Lecture Notes Part 1
Economics of Sustainability
K Foster, CCNY, Spring 2016

Table of Contents

Introduction

This class aims to teach at least three different things – which are interrelated enough to make it sensible enough to jam into one class, but different enough to make it all complicated. These are:

1. Basic economics of sustainability and environment,
2. Basic business principles as applied to environmental enterprises.
3. Basic development concepts to understand the problem of global climate change,

The current version of these notes begins to cover part 1. More to follow.

These notes are based on a number of different texts including Principles texts by Frank and Bernanke and by Mankiw, Intermediate text by Varian, finance text by Hull, environmental texts by Anderson, by Kolstad, and by Hanley, Shogren and White.

Basics

Although there are hard-core environmentalists who dispute it, I believe that markets are among the best way ever discovered by human ingenuity to efficiently allocate scarce resources and to ensure that resources are most effectively used. This is true for many resources but not all – prominent goods not well provided by free markets include education, health care, infrastructure and environment.

It is not true for all resources; this does not mean that no government intervention is ever justified. One of the objectives of this course is to figure out what institutional arrangements and structures allow markets to work, and which ones need to be improved. Where should government policy step in?

But a typical firm is run by managers who have a sharp incentive to cut costs: to limit the use of expensive inputs and to cut expenditures which do not directly impact customer satisfaction. Most consumers are looking for ways to cut their expenditures on items that do not bring adequate satisfaction. They're being environmental in the sense that they're looking for ways to use fewer resources.

So to begin, we will review basic economic theory about the allocation of scarce resources. In a perfect economy people don't need to understand all the implications of their consumption on different resources; they only need to know the price. The price is the sole sufficient indicator of scarcity. So much energy is expended by modern consumers trying to balance off different criteria, even for simple choices like a lightbulb. An incandescent bulb uses too much energy relative to a fluorescent, but fluorescent bulbs usually contain mercury (hazardous disposal), other types of bulb might consume particular resources (rare earth metals) in being made. How ought consumers to trade off greater electricity usage versus mercury contamination? A consumer can be left swamped with information, trying to compare the incommensurable! But in a perfect economy consumers only need to look at the price. Clearly we don't live in a perfect economy.

But many resources are already included in the price of even the most quotidian consumption item. When we choose to buy an apple we needn't worry about whether the farmer has sufficient land or uses the proper fertilizer, or if the wholesaler has a good enough inventory-control system, or if the retailer uses scarce real estate optimally. We just choose whether or not to buy it. It's only when we try to trade off between organic apples or locally-grown apples or fair-trade apples or whatever – that's difficult, because there's no single scoring system.

In a system of optimal economic competition, the price reveals relative scarcity. If supply is low relative to demand then the price will be high; if supply is great relative to demand then the price is low. Early economists often wrote about the apparent incongruity that water, necessary for life, was available for free while diamonds, not necessary for anything, were

expensive. Why this apparent paradox? Because of their relative scarcity. (And thus marginal utility, but that's for later.)

Over a longer time period, firms will direct their Research & Development (R&D) budgets towards economizing on items which are most scarce (i.e. have high prices) – again, just because it's profitable for them to do so.

These market processes are the basis for extraordinary wealth. For much of human history a person needed to work all year just to get enough calories to (maybe) fend off starvation. Nowadays the developed world worries more about obesity.

Markets are extraordinarily powerful. Recall that many countries experimented with central planning (called Communism) and that was a disaster. The best efforts by very smart people (motivated, at times, by fear for their lives) were not enough to supply even a fraction of the goods that could be provided by a market economy. Wise policy will use markets wherever possible. However markets are neither all-powerful nor omniscient. There will be cases where the simple assumptions underlying the Welfare Theorems are no longer valid, particularly where there are substantial amounts of goods with imperfect property rights (with externalities) and/or substantial transactions costs. Bob Solow, the Nobel-prize-winning economist, refers to the free-marketeers who see the doughnut while the interventionists see the hole (Solow 1974 AER).

(e.g. Brad Delong delong.typepad.com/sdj/2010/12/what-do-econ-1-students-need-to-remember-second-most-from-the-course.html but also http://delong.typepad.com/sdj/2014/11/2014-11-12-eg-on-jeff-madricks-how-mainstream-economic-thinking-imperils-america.html)

Define Economics

"Economics is the study of **choice** in a world of **scarcity**" (from intro text by Frank & Bernanke – yes, that Bernanke, who was Fed Chair)

- Some resources, which were once thought to be inexhaustible, are now known to be scarce; e.g. atmosphere (CO_2 levels), clean air, fish in the sea
- **Scarcity**: No Free Lunch (TANSTAAFL) – more of one thing means less of something else. This applies to buying groceries (more apples & fewer bananas) or choosing between car emissions & safety (lighter cars mean better MPG & less emissions but also less safe in accident).
- **Choice**: people are free agents who take actions based on their own information and desires – which do not necessarily match those of policymakers. Usually assume people are rational.
- **Rational** people think on the margins (Mankiw's intro text)
- **Cost-Benefit Principle**: it is rational to take action if and only if the extra benefits are as big as, or bigger than, the extra costs
    - **Economic Surplus** = Extra Benefit – Extra Cost. So Cost-Benefit Principle can be restated as "Do actions with nonnegative Economic Surplus".

    - **Opportunity Cost**: The Extra Cost is the value of next-best alternative that must be given up to do something so Cost-Benefit means take an action only if it has nonnegative Economic Surplus; only if the extra Benefit exceeds the Opportunity Cost. Tim Taylor quotes Eisenhower on opportunity cost, http://conversableeconomist.blogspot.com/2015/12/eisenhower-on-opportunity-cost-of-war.html "Every gun that is made, every warship launched, every rocket fired signifies, in the final sense, a theft from those who hunger and are not fed, those who are cold and are not clothed. This world in arms is not spending money alone."
- If prices reflect true scarcity of all goods then people take proper account, not because of any moral feeling but to maximize profit. This goes back to Adam Smith's propositions and observations.
- **Environmental Economics** is generally concerned with choices where the benefits and costs are shared even though the decision-making isn't necessarily

Here's a nice overview of Environmental Economics

Commodities and Goods/Services

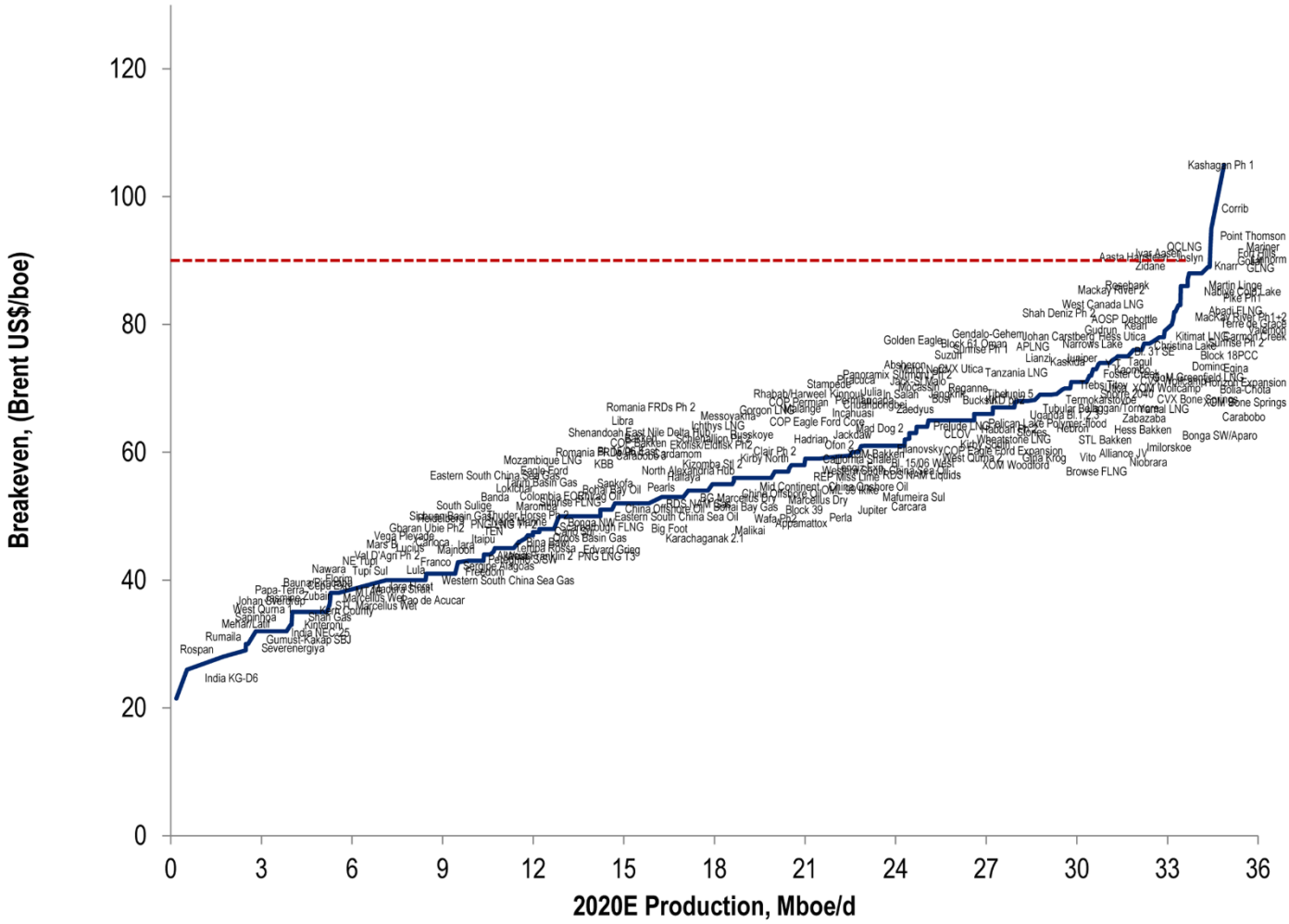
- People buy and sell a multitude of different goods and services, many of them extremely specialized.
- Commodities are generalized goods, items that have been laboriously standardized in order to make them comparable.
- Commodities are created by people in particular situations (commoditization) – for example, the cafeteria buys apples as commodities by the thousand but then these same apples are chosen as individual goods (look for the ripest and least bruised fruit on display).
- Example, WTI Light Sweet Crude Oil (http://www.cmegroup.com/trading/energy/crude-oil/light-sweet-crude.html) is traded in units of 1000 barrels (each barrel is 42 gallons), delivered in Cushing Texas, where "light" and "sweet" are carefully defined physical qualities. Many lawyers worked to write up the documents that define this commodity and specify how variations are recompensed. Some details are in Chapter 200 (!) of the basic NYMEX rulebook http://www.cmegroup.com/rulebook/NYMEX/2/200.pdf. Oil companies work hard to ensure that a particular quantity of oil meets these standards. It took a great deal of human ingenuity (and lawyers' billable hours) to create this commodity.
- An exchange might create a new commodity that doesn't exist, such as "Crack Spread," the difference between crude oil prices and the value of the refined products such as gasoline.

Basics of Supply and Demand Curves

- Demand Curve:
    - For each person: shows the extra benefit gained from consuming one more unit
    - by Cost-Benefit Principle, if the extra benefit from consuming one more unit is greater than the price, then consume; if not then don't

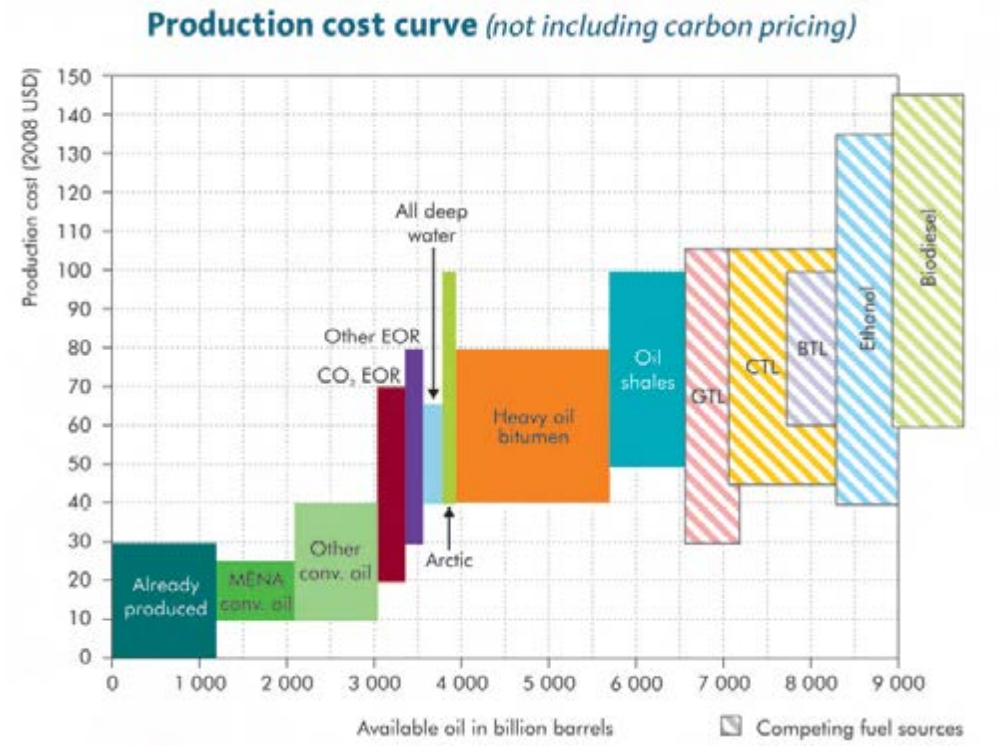
- so Individual Demand Curve shows how many are purchased at any given price
- Individual Demand Curves are combined to get a market demand curve of how many would be purchased by all the people in the market at a given price (horizontal sum)
- Depend on other factors than price (which shift the demand curve).

- Supply Curve: opportunity cost of producing certain quantity of output.
  - If no fixed costs and no barriers to entry then firms produce commodities at marginal cost
  - Depend on other factors than price (which shift the supply curve)
  - Citi provided this graph of the supply curve for oil, plotting each major oil field in the world:



(Now "breakeven" is not a simple concept; if you think for a moment then there are different costs – a well was drilled in the past at some cost, how is that to be allocated to present decisions? We'll return to that.)

Alt from Saudi Aramco



from Saudi Aramco, http://www.world-petroleum.org/docs/docs/publications/2010yearbook/P64-69_Kokal-Al_Kaabi.pdf

- Behavior of Markets: markets are a wonderful institution; we analyze with some assumptions
    - Depend on composition of good
    - Depend on supply characteristics (how many firms, if there are fixed costs or other barriers to entry, rules & regulations and social norms
    - property rights are completely known, specified & enforceable
    - all property rights are exclusive (no externalities)
    - property rights are transferable
    - perfect information
    - items for sale have substitutes
    - Commodities closely approximate these assumptions; other markets might be very far off (e.g. labor)
    - What happens if demand is greater than supply? Vice versa?
- Equilibrium: price and quantity that have no tendency for change
- Some Common Mistakes
    - Ignore Opportunity Costs
    - Fail to Ignore Sunk Costs (since they're no longer on the margin)
    - Fail to understand Average/Marginal Distinction

Jodie Beggs "Economists Do It With Models" on demand curves (follow youtube links for next lectures on supply; also Chapters 4, 5, 6 and 7 here, http://www.economistsdoitwithmodels.com/economics-classroom/)

Analyzing Supply and Demand Curves

- Consumer Surplus (CS)

  You've surely had the experience: you go to a store to buy a particular item, ready to spend a certain amount of money. But surprise! You find it's on sale and you pay less than you expected. You've gotten Consumer Surplus. This did not come from the benevolence of the retailer (although they might try to convince you otherwise). This actually was a mistake by the retailer: they were targeting people whose choice could be influenced by the price reduction but accidentally got you too. You got a benefit from the fact that other people shop smart, with a keen eye on prices charged. You would have been willing to pay more, but because there's a market you paid less.

  Take all of the people who would have been willing to pay more than the actual market price and add up how much they each benefited. This total amount is CS: the area under the demand curve and above the market price. Consumers were willing to pay more than the market price; their marginal benefit from consuming those goods was above the price they paid, so they gained from this market.

  Examples: online websites, from eBay to used cars, allow people to see the prices paid for other similar products. Compare with buying a used car without internet research – must go to each dealer and haggle; don't know if price is good or bad without substantial experience.

  This could sound like an abstract concept, but ordinary people have an intuition of it. For example, people regularly pay a flat fee to join a "warehouse club" like Costco. They benefit from shopping at lower prices (i.e. they get consumer surplus) and are willing to pay for that benefit – as long as their payments are less than the benefits, of course.

  People get consumer surplus from free stuff too – for instance, Hal Varian (chief economist at Google; he's got a dog in the fight!) tried to figure out the consumer surplus from Google,
  http://www.economist.com/blogs/freeexchange/2013/03/technology-1

- Producer Surplus (PS)

  Producers also gain from a market. You are a producer and seller of your own labor. If you applied for a job and would have accepted a pretty low wage – but you were surprised and the company offered you a better wage than you would have accepted – then you got Producer Surplus. You benefit from the fact that there is a market with competitors trying to buy the product.

  Find the difference between the lowest price that the producer would have accepted (supply curve) and the actual price received. Add these all up for PS: the area above the supply curve and below the price is Producer Surplus. Producers were willing to accept less than the market price; their opportunity cost was lower than their revenue so they gained from the market.

  Examples: In a natural resource case, a dairy farmer might be willing to sell milk at even a very low price because the milk is tough to store and spoils quickly. But in a

large market the milk can find a buyer at a decent price so the farmer gets PS. A mine where the ore is near the surface and easily accessible would sell the product even at a very low price. But the market offers a higher price because buyers compete for it, so the existence of the market provides a benefit to the producers. (Look back at the supply curve for oil, think about how that implies different profits for various oil fields.)

- Pareto Improving Trade: a trade that makes both sides better off. If markets allow all Pareto-Improving trades then the market maximizes Total Surplus (= sum of Consumer Surplus plus Producer Surplus)
- Deadweight Loss (DWL): a loss that is nobody's gain.

  Example: Traffic to get over a bridge. Everybody pays a price of lost time and aggravation but this cost is nobody's gain. If everybody paid an equivalent price in money (as a toll) then this cost would be somebody's gain (the government, the public, and/or politicians' cronies). Or Uber which has transferred some time cost of taxi (waiting while trying to hail a cab from street side) into money cost (surge pricing). People complain but many still choose it.

  This is one of the less widely-understood concepts; for example take voters' dislike to road pricing here in NYC or even paying for parking.
- Price floor/ceiling effects – examples where Total Surplus is smaller & there is DWL; "Short side rules"
- Effects of changes in demand or supply
- Private equilibrium leaves no unexploited opportunities for individuals (no-cash-on-the-table); but might leave opportunities for social action. (See Yoram Bauman, the Stand-up Economist)
- Elasticity allows easy characterization of how changes in demand or supply affect market; is percent change in quantity per 1-percent change in price;

$$\frac{\frac{\Delta x}{x}}{\frac{\Delta p}{p}} = \frac{\Delta x}{\Delta p}\frac{p}{x} = \frac{\frac{(x'-x)}{x}}{\frac{(p'-p)}{p}}$$

- Elasticity works in both directions:

  if amount supplied were to fall by 10%, what would happen to price?

  if price rose by 5%, what would happen to the amount demanded?

  Example of analysis by Jim Hamilton (EconBrowser Jan 15, 2012): what would be the effect of stopping the flow of oil from ____ country (whatever is in the news recently)? If ___ is about x% of global market and elasticity is something like ¼ to 1/6 or even 1/10, then this means a x% drop of supply would produce a 4x-6x%or even (worst case) 10x% increase in crude oil prices.
- Cross-Price Effects

  Finally check the effects of a change in the price of one good on the consumption of the other good, so $\frac{\Delta x_i}{\Delta p_j}$. If this cross-price effect is positive then the goods are substitutes: an increase in the price of one leads consumers to buy more of the

other instead (chicken vs beef). If the cross-price effect is negative then the goods are complements: an increase in the price of one leads consumers to cut back purchases of several items (hamburgers and rolls).

What are cross-price elasticities for oil? When oil price falls, what happens to demand for other goods? Supply of other goods? (Think – cars & trucks? Suburban real estate?)

One important question that keeps coming up in environmental questions is: are social choices about safety substitutes or complements to private choices about safety? If I drink bottled water does that reduce my willingness to pay for municipal water improvements? If I move away from the shoreline, am I as worried about flooding? (Spoiler Alert: "it depends"!)

- Elasticity: when a price rises from p to p', so demand changes from x to x'

linear

Linear elasticity is $\frac{\frac{\Delta x}{x}}{\frac{\Delta p}{p}} = \frac{\Delta x}{\Delta p}\frac{p}{x} = \frac{(x'-x)}{\frac{x}{(p'-p)}{p}}$ or $\frac{\frac{\Delta x}{x}}{\frac{\Delta p}{p}} = \frac{\frac{(x'-x)}{x'}}{\frac{(p'-p)}{p'}}$.

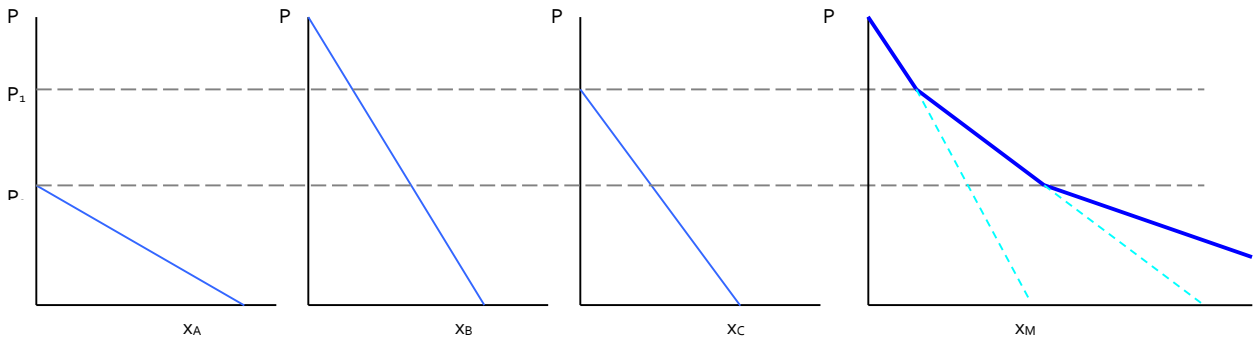
point

As p' and p get closer and closer together (so that x' and x get closer as well), then the term, $\frac{\Delta x}{\Delta p} \to \frac{dx}{dp}$ so that the elasticity formula can be written as $\frac{dx}{dp}\frac{p}{x}$ (and recall that x is a function of p). For a linear demand curve, note that elasticity is not constant. The slope of a line is constant, then $\frac{\Delta x}{\Delta p}$ is constant but elasticity is this constant times $\frac{p}{x}$, which is the slope of a ray from the origin to the point under consideration.

Individual Demand to Market Demand

- horizontal sum

At a quoted price, each person chooses to demand a certain quantity of the good (which might be zero). So if there are 3 people, A, B, and C,



At a price above P_1, only person B is in the market, so the market demand is just her demand. At a price lower than P_1 but above P_2, a reduction in price will prompt both B and C to demand the good. At a price lower than P_2, all three people A, B, and C, are in the market. So a reduction in price induces all three to demand more. The market demand curve becomes more elastic since now a fall in price means $\Delta x_A + \Delta x_B + \Delta x_C$. The market elasticity arises both from intensive changes (each person's demand changes) and extensive changes (people enter or leave the market in response to price changes).

Example of Algebraic Supply and Demand

Demand curve:
Qd = 20 – Pd <-> Y = 20 - X
Supply Curve:
Qs = 1 + Ps <-> Y = 1 + X
Qs = Qd; Ps = Pd

20 –P = 1 + P
20 – 1 = P + P
19= 2P
P=19/2 = 9.5; Q = 10.5

Intertemporal Choice and Discount Rates

In general people value a sum of money paid in the future less than a sum of money paid now. This is represented by a "discount" factor: $100 in the future is worth $100*D now, where D<1.

The reason for this goes back to one of the most basic propositions of economics, opportunity cost. A thing's value is its opportunity cost, what must be sacrificed in order to get it. The opportunity cost of $100 in one year is not $100 now – I could put less than $100 in the bank, get paid some interest, and end up with $100 after one year. How much would I have to put in now? If I put $Z into the bank then after a year I would have $Z(1+r), where r is the rate of interest. Set this equal to $100 and find that Z=100/(1+r).

A common misconception is that this is about inflation – it's not! A world with perfect zero inflation could still have positive interest rates, so money in the future would be worth less than money now. Economists distinguish between the real rate of interest and the nominal rate of interest; the real rate of interest is the nominal rate minus the inflation rate. For example, if your money grew by 8%, but inflation made each dollar 5% less valuable, then the real rate of interest would be just 3%. (Interestingly, this works in reverse just as well: a country with deflation, where currency can buy more, could have a real rate of interest above the nominal rate.) We'll usually focus on the real rate here, net of inflation.

Why is the interest rate at the level that it is? We can accept the logic of opportunity cost, given above, but still ask why the interest rate is set at some level. Over history it has been

level for long stretches of time; the prevalence of anti-usury laws and religious prohibitions would imply that questions about the proper level of interest rates have been common. Part of the answer is that people are impatient: we all want more now! Children are extremely impatient (most hear "wait" and "no" as synonyms); maturity brings (a little bit) more patience. Then there is the demand from entrepreneurs, people who have a good idea and need capital. On the supply side there are many people who want to smooth their consumption over their lifetime: save when they have a high income so that they can retire.

The logic of opportunity cost holds just as much for government policy as for individual choice. A government trades off money now versus money in the future (e.g. choice of deficit spending). What is the appropriate rate that they should use? Should the government act like an individual? But it lives longer than any individual – does that matter?

Of course people make all sorts of crazy decisions and there are a variety of psychological experiments that show this. For instance, offered a choice about being paid, subjects were asked to choose either to get $10 tomorrow or $12 in a week; alternately they were offered $10 in one week or $12 in two weeks – the choices should be the same but systematically aren't. People are willing to wait if the waiting is postponed. (Males who are shown porn subsequently act with a much higher discount rate; females don't seem to be so simple-minded.)

This calculation to figure discount rates is straightforward for time horizons for which we observe prices: there are very popular markets for financial securities such as Treasury bonds offering payments of money as far as 30 or even 50 years into the future. There are big markets where people evaluate the relative price of a promise by US government to pay money in the future, versus promise by Swiss government to pay money in the future, versus promise by Apple to pay money in the future, etc... But how do we discount money farther into the future, perhaps at some point beyond the lifetime of anyone currently alive?

A few factors might be considered relevant. First, we might consider that in the future there will likely be more people – the world's population keeps increasing (although most projections show that it will eventually level off at something like 10 or 11 billion). But if there are more people around to share the burden, then a dollar, when the population is twice its current level, should be worth around half of a dollar today. Second, economic growth (partly through the steady accumulation of technology) will mean that future generations will be richer than current generations, so again a dollar to a rich person (in the future) could reasonably be considered to be worth less than a dollar today (to the relatively poorer).

Finally the impatience of the current population must be taken into account, although this calculation is fraught. On one hand, we want to model the way people make decisions, and it is surely true that people are impatient. But is this a form of discrimination against the unborn? Later we'll read more: Nordhaus gives a convincing argument about taking account of the actual preferences of actual people; Stern argues from a lofty perspective about what the discount ought to be, based on ethical values. There is no single easy answer.

The broad question is whether policymakers ought to discount in this way. Is it ethical for a society to take on expensive debts? (Again, many governments do. However this is irrelevant to deontology.) This question is large and multi-faceted; a paragraph cannot do justice to either side of the argument. To make the problem most pointed: some government spending can save lives so a discount rate, applied to government spending choices, means that government is willing to save fewer than 100 lives today, in return for sacrificing 100 lives in the future. These sorts of questions have dogged philosophers for ages and we've mostly abandoned any hopes of coming up with a solution that could be broadly agreed upon. (Ethical questions are often put in railroad terms: you control a switch that can change the track upon which a runaway trolley will roll; would you switch from killing 2 people to killing one person? What if the act of controlling the switch involved murdering someone? This is how philosophers while away the hours.) But the lack of clear moral guidance about the single right choice does not allow us to postpone these decisions.

Government policy chose to build transportation infrastructure in NYC such as airports and highways, which increase current well-being, at the expense of poverty-reduction or poverty-alleviation in the past. Was that right? Is it better, if the government has $1bn dollars to spend, to vaccinate children or build bridges or abate CO_2 emissions?

In all of this, we note that governments must make choices about spending money now even if it means spending less money later. We attempt to describe this trade-off with discount rates. A higher interest rate means that future outcomes receive less weight; you can think of it as a "hurdle rate" for public projects. If the future is discounted at 4%, fewer projects will clear the hurdle than if the rate is 2% or 1%. The higher interest rate also means that future benefits are discounted more heavily so have a smaller current value. Current government policies use a panoply of discount rates. (Different agencies use different discount rates – not rational, but that's government.)

Terminology: a "**basis point**" is one-hundredth of a percentage point. So if the Fed raises rates by one half of one percent (say, from 0.25% to 0.75%) then this is 50 basis points (bp, sometimes pronounced "bip") from 25 bp to 75 bp. Ordinary folks with, say, $1000 in their savings accounts don't see much of a change (50 bp means $5) but if you're a major institution with $100m at short rates then that can get into serious money.

Rate of Compounding

Sometimes use continuously-compounded interest, so that an amount invested at a fixed interest rate grows exponentially. Unless you've read the really fine print at the bottom of some loan document, you probably haven't given much thought to the differences between the various sorts of compounding – annual, semi-annual, etc. Do that now:

If $1 is invested and grows at rate R then	annual compounding means I'll have	(1 + R) after one year.

If $1 is invested and grows at rate R then	semi-annual compounding means I'll have	$\left(1+\frac{R}{2}\right)^2$ after one year.
"	compounding 3 times means I'll have	$\left(1+\frac{R}{3}\right)^3$ after one year.
…	…	…
"	compounding m times means I'll have	$\left(1+\frac{R}{m}\right)^m$ after one year.
"	…	…
"	continuous compounding (i.e. letting $m \to \infty$) means I'll have	e^R after one year.

This odd irrational transcendental number, e, was first used by John Napier and William Outred in the early 1600's; Jacob Bernoulli derived it; Euler popularized it. It is $\lim_{x\to\infty}\left(1+\frac{1}{x}\right)^x$ or $\sum_{x=0}^{\infty}\frac{1}{x!}$. It is the expected minimum number of uniform [0,1] draws needed to sum to more than 1. The area under $\frac{1}{x}$ from 1 to e is equal to 1.

Sometimes we write e^R; sometimes exp{R} if the stuff buried in the superscript is important enough to get the full font size.

Since interest was being paid in financial markets long before the mathematicians figured out natural logarithms (and computing power is so recent), many financial transactions are still made in convoluted ways, e.g. assuming every year has 360 days.

For an interest rate is 5%, this quick Excel calculation shows how the discount factors change as the number of periods per year (m) goes to infinity even after one year:

m per year	(1+R/m)^m	Discount Factor
1	1.05	0.952380952
2	1.050625	0.951814396
4	1.0509453	0.951524275
12	1.0511619	0.951328242
250	1.0512658	0.95123418
360	1.0512674	0.951232727
Infinite	1.0512711	0.951229425

So going from 12 intervals (months) per year to 250 intervals (business days) makes a difference of one basis point; from 250 to an infinite number (continuous discounting) differs by less than a tenth of a bp. This is in one year; over a 30-year loan these add up.

This assumes interest rates are constant going forward; this is of course never true. The **yield curve** gives the different rates available for investing money for a given length of time. Usually investing for a longer time offers a higher interest rate (sacrifice liquidity for yield). Sometimes short-term rates are above long-term rates; this is an "inverted" yield curve. Nevertheless for many problems assuming a constant interest rate is not unreasonable.

Do people behave quite in the way that this assumes? In some senses, yes: they generally value future benefits less than current benefits. However they do not do this uniformly: there is generally a conflict between how impatient people actually are, versus how impatient they want to be.

Discounting over generations gets more complicated since we can no longer appeal to individual decisions as a guide. Some people argue a link to social valuation across current incomes. Arguing that current generations ought to sacrifice for the good of future generations (for example by mitigating climate change) is a statement that the poor (people living today) ought to make sacrifices for the rich (people in the future). We can observe policy choices about the relative interests of poor and rich people now; for example social payments such as welfare and unemployment payments can be viewed as insurance paid by rich to help the poor. We observe different societies making different choices about this tradeoff.

Can read Tyler Cowen's article in Chicago Law Review (online).

Appendix: A reminder about Percents and Growth Rates

A percent is just a convenient way of writing a decimal. So 15% is really the number 0.15, 99% is 0.99, and 150% is 1.50. When you remove the " % " sign you have to move the decimal point two digits to the left. This can be particularly confusing with single-digit numbers where the decimal point is at the end and therefore omitted: 5% represents the number 0.05 and 1% represents 0.01. If there is already a decimal point then it moves two places: 0.5% is therefore the number 0.005. This can get confusing as for example with US inflation data, commonly reported as, for example, "0.2%" last month. This means that typical prices increased by 0.002.

If A is half the size of B then we can say that A is 50% of B. If it were a quarter of the size, it would be 25%. If a number is increasing then there are many ways of expressing this. Sometimes we say that Z is 125% as large as Y; this is the same as saying that Z is Y plus a 25%

increase. You can see this from the decimals: 125% = 1.25 = 1 + 0.25, so it is equal to one plus 25%.

This can also get confusing when finding percentages of percentages. Many stores try to fool people with this: they offer "50% off and then take another 25% off additionally!" Does this mean that you get 75% off the regular price? No! Think for a minute: if they offered "50% off and then take another 50% off additionally," would that mean that they were giving it away for free? No, they're taking half off and then another half off – so you get it for a quarter of the original price (since ½ * ½ = ¼ or 0.5 * 0.5 = 0.25). So offering "50% off and then take another 25% off additionally!" means you get 0.50 off and then another 0.50 * 0.25 = 0.125 off, so the total is 0.50 - 0.125 = 0.375, which is 37.5% of the original price.

For instance, we might want to find 10% of 10%. We CANNOT just multiply 10*10, get 100, and leave that as the answer! Rather we first convert them to decimals and then multiply: so 0.10 * 0.10 = 0.01 = 1%.

So if I want to know, for instance:

- 4 is what percent of 25? I'd divide 4/25 = 0.16 so 16%.
- If some country has GDP of $125 bn and invests $33bn, what is its investment rate? 33/125 = .264 so 26.4%.
- A state had 47.3m jobs; employment grew at 2% so how many jobs does it have now? 47.3(1+.02) = 48.2 m jobs.

You can see from the examples that one of the other good things about percentages is that we don't have to worry about units. If the top and bottom are both expressed in the same units then the percentage is unit-less.

In economics the data are commonly used to try to persuade you to think one thing or another. Therefore, even if someone's not just outright lying, they're often telling you about the data in a way that persuades you one way or another. Whether it's stores and companies or politicians, they're trying to play with the data so you've got to be careful not to get played.

Calculus

If you know calculus then you can read on; if not then come back once you've been enlightened:

A final note, since I mentioned logarithms, I'll mention their relationship to calculus and to percent growth, since so many students miss it: the derivative of the log of x is the percent change in x. Or

using the notation of %△X to represent the percentage change in X,
then $\frac{d}{dx}\left(ln(x)\right) = \frac{dx}{x} = \frac{\Delta x}{x} = \%\Delta x$.

On using these Lecture Notes:

We sometimes don't realize the real reason why our good habits work. In the case of taking notes during lecture, this is probably the case. You're not taking notes in order to have some information later. If you took your day's notes, ripped them into shreds, and threw them away, you would still learn the material much better than if you hadn't taken notes.

The process of listening, asking "what are the important things said?" answering this, then writing out the answer in your own words - that's what's important!

So even though I give out lecture notes, don't stop taking notes during class. Take notes on podcasts and video lectures, too. Notes are not just a way to capture the fleeting sounds of the knowledge that the instructor said, before the information vanishes. Instead they are a way for your brain to process the information in a more thorough and more profound way. So keep on taking notes, even if it seems ridiculous. The reason for note-taking is to take in the material, put it into your own words, and output it. That's learning.

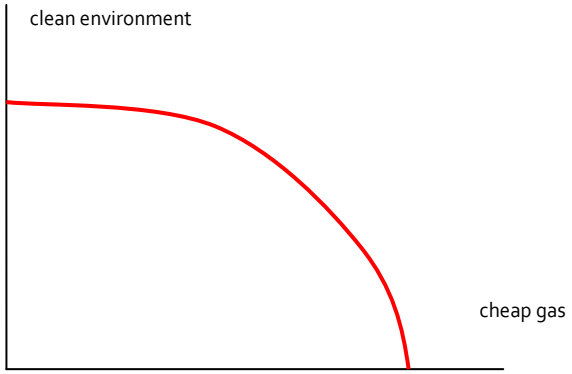
Production and Choice

Production Possibility Frontier (PPF)

In analyzing choices we distinguish between what is possible and what is desirable; an optimal choice balances these two considerations. To analyze what is feasible or possible we sketch a Production Possibility Frontier.

The Production Possibility Frontier (PPF) represents the combinations of two goods which can possibly be attained. (The PPF shows the maximum; certainly less of both is possible!)

For example, politicians debate the tradeoff between cheap oil/gas (Drill Baby Drill!) and a clean environment. We can represent this tradeoff as



This shows that a society could have a completely clean pristine environment with zero cheap gas (where the PPF intersects the vertical axis). Or an utterly dirty environment and ultra-cheap gas (where the PPF intersects the horizontal axis). We would never want to be interior to the PPF, since this would mean that society could have more of both without any sacrifice. It is a frontier because anything beyond it is infeasible; anything within it is inefficient. Changing technology would allow the PPF to move outward so that society could have more of both.

The opportunity cost is proportional to the slope of the PPF. The slope changes depending on how much drilling or environment we already have. If we already have a very clean environment with a low level of cheap gas (at a point near the upper left of the PPF), then getting even cleaner (moving up and left) requires a huge reduction in cheap gas to get only a small improvement in clean environment – the opportunity cost of the last bits of environment is huge. Oppositely, if we have a lot of cheap gas but little clean environment (we're on the lower right), then cleaning up some means a small sacrifice of cheap gas (a low opportunity cost). People can have different preferences about what sacrifice is reasonable and so where on the PPF the society ought to be.

From the PPF we can immediately define the opportunity cost: how much does a completely unspoiled landscape "cost"? The value of the gas which must be foregone. How much does gas "cost"? The value of the habitat spoiled. If choices must be made between the two priorities then every step toward one priority means some diminution of progress to the other priority.

Many examples: a lake can be used for recreation or reservoir of water supply; rainforest can be used for biodiversity or crops; land can be mined or left open; coast used for wind farm or beautiful scenery; etc. Application to Global Climate Change.

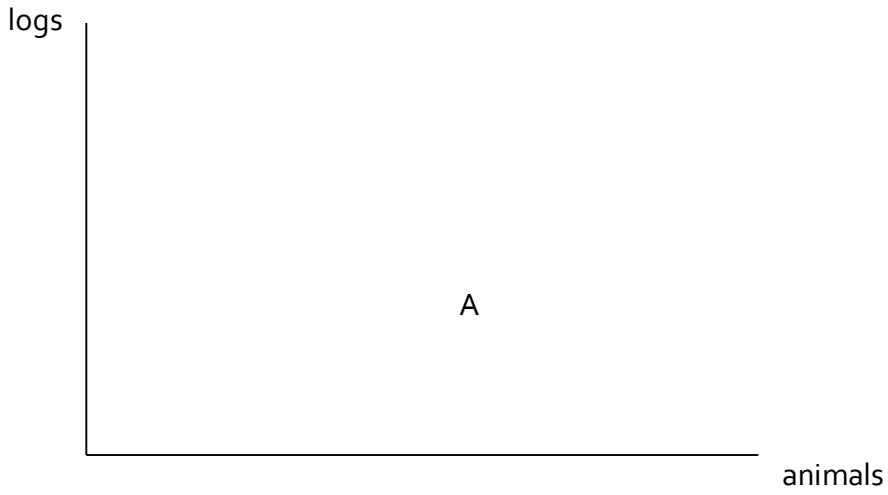
Indifference Curves

We analyze the choice of an individual balancing two desired outcomes. There are some cases where both outcomes are easily achieved; here economics has little to add. There are other

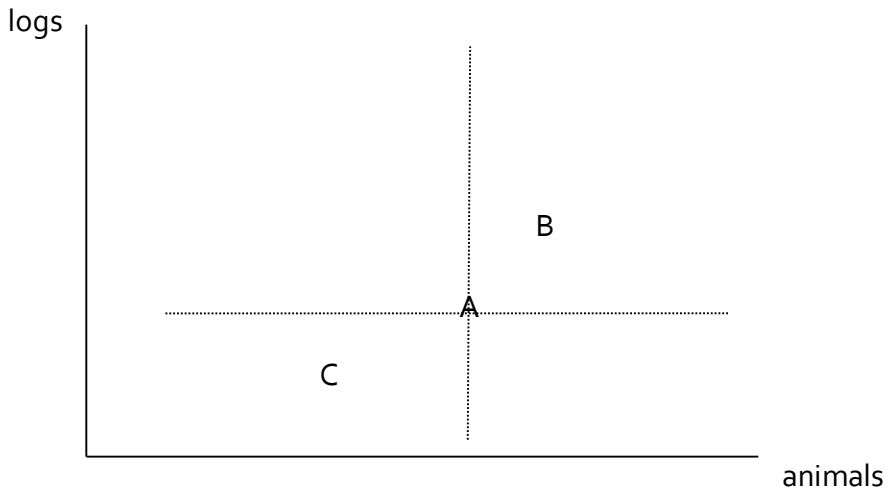
cases where there is a trade-off, where progress toward one goal must mean that the other goal becomes farther off. These cases are more difficult.

Consider the choices of people who like forests for recreational use (including habitat preservation) as well as for a source of logs (supporting the local economy). We will shorten these two outcomes as "animals" and "logs".

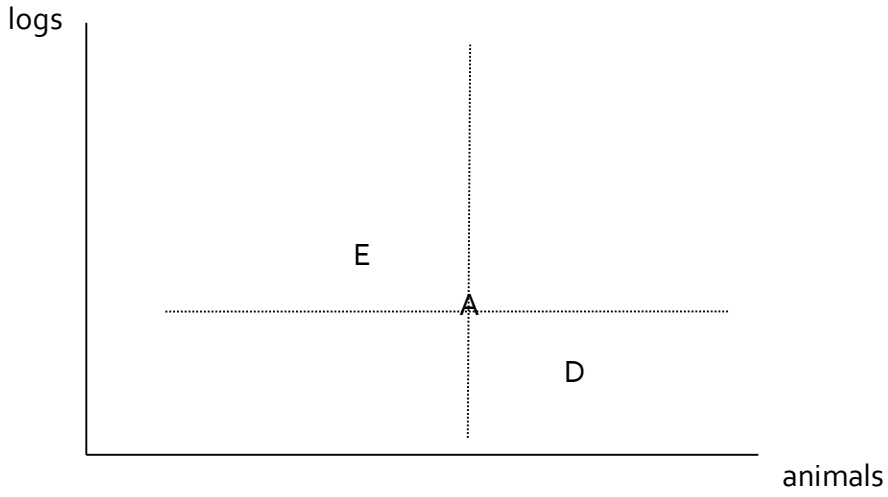
Start from a particular point, where there is some amount of both logging and preservation, so point A:



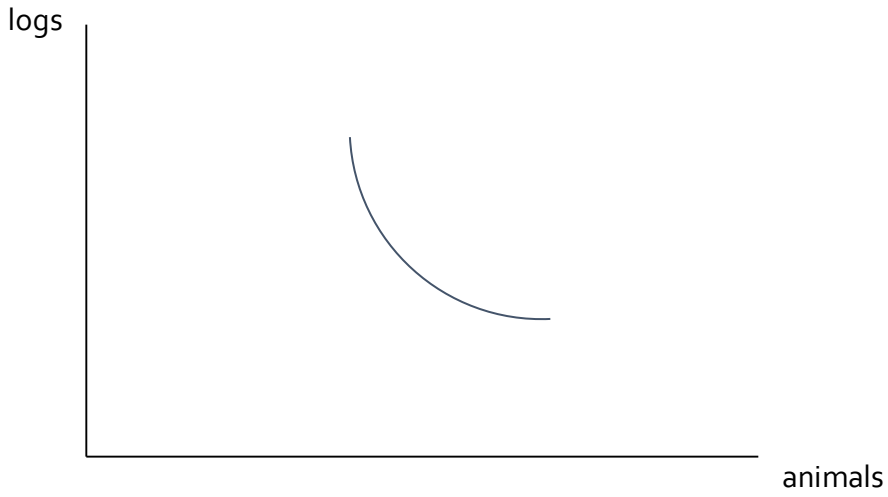
Assuming the person likes both logging and preservation of habitat, any combination (such as B) that gave more of both would be preferred; any combination (such as C) that gave less of both would be less preferred (the dotted vertical and horizontal lines through A mark the current amounts of logs and animals).



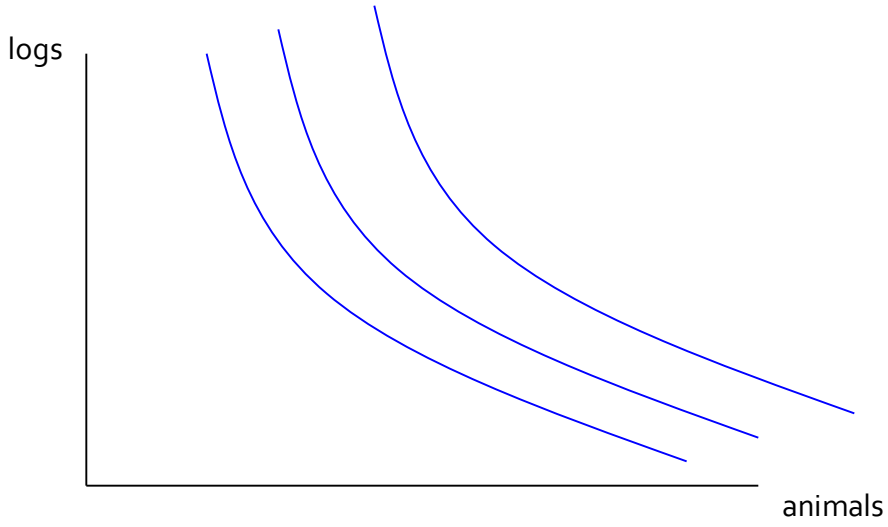
Preferences get complicated when we ask how a person would trade off one good for another. What increment more wildlife habitat (more animals) would balance slightly less logging? Call this point D. What increment more logging would balance slightly less habitat? Call this point E.



Connect together these points into a smooth curve, which we call an "indifference curve" because the person is indifferent between the various options.

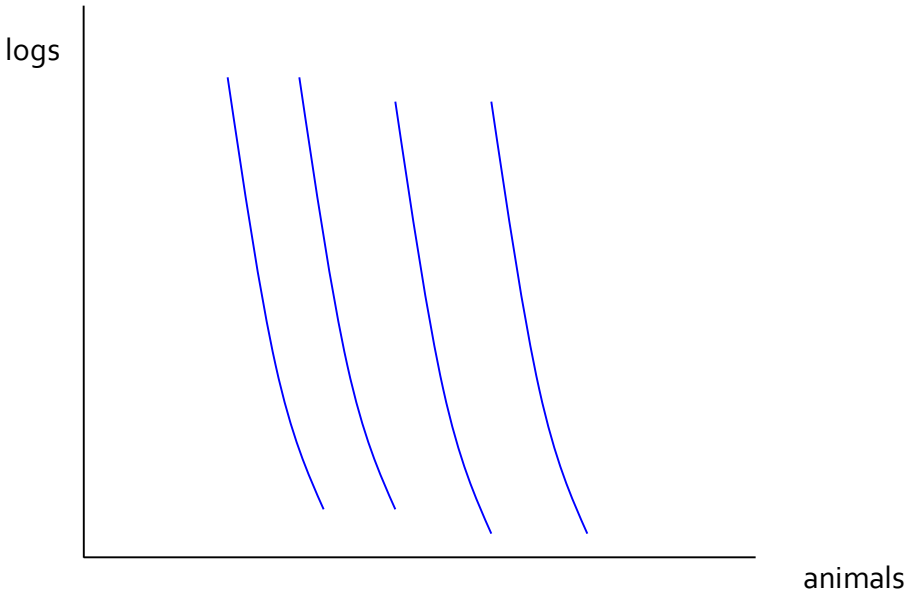


One person's preferences might look like this:

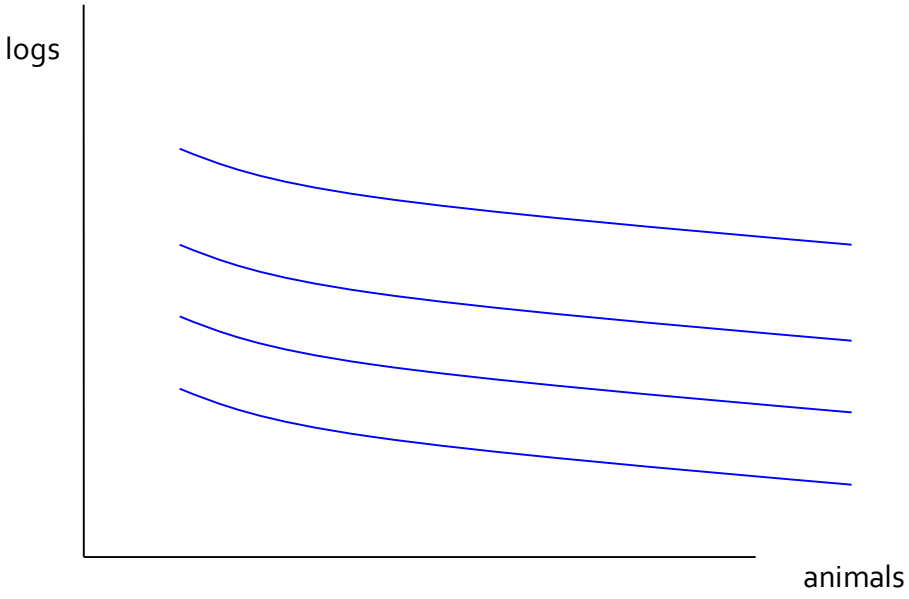


which implies that this person likes both logs and animals. Indifference curves above are preferred; indifference curves below are less preferred.

Different people might have different preferences. This person likes animals and cares very little about logs:

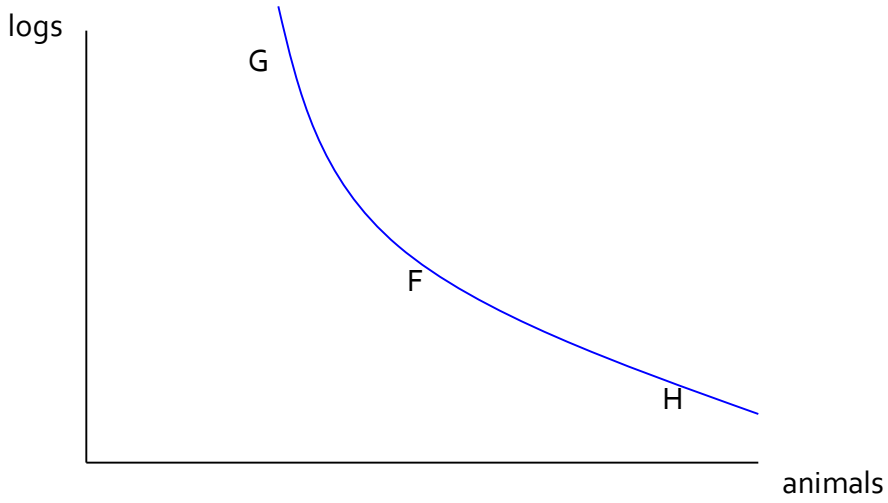


While this person cares about logging jobs and not much at all for animals or habitat:



Horizontal or vertical curves would represent complete lack of caring for a particular outcome. This might accurately represent the views of some people on the extremes.

Why do we usually sketch the indifference curves as bowed? This is again an assumption about behavior on the margin. Return to an individual with preferences that are not too extreme,

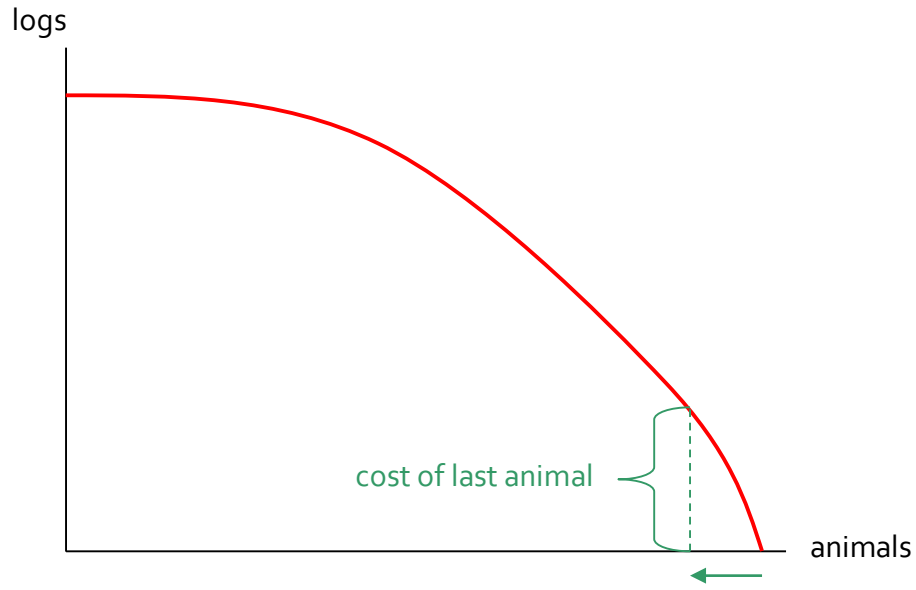


From a point in the middle, such as point F, the person might make an almost equal tradeoff – a 1% diminution of habitat for a 1% increase in logging (for instance). However as the person moved upwards and leftwards (toward G), they might want a greater compensation of logging increase for equal diminutions of animal habitat. If there is a giant park then people might be willing to allow logging in a few areas but as the size of the wilderness shrinks, they become less willing to give up the remaining bits. (Logging in Central Park?) Oppositely as the choices move from F toward H: more and more habitat is protected and so becomes less valued. This is the principle of diminishing marginal utility. (Diminishing marginal utility is the idea that, when I'm thirsty, that beer tastes great; when I've already had a few, I don't get quite as much enjoyment from one more beer.)

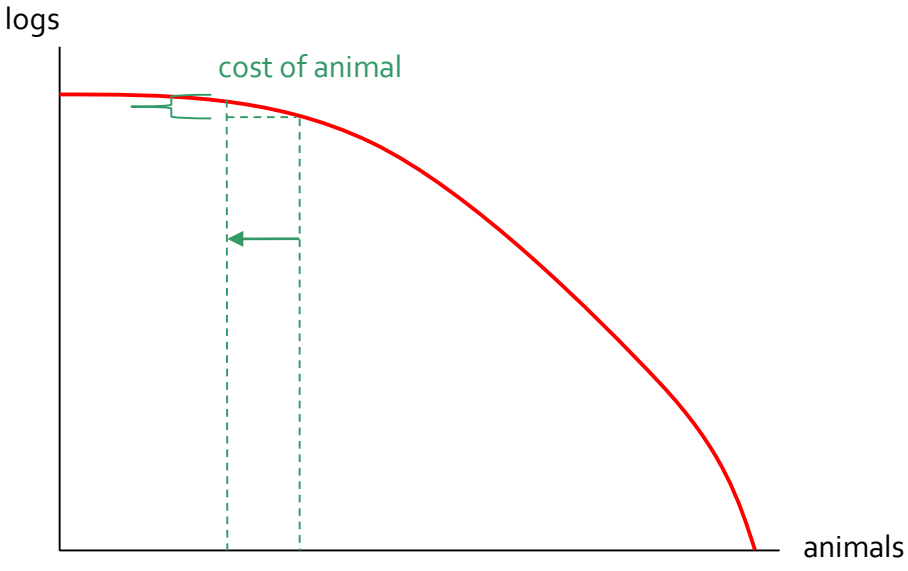
Note on Aggregating Preferences: although we derived a market demand curve from individual demand curves above, aggregating indifference curves is not so easy (in fact it's generally impossible!). Aggregating PPFs is simple, though.

Optimal Choice

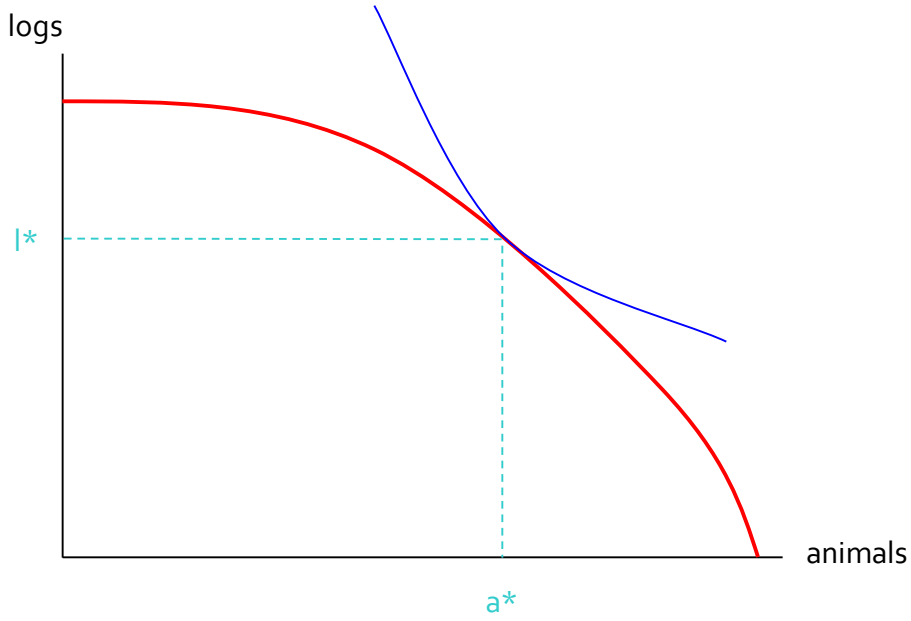
Make the (not entirely serious) assumption that we have some units to measure "animals" and "logs". Starting from a value of zero logs and all animals, suppose we reduced the number of animal units by one? How many more logs could we get? This gives the opportunity cost of the last unit of animals.



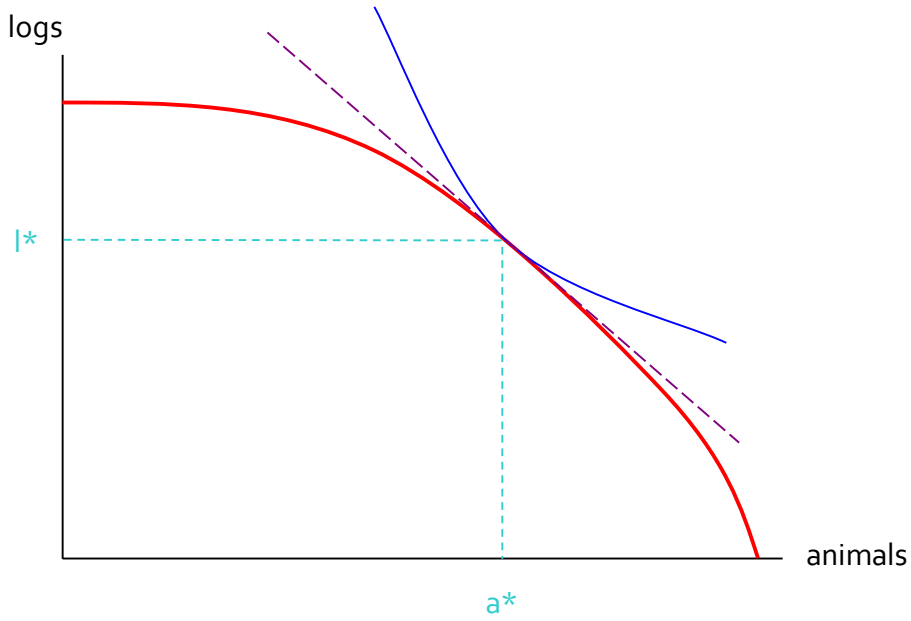
But compare this high cost with the cost (in log units) of reducing the amount of animal, if the amount of animal is already small:



Somehow the society must figure a way to bring these two considerations of production possibilities and choice into equilibrium, to find the tangent of PPF and indifference curve:



A rational maximizing individual who does all of the production by him or herself, and knows his or her own indifference curves, would make this choice. In a world where production and consumption are separated, each side sees only the price,



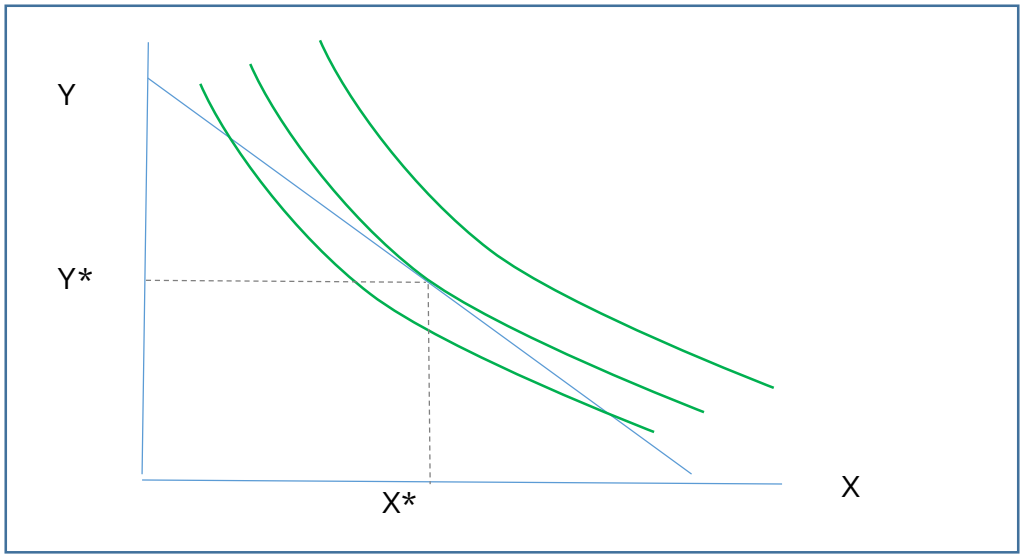
So producers see only the relative price of **a** to **l** but choose optimally; consumers see the relative price and also consume optimally.

Consumer Choice and Fees/Taxes

There may be cases where policymakers are reluctant to impose fees for worry about the distributional impacts. For example, water pricing may lead to more efficient outcomes but this could lead to the poorest people suddenly facing a steep price hike for a necessary good. A gas tax, carbon emissions permits, and other programs all have this feature.

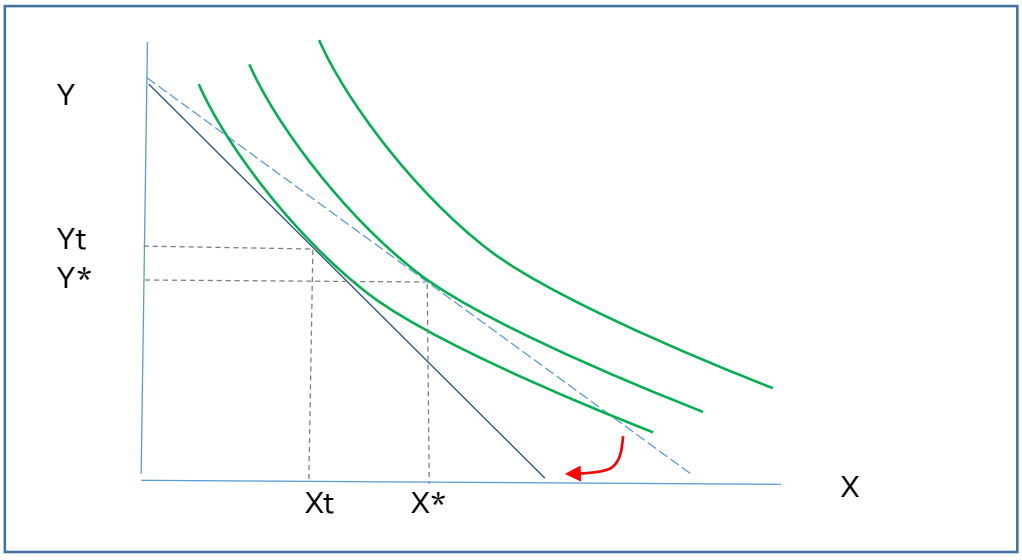
The simple way to fix this is to rebate the tax revenue to each person (but regardless of how much was purchased). It might seem that this would undo the effect entirely but with some basic micro we can show that although the increased income will stimulate spending on the good, nevertheless the price rise will diminish spending (this is the Slutsky decomposition of substitution and income effects).

Consider a typical consumer who chooses between good X and good Y (where Y is a composite of "all other goods"). Assume the price of Y is $1 and the price of X is P. The consumer has income of M. Then her budget constraint looks like this:

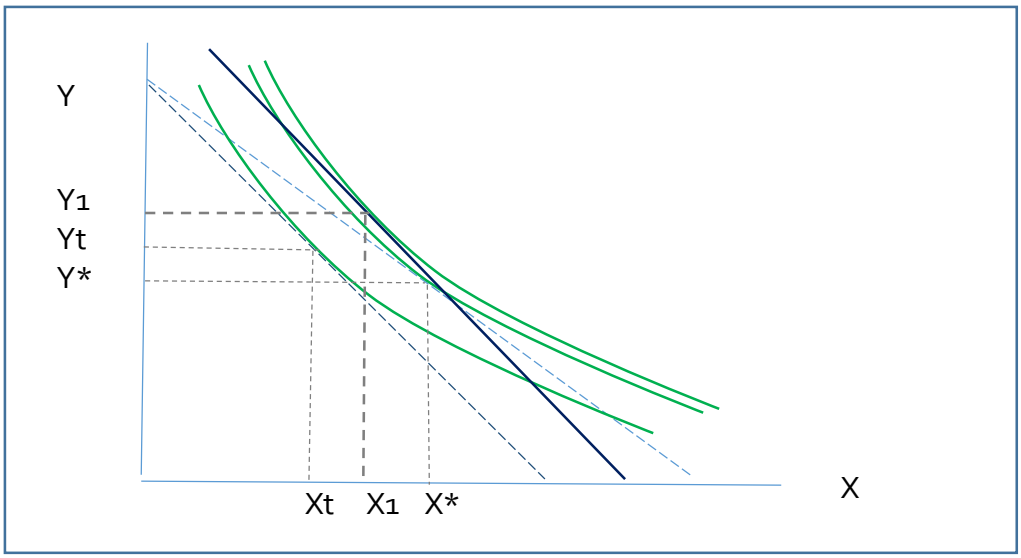


And assume she chooses the point, (X*,Y*) as indicated.

Now a tax of T on good X would result in a rise in the price of X to (P + T) and shift her budget set inward, getting her to a lower utility level:



Now suppose that some of the revenue from this tax were rebated, to raise the person's income from M to M' to make the old X*,Y* just affordable.



Then the person is no worse off but still is using less of the good x – through only the substitution effect not the income effect. The reduction in consumption of X is not as large as in the un-rebated case but the difference is only due to consumer income.

Further refinements could adjust the marginal prices so that, for example, the first few units are available at a low cost while remaining units are more costly. This would provide people with a minimum level of the good without substantial deleterious effects on efficiency. Discussions about water pricing often come back to ideas like this: allow each household to get a basic amount very cheaply, then they pay for additional amounts (perhaps at increasing rate), then revenues rebated.

However if the primary concern is for the welfare of the poor, there is substantial evidence that the best way to help poor people is to get them more money, not make certain of their purchases cheaper. Then they can make their own evaluation of which purchases will be most useful, rather than only certain prescribed purchases. There have been Randomized Controlled Trials finding that "give poor people money" is quite effective.

Jevons Paradox

The flip side of this income/substitution is the "Jevons Paradox," that as the price of some items (such as natural resources) falls, people become richer and choose to consume massively more of the item. Nordhaus gives an example of lumens of light, which were once so expensive that most people went to bed when the sun didn't shine – but now electric light is so cheap that people use it for everything. As lights get more efficient (even from incandescent to LED), people might choose to buy much more (does your computer really need a light-up keyboard? How many LEDs in your place stay on all of the time?). Jevons originally considered

the coal industry, where increased technological efficiency did not lead to the use of less coal but rather the use of more. This leads to the question of to what degree energy efficiency actually leads people to use fewer resources – the empirical evidence is not entirely settled. (A colleague said that learning this was the single most depressing part of his entire education.) The "strong form" Jevons paradox would imply that efficiency gains are entirely lost (i.e. that the income effect is huge, which is certainly rare) while the "weak form" Jevons paradox would simply imply that the first-order effects are lessened. (Cars improving fuel efficiency by 10% would lead to a less-than-10% decrease in fuel consumption; how much less? It depends.) This is also called the Rebound Effect – David Stern gives a nice explanation here http://stochastictrend.blogspot.com/2015/01/the-rebound-effect.html . This is basis for debate on "Environmental Kuznets Curve" – whether environmental quality eventually improves with economic progress or not – more from Stern here, http://stochastictrend.blogspot.com/2016/01/the-environmental-kuznets-curve-after.html. This is distinct from Kaya factors, e.g. http://conversableeconomist.blogspot.com/2015/07/global-carbon-intensity-rises-kaya.html

Important Conditions for Competition

Depend on Secure and Complete Property Rights (as well as other limits, for example on market power)

- property rights are completely specified – no uncertainty, complete markets across time and states of the world
- all property rights are exclusive (no externalities)
- property rights are transferable and enforceable

In considering these necessities, recall Arrow's Theorem of Second Best: a system of property rights that satisfies most (but not all) of the conditions is not necessarily better than a system satisfying fewer conditions – counting up the satisfied assumptions does not measure how near are the outcomes.

Markets

Microeconomic theory proves the First Welfare Theorem, which guarantees that a competitive market economy (with only commodities with complete property rights and no transactions costs) is Pareto efficient – meaning that we can't make any person happier without impairing someone else. This is one theoretical justification for why economists believe that markets are generally the best way to distribute resources.

Recall supply and demand graph, plus PS, CS, DWL, so competition maximizes total surplus.

In production, supply prices in a perfectly competitive industry are determined from the minimum point of average total cost – this is the long-run industry supply curve. Firms compete to supply each commodity for the lowest price, meaning that they try to economize on inputs (use the fewest and cheapest possible).

Over a longer time period, firms will direct their Research & Development (R&D) budgets towards economizing on items which are most scarce (i.e. have high prices) – again, just because it's profitable for them to do so.

There is a folk belief that economists are all wingnut free marketeers but this is false in general (although with exceptions of course!). Rather economists believe that there are many goods for which government intervention can be minimal (although even a minimal set of necessary government policies include the whole set of policies and procedures to secure property rights) then there are some goods where government intervention is necessary. Different people put the boundary at different locations, then there are discussions about which interventions work best. But part of the study of economics is to begin to see the places where markets don't function.

Externalities

Externalities are cases of imperfect property rights. If my decision to consume some item has an impact on someone else, then who owns that spillover effect? This can be particularly acute in trying to resolve intertemporal or intergenerational allocations – what if my decisions affect people who will not even be born until the next century?

Examples. Smoking carries an externality: my choice to inhale smoke means that people near me will also inhale smoke. That consumption choice imposes a negative externality. Other consumption choices might impose positive externalities: economists have found significant positive externalities from education, so your decision to get more education will tend to raise the wages that your family and people around you will get. Externalities can arise from production as well as consumption. A factory belching smoke imposes negative externalities on those down-wind. A flower farm might impose positive externalities (more commonly, a beehive kept by someone who wants honey will have positive externalities because the bees can pollinate other flowers of fruits or vegetables). There can be positive or negative externalities; these externalities can arise in production or consumption. Carbon dioxide emissions are externalities.

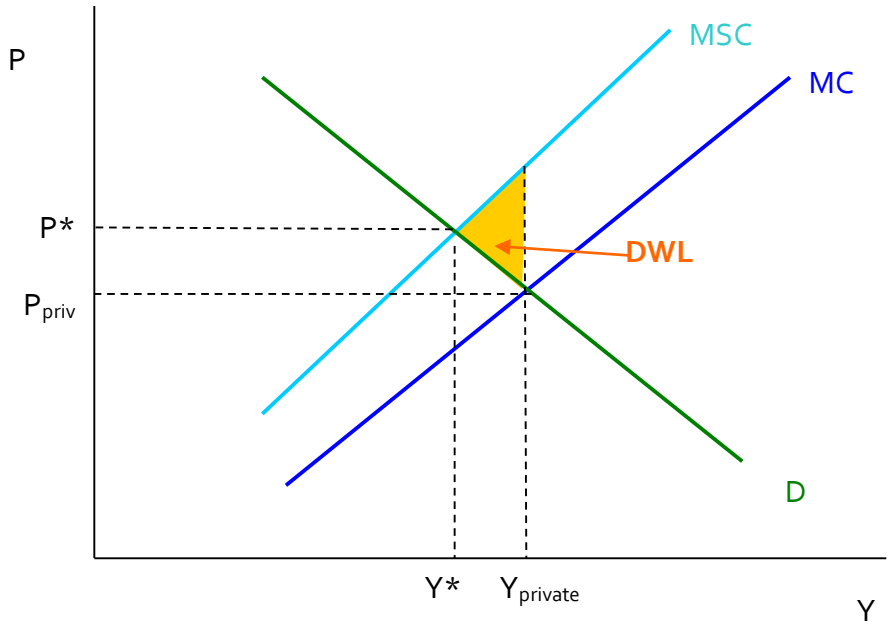
Hanley, Shogren, & White quote Ken Arrow that an **externality** is

> a situation in which a private economy lacks sufficient incentives to create a potential market in some good, and the nonexistence of this market results in a loss of efficiency.

Each word is essential: "lacks sufficient incentives" makes clear that it's not necessarily about technologies but organizations, "potential market" notes that even a possible market has effects (threat of entry or calls/puts), and the final phrase makes clear that not every market failure is insoluble and requires government action.

A lack of a positive externality can be considered a negative and vice versa.

Negative externalities of production produce marginal external costs (MEC) above Marginal private costs (MC, the supply curve). Since these MEC are external to the firms they do not enter into a private firm's calculations of profit maximization so the private firm produces until P=MC. But this creates a deadweight loss since at this level the total social costs (MSC = MEC plus MC) are greater than the price, which measures the marginal benefits that people attach to this good. So it costs society more to produce than people value it, which is DWL. Graphically,



So in this case government intervention can reduce or eliminate DWL. A tax that is just equal to the MEC, or a regulation that limits industry output to Y*, would reduce the DWL to exactly zero. Consumers should pay more, P*, since that is the true cost. These taxes are called Pigou taxes after the economist who proposed them originally[1].

Examples of marginal social costs over and above the marginal private costs are pollution. Decades ago, a firm generating waste might simply dump it into the nearest river. This raised costs for other firms downstream if they needed clean water. (Where by 'firms' I'm including government operations for instance drinking-water treatment plants.)

Externalities loosen the case that individual maximization behavior will inevitably lead to social maximization. Consider the simple case of conversation at a party or bar: you want to talk with someone but there's so much noise that you have to speak loudly to be heard. As everyone in the bar makes this same choice, the general level of noise must rise and so everyone must, again, choose to speak even louder.

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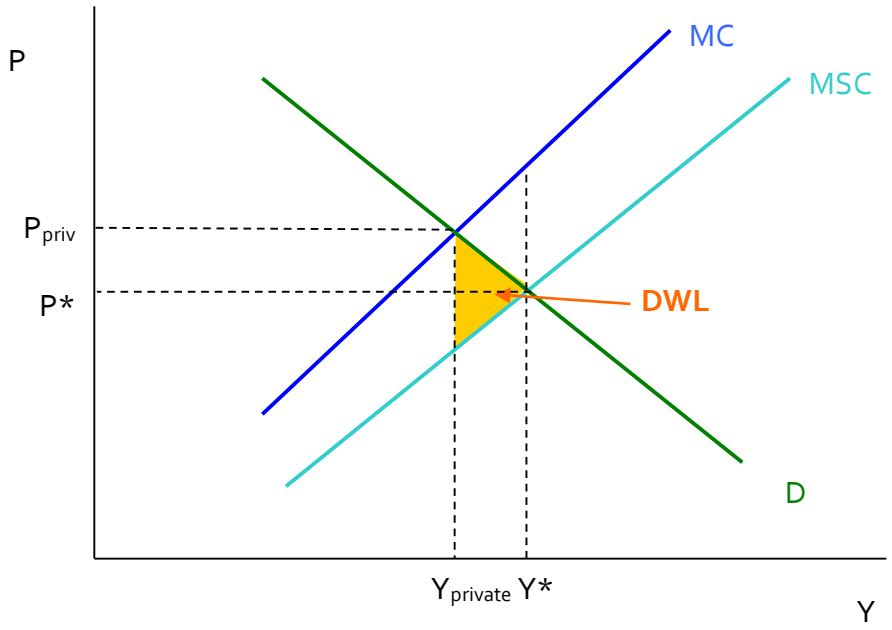
[1] Paul Krugman blogged about Pigou, the English economist who first theorized about externalities. http://krugman.blogs.nytimes.com/2009/09/25/pigou-glenn-beck-and-the-false-case-against-cap-and-trade/

Generally externalities break down the argument that all government intervention must produce deadweight loss. Of course government actions are determined by politicians and so are often heavy-handed or even completely wrong, but this must be determined carefully and on the particular facts of each case. General statements, of the sort that politicians and newspaper editorials make, that all taxes are bad or all regulation is wrong – these statements are pure foolishness.

This is the basis for economists suggesting, for example, higher taxes on gasoline. Greg Mankiw, who advised President G W Bush, had a "Pigou Club" of economists lobbying for higher fuel taxes for just this reason (*http://gregmankiw.blogspot.com/2006/10/pigou-club-manifesto.html*). [Note: Mankiw is a clear communicator, which got him into trouble, since his views about the advisability of a gas tax, plus his views that 'outsourcing' is not really a problem, didn't mesh with that administration's overall message. I can disagree with him on many policy issues but still appreciate him for being intellectually honest in this case even when it was not in his best interest!]

A positive externality in production would shift marginal external costs to the right of marginal cost, creating a different DWL triangle because there would now be *insufficient* production.



Sometimes government intervention in "strategic industries" or to subsidize R&D (in solar power, for example) is justified by this argument. Any single firm might have relatively high costs but the total social cost is lower, so government intervention (subsidizing production) might be justified.

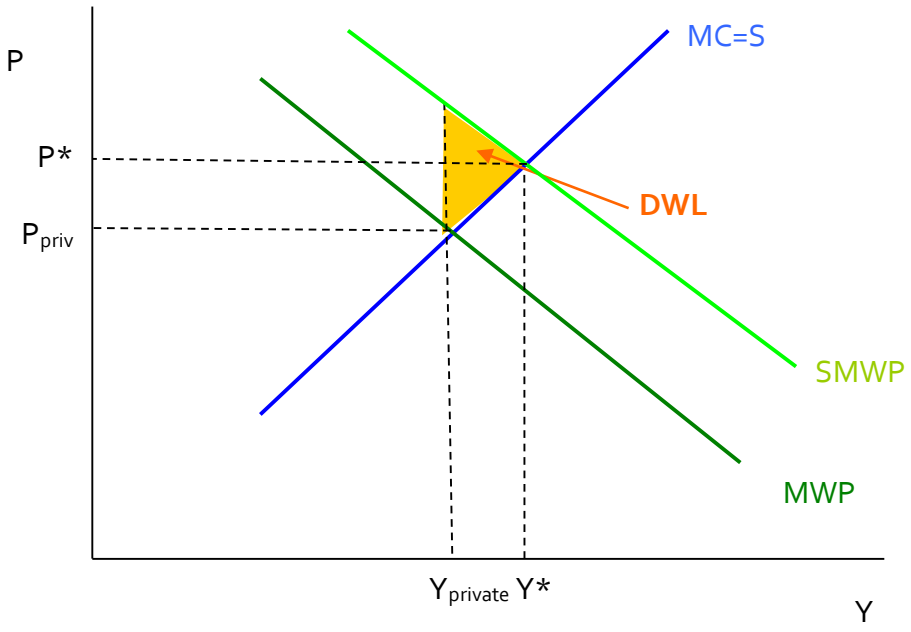
Research into some area, say the basic biological science behind pharmaceuticals, is expensive. There are important knowledge spillovers so a breakthrough in a particular area is likely to lower costs for the whole industry. This is the theory behind government funding for basic science. If you've had a class in Urban Economics you know that many firms choose their location based on these sorts of knowledge spillovers. Government-sponsored research in the

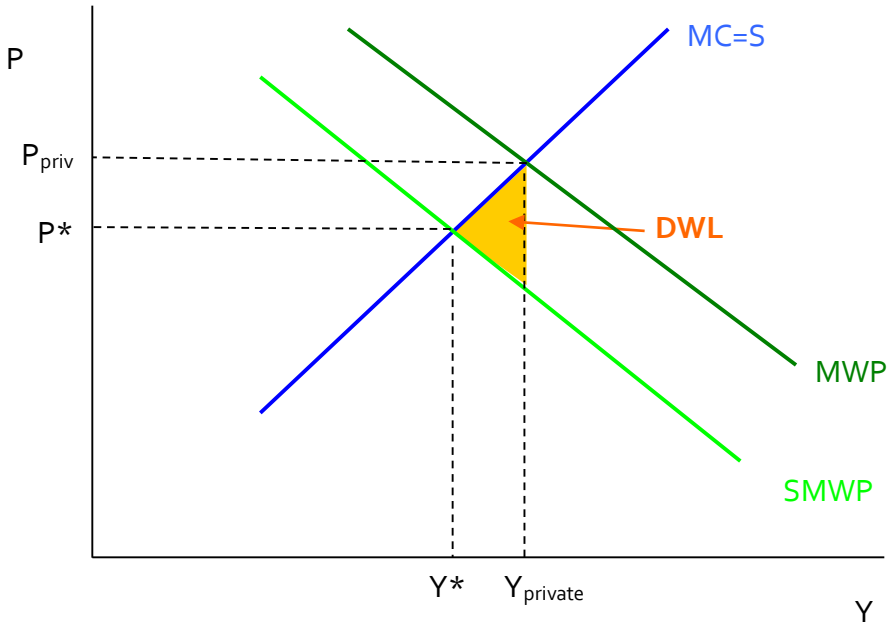
San Francisco Bay area led to many hi-tech firms starting up there; now Silicon Valley is a highly productive location for a wide variety of tech firms. In New York, hip design firms choose to locate in areas where there is already a density of other hip design firms (Brooklyn or wherever) – there are positive externalities to these locations that are not available in Flushing or Jersey (yet – who knows where the next hip neighborhood will be!).

Externalities in demand would shift the marginal social benefit curve to the left or to the right of the marginal private benefit (demand) curve. Positive externalities of demand are "bandwagon" effects or "network" effects – Facebook is popular because 'everybody' has a FB account so MySpace died (and Google + limps along). Many phone features work better if both sender and receiver have the same type of phone and/or provider.

Negative externalities of demand are congestion effects – when the iPhone was introduced on AT&T's network, the huge demands for bandwidth slowed down everybody's phone. City traffic has this effect. Social marginal willingness to pay can also differ if consuming the item (recreational drugs or porn) is believed to have negative spillovers.

Where the individual demand curve showed the "marginal willingness to pay" (MWP is another name for demand curve) of individuals, there can be a distinct social marginal willingness to pay, SMWP. The disconnect between individual and social MWP can again create deadweight loss.





So in each case, a tax or price/quantity restriction can actually reduce the deadweight loss and make everybody better off.

Vertical Sum not Horizontal

Unlike the case of private demand where the market demand is the horizontal sum of the individual demands, the SMWP is the vertical sum of each individual's marginal willingness to pay (MWP). Because the nature of the externality means that the consumption is shared, we don't add up how many are demanded by each individual, at a given price. Rather we ask, if society were to consume one more unit (such consumption would be shared by many individuals), how much each individual would be willing to pay – and add up each individual's marginal willingness to pay.

These items can be positive or negative: I might be willing to pay something for public consumption of some good, or I might be willing to pay an amount to *avoid* the public consumption of that good.

Rival and/or Excludable Goods versus Pure Public Goods

A problem with providing public goods is that everybody tends to wait around for someone else to do the hard work. The idea is that, if the problem impacts somebody else, then that person might do the hard work and then I can just take the externalities – get the benefits without any of the costs. For example the global campaign to restrict carbon emissions suffers from this free rider problem: every country wants the other countries to take all the pain.

We can generally distinguish goods as either **excludable** or **non-excludable** and either **rival** or **non-rival** (in any combination).

Excludable goods mean that the technology exists to keep other people from using my stuff – kids fight in order to make their toys excludable, a mass of laws against theft and robbery help me keep my stuff excludable. Non-excludable is the opposite: I can't keep people from using it. Perhaps it's an architecturally lovely building that every passer-by can enjoy. Or the neighbor without curtains. Intellectual property law (DRM) exists to try to make certain goods excludable.

Rival means that someone else's consumption of the good interferes with my own. If someone else eats my cookie then I can't eat it – cookies are rival. Non-rival is the opposite. Sometimes these distinctions are a bit arbitrary: parents don't understand why kids can't share toys, "If you're not playing with it now, why is it a problem if the other child plays with it now?" just like many people would consider their jewelry rival (even though the same argument could apply – but almost nobody, really, rents jewelry for a night out. The bling is only valuable if it's yours.). Private parks like Gramercy? Some rivalry is simply that people want exclusivity. When music was on circular pieces of vinyl, it was rival; when it became a compressed mp3 file it became non-rival and the whole music business shifted. A good seat at a concert is now the major rival good that many musicians sell. (Except Wu-Tang.)

Economists label goods that are non-rival and non-excludable "pure public goods." These are often goods that are provided by governments. Police and fire protection are difficult to exclude (both because of externalities) and, given the infrequency of occurrences, are basically non-rival. There are private security guards but these are not as common as police. National defense is non-excludable and non-rival.

But other goods, which the US government does not often produce, are also non-rival and non-excludable. Radio is – my listening to a particular station does not impact your listening (assuming the volume levels are low enough). (In other countries radio is produced by the government; in the US there is a modest subsidy to public radio.) Record companies and software companies are battling (mostly, failing) to make music and software excludable – even though any teen-ager with internet access can rip and burn music. Certainly it is non-rival, since I can copy a single mp3 file as many times as I like, without impairing my own enjoyment of it. The movie studios are going the same way as users swap movies peer-to-peer. Their attempts at ramping up the movie theater experience (IMAX, 3D) try to push customers toward the excludable theater.

While these goods are not provided publicly, their peculiar character means that pricing must take different forms. Radio stations play advertisements if they broadcast for anyone; satellite radio makes their product excludable by encoding the broadcasts and selling the decoders. Some sports broadcasts are ad-supported while others are pay-per-view. Apps might be free initially but have various paid levels – in-game purchases, "pro" versions with extra options, etc. Making a great app is easy, compared with the difficulty of making money off a great app. You can think of many more examples.

But in general, whereas we were able to prove that private markets produce Pareto-optimal outcomes (the First Welfare Theorem) in the case of no externalities and perfect property rights, this is no longer the case when there are externalities or imperfect property rights. Markets may be best wherever possible but they are not always possible.

This does not mean that every externality demands government intervention! Markets are dynamic and give participants incentives to figure out ways to exclude rivals, as the examples above clearly show. TV stations originally broadcast over the airwaves to everyone; now cable and satellite broadcasts require de-coders (see Aereo decision from the Supremes). Music companies are slowly trying to figure out how to exclude copying of their products (or figure out other ways of getting revenue). Spotify, Pandora, and YouTube are complicating; Apple's iTunes store crunches the music companies' margins but recently seems to be falling behind. Although DRM and copyright laws are significant government interventions.

There are also cases where private citizens will join together and voluntarily restrict their own choices. Buying a coop or condo means that you agree to be bound by the decisions of a managing board, exactly in order to keep others from imposing externalities on you. If one person doesn't maintain his unit then the board has a legal basis to force the owner to make improvements. Business Improvement Districts (BIDs) have some of this character.

Free Rider Problem

People have an incentive to 'free ride' on other people's willingness to pay. Each would want the other consumer to pay more. I might claim that, actually, my preferences are not like my neighbor's; my neighbor cares greatly about the quality of the public good while I hardly care at all – so my neighbor should pay most of the cost. My neighbor, of course, will likely make the same claim.

Consider common debates about public taxation levels. Some people want the government to levy higher taxes and provide more services; others want lower taxes and fewer services. Sometimes lower-tax supporters will assert, "Well, if you want higher taxes, why don't you start by volunteering to pay more tax yourself?" The public good argument and marginal-willingness-to-pay argument shows why that argument is fallacious.

This problem, of consumers having an incentive to "fake" their marginal willingness to pay for an item, does not occur in the case of private goods, because for ordinary goods, if I don't pay the price I don't get to consume the item. If I go to the coffee shop and offer just 20 cents for a cup of coffee, they won't give it to me. But with a public good, I have an incentive to try to get my neighbor to pay for the public good so that I can consume it for free.

Advanced: The Consumer's Problem for the case of Externalities

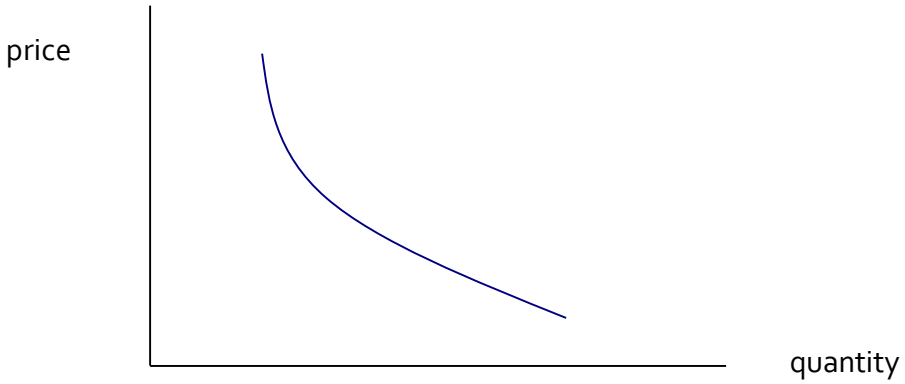
Economics investigates many cases of externalities; some of these relate directly to the environment. My decision to purchase organic food might help the people who live near

the farmer's fields (which no longer are sprayed with dangerous chemicals). Or externalities could relate to networks or other non-environmental issues.

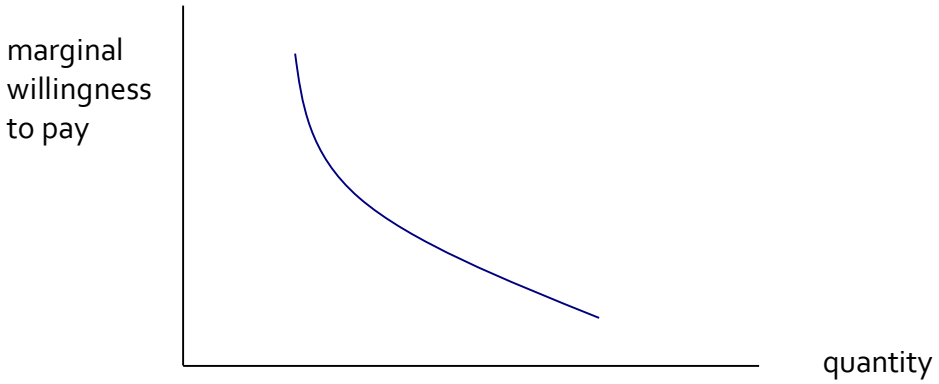
But for now consider two consumers choosing between two goods, x and y, where y is a pure public good (define) that would only be provided by some external organization (like a government). How much of the public good should be provided? Or, equivalently, how much would the two people be willing to spend?

This decision can be enormously complicated if we worry too much about income effects and complementarities among goods. If the free public goods are mp3 files of top music, provided by the internet, then my marginal utility for these goods might depend quite heavily on my possession of an iPod or computer. More seriously, there has been a lengthy debate on the degree to which people demand environmental services as they get wealthier.

But for now we start simply and work our way up. For any ordinary good we can graph a consumer's demand curve: the marginal benefit gained by consuming one more unit of the good. In general this demand curve will slope downward due to diminishing marginal utility.



For a public good we can ask the same question: what is the marginal willingness to pay by the consumer for a one more unit of this public good? Again, this will generally slope downward.



This can be again caricatured as the demand curve for the public good, although it has significant differences from a typical demand curve – crucially, that payment for public goods can be difficult to arrange.

One utility function, which is easy to work with, is the quasi-linear utility, where x is typically interpreted as a composite good (a basket of ordinary consumption items) with price normalized to one and y is the public good, $U(x,y) = x + \sqrt{y}$ so that $MU_x = 1$ and $MU_y = \frac{1}{2}\frac{1}{\sqrt{y}}$.

The marginal condition, that $\frac{MU_1}{p_1} = \frac{MU_2}{p_2}$, gives $\frac{1}{1} = \frac{\frac{1}{2}\frac{1}{\sqrt{y}}}{p}$ once we substitute in for each term, where p is the price that people would be willing to pay for the public good (not necessarily the price that they actually pay). Take the marginal condition and simplify to get $p = \frac{1}{2\sqrt{y}}$ or $y = \frac{1}{4p^2}$; the graph looks like the "Marginal Willingness to Pay" above [assuming the person has adequate budget to buy it]. There is an inverse relationship between the amount of the public good consumed and the marginal value attached to it.

Note that this is not the total value attached to the public good, just the willingness to pay for an additional unit more – that's why it's called *Marginal*. This is just the same as the case with ordinary private goods: the fact that I willingly pay $1 for another cup of coffee does NOT imply that I would give up all of my coffee intake for $1, only that my caffeine consumption is already high enough that I would only pay $1 for yet another cup.

Now suppose there were two people who could consume this public good. How much would these two people be willing to pay for this public good?

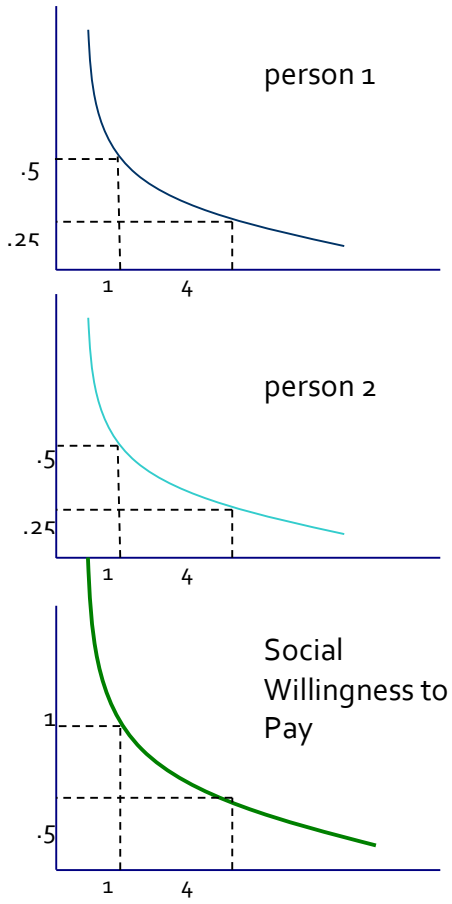
We figured out a relationship for the first person, $p_1 = \frac{1}{2\sqrt{y}}$, where p_1 denotes the marginal willingness to pay of the first person, and p_2 the marginal willingness to pay of the second person. So if the government provided a unit of y, which was nonrival and so could be used by both consumers, then society would be willing to pay up to $p_1 + p_2$ (as mentioned, this is the vertical sum). If the two people had identical preferences then

$$p_1 + p_2 = \frac{1}{2\sqrt{y}} + \frac{1}{2\sqrt{y}} = \frac{1}{\sqrt{y}}.$$

Graphically, this is a 'vertical' summation: add up the amounts that each person is willing to pay and that total price is the marginal amount that society would be willing to pay.

From micro theory, demand curves for private goods are the horizontal sum of individual demands, not the vertical sum.

So we can graph this to the right:



This basic principle applies whether the public goods have positive or negative externalities. Basically, the lack of a bad thing can be considered a good thing, for example if trash piling up is a bad then we can redefine and set trash collection as a good (a few years ago this was a pressing concern in Naples).

Of course this assumes that there is some way to get people to reveal how much they'd be willing to pay for these public goods. This can be difficult…

Person 1 would willingly pay 0.5 in order to get 1 unit of the public good, y – which assumes that the other person is also paying 0.5. If there is not a full unit of the public

good provided then Person 1 would not be optimizing. Person 2 will get utility from the public good provided by Person 1, even if Person 2 contributes nothing.

Consider now the case of two consumers with slightly different preferences: now person 2 has quasi-linear utility of the form $U_2(x,y) = x + 2\sqrt{y}$ so that $MU_y^2 = \frac{1}{\sqrt{y}}$. Now the marginal condition gives $p_2 = \frac{1}{\sqrt{y}}$ and so the Social Marginal Willingness to Pay is $p_1 + p_2 = \frac{1}{2\sqrt{y}} + \frac{1}{\sqrt{y}} = \frac{3}{2\sqrt{y}}$, so that, for example, if y=1 then person 1 is willing to pay 0.5 but person 2 would pay 1. So society overall would pay as much as 1.5.

How could these two people find this out? They have no incentive to tell the truth because they have no way of finding out the other person's true utility function.

What levels would be chosen, if the people were choosing individually? For simplicity we'll return to the case of two identical individuals with $U(x,y) = x + \sqrt{y}$, $MU_x = 1$ and $MU_y = \frac{1}{2}\frac{1}{\sqrt{y}}$. But now we differentiate between how the individual could get this 'y' good, since it is non-rival. Either the consumer could buy her own or she could just use what others have bought.

Notate the amount of the public good bought by an individual y; the amount of the public good that others have already bought is Y (capital letter). Each unit purchased costs price p. So an individual consumes an amount (Y + y) of the public good and (x - py) of the private good (since after paying for y units of the public good she has only that much income left over for spending on x).

With the given utility function this is $U(x,y) = U(x - py, Y + y) = x - py + \sqrt{Y + y}$, where the person is choosing x and y, so we need marginal conditions for these two goods but not for Y since this is not chosen. So $MU_x = 1$ and $MU_y = \frac{1}{2\sqrt{Y + y}} - p$ (where the latter term, -p, comes from taking the derivative, with respect to y, of x-py) and we set the marginal conditions as $\frac{MU_x}{1} = \frac{MU_y}{p}$ (as usual we set the price of the private good equal to 1) and so we get $\frac{1}{1} = \frac{\frac{1}{2\sqrt{Y + y}} - p}{p}$, which we simplify to get $p = \frac{1}{2\sqrt{Y + y}} - p$ or

$p = \frac{1}{4\sqrt{Y+y}}$, which we invert to find the demand curve, $y = \frac{1}{16p^2} - Y$. But how much of Y will be produced? If we assume that all of the consumers are identical and that there are n of them, then the other (n-1) will do the same as the person under consideration, so $Y = (n-1)y$. Substituting in to find y_n, the amount chosen in private equilibrium, gets $y_n = \frac{1}{16p^2} - (n-1)y_n$ so $y_n = \frac{1}{16np^2}$, which means that the total amount chosen is $ny_n = \frac{1}{16p^2}$. *(Note to those who know micro theory: yes, this is the Nash game solution.)* Most worryingly, the amount chosen by each individual falls when there are more other people around, who I believe will 'pick up the slack.'

But how much would be produced, if the people could get together and agree on an optimal social amount (somehow read each others' minds to find out how much they'd be willing to pay)? Now people would maximize their utility, $U(x,Y) = x + \sqrt{Y}$, but the price of Y is $\frac{p}{n}$ since all of the population will pay for an equal part of the total amount that is consumed. So now the marginal condition sets $\frac{MU_x}{1} = \frac{MU_Y}{\frac{p}{n}}$ = $\frac{1}{1} = \frac{\frac{1}{2\sqrt{Y}}}{\frac{p}{n}}$ so Y^*, the optimal amount chosen by the optimal social welfare maximization, is $Y^* = \frac{n^2}{4p^2}$.

Compare this amount with the private solution amount to see that $Y^* - ny_n = \left(n^2 - \frac{1}{4}\right)\frac{1}{4p^2}$, which will be positive whenever $n > \frac{1}{2}$ -- i.e. it will always be positive for public goods! The divergence will get bigger for larger populations, as well.

So while there will generally be some private provision of the social good, this will generally be much smaller than the amount that would be socially optimal. And the size of this divergence will grow bigger when there are more people sharing the externality.

You should be able to do this same analysis with a different utility function, such as Cobb Douglas. For this, $U(x,Y) = \sqrt{xY}$ and $MU_x = \frac{1}{2}\sqrt{\frac{Y}{x}}$, $MU_Y = \frac{1}{2}\sqrt{\frac{x}{Y}}$. For the private-provisioning case, $U(x - py, Y + y) = \sqrt{(x - py)(Y + y)}$,

$MU_x = \frac{1}{2}\left(\frac{1}{\sqrt{(x-py)(Y+y)}}\right)(Y+y)$, $MU_y = \frac{1}{2}\left(\frac{1}{\sqrt{(x-py)(Y+y)}}\right)(px-2y-pY)$ (this looks really ugly but many of the terms cancel so it's not quite as bad as it looks).

In our society probably the most common method of determining optimal social policies is voting, which will not in general produce optimal results but might be satisfactory. Recall the Arrow Impossibility Theorem which stated that democracy is not rational; also Churchill's "democracy is the worst form of Government except all those other forms that have been tried from time to time."

If people's preferences have some homogeneity (they're not too diverse) then voting can even be optimal.

Society has created a wide array of institutions that counteract the problems that arise from externalities. At one point these were largely based on sociological mores and traditions. Now many are contractual; in some cases governments have stepped in to formalize particular legal constructions – from the modern corporation to housing coops, condominium associations, business improvement districts, and so on.

The formal analysis mirrors the Nash game of oligopoly: although each participant would like to buy more Y (or charge a higher price), they do not do this because they assume that others would not be so 'public spirited' as to also buy more Y (or charge a high price) so they compete.

It is like a Prisoner's Dilemma. Return to the case of two identical individuals with $U(x,y) = x + \sqrt{y}$, $MU_x = 1$ and $MU_y = \frac{1}{2}\frac{1}{\sqrt{y}}$. Their social optimum is to pay 1 and get 1 unit of public good (assuming p=1; this is $Y^* = \frac{n^2}{4p^2} = \frac{(2)^2}{4(1)^2}$). But if they choose individually then they'd each choose $y_n = \frac{1}{16np^2} = \frac{1}{16(2)(1)^2} = \frac{1}{32}$ so there would be just 1/16 of this public good in total.

We could simplify this as a Prisoner's Dilemma:

	Person 2 Cooperate	Person 2 Compete
Person 1 Cooperate		
Person 1 Compete		

But we need to fill in the Utility values in each bin. We assume that each person has a budget of 1; the amount of good x that is chosen is simply the remaining budget. Setting Y=1 implies that each chooses y=1/2 so x=1/2 and $U = \frac{1}{2} + \sqrt{1}$=1.5. Setting y=1/32 so

Y=1/16 means instead $U = \frac{31}{32} + \sqrt{\frac{1}{16}}$ =1.22. But if the other person buys 1/2 then I buy $y = \frac{1}{16p^2} - Y = \frac{1}{16(1)^2} - Y = \frac{1}{16} - y - y'$ (where y' is the other person's choice of y). If the other person sets y'=1/2 then I would set my own y at zero (can't be negative) so my utility would be 1.71; the other person's would be 1.21.

So this gets us this Prisoner's Dilemma table:

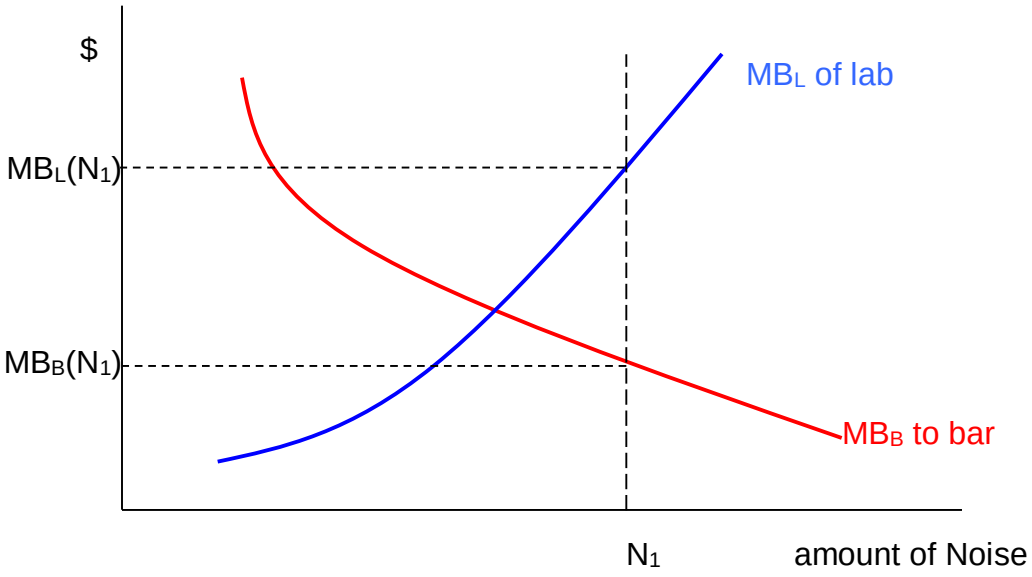
	Person 2 Cooperate	Person 2 Compete
Person 1 Cooperate	1.5, 1.5	1.21, 1.71
Person 1 Compete	1.71, 1.21	1.22, 1.22

So "Compete" is a dominant strategy. As typical with this analysis, it could be extended to multiple interactions, complete with reputational games, random strategies, etc.

Coase Theorem

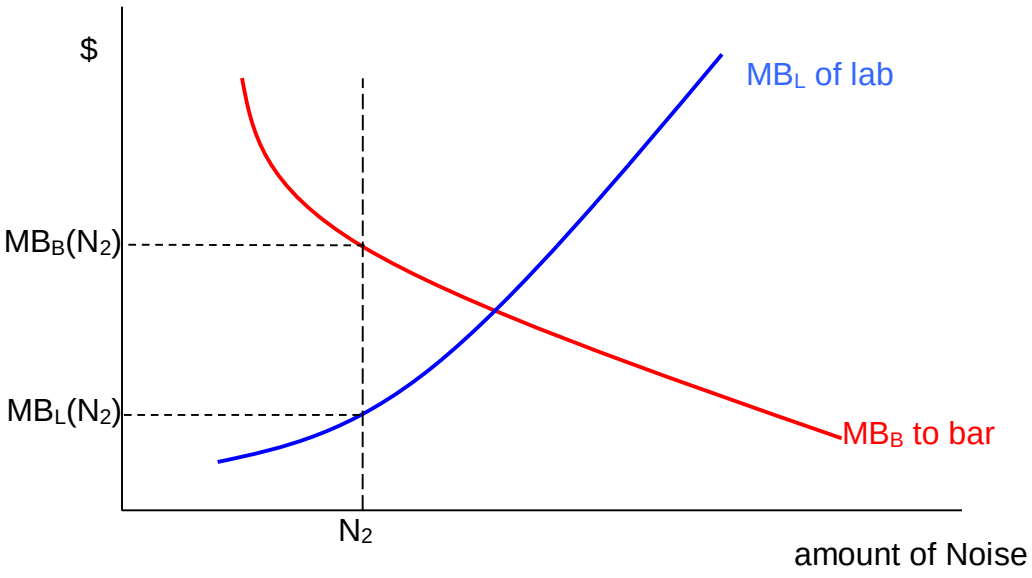
The Coase Theorem specifies why we link transactions costs with imperfect property rights: in the absence of transactions costs, many imperfections in property rights (many externalities) will be properly priced and so may be produced at Pareto optimal levels.

Consider the case of two neighbors sharing a building. One is a bar, which, in the course of ordinary business, produces loud music and loud people. The other is a laboratory which operates best without noise or vibrations; as these levels increase the lab must spend more money to shelter its experiments. Starting from zero noise, the bar gets a significant marginal benefit (MB) from the first few decibels of noise, however the marginal benefit falls as the level of noise rises. The lab can, with low cost, abate low levels of noise but its costs rise as it tries to abate more and more noise. Costs avoided are net benefits so we can consider this as a marginal benefit to the lack of noise: a small lack of noise has a small marginal benefit but as the noise rises the marginal benefit rises. So we can draw their respective marginal benefits (MB_L to the lab and MB_B to the bar) to different levels of noise (N):



Suppose that the level of noise were initially to be at some high level, N_1. Then the lab must be spending a large amount of money to abate the noise, $MB_L(N_1)$, while the bar gets a much lower marginal benefit from the noise, $MB_B(N_1)$.

If, instead, there were a low level of noise, N_2, then the lab could abate it at low cost, $MB_L(N_2)$, while the bar would place a high marginal value ($MB_B(N_2)$, a high marginal profit) for making more noise.

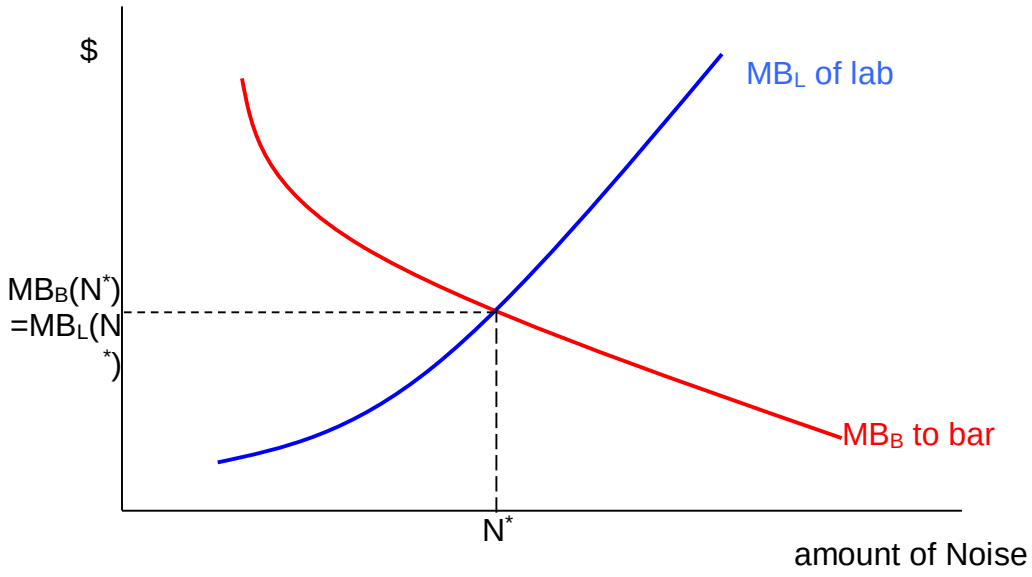


If there are clear property rights then the participants can trade. It may not matter if the law establishes that businesses have a right to silence or if the law establishes that businesses can

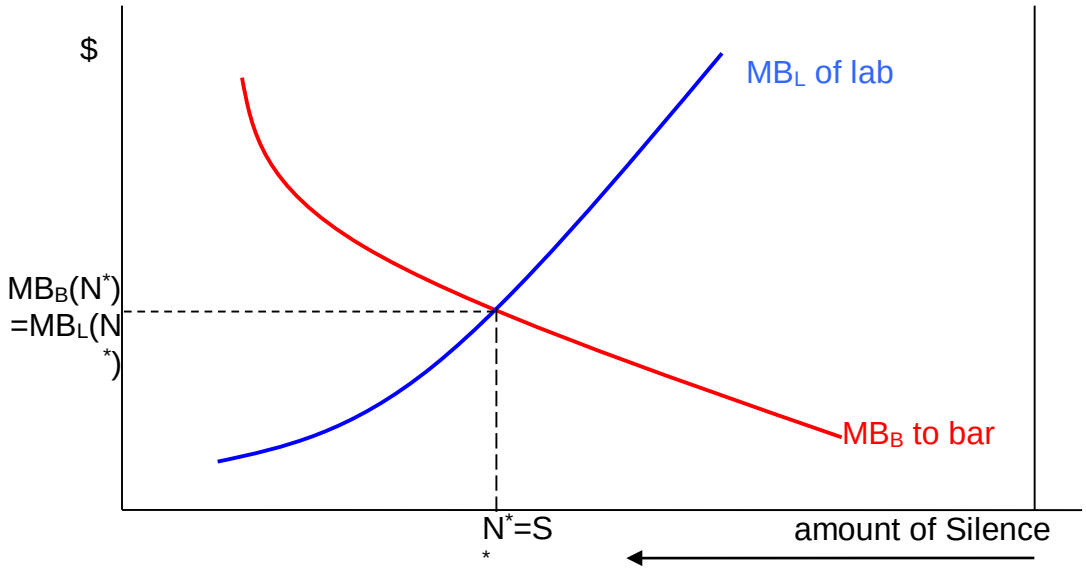
make as much noise as they want – in either case the parties can then trade. If there is no clear law, either because there are no clear precedents or enforcement is capricious, then the two sides have an incentive to fight.

But suppose, for example, zoning laws mandate silence so that the lab has "ownership" of the lack of noise. In this case the lab can supply certain levels of noise by buying noise-reduction, so MB_L is a supply curve of noise. The bar would like to buy up the right to make a certain amount of noise, so MB_B is a demand curve. If we begin from cacophony, where the initial level of noise is at a high level such as N_1, then the lab would clearly want to lower the noise level: the last increment of noise could be sold at only a low price, $MB_B(N_1)$, but it costs the lab much more, $MB_L(N_1)$, to abate that noise. It will enforce a lower noise level. But not necessarily complete silence.

If, instead, the noise level were at a whisper, at an amount like N_2, then the bar would be willing to pay a large amount, MBB(N2), to be noisier, while the lab could abate that noise at a small cost, MBL(N2), so it would be profitable to sell the noise, buy the abatement technology, and make a profit from the difference. This will continue until the noise level reaches an equilibrium level, N*, where the marginal benefits to each side are balanced.



If, on the other hand, there were no restrictions on noise emissions, then the bar would have the right to emit as much noise as it chose. We can think of the bar as now supplying silence (the absence of noise, measured backwards on the horizontal axis) and the lab demanding silence. Since we're flipping the horizontal axis this gives a downward sloping demand (the MB_L) and upward sloping supply (MB_B).

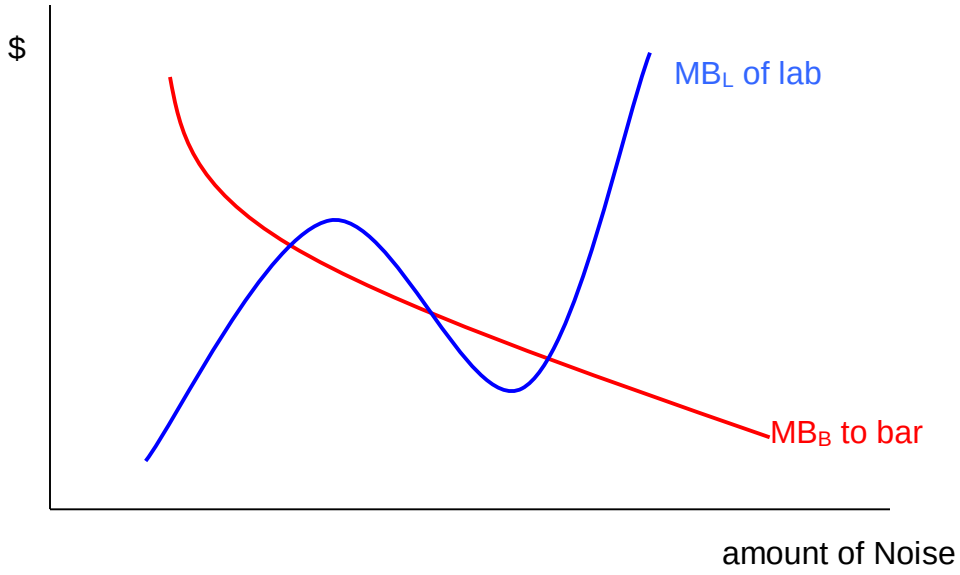


If the amount of noise were at cacophony N_1, then there would again be an incentive for trading: the bar could make a profit since it could reduce noise at only a small cost while the lab would be willing to pay a large amount for that reduced noise. If the noise were at a whisper, N_2, then the bar would find it profitable to emit more noise, and the lab could not "outbid" it since the bar would demand a high price of $MB_B(N_2)$ while the lab would only be willing to pay $MB_L(N_2)$.

The big insight is that no matter whether the lab has a right to silence or if the bar has a right to noise, the final amount of noise is unchanged at N*. The initial allocation of property does not change the outcome. All that changes is the direction of money payments: if the lab has a right to silence then the bar will pay it for the amount N*; if the bar has a right to make noise then the lab will pay it. The direction of the flow of money changes but not the amount of noise chosen. This was the insight of Coase. He did not believe that zero transactions costs were universal or even common, but his insight clarifies how the problems of externalities might be solved by private transactions.

Note that this result depends on the absence of "income effects" which, while reasonable in the case of firms (without financing constraints) might not be as reasonable for consumers. If poor people must buy a lack of pollution then they might not have enough income.

This also assumes that both sides to the transaction have continuous and monotonic marginal benefit schedules. If either MB curve were not continuous, i.e. with jumps, then the price might not be fully determined – but the two sides should be able to bargain. If either MB curve were not monotonic then there could be multiple equilibrium points, such as this:

