 1/I1^{.5} = 1/I2^{.5} \Longrightarrow I1^{.5} = I2^{.5}(1+r) \Longrightarrow I1 = I2(1+r)^2$.

$I2 + (1+r)^2(I2) = 100$, if $r = 10\%$, $I2 = 100/2.21 = 45.25$, $I1 = 54.75$

Suppose $Q = 100 - P$, $MC = 10$, simple 2 period model.

Under perfect competition, $P = MC = 10$, $Q = 90$

If total $Q > 180$, no problems.

What if $Q = 100$?

Set MNB(1) = MNB(2) Do graph like page 87.

Theory and mathematics of depletable resource use.

Constrained maximization.

Lecture #10 Friday, February 6

Demand curve: Q = 100 - P, P = 100 - Q

Area under curve = 100Q - Q^2/2 - 10Q (Do graph: PQ - 10Q + Q^2)
Can find this through calculus or through geometry.

From yesterday, can find Q under perfect competition, Q = 90, P = 10.

No problem if total Q >= 180.

What if total Q = 50.

Can solve this either through substitution or through LaGrange.

Now WTP is as before except for two periods, 2nd period discounted.

$$U = \sum_{t=0}^{T} \frac{\mathrm{WTP} - \mathrm{C(q)}}{(1+\mathrm{r})^{t}}$$

Key here is want marginal utility of good to be equal in both periods. Don't want feast then famine. However, you would rather consume now than later.

Max U = 100Q1 - Q1^2/2 - 10Q1 + (100Q2 - Q2^2/2 - 10Q2)/(1-r)
s.t. Q1 + Q2 = 50

U = 100Q1 - Q1^2/2 - 10Q1 + (100Q2 - Q2^2/2 - 10Q2)/(1-r) + L(50 - Q1 - Q2)

dU/dQ1 = 100 - Q1 - 10 - L = 0
dU/dQ2 = (100 - Q2 - 10)/(1+r) - L = 0
dU/dL = 100 - Q1 - Q2

Solving at r = 10%, 90 - Q1 = (90 - Q2)/(1.1) ===> 1.1Q1 - 9 = Q2
Q1 + 1.1Q1 - 9 = 50
Q1 = 28.10, Q2 = 21.90, U = 3708

Social planner's problem. Maximize utility across time.

Now instead imagine that the mine is operated by firms rather than individuals. In case of unlimited firms and unlimited resources we get answer just like before. Perfect competition leads to social optimum.

Max U = 100Q - Q^2/2 - 10Q
dU/dQ = 100 - Q - 10 = 0, Q = 90, P = 10

Use everything now and nothing later.

Now imagine unlimited firms and limited resources. Produce 50 in period 1 with 0 remaining in period 2. Could also have rent seeking behavior. Imagine an oil field. Everyone wants to work to get the biggest share before its gone.
Q1=50, Q2 = 0, U = 3250

Now imagine monopoly and unlimited resources. Produce 45 in each period. Dead weight loss but monopoly profits. (Set MR = MC.)

max Profit = TR - TC = PQ - 10Q = Q(100 - Q) - 10Q = 100Q - Q^2 - 10Q

dT/dQ = 100 - 2Q - 10 = 0 ====> Q = 45 ====> P = 100 - 45 = 55

T = 45*55 - 45*10 = 2025, CS = 1,012.5

Now imagine monopoly and limited resources. Monopolist doesn't want to flood the market too early. Rather string its profits over many periods.

Which seems more like an optimal solution?

1. Monopoly where firm restricts output to save resource over time.
2. Competition where firms compete to use up the resource before someone else.

Monopolist wants Max T = Q1P1 - 10Q1 + (Q2P2 - 10Q2)/(1+r)

Substituting, max T = 100Q1 - Q1^2 - 10Q1 + (100Q2 - Q2^2 - 10Q2)/(1+r) - L(50 - Q1 - Q2)

dU/dQ1 = 100 - 2Q1 - 10 - L = 0
dU/dQ2 = (100 - 2Q2 - 10)/(1+r) - L = 0
dU/dL = 50 - Q1 - Q2 = 0

(45 - Q1)1.1 = 45 - Q2 ===> Q2 = 1.1Q1 - 4.5 ===> Q1 + 1.1Q1 = 54.5
Q1 = 25.95, Q2 = 24.05, U = 3,704

Which seems more like an optimal solution?

1. Monopoly where firm restricts output to save resource over time.
2. Competition where firms compete to use up the resource before someone else.

Go through different possibilities.

Monopolist sets MR = MC or max total profit

Revenue = PQ = Q(100-Q), MR = 100 - 2Q = 10, Q = 45, P = 55, T = 45*55- 45*10 = 2025, CS = 45*45/2 = 1012.50. Total = 3037.5

T = TR - TC = PQ - 10Q = 100Q - Q^2 - 10Q

Industry Setup	**Resource**	**Method**	**Output/period**
Consumer is producer	Infinite	P=MC	q = 90, P = 10, T = 0, CS = 4050
Perfect Competition	Infinite	P=MC	q = 90, same
Simplistic	W = 80	Set q1=q2	q1 = 40, P1 = 60, T1 = 2000, CS = 800, 2800/1.1 = 2545 = 5345 total
Consumer is producer	W = 80	Set MU equal	q1 = 42.4, p1 = 57.6, T = 2018, CS = 899 q2 = 37.6, p2 = 62.4, T = 1970, CS = 707 2677/1.1 = 2434 + 2917 = 5351
Perfect Competition	W = 80	P=MC	q1 = 80, P1 = 20, T1 = 800, CS = 3200 q2 = 0, P1 = -, T1 = 0, CS = 0 0/1.1 = 0 + 3200 = 3200
Monopoly	Infinite	MC = MR	q = 45, P = 55, T = 2025, CS = 1012.5
Monopoly	W = 80	Set MΠ equal	q1 = 40.2, p1 = 59.8, T = 2002, CS = 808 q2 = 39.8, p2 = 60.2, T = 1998, CS = 792 2790/1.1 = 2536 + 2810 = 5346

Industry Setup	**Resource**	**Method to Solve**	**Output/period**	
Consumer is producer	Infinite	P=MC	q = 15 in every period	
Perfect Competition	Infinite	P=MC	q = 15	
Consumer is producer	W = 10	Set MU equal	q1 = 5.47	q2 = 4.53
Perfect Competition	W = 10	P=MC and rent seek.	q1 = 10	q2 = 0
Monopoly	Infinite	MC = MR	q = 7.5	
Monopoly	W = 10	Set MΠ equal	q1 = 5.12	q2 = 4.88

Lecture #11   Monday, February 9

Next, common thread running through all of the topics we are covering, is why don't we do the right thing. Where and why are there deviations from maximizing behavior is our different areas. We will look for several in relation to resources.

- We found the next one last time when there was no ownership of the resource. Free entry led companies to produce too quickly. We get feast then famine. Furthermore, it might be even worse than we fear because of rent seeking behavior. (Overcapitalization is a huge problem in the fishery industry for example.)
- Bad discount rate. Especially for countries in serious financial or debt problems, discount rate becomes sub-optimal. For example, many countries with serious debt problems depend on just a few minerals for a substantial portion of export earnings. Need to mine as much as possible to get out of debt.

Did examples of rent seeking.

Lecture #12   Wednesday, February 11

Buffalo Springfield, Dewey Martin, Young and Stills.

In fact, 84 percent of executives polled by Robert Half International said it takes just one or two typographical errors on a resume to remove a candidate from consideration for a job opening; 47 percent said a single typo can be the deciding factor.

Well, given that we are working with a fixed set of resources, we might as well attempt to utilize these resources as effectively as possible. Thus we move to next big section: Resource Use

We will look at the optimal way to consume resources depending on renewability, recyclability, ownership, competition, substitutes, environmental costs, etc.

Taxonomy:
- Depletable: Can be used up.
- Renewable: Replenishable. (rapidly, not fossil fuels for example)
- Recyclable: Can be used over and over (although 100% recovery is unlikely)

In terms of energy:
- Depletable includes fossil fuels, perhaps uranium.
- Renewable includes biomass (wood, ethanol, garbage), solar, wind, hydro, geothermal. Biomass can be used faster than it replenishes. Same with geothermal.

Current Reserves: Known resources that can be profitable extracted at current prices. A measure of measured and indicated (Demonstrated) and inferred resources combined with economics.

Potential Reserves: Vague. Depends on price, technology, etc. Examine oil: at $11.62 we have 21.2 billion barrels while at $30.00 we have 49.2 billion barrels.

Resource Base: How much is there if you can get to it or not. Excludes technology or economics.

I don’t find these terms, however, to be what is used in the data.

Proved reserves are those reserves claimed to have a *reasonable certainty* (normally at least 90% confidence) of being recoverable under existing economic and political conditions, and using existing technology. Also known as 1P

Unproved reserves
Probable reserves are based on median estimates, and claim a 50% confidence level of recovery. Industry specialists refer to this as **P50** (i.e. having a 50% certainty of being produced). Referred to in the industry as 2P (proved plus probable).

Possible reserves have a less likely chance of being recovered than probable reserves. This term is often used for reserves which are claimed to have at least a 10% certainty of being produced (P10). Reasons for classifying reserves as possible include varying interpretations of geology, reserves not producible at commercial rates, uncertainty due to reserve infill (seepage from adjacent areas), projected reserves based on future recovery methods. Referred to in the industry as **3P** (proved plus probable plus possible).

Reserves and usage of various energy sources.

Oil

Tar Sands in Alberta: roughly 600 billion barrels of oil at $70/barrel.

(12/31/00)	17.2 billion barrels, production 1.55 billion barrels (consumption 3.1 bbls)

Static Reserve Index: Years of proven reserves at current consumption rates. Proven reserves defined as those minerals that are known to exist and are recoverable at current market prices.

1. Consumption stays constant over time.
2. No addition to reserves occur. (Either price or discovery.)
3. Underlying assumption is that price stays constant as supply dwindles.
4. Also assumes no substitutes exist.

Examples: SRI Copper 1934, 40 years: 1974, 54 years
U.S. Oil, 1984, production 3.79, proven reserves, 34.5 billion 9 years
World production 21.10, reserves 707.2 34 years

Also, a Exponential Reserve Index, consumption grows over time due to economic growth.
This does even more to under-estimate the time until resource is gone.

Major reasons not to believe in exponential growth of resource use.

1. Major changes in composition of economies. Switch to high-tech lessens demand for primary resources.
2. Reduced demand due to energy efficiency. Incandescent vs. Flor. vs. LED.

59% of steel come from scrap.

3. Substitutes. Fiber Optics for copper wire. Plastic and ceramics for minerals.

Economy grows faster than resource use. Use of the eight major minerals in U.S all grew under 2% a year from 74-87.

Lecture #13   Friday, February 13

Examples of elasticity.

Lecture #14   Monday, February 16

A cartel occurs any time two or more producers join together to reduce production in order to raise price. This is effective because two producers working in union have a much stronger ability to reduce price than any one producer on its own.

Cartel can be especially effective when:

- Demand for good inelastic. This means even small decreases in quantity produced can result is large price changes. (Certainly true for oil in short-run.)
- When producers control a large percentage of the production. (For OPEC the critical issue was that OPEC controlled a huge portion of oil exports.)

Calculating elasticities.

Elasticity measures how much quantity changes with a change in another variable. An elasticity of 1 means that a 1% increase in one variable causes a 1% increase in demand. An elasticity of 2 means a 1% increase in, say price, causes a 2% increase in quantity.

Elasticity of demand = percentage change in quantity demanded/percentage change in price.
Take a demand schedule and find elasticities. What kind of goods have high or low elasticities?

- If elasticity > 1 then the good is elastic. If elasticity = 1 then the good is Unit elastic. If elasticity < 1 then good is inelastic.
- If elasticity is infinite it is called perfectly elastic. Horizontal demand curve.
- If elasticity is zero then it is perfectly inelastic. Vertical demand curve.
- In long-run elasticities are higher than in short run.

Does total amount spent on a good change if price goes up? Yes if inelastic.

Elasticity of supply = percentage change in quantity supplied/percentage change in price.
Take a supply schedule and find elasticities.

- If elasticity > 1 then the good is elastic. If elasticity = 1 then the good is Unit elastic. If elasticity < 1 then good is inelastic.

Income Elasticity of demand = percentage change in demand/percentage change in income.

- If elasticity < 0 then good is inferior. What kind of goods? (Black label beer.)
- If elasticity > 0 then good is normal.
- If elasticity >1 then good is luxury.

Cross-Price Elasticity of demand = percentage change in demand/percentage change in another good's price.

- If elasticity < 0 then goods are compliments. What kind of goods?
- If elasticity > 0 then goods are substitutes.

Finally note long-run vs. Short run supply and demand.

Long-run means: after people have fully adjusted to a change. No set time.
OPEC is a good example of a situation where short run demand was much less elastic than long run demand.

The equation for elasticity is percent change in quantity/percentage change in other variable.

First a little math. Percent change = (New Price - Old Price)/Old price

Midpoint method = (New Price - Old Price)/Average price. We use midpoint method rather than simple percent increase so that at a given point, elasticities are the same whether price is increasing or decreasing.

In percentage terms what is the difference between $1.00 and $1.50?

Elasticity is not the same as slope. Elasticity is percentage change while slope is rate of change.

Examples: When income rises from $10,000 to $30,000, money spent on airline tickets rises from $50 to $550. (500/300)/(20000/20000) = 1.67 (airline tickets are a luxury good)

Finally note long-run vs. Short run supply and demand.
Long-run means: after people have fully adjusted to a change. No set time.
OPEC is a good example of a situation where short run demand was much less elastic than long run demand.

How about the market for illegal drugs? Quantity consumed of illegal drugs may not change much based on price. Demand curve is very steep.

In this case reducing supply will not affect equilibrium quantity greatly but will only increase price. Supply tactics are ineffective if curves look the way we hypothesize.

If a cartel can lead to big gains for the cartel members, why are they not more common?

- May be illegal with countries. (Anti-trust laws.)
- Demand may be inelastic in short run but very elastic in long-run. Thus cartels are doomed to failure in the long-run. For OPEC huge new producers come on line. Conservation becomes key issue. Good substitutes for oil for many uses.
- Prisoner’s dilemma. Each member country has incentive to cheat on arrangement and over produce. Imagine two countries each controlling 30% of production. A 1% drop in production raises prices 2.5%. Each country considers a 20% drop in production. Q=10, P=1 or Q=8/10, P=1.15 or Q=8,8, P=1.75

1\2	Cheat	Cartel
Cheat	10,10	11.5,9.2
Cartel	9.2,11.5	10.4,10.4

No matter what the other person does, it is always better for you to cheat than play cartel.

Lecture #15   Wednesday, February 18

Show history of energy usage in the United States. Www.eia.doe.gov/emeu/aer/eh/frame.html

Wood gives way to coal gives way to oil. Why is oil so popular?

2.5 gallons of oil.

1 gallon of gasoline = 125,000 BTU (Diesel is roughly 150,000 BTU while ethanol is 84,400 BTU)

2.5 gallons = 312,500 BTU = 91.6 KWH (3416 BTU/KWH)

My laptop battery = 85 wh for $159 (roughly 1 pound of weight, on sale for $109)
My drill battery = 40 wh for $40 (roughly 2 pounds of weight)

One $5.99 gas can holds the equivalent of 1,078 laptop batteries ($173,345) or 2,290 drill batteries ("only" $57,000 but would weigh 4,500 pounds, just less than the curb weight of an Escalade.)

And the gas can is durable, etc.

Note that the gas is in a less usable condition. Easy to get heat, hard to get mechanical or electrical usage (1/3 efficient), so maybe we only need 350 laptop batteries (for $35,000).

The problem with the electric car is the battery, nothing else.

Gasoline is also better than natural gas (although many vehicles such as UPS trucks are powered by methane) because it is easier to safely store. Coal can't easily be transferred from tank to engine.

Started the game theory piece. Went through Prisoner's dilemma, battle of the sexes, and Rock-Paper-Scissors, as well as Nash Equilibrium and pure and mixed strategy equilibrium.

Lecture #16 Friday, February 20

If a cartel can lead to big gains for the cartel members, why are they not more common?

- May be illegal with countries. (Anti-trust laws.)
- Demand may be inelastic in short run but very elastic in long-run. Thus cartels are doomed to failure in the long-run. For OPEC huge new producers come on line. Conservation becomes key issue. Good substitutes for oil for many uses.
- Prisoner's dilemma. Each member country has incentive to cheat on arrangement and over produce. Imagine two countries each controlling 30% of production. A 1% drop in production raises prices 2.5%. Each country considers a 20% drop in production. Q=10, P=1 or Q=8/10, P=1.15 or Q=8,8, P=1.75

1\2	Cheat	Cartel
Cheat	10,10	11.5,9.2
Cartel	9.2,11.5	10.4,10.4

No matter what the other person does, it is always better for you to cheat than play cartel.

Repeated game.

Strategy: I will play cartel until you cheat. If you ever cheat I will play cheat forever.

I can make a one-time gain of 1.1 for a permanent loss of .4 per turn. At a discount rate of 10% that is a loss of 4.

Regulation of natural gas.

Lecture #17   Monday, February 23

Regulation of natural gas.

Gas accounts for roughly 25% of U.S. energy use. Lots of electricity plus home use for heating.

Very clean fuel. Low capital costs for equipment.

Hard to transport. LNG is dangerous. Pipelines are expensive.

Lecture #18   Wednesday, February 25

Regulation and deregulation of natural gas.

Natural gas prone to monopoly due to high fixed costs.

Problem largest as retail level. Regulated by state utility regulators.

Second biggest problem at wholesale level. Regulated by 1938 Natural Gas Act.

Third biggest problem is wellhead or field level. Phillips v. FPC 1955 required regulation of wellhead prices.

Significant administrative difficulties.

1955-1959: waiting period
1959-1973: imposition of "temporary" price ceilings.

Prices fell 20% in real terms. Shortages, disguised due to intertemporal nature. Static reserve index fell from 20 years in 1963 to 8 years in 1978.

Exploratory wells:

1949	420	
1955	870	(Positive network externalities)
1959	910	Boom is over
1971	470	Lack of incentive to drill.]
1973	1080	New regulations for new gas.
1981	2530	Big increase in activity due to incentives.

Fairness. Windfall profits.
Smaller than efficient
Incentive to do things the hard way

Lecture #19 Friday, February 27

No lecture. Midterm exam.

Lecture #20   Monday, March 9

Went over test.

Mean = 72
Median = 74

90	3	A
80	8	A
70	13	B
60	9	C
50	3	C-
lower	3	lower

1. For $800 you can currently buy a photovoltaic solar panel that generates 160 watts of electricity at peak power. In Massachusetts' climate, solar panels operate on a year-round basis at roughly 13% of peak efficiency. Utility rates in Massachusetts average roughly 15 cents/kwh.

   For practical purposes, photovoltaic solar panels require no maintenance and have an unlimited lifetime. Based on your knowledge of energy economics, would it make sense to install photovoltaic solar panels on your Massachusetts home? Explain, and show your work. (30 points)

Answer: 160w @ 13% efficient would produce 160(24)(365)(.13) = 182,208 wh per year or 182.2 khw/year.

At 15 cents per kwh, this is a benefit of $27.33 per year.

If we assume that the price of electricity will rise at approximately the same rate as overall prices, then we should apply a real discount rate for future streams of income. Real discount rates typically range from 2% to 4%.

The NPV of a steady stream of payments forever = P/r. Thus,
@ a discount rate of 4%, this project pays $27.33/.04 = $683.25 < $800
@ a discount rate of 3%, this project pays $27.33/.03 = $911.00 > $800

The IRR = 3.4%, and the payback period is no less than 800/27.33 = 29 years even at r = 0%.

These panels are likely to ultimately pay off, but it will take a long time to do so. Obviously factors like available subsidies, expected increases in electricity prices, and installation costs may all affect the decision.

2. Assume your utility can be represented by the function U = ln(income). Now imagine you are offered the chance to purchase a raffle ticket for a cost of $100 that gives you a 1 in 1,000 chance

of winning \$250,000. (30 points)

a. Suppose you are a poor college student earning \$10,000 per year. Should you buy this ticket? Explain, and show your work.
b. Suppose you are a rich college graduate earning \$100,000 per year. Should you buy this ticket? Explain, and show your work.

Answer: U(no ticket) = ln(10,000) = 9.2103
U(ticket) = .999 ln(9900) + .001 ln(259900) = 9.1911 + 0.0125 = 9.2036 < 9.2103. Bad idea.

b. U(no ticket) = ln(100,000) = 11.5129
U(ticket) = .999 ln(99900) + .001 ln(259900) = 11.5004 + 0.0128 = 11.5132 > 11.5129. Good idea.

3. Suppose the demand for a depletable good like natural gas is P = 20 - q in each period. Assume the marginal cost of extracting natural gas is constant over time and production and MC = 4.

Assume that a monopolist produces the natural gas over two periods but that the total amount of natural gas is 10 units and the discount rate is 10%. How much natural gas will be sold in each period, what will be the price, what will be the monopolist's profits, and how much consumer surplus will the consumer realize?

Now suppose that the natural gas regulator places a price ceiling on the gas of P = 12. Again, assume that a monopolist produces the natural gas over two periods but that the total amount of natural gas is 10 units and the discount rate is 10%. How much natural gas will be sold in each period, what will be the price, what will be the monopolist's profits, and how much consumer surplus will the consumer realize? (30 points)

Answer: With a monopolist we want to max π = TR - TC = pq - 4q for two periods.

Using the LaGrangian method

$\max \pi = p_1q_1 - 4q_1 + [p_2q_2 - 4q_2]/(1+r) - \lambda(10 - q_1 - q_2)$

$\max \pi = (20 - q_1)q_1 - 4q_1 + [(20 - q_2)q_2 - 4q_2]/(1+r) - \lambda(10 - q_1 - q_2)$

$\partial U/\partial q_1 = 20 - 2q_1 - 4 - \lambda = 0$

$\partial U/\partial q_2 = (20 - 2q_2 - 4)/(1+r) - \lambda = 0$

$\partial U/\partial \lambda = 10 - q_1 - q_2 = 0$

$20 - 2q_1 - 4 = (20 - 2q_2 - 4)/(1+r)$

$q_1 + q_2 = 10 \Longrightarrow q_1 = 10 - q_2$

$20 - 2(10 - q_2) - 4 = (20 - 2q_2 - 4)/(1+.10)$

$-4 + 2q_2 = (16 - 2q_2) / (1.1) = 14.545 - 1.818q_2$

$3.818q_2 = 18.545 \Longrightarrow q_2 = 4.86, q_1 = 5.14, p_2 = 15.14, p_1 = 14.86, CS_2 = 4.86(20 - 15.14)/2 = 11.81,$
$CS_1 = 5.14(20 - 14.86)/2 = 13.21, \pi_2 = 4.86(15.14 - 4) = 54.14, \pi_1 = 5.14(14.86 - 4) = 55.82.$

Total welfare = (13.21 + 55.82) + (11.81 + 54.14)/1.1 = 69.03 + 59.95 = 128.98

Under a price ceiling, the price in period 1 is now 12.

$p_1 = 12 \Longrightarrow q_1 = 20 - p_1 = 8, \pi_1 = 8(12 - 4) = 64, CS_1 = 8(8)/2 = 32$

$p_2 = 12$, $q_2 = 10 - 8 = 2$ (shortgage), $\pi_1 = 2(12 - 4) = 16$, $CS_2 = 2(2)/2 + 2(18 - 12) = 14$
Total welfare = (64 + 32) + (16 + 14)/1.1 = 96 + 27.27 = 123.27

The imposition of the price ceiling has increased consumer surplus at the expense of firm profits. Overall welfare is lower under the price ceiling since we get shortages in the future years.

4. The recently passed stimulus package contains $6.5 billion in subsidies for energy efficiency projects for low and middle income households. Given the fact that taxes and subsidies generally result in dead-weight loss, why would anyone believe that this spending will result in an increase in societal welfare? Give at least three reasons.

Answer: There are many acceptable answers here.

- Since the benefits are accruing primarily to the poor and middle class, if we have a distributional preference towards these groups, we may favor the project even if it has negative benefits overall.
- These projects may have positive benefits but they are not undertaken due to status quo bias. The subsidy may help eliminate this bias.
- These projects may have positive benefits but they are not undertaken due to informational bias. Consumers may not realize their benefits. The subsidy may help eliminate this bias.
- Consumers may not have personal discount rates that are far higher than societally efficient discount rates. The subsidy may help eliminate this inefficiency.
- There may be environmental or national defense externalities associated with energy consumption that consumers do not take into account when making decisions. Subsidizing conservation may move to a more efficient allocation.
- There may be inefficiencies in the intertemporal distribution of resources over time that subsidizing conservation may help alleviate.
- From a macroeconomic aspect, since this is stimulus spending rather than investment spending, it does not need to satisfy cost benefit analysis in the same way.Talk about suntans.

Why do people get them when they cause cancer? (Over 1,000,000 cases in U.S. and about 10,000 deaths, mostly from melanoma.)

Lecture #21 Wednesday, March 11

Nuclear power: Chemical vs. Nuclear

Chemical power comes from energy released from breaking bonds between atoms in molecules.

Nuclear power comes from breaking bonds within the atom.

Atoms have protons and neutron in nucleus and electrons in orbit.

- Number of protons defines the element (Hydrogen is 1, Uranium is 92, etc.)
- Number of neutrons defines isotopes (Hydrogen comes in H-1, H-2, and H-3 forms with 0, 1, and 2 neutrons respectively.)

Not all proton/neutron combinations in a nucleus are stable. Unstable combinations are known as radioactive elements/isotopes.

Radioactive elements have a tendency to break down naturally, releasing energy (as radiation and/or kinetic energy) and/or particles such as new elements and neutrons.

While the breakdown of any particular atom is completely random, in large quantities, radioactive isotopes behave according to the law of large numbers. Half-life is the amount of time is takes for one half of the element to break down on average.

Depending on the stability of the radioactive element, the half life can range from fractions of a second to 100,000 years (Element 116 ranges from 7.2 - 61 microseconds while some forms of plutonium have half lives of up to 88 million years.)

An example: Carbon-14 is a radioactive isotope of carbon. Carbon is element 8 and C-14 have 6 neutrons. Its half-life is 5,730 years and by measuring the amount of C-14 in a dead body, one can estimate how long it has been dead. A tree with half the amount of C-14 expected will have been dead roughly 5,730 years.

Nuclear reactions in power generation:

Fusion: putting two atoms together. H + H ===> He plus kinetic energy (plus potentially a neutron). Energy of the sun, also hydrogen bombs, very difficult to control.

Fission: taking an atom apart. Hit U-235 with a neutron and it generally splits into krypton, barium, some neutrons, and kinetic energy. First atomic bombs and nuclear plants.

Fissile material can create a sustaining reaction because it releases neutrons going fast enough to split further atoms. Only U-235, U-233, and P-239 are fissile.

Neutrons have a habit of breaking down into a proton and electron. C-14 become N-14

Th-232 U-233, U-238, P-239, Th 232

Potential energy of fissile material is huge.
82,000,000,000,000 joules/kg U-235 = 77,725,000,000 BTU

1 gallon of gas = 125,000 BTU

Thus, 621,800 gallons of gas or 4,000 tons of coal = 1 kg U-235

You could power Toyota Camary for 100,000 miles with a lump of U-235 the size of a quarter.

Major problems:
- Potential for accidents or terrorism. Three Mile Island, Chernobyl
- Regulatory problems
- High start up costs
- Complex
- Reasonably low usable Uranium deposits
- Nuclear proliferation
- Waste storage

Major advantages:
- Large friendly source of fuel material
- Low variable costs
- Expandable
- Carbon neutral
- Potential for large reserves
- Constant flow

443 operating reactors in 30 countries supplying 365 gigawatt of capacity
US has 104 reactors in about 20 states supplying 806,000,000,000 kwh/year of 20% of total.

As the Holy Name wind turbine produces 1,100,000 kwh/year, you would need roughly 7,000 turbines to replace the electricity production of the average U.S. nuclear plant.

Marginal abatement and damage

Abatement vs. cost.

Liability ceiling of $560 million, $60 million from power plant.

Requires regulation.

Lecture #22   Friday, March 13

Class canceled due to power outage. How ironic...

Lecture #23 Monday, March 16

Major advantages:

- Large friendly source of fuel material
- Low variable costs
- Expandable
- Carbon neutral
- Potential for large reserves
- Constant flow

As the Holy Name wind turbine produces 1,100,000 kwh/year, you would need roughly 7,000 turbines to replace the electricity production of the average U.S. nuclear plant.

Marginal abatement and damage

Abatement vs. cost.

Suppose a safety technique increases safety by 90%.

Liability ceiling of $560 million, $60 million from power plant.

Requires regulation.

Lecture #24 Wednesday, March 18

Electricity markets

Interesting economically for a number of reasons:

- Large and growing part of energy sector. Most growth in energy usage in last 30 years has been electricity.
- Huge differences in marginal costs by source.
- Huge differences in fixed costs by source.
- Large variability in electricity usage. (Electricity cannot be easily stored or transported.)
- Natural monopoly in electricity distribution.

It takes about 1,000,000 BTU of heat to generate 100kwh.

You can get 1,000,000 from about 80 pounds of coal (but varies by type of coal), 1000 cu ft. of natural gas, or 7 gallons of crude oil (varies slightly by type of oil).

\$ 0.75 @ \$13/ton for Wyoming coal at mine entrance
\$ 1.25 @ \$22/ton for Wyoming coal delivered to Minneapolis
\$ 4.25 @ \$75/ton for coal delivered to New England
\$ 6.50 @ December natural gas prices
\$12.60 @ at record June natural gas prices
\$ 1.78 @ oil for each \$10/barrel.
\$ 7.14 @ oil of \$40 barrel
\$26.25 @ at record \$147 oil/barrel
\$ 0.01 @ \$30/kg for uranium at 5% usable material (too cheap to meter)
\$ 0.00 @ solar, wind, geothermal, hydro, tidal, etc.

Cost of generating facilities

- Nuclear @ \$5 billion for 1000 MW plant operating at 90% yields about \$0.05 per KWH
- Coal @ \$1.5 billion for 1000 MW plant operating at 90% yields about \$0.015 per KWH
- Gas @ \$250 million for 1000 MW plant operating at 90% yields about \$0.0025 per KWH
- Solar photovoltaic @ \$5 billion for 1000 MW plant operating at 13% yields about \$0.35/KWH
- Wind @ \$2.5 billion for 1000 MW plant operating at 21% yields \$0.08 - \$0.10/KWH
- Hydro is probably about 2-3 cents per KWH depending on how you value the environment.

Electricity markets

Peak-load vs. total energy.

Fixed and variable costs.

Nuclear very high fixed, low marginal
Wind/solar very high fixed, low marginal
Coal medium fixed, medium marginal
Oil low/medium fixed, high marginal
Gas low fixed, high marginal

Suppose one wanted to build a electricity grid.

Fixed electricity usage, no variability:

- Coal, nuclear, hydro ===> 3-5 cents/kwh if used all of the time. (Higher in MA due to coal transport costs.)

Base load electricity

What if electricity usage is more variable?

- Variability due to location, season, time of day, income.
- Gas, oil better than nuclear. If a nuclear plant is only used 10% of time, fixed costs are $.50/kwh + fuel (= $0). If a gas plant is only used 10% of the time, fixed costs are $0.025/kwh plus $0.06 - $0.10/kwh for fuel.

Gas plants are much cheaper for peaking capacity.

Lecture #25 Friday, March 20

How can one cut energy costs?

- Conservation (as seen in HW #1)
- Smoothing (smart grid technology) At peak during day, running a clothes dryer can be twice as expensive and during the low point.
- Choose right mix of generation.

Regulation:

As with natural gas generation is not necessarily a monopoly but distribution is a natural monopoly. Traditionally, utilities have been generators and distributors regulated on a cost plus basis for final retail prices.

Cost plus creates a lack of incentive problem for cutting costs. For example, little reason for utility to promote conservation or any movement to lower cost alternatives.

Shift to competitive auctions. With perfect competition, bidding process leads firms to reveal their marginal cost.

Problem is that this only works when markets are truly competitive. California energy example. Also,

"...supply-demand imbalance, flawed market design and inconsistent rules made possible significant market manipulation as delineated in final investigation report. Without underlying market dysfunction, attempts to manipulate the market would not be successful."

"...many trading strategies employed by Enron and other companies violated the anti-gaming provisions..."

"Electricity prices in California's spot markets were affected by economic withholding and inflated price bidding, in violation of tariff anti-gaming provisions."

Lecture #26   Monday, March 23

Electricity production:

Coal: Large resources. Huge environmental damages, mining, acid rain, global warming (44% more CO2 per unit) U.S. about 50%.

Oil: Small resources. National defense externalities. Too useful as a portable fuel. 1% Global warming (25% more per unit)

Renewables:

Hydro: Falling water turns turbines. Limited availability, environmental damages. Small hydro. 10%

Geothermal: Heating or cooling from ground. Iceland uses geothermal for 90% of building heating and 25% of electricity. U.S. 2,000 MW capacity (about 2 large nuclear plants, we need about 500), plus a small amount of home heating and cooling. Limited availability.

Wind: Intermittent, visual and noise pollution, bird kills.

Solar: Intermittent, costly. Thermal and photovoltaic.

Biomass: Limited availability, think of ethanol. Is it renewable, wood, garbage, landfill gas, sawdust.

Tidal: Expense

Lecture #27 Wednesday, March 25

Finished up with renewable energy sources.

What sort of decision making process leads to the best outcome, the best choice under CBA, the highest societal utility. Welfare economics (Alfred Marshall, late 1800s) gives a specific answer. Competitive market equilibriums are Pareto Optimal.

Def: An allocation is P.O. if no other feasible allocation exists that makes someone better off without making someone worse off. In other words, you can't improve upon the market.

Pareto Optimality has nothing to do with fairness. Example of dividing up money.

There are a number of areas where the market fails and therefore improvements may be possible. Market failure is any time private and public costs or benefits don't match.

- Informational problems. Government has USDA, SEC, FDA. Akerlof Lemons problem.
- Monopoly. Anti-trust laws. FTC. FERC, Utility regulators. (Of course, we have learned that in some cases monopoly is actually better.)
- Government screw-ups. Improper subsidization, etc.
- Public goods. (Parks, highways.) Two types: rival and non-rival. Excludable and nonexcludable. All goods have some degree of each of these factors. A pure public good is both non-rival and non-excludable.
    - Car, food, clothing: Rival and excludable. (Private good.)
    - Patriots: Non-rival and excludable. (Club good, no serious problem.)
    - National Defense/Environment: (Pure public good) Non- rival / non-excludable.
    - Fishery: Rival and non-excludable. (Commons) Biggest problem.)
    - National park: Some degree of both.
    - Many people consider income equality a public good.
- Externalities. (Private costs/benefits don't match public costs/benefits.) Pollution, education, noise, etc. Definition: *an externality is present whenever some individual's utility or production relationships include real variables (Non-monetary) whose values are chosen by another party without particular attention to the effects on the first person's welfare.* Difference between shift in production curve and shift along curve. Those that just affect prices are pecuniary externality. Affects prices and is a transfer. Technological externalities affect ability to produce goods or utility and are a net loss to society. Do graphs.

Lecture #28 Friday, March 27

Continue with market failure.

- Informational problems. (Option Value) Government has USDA, SEC, FDA.
- Monopoly. Anti-trust laws. FTC. (We will learn that in some cases monopoly is actually better.)
- Government screw-ups. Improper subsidization, etc.
- Public goods. (Parks, highways.) Two types: rival and non-rival. Excludable and nonexcludable. All goods have some degree of each of these factors. A pure public good is both non-rival and non-excludable.
  - Car, food, clothing: Rival and excludable. (Private good.)
  - Patriots, pay-per view tv: Non-rival and excludable. (Club good, no serious problem.)
  - National Defense, volcano monitoring, basic research, broadcast tv: (Pure public good) Non- rival /non-excludable.
  - Fishery, some energy deposits: Rival and non-excludable. (Commons, Biggest problem.)
  - National park: Some degree of both.
  - Many people consider income equality a public good.
- Externalities. (Private costs/benefits don't match public costs/benefits.) Pollution, education, noise, etc. Definition: *an externality is present whenever some individual's utility or production relationships include real variables (Non-monetary) whose values are chosen by another party without particular attention to the effects on the first person's welfare.* Book page 22. Difference between shift in production curve and shift along curve. Those that just affect prices are pecuniary externality. Affects prices and is a transfer. Technological externalities affect ability to produce goods or utility and are a net loss to society. Do graphs. Pollution, housing crisis/abandoned homes.

Two final problems:

- Undesirable market outcomes. Market is working fine but you don't like the outcome.
  - Inequitable distribution of income across people.
  - Inequitable distribution of income across time.

Can be seen as a property rights problem. Well-defined property rights solve most problems. -Unfortunately for many things property rights cannot be well-defined.

Dynamic effects: same sort of deal. Problems if social and private costs don't match.

Again, explore issue of when private costs and benefits differ from public costs and benefits.

Do a graph of Pollution. (Externality.) Benefits of polluting are the same for public and private but costs of pollution are higher for society and private. Equilibrium is too much pollution.

What is the economically efficient level of pollution? In a perfect world, how much pollution would there be. Of course for economists, perfect world is one where there is Pareto Optimality (i.e. economic efficiency.)

Choose where MC of abatement = MC of allowing it to spread.

MC abatement rising, use successive treatment example. Removing 90% costs $100.

MC allowing rises, can only assimilate so much.

In general optimal level is not zero. May be close. Think of dioxin. Nasty enough that they had to redefine the standards. Used to be less than 1 part per million = 0. Now talking PPB, PPT. Ultimately can eliminate all pollution by stopping production. Some people have problems when you say it is good to have some level of pollution, but that is in fact correct.

Usually market sets MC=MB. Why is there a problem here. Externality problem.

Three big areas: Air, water, and solid waste.
Big sources: Point, non-point, mobile.
Big damages: local, regional, global.

Can be seen as a property rights problem. Well-defined property rights solve most problems. - Unfortunately for many things property rights cannot be well-defined.

Dynamic effects: same sort of deal. Problems if social and private costs don't match.

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Usually market sets MC=MB. Why is there a problem here. Externality problem.

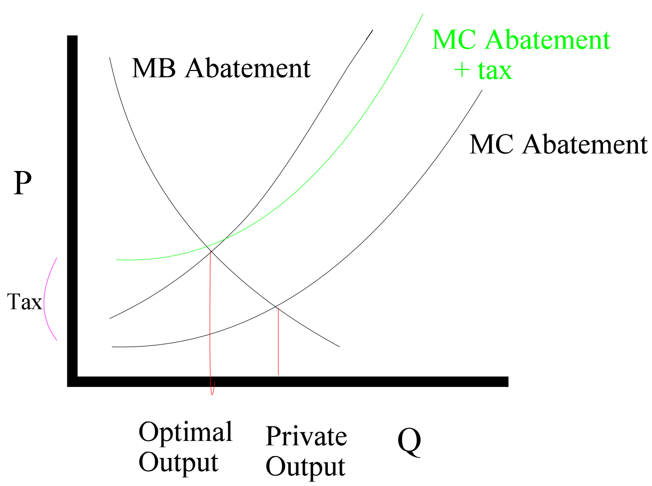
First, assume you start at some level of pollution. From this point how expensive is it to reduce pollution and how much benefit do you gain. In general you will have increasing marginal cost of reduction and decreasing marginal benefits. Where the two meet is optimal level of reduction. (Level of reduction could be negative meaning control levels are already too stringent.)

Assume MC of reduction is $2 + 2q$ when initial level of pollution is 20 units.
(For some firms might even look like $-1 + 7q$.)
Assume MB of reduction is $17 - q$ when initial level of pollution is 20 units.

Set MB = MC and you get $q = 5$. Optimal level of pollution is 15 units (20 - 5).

Big thing to look at is the fact that optimal level of pollution is not zero. If you get more use out of using your car than the harm the pollution from your car causes society, then there is no problem with you using your car and producing pollution. Real problem comes when (as in the case above) a private person or firm chooses to emit 20 when efficient level is 15. See above that there is no reason for the firm to move from 20 to 15 without coercion.

Now the question is once you decide what the efficient level is, how do you get firms to move to that level and how do you get them to that level in the most efficient manner? Critical part here is that you have already decided what the efficient level of pollution will be. On Friday your distinguished lecturer will talk about the reasons behind different solutions. Today we just find the solutions.



Lecture #29 Monday, March 30

First, assume you start at some level of pollution. From this point how expensive is it to reduce pollution and how much benefit do you gain. In general you will have increasing marginal cost of reduction and decreasing marginal benefits. Where the two meet is optimal level of reduction. (Level of reduction could be negative meaning control levels are already too stringent.)

Assume MC of reduction is 2 + 2q when initial level of pollution is 20 units.
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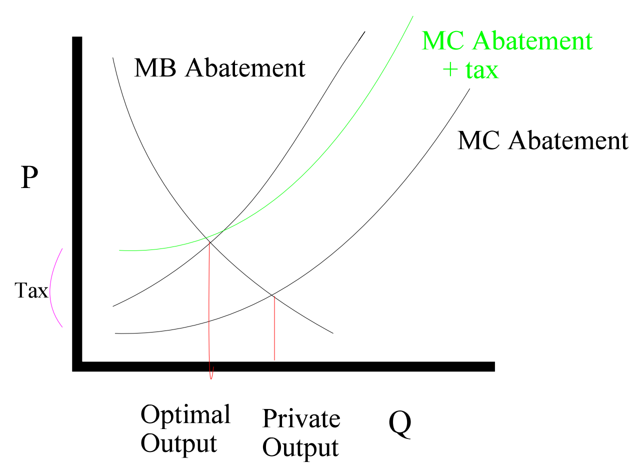
Four lines of thought on how to arrive at optimal solution when an externality arises.

A.C. Pigou's Solution (1930): Government will tax private individuals to raise private cost up to social cost. (Could do a simple graph here.)



Problems with Pigou's solution:

- Need accurate estimates of MC and MB in order to correctly set taxes. As we know, values of non-priced goods are hard to measure.
- Problem of moral-hazard. If taxation is transferred to victims of pollution it lowers the incentive for individuals to stay out of high pollution areas. People may move to high pollution areas simply to collect a pollution compensation check.

Ronald Coase's Solution (1960): Market will take care of things. The victims of pollution should always join together and pay (bribe) the polluter not to pollute. Market works since all victims pay up to their WTP to reduce externality. Has further advantage over Pigou in that it works regardless of how property rights are structured. Could have polluter paying for right to pollute or victims paying for right to stop pollution.

Benefits of Coase's solution:
- Requires no government intervention.
- Works regardless of who is assigned the property rights.

Problems with Coase's solution:
- Information. Firm may know something individuals don't know. Coase favored government subsidy for information gathering systems.
- Free-Rider issue. Works less and less well as additional people join in. In cases where one polluter affects a large area (a city of 10000), the Coase Theorem will probably not work.
- Problem when negotiation is costly.

Benefits of Command and Control
- Good when individual monitoring is costly or impossible.
- Close to efficient when optimal pollution levels are at or near zero.
- Can lead to economies of scale in pollution control equipment. (Auto emission standards vigorously supported by auto industry to prevent multiple standards from different states.)

Problems with Command and Control
- Requires all polluters to reduce in the same fashion regardless of cost.
- May reduce innovation in pollution control.

Benefits of Pollution Taxation
- Raises revenue. (May wish to combine with other tax cuts. Tax switching.)
- Efficient
- Increases pollution reduction as technology advances.
- Gives incentives for firms to innovate in pollution control.

Problems with Pollution Taxation
- Politically unpopular. Firms pay more under Pollution Taxation than Command and Control even though society pays less.
- May result in "hot spots."
- Requires guesswork to achieve correct pollution level.
- Tax is likely to be regressive compared to the tax it replaces. (Although command and control's hidden costs are likely to be every bit as regressive as costs are passed along to consumer.)

Benefits of Tradeable Permits
- Automatically achieves desired pollution reduction.
- Politically popular.
- Efficient
- Give incentives for firms to develop new pollution control methods.

Problems with Tradeable Permits

- Development of better technologies does not reduce pollution but simply lowers permit price. (Could have permits with expirations.) What if firm 1 figured a new way to reduce pollution that lowered costs to firm 2's level? Under quota each firm will now emit 50 units. Under tax, each firm will emit 34 units, a total reduction of 32 units.
- Questions about how to distribute initial permits.
- May result in hot spots.

Lecture #30 Wednesday, April 1

Assume you have two firms that can reduce pollution at the following costs:

$C1 = 4q1 + .2q1^2$ $MC1 = 4 + .4q1$ Assume desired reduction is $q1+q2 = 100$.
$C2 = 10q2 + .3q2^2$ $MC2 = 10 + .6q2$ Assume each firm current produces 100 units.

Command and control: Each reduces pollution 50%.

$C1 = 4*50 + .2*50*50 = 700$
$C2 = 10*50 + .3*50*50 = 1250 = 1950$ total

Optimal: min C1 + C2 w.r.t q1 and q2 s.t. $q1+q2 = 100$.

Set MC1 = MC2 s.t. $q1+q2 = 100$

$4 + .4q1 = 10 + .6(100-q1)$ $q1 = 66$ $q2 = 34$
$C1 = 4*66 + .2*66*66 = 1135.2$
$C2 = 10*34 + .3*34*34 = 686.8 = 1822$

Benefits of Command and Control

- Good when individual monitoring is costly or impossible.
- Close to efficient when optimal pollution levels are at or near zero.
- Can lead to economies of scale in pollution control equipment. (Auto emission standards vigorously supported by auto industry to prevent multiple standards from different states.)

Problems with Command and Control

- Requires all polluters to reduce in the same fashion regardless of cost.
- May reduce innovation in pollution control.

Taxation: Need a tax such that pollution is cut by proper amount. Set t = MC of desired abatement.

Firm #1: $4 + .4(66) = tax = 30.4$ Total tax $= 34 * 30.4 = 1033.6$
Firm #2: $10 + .6(34) = tax = 30.4$ Total tax $= 66 * 30.4 = 2006.4$

If cost of tax is greater than cost of pollution reduction, they would rather reduce than pollute so they cut pollution to the point where tax = MC.

Downside: In reality, imperfect information leads to a situation where government doesn't exactly know how much a given tax will reduce pollution. Thus, usually need a incremental thing that is unpopular and what if a certain reduction is mandated by big government? Uncertainty rises. Say start with a tax of $20. Reduces pollution by $q1 = 16.7$ and $q2 = 40$ so they would have to bump it up.

Benefits of Pollution Taxation

- Raises revenue. (May wish to combine with other tax cuts. Tax switching.)
- Efficient

- Increases pollution reduction as technology advances.
- Gives incentives for firms to innovate in pollution control.

Problems with Pollution Taxation

- Politically unpopular. Firms pay more under Pollution Taxation than Command and Control even though society pays less.
- May result in "hot spots."
- Requires guesswork to achieve correct pollution level.
- Tax is likely to be regressive compared to the tax it replaces. (Although command and control's hidden costs are likely to be every bit as regressive as costs are passed along to consumer.)

Tradable Emissions: Issue a right of 50 units of pollution to each firm.

At 50 units it costs 24 for firm 1 to reduce pollution by 1 unit.
At 50 units it gains 40 for firm 2 to increase pollution by 1 unit. Along the lines of Coase, there is a beneficial trade to be made here so market will adjust. Following the pattern, the trades stop when firm one has sold 16 emission rights to firm 2 at a price between 435.2 and 563.2.

Benefits of Tradeable Permits

- Automatically achieves desired pollution reduction.
- Politically popular.
- Efficient
- Give incentives for firms to develop new pollution control methods.

Problems with Tradeable Permits

- Development of better technologies does not reduce pollution but simply lowers permit price. (Could have permits with expirations.) What if firm 1 figured a new way to reduce pollution that lowered costs to firm 2's level? Under quota each firm will now emit 50 units. Under tax, each firm will emit 34 units, a total reduction of 32 units.
- Questions about how to distribute initial permits.
- May result in hot spots.

Has it been worthwhile? CBA estimates for stationary sources: Freeman (1978)
Costs: \$9 billion   Benefits: \$4.8-49.4 billion with median \$21.2 billion.

So benefits outweigh costs and this is a good program. By 1992 costs \$38 billion for all air.

- Has it been efficient? C&C standards for all places. Emissions tests for cars were bad. Timing of pollution. Lowest Achievable Emission Rate. Numerous studies done:
  Particulates in Lower Delaware Valley ratio of cost to least cost of 22.
  NO2 in Chicago 14.4 ratio.
  SO2 in four corners 4.25.
  Hydrocarbons in DuPont 4.15.

All major studies had major differences with 1 exception. Sulfates in LA. Near zero standard means no room for improvement.

BIG DEAL: Where efficient levels are near zero, C&C close to efficient. Also think of aerosol cans.

So we clearly violate efficiency.

Lecture #31   Friday, April 3

History of environmental legislation in the U.S.

Air Pollution:

First Clean Air act of 1970. Largely a Command and Control document.
Tailored to fit worst cities so pollution control does not match need. Certainly not efficient and possibly not economically justified. Why use C&C instead of market incentives?

Almost all air pollution is a result of direct energy usage although some is released in manufacturing processes (for example CFCs or many VOCs)

- First, has it been effective? From 1970-2005 EPA reports of emissions in 6 criteria pollutants

			1970	1980	1990	2000	2005
Particulates	Smog, health	Factories, diesel	100	51	26	19	16
SO_2	Acid rain	Coal	100	83	74	52	48
Volatile Organics/O_3	Smog, health	Autos, other	100	89	69	50	47
CO	Health	Autos, other	100	90	73	52	45
NO_x	Acid rain	Autos, other	100	101	94	83	71
Lead	Health	Autos	100	38	2	1	1
Population			100	111	121	134	142
Real GDP			100	137	189	260	293

So air quality has definitely improved despite a growing population and economy.

Per capita or per unit GDP has even greater reductions.

- Has it been worthwhile? CBA estimates for stationary sources: Freeman (1978)

  Costs: $9 billion   Benefits: $4.8-49.4 billion with median $21.2 billion.

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So we clearly violate efficiency.

What has been done to change this? Emissions Trading Program begun in 1980.

- Pollution credits: More than adequate reduction means credits could be banked and used in Offsets, Bubbles, and Netting.
- Bubble. Think of an entire factory under 1 bubble. Less stringent controls on one part of the factory made up for by more stringent in other parts. Could also include different firms.
- Offset: Allowed to expand production in non-attainment areas by reducing production of pollution by another means. (For instance, companies have bought out bankrupt dry-cleaners and shut them down.) Solves problem of pollution reduction vs. economic growth.
- Netting: Allows expansion of plant to forego stringent review as long as net plant emissions remain constant. Usually done by shutting down old facilities.

7,000-12,000 transactions completed but almost all have been intrafirm. Very few between firm trades have occurred so market is not working well yet.

1990 Clean Air Act Title IV: Sulphur Dioxide reductions. Largely works to solve the problem.
Why SO2? Big acid rain contributor. Easy to solve problem since there are only limited sources of emissions.

Fully marketable permit with $2000 ton fine for non-compliance. Cuts emissions in half (roughly) between 1980 and 2000. Specific standards for different regions. Measures of pollution, no standards to how reductions must be acheived. In past, thanks to Robert Byrd, Senate Appropriations, WV, couldn’t substitute low-sulphur coal for scrubbers to acheive same SO2 reduction.

Lecture #32   Monday, April 6

Reviewed problem on HW #5 with Enron.

Two major areas of concern in the book:

Acid deposition and Global warming, and should add ozone depletion.

Common charcteristics:

- Trans-border pollution. Requires intercountry management.
- Both are potentially major problems.
- Effects are different in all places.

Uncommon characteristics:

- Scientists are absolutely sure about cause and effect mechanism in SO_2. Clear understanding of process and problem. Clearly measurable costs and benefits today. Eastern Europe probably worst off. C1989 UN finds 82% poland, 78% Bulgaria, 73% Slovak, etc. forests with signs of damage.
- CO_2 has huge degree of uncertainty associated with it. Scientists cannot predict how things will be affected. And certainly not at the regional level. Carnations. Ice age.
- SO_2 is largely our fault. 50 million metric tons/year world while 40 million from sea salt and 90 million from other biogenic sources. 2 billion tons of CO_2 from fossil fuels while 8 billion tons from other sources. Similar situation with methane, etc.

Ultimately, we deal with 3 big issues in different ways.

Acid rain is easy solution with tradable permits. Easy to monitor, limited number of polluters, and definite scientific proof of problem leads to economic action.

Ozone also easy. Since optimal levels of CFC emissions are close to zero, C&C policies are very close to minimum cost policies. Note that CFC's underwent a multi-tiered phase-out with least essential uses going first and then uses with fewer substitutes. (Aerosols then Freon.)

Global warming not easy. Many polluters, nature itself is a polluter, evidence not 100% certain that global warming will have serious negative effects. Thus, no action taken. Even economists recommending carbon taxes want tax to be limited. ($5 vs. $100/ton)

Areas of no debate:

- CO_2 is a warming gas.
- CO_2 concentrations have risen over past 250 years by about 35% (from 280 PPM to 380 PPM)
- Burning of fossil fuel releases huge quantities of CO_2 (roughly 1 billion metric tons of carbon/year) land use changes add another .5 billion tons. Only a small part of carbon cycle, but enough to tip the scales.

Unless you can make a strong “other things not equal argument” the only questions are how much warming will occur. Obviously other things do occur.

“Theory” in common language means a guess. “Theory” in science simply means that the given explanation is to falsifiable. If a better explanation comes along, the old one can be thrown out. Thus, even gravity is a theory. Separates science from religion, for example. Critics of intelligent design don’t really criticize the theory only the method.

Computer modeling is not bad. How do you think they do the daily weather reports, fly to Jupiter, or build bridges. Computer modeling of a rock falling. Doesn’t “prove” anything but would make an awfully accurate prediction if I put the right numbers in.

Ranges are not bad: What if a large number of doctors predicted that you would break 1-20 bones from jumping off a cliff. Would you discount the estimates because they differed by 2000%?

Lecture #33   Wednesday, April 8

Biases of researchers. Yes and no. Lets look at me. I have a strong vested interest in sports. I continue to collect data that supports my side rather than suppress others. Tenure prevents a lot. I'm paid by tuition and endowment, not people's pockets. Blind review also helps. True critics are actually rewarded while saying the same old thing doesn't count for much. Also, the process is quite open. You can read any results and tie names directly. Climate scientists are open about their critics and about where uncertainty lies.

Went through the IPCC report on the science behind global warming.

One gallon of gas creates (19.6) 20 pounds of CO_2 or contains about 5.5 pounds of Carbon.

Estimates of social costs of carbon from 100 peer-reviewed articles from IPCC4 are $43 ton for carbon with a range of -10 to 350.

2205 pounds per metric tonne.

The 25-member European Union, representing nearly half-a-billion people, recently voted a carbon tax of $13/ton to be inaugurated during 2006-07, increasing to $33/ton during 2008-12. Japan has mandated a "household energy tax" equivalent to $21/ton of carbon, and voters in Boulder (Colorado) passed a carbon tax referendum on Nov. 7. While Boulders tax equates to just $7/ton and applies only to electricity, it nonetheless establishes an important precedent: the first climate-protecting tax ever levied in the United States.

Coal: about 1 tonne CO_2 per 1000 KWH or 1 tonne carbon per 3700 KWH.
Natural gas: 42% less
Oil: some less 25% less

Small fridge about 1KWH/day
Hair dryer about 1KWH for 40 minutes.
AC big.

2.3 lbs CO_2 per KWH or just over 1 kg CO_2 per KWH.

Q

I am curious about the global warming potential of water vapor. Do you know if estimates are done of this in the same way as global warming potentials are calculated for other greenhouse gases? I am also interested in why no mention is ever made of the enhanced greenhouse effect caused by anthropogenic emissions of water vapor. Are the anthropogenic emissions not significant?

A

Water vapor is indeed a very potent "greenhouse" gas, in terms of its absorbing and re-radiating outgoing infrared radiation. It is commonly not mentioned as an important factor in global warming, because it is not clear that the atmospheric concentration (as compared with CO_2, methane, etc.) is rising. Some (Richard Lindzen at MIT, prominently) have argued that the uncertain potential feedbacks involving water vapor represent a serious shortcoming in models of climate warming. See the following online resource for a good discussion of this issue:

http://www.eia.doe.gov/cneaf/pubs_html/attf94_v2/chap2.html

Lecture #34   Wednesday, April 15

Quick review of nuclear power assignment.

Finished global warming.

Stable vs. unstable equilibria. Also momentum (global warming, population, etc.)

Estimates of optimal carbon taxes are way to small to arrest the increase of CO2 into atmosphere.

Between $12/ton and $45/ton.

Would generally only serve to increase energy prices by 30%. This has almost no effect on short-run demand and only moderate effects on long-run demand.

First steps, Kyoto Protocol passed but little enforcement and excluded most developing nations. (Equity consideration and less important at time.)

Montreal Protocol for CFCs brought an end quickly, at low cost, and ahead of schedule.

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Derivative markets.

Many assets are bought and sold on two different markets: spot markets and forward markets.

In spot markets, the settlement is immediate. This is what is thought of as a normal purchase. Consider going to the grocery store and buying groceries. Exchange of money is immediate and you get to take home food right now.

Purchasing any type of good with borrowed money is known as margin trading. Do example of stocks in 1920s, stocks in 2000s, and housing.

In forward markets, the transaction is conducted now, but the exchange occurs in the future.
There are two major types of forward transactions: futures (which are also sometimes referred to as forward contracts) and options.

Futures allow people to purchase goods now for delivery later. A futures contract includes a price, quantity, and settlement date. Basically, it allows buyers and sellers to lock in a guaranteed price for a sale in the future, thereby reducing risk. The payment for the option can occur immediately or upon delivery.

- Used to be primarily a tool for agricultural commodities (wheat) since farmers needed a way to get money for crops before a harvest. A futures market allowed them to sell their crops before they actually harvested them.
- Recently become more significant in financial markets (T-Bills, foreign exchange, stocks/indexes.) Market share of commodities as a percentage of all futures contracts has fallen from 70% in 1981 to 35% in 1992. Sellers of futures have the **short position** and buyers have the **long position**. (Look on homework sheet to see foreign exchange futures. What would it mean about expectations if the future price was above the current price? Below the current price?)

How to gamble on the short position.

Options give persons the right to buy or sell a good at an agreed upon price at some date in the future. All options have six required characteristics.

- **Strike price** is the agreed upon price.
- **Maturity date** is the time the option expires. You can have two types of options, one of which allows you to exercise the option at any time before the maturity date (American option) while other types allow you to only exercise the option on the maturity date (European option).
- **Type** is whether the option gives a right to buy or sell. A **put** is the option to sell A **call** is an option to buy.
- **Volume** is how many rights to buy or sell you have.
- **Position** is whether you are the buyer or seller of the option. The buyer has the right to buy or sell at a given price. The seller has the obligation to buy or sell at the given price.
- **Price** is how much the option costs.

How do you make money from a hunch?

Today Exxon is selling at 68 3/16. Suppose you are sure that it will be at $90 by Halloween.

- Buy Exxon: 146.65 shares. Investment increases to $13,198.90 by Halloween.
- Buy Exxon on margin: Borrow $10,000 on first $10,000. Value = $16,347.80.
- Buy Exxon options. An option with a strike price of $75 costs 7/16. Can buy 22,857 options. You will make $15 per option or $342,857.

Problem is if Exxon only goes to $75 per share. Options only valuable if stock rise above strike price.

- Buy Exxon: 146.65 shares @ $75 = $10,998.75
- Buy Exxon on margin; Value = $11,947.50
- Buy Exxon options: Value = $0

Can you make money if you think a stock will go down in value? Oracle = $27 13/16 now $20.

- Simply don't buy Oracle. No gain but no loss.
- Don't buy Oracle on margin. Still no gain.
- Buy a futures contract. Sell Oracle short. Sell now for $27 13/16 but need collateral. 360 shares. Will cost you only $7,200 when you have to deliver.
- Buy a option contract. The right to sell at 30 will cost you $3.00. Can buy 3,333 options. Will make $10 per share or $33,333.

As the seller of an option you have the obligation to buy or sell at a specified price.

The seller is subject to potentially unlimited losses since there is to limit to how high a stock can rise in value.

Lecture #35 Friday, April 17

Continued with derivative markets. See notes from Lecture #17, October 6.

Options can be used to increase or decrease risk. When you are right you can make big money, but when you are wrong you can lose it all. Even worse, sellers of options have an unlimited downside.

This is how the U of MN and Orange County got burned. They bought derivatives (options) that bet on interest rates falling. Instead interest rates rose. If they had invested in long-term bonds, rising interest rates would have caused the value of the bonds to fall. By investing in the much riskier area of options, their portfolio crashed. U of MN lost tens of millions, Orange County lost billions and went bankrupt.

Barrings Bank: One single 27-year old trader lost $1 billion in derivative markets on Japanese stock market. Went bankrupt.

Sumitomo Bank: Single trader lost $3-4 billion in copper futures.

AIG: remember that insurance is essentially a type of option.

Think of the stock market as blackjack but with the cards stacked in your favor. If you play enough, on average you will come out ahead. Options, when you play them to increase risk, is like pure roulette. You might as well invest your retirement money down at Grand Victoria.

- "Former Orange County Treasurer Robert L. Citron, who is awaiting sentencing for fraud in mishandling the county's finances, said in December that the reason his investment decisions plunged the county into the biggest local-government bankruptcy in history in 1994 was the bad advice he had received on interest rates from a mail-order psychic. The good news for Citron, according to Anaheim channeler Barbara Connor, is that Citron told her that he learned during two trances last year that he would receive community service but no jail time for his conviction." In fact, while in bankruptcy, every county program budget was cut, about 3,000 public employees were discharged and all services were reduced. Citron was ordered to serve five years of supervised probation, and to perform 1000 hours of community service. Citron did not serve any time in prison.

To sum up: options are <u>not</u> necessarily bad. They can be used by some persons to reduce risk. However, the reduction of risk for one person leads to an increased risk for the other and for certain types of investment portfolios (like Orange County's pension fund or the U of MN's endowment) should not be invested in financial instruments with this level of risk.

Lecture #36   Monday, April 20

First, EPA announcement that it will regulate CO_2.

The Environmental Protection Agency's (EPA) landmark decision Friday to set in motion the process of regulating greenhouse gases had a little bit of the sardonically threatening spirit of that magazine cover. Concluding a scientific review initially ordered by a two-year-old Supreme Court case, the EPA issued its long-awaited "endangerment finding," formally declaring that carbon dioxide and five other greenhouse gases are pollutants that threaten public health and welfare. Under the Clean Air Act, that finding means that the EPA has a responsibility to address the damage caused by greenhouse gases, possibly through direct regulation of CO_2 — just as it regulates other air pollutants, like acid rain-causing sulfur dioxide.

Finish options.

Black, Scholes. Influence as a paper.

Price of an option based on:
- Spot price/strike price spread
- Maturity: the longer the expiration, the pricier the option.
- Volatility: the more volatile the good, the more expensive “insurance” is.
- Discount rate

Read Chapter 18

Lecture #37   Wednesday, April 22

Went over grade slips.

Went over George Will assignment.

Difference between an editorial and fact-checking an editorial.

It is probably easiest to simply go through the article point-by point and examine Will's claims.

1. Will states, "Chu recently told the Los Angeles Times that global warming might melt 90 percent of California's snowpack, which stores much of the water needed for agriculture." What Chu actually said was, "In a worst case, up to 90 percent of the Sierra snowpack could disappear, all but eliminating the natural storage system that feeds the valleys at the heart of the state's $35 billion farm industry." Thus, Chu is not saying what will happen but the worst that could happen. Furthermore, the original article goes on to note, "Gov. Arnold Schwarzenegger told California's farmers to prepare for a third straight year of drought due to low Sierra snow levels and some of the state's top farming counties may get little or no deliveries of water." (http://www.reuters.com/article/environmentNews/idUSTRE5135OY20090205)

2. Will talks at length about how, "In the 1970s, 'a major cooling of the planet' was 'widely considered inevitable...'" All of the sources he cites obviously make a case for global cooling, but global cooling was far from "widely considered inevitable." In fact, the very first paragraph of the first New York Times article Will cites states, "The world's climate is changing. Of that scientists are firmly convinced. But what direction and why are subjects of deepening debate." (New York Times, May 21, 1975, pg. 92) The article goes on to compare the theories of global cooling advocates and global warming advocates. "If worldwide energy consumption continues to increase at its present rates, catastrophic climate changes have been predicted by M. I Budyko, a leading Soviet specialist. This [warming] will lead to a complete destruction of the polar ice covers." This does not sound much like scientists were considering global cooling to be inevitable.

A review of climate studies from the 1970s ("The Myth of the 1970s Global Cooling Scientific Consensus" Thomas C. Peterson, William M. Connolley, and John Fleck, Bulletin of the American Meteorological Society, September 2008) found that "There was no scientific consensus in the 1970s that the Earth was headed into an imminent ice age. Indeed, the possibility of anthropogenic warming dominated the peer-reviewed literature even then." Their examination of peer-reviewed articles found, during the period from 1965 through 1979,
7 paper suggesting global cooling, 20 neutral papers, and 44 warming papers suggesting global warming. Since that time, the consensus has turned even more sharply towards supporting the theory of global warming with between 90-94% of studies included in the IPCC's 4^{th} report suggesting global warming is occurring.

Two final points here. First, with thousands of studies being performed regarding climate change, even if 90-94% of these studies support the theory of global warming, a global warming denier can always cherry-pick literally hundreds of scientific articles that fail to find a trend of global warming. Of course, these studies are balanced out with thousands on the other side suggesting warming is happening. Second, even if the global consensus in the 1970s was that of global cooling (which is wasn't), such a consensus is irrelevant in the face of newly collected data. Similarly, just because the global consensus in the 1400s stated that the Earth was at the center of the universe doesn't meaning that Copernicus (1473-1543) and Galileo (1564-1642) were wrong in rejecting the previous consensus.

3. The famous bet between Paul Ehrlich and Julian Simon is true but is somewhat an artifact of the time periods chosen. Below are the nominal and real values of Chrome, Copper, Nickel, Tin, and Tungsten for the years 1970, 1980, 1990, and 2007, the latest year available via the U.S. Geological Survey (http://minerals.usgs.gov/ds/2005/140/#data).

Real	Chrome	Copper	Nickel	Tin	Tungsten
1970	538	5,375	11,900	16,100	23,700
1980	1,260	4,419	12,300	36,900	36,600
1990	1,110	3,383	11,100	10,600	10,600
2007	1,620	5,685	29,200	15,600	28,200

Nominal	Chrome	Copper	Nickel	Tin	Tungsten
1970	128	1,280	2,840	3,840	5,640
1980	638	2,234	6,230	18,700	18,500
1990	892	2,712	8,860	8,520	8,480
2007	2,010	7,231	37,200	19,800	35,900

There are plenty of reasons to believe that technology can make resources more plentiful, but commodity prices can also be affected by many other factors besides true scarcity such as cartels, speculation, etc. Between 1980 and 1990 all five commodities declined in real price with the basket falling 37%. However, between 1980 and 2007 only two of the five declined in real price with the basket rising 23%, and between 1970 and 2007, only one out of five declined in price with the basket rising 74%.

4. According to Will, "As global levels of sea ice declined last year, many experts said this was evidence of man-made global warming. Since September, however, the increase in sea ice has been the fastest change, either up or down, since 1979, when satellite record-keeping began. According to the University of Illinois' Arctic Climate Research Center, global sea ice levels now equal those of 1979."

While there is no officially named "Arctic Climate Research Center," the Polar Research Group in the Department of Atmospheric Science at the University of Illinois stated in response to the article, author is comparing the GLOBAL sea ice area from December 31, 2008 to same variable for December 31, 1979. In the context of climate change, GLOBAL sea ice area may not be the most relevant indicator. Almost all global climate models project a decrease in the Northern Hemisphere sea ice area over the next several decades under increasing greenhouse gas scenarios. But, the same model responses of the Southern Hemisphere sea ice are less certain. In fact, there have been some recent studies suggesting the amount of sea ice in the Southern Hemisphere may initially increase as a response to atmospheric warming through increased evaporation and subsequent snowfall onto the sea ice.

Observed global sea ice area, defined here as a sum of N. Hemisphere and S. Hemisphere sea ice areas, is near or slightly lower than those observed in late 1979, as noted in the... article. However, observed N. Hemisphere sea ice area is almost one million sq. km below values seen in late 1979 and S. Hemisphere sea ice area is about 0.5 million sq. km above that seen in late 1979, partly offsetting the N. Hemisphere reduction.

Global climate model projections suggest that the most significant response of the cryosphere to increasing atmospheric greenhouse gas concentrations will be seen in Northern Hemisphere summer sea ice extent. Recent decreases of N. Hemisphere summer sea ice extent are consistent with such projections. Arctic summer sea ice is only one potential indicator of climate change, however, and we urge interested parties to consider the many variables and resources available when considering observed and model-projected climate change. For example, the ice that is presently in the Arctic Ocean is younger and thinner than the ice of the 1980s and 1990s. So Arctic ice volume is now below its long-term average by an even greater amount than is ice extent or area. (http://arctic.atmos.uiuc.edu/cryosphere/global.sea.ice.area.pdf)

5. Will also states, "A recent Pew Research Center poll asked which of 20 issues should be the government's top priorities. Climate change ranked 20th." This is simply a logical fallacy. Just because the general public doesn't think this is a priority doesn't mean the general public is right. In fact, the general public's perceptions may have been influenced by the misleading opinions and factual errors published in newspapers like the Washington Post.

6. Will concludes, "Besides, according to the U.N. World Meteorological Organization, there has been no recorded global warming for more than a decade, or one-third of the span since the global cooling scare." This statement is true but misleading. While 1998 is the warming year on record according to WMO, 8 of the 10 warmest years on record have occurred since 1998 although none have actually eclipsed this number. (http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WMO1031_EN_web.pdf) If one only looks at the last ten years, an upward trend cannot be determined. If one looks at the past one-hundred years, the warming trend is very clear. Furthermore, NASA's weather measurements actually list 2005 as the warmest year on record, eclipsing 1998. (http://data.giss.nasa.gov/gistemp/2008/)

Overall, and this is my opinion now, this article is an embarrassment to both George Will and the Washington Post. While opinion articles are meant to persuade, they should not do so using erroneous or misleading facts. To reiterate what I have said in class, what is particular disappointing is that Will wasted valuable column space debating whether warming is actually happening, a question of little scientific debate, instead of arguing what, if anything, we should do about warming, a question of significant real disagreement.

Lecture #38   Friday, April 24

CAFÉ vs. fuel taxes. Corporate average fuel economy.

Currently ...

And 5 dollars per vehicle per .1 failure in CAFÉ standard.

An increase in CAFE standards by 3.8 MPG would reduce gasoline usage 10% within 14 years.
A tax of 30 cents/gal. would do same thing (but at a cost 71% lower). Think about elasticities. Seems about right.

CAFÉ increases incentive to drive at the margin while taxes lowers incentive. CAFÉ not good at lowering traffic, parking, or accident externalities.

Since people consider mileage when purchasing a car or when driving, CAFÉ standards are probably not necessary.

Energy Star, however, may be a winner. Essentially CAFÉ for products.

Transportation and mobile source pollution.

Generally command and control (plus gas taxes - poor substitute for true pigouvian taxes)

Implicit subsidies: insurance is experience rated but not miles rated.
Road construction. Generally no marginal cost.
Parking subsidies.
Air pollution.
Traffic externality.
Accident externality.

Cultures built around subsidized transportation.

Technological certification.
Warranties required.
Banning of lead in gasoline due to catalytic converters and lead air problems.
Inspection and maintenance programs in non-compliance areas.
Alternative fuels
Subsidization of public transport.
HOV lanes.
Car sharing. (Does it lower miles or just cars.)
Technology forcing - not a credible threat -see California zero-emissions
Regulation between new and existing. Perverse incentive to keep bad cars.

Uniform controls - inefficient but economies of scale and monitoring problems.
Costs of reduction 2-3 times that of stationary per ton compared to Inspection and maintenance.
CAFE standards: inefficient. 3.8 miles per gallon over 14 years would reduce gasoline consumption by 10% vs. a 30/cent gallon tax over same period. 71% lower cost of

Ozone action days. No burn days. 10% produce 50% of CO.
What is most effective way to reduce emissions?
Congestion pricing.

Mexico licence plates.

Lecture #39   Monday, April 27

Macroeconomic modeling of the economy including the environment.

Perhaps the most widely recognized of any economic statistic is GNP/GDP. GDP measures sum of goods and services produced within a country's borders. (We used to use GNP which measures sum of goods and services produced by a country's factors. Changed to bring U.S. in line with the rest of the world.) The key issue is really the fact that many equate national income with national welfare. How much you earn is the same as how well off you are.

Problems with GDP in general:

- Intertemporal measurement. Problem of inflation can be handled through the use of a GDP deflator. However, this relies on having the price of a bundle of goods, and there is no guaranteed that this bundles stays the same over time. Common example is buggy whip or my computer is an excellent example. Goods are not perfectly comparable over time.
- Problem of non-paid labor or non-market activities. A maid who cleans your house counts in GDP, but if you do it yourself it doesn't count. This has been questioned by women's rights groups since many traditionally female jobs (cleaning, cooking, childcare) are not counted in national income. Essential it discounts the value of this work. This problem is being explored.
- Problem of inter-country measurement. How can you compare Japan vs. Mexico vs. the U.S. Mexico's currency fell by 30% in three weeks in December. Does this mean they are 30% poorer? Yen has gone from 270 to 90 in last 10 years. (Just remember that anyone who quotes foreign earnings in dollars is full of crap.) This problem is being largely handled by the concept of PPP.
- Fails to use consumer surplus.
- Many examples of non-productive contributions to GDP. Money spent to clean environment or to prevent crime are counted as good not bad.
- Durable goods are generally counted in only one time period. Buying a car today and using it for next ten years only counts as consumption in year 1. Exception is owner occupied housing where all homeowners are counted as businesses who rent housing to themselves.
- For our purposes, the biggest problem is that of depreciation. What if you use something up in order to consume today. There is the measure of NDP which is GDP minus physical depreciation. Accounts for using up capital in determining income. Problem is that even this is not widely used because economists are skeptical of the methods used.

The attempt today will be to convert our sense of national income into a sense of National Welfare. There have been many attempts in three main directions.

- Ecological footprint.
- Compilations. Human Development Index (HDI) and PQLI for example. HDI measures weighted income plus life expectancy plus education. (Literacy and school years.) The United Nations believes that income tells only part of the story so mixes income with other measures of welfare to get a single number between 0 and 1. Example is China with income of $2,946

has same HDI as Oman with income of $9,230. (Higher education and life expectancy.) Good because the data is already there and thus this measure requires little additional theoretical work. Also, there is a strong measure of declining marginal utility of income. Argentina has income of $5,120 of which $5,120 is counted as increasing welfare while the U.S. has income of $22,130 of which $5,371 is counted. In last survey, Canada, Swiss, Japan, Sweden, Norway, France, Australia, U.S., Holland, U.K.. U.S. led in income and education but dropped in life expectancy. (U.S. lower than Costa Rica in life expectancy.)

- Measure of Economic Welfare/Net National Welfare: Adjusted Net Savings in books. An attempt to adjust current concepts of accounting to account for environmental degradation and externalities. NNW = NNP - environmental depreciation - costs of externalites. Nordhaus and Tobin(1972) 1929-1965 1.7% vs. 1.0%   1947-1965 2.2% vs. 0.4%   Zolatas (1981) 1947-1965 same 1965-1977 2.2 vs .7: Daly and Cobb, 1950-1960 1.0 vs. 0.8 1960-1970 2.6 vs. 2.0, 1970-1980 2.0 vs. -0.1, 1980-1986 1.8 vs -1.3.
- Sustainable Income: The concept of income should be tied to whether or not this level of income is sustainable. Only count as income that portion of GDP that is consumable again and again.

Poverty: Is it reasonable to assume that the very poor will value the environment in the same as the rich? No.

By the “$1 a day” threshold, the Headcount Index for the developing world was 20.6 percent in 2001 corresponding to just under 1 billion persons in poverty. These figures represent significant decreases from past numbers largely due to declining poverty rates in India and China. In 1981 and 1990, the Headcount Indices for the developing world were 40.7 and 27.9 percent, respectively; however, due to population growth, the total number of persons below the “$1 a day” threshold has declined must less rapidly, falling from 1.40 billion in 1981 and 1.14 billion in 1990.

5/5 morning EE2
5/6 morning EE1

Office hours
T 4/28, W 4/29, F 5/1: 10-12, 1-3
M 5/4, 10-12, 1-3
T 5/5, 1-3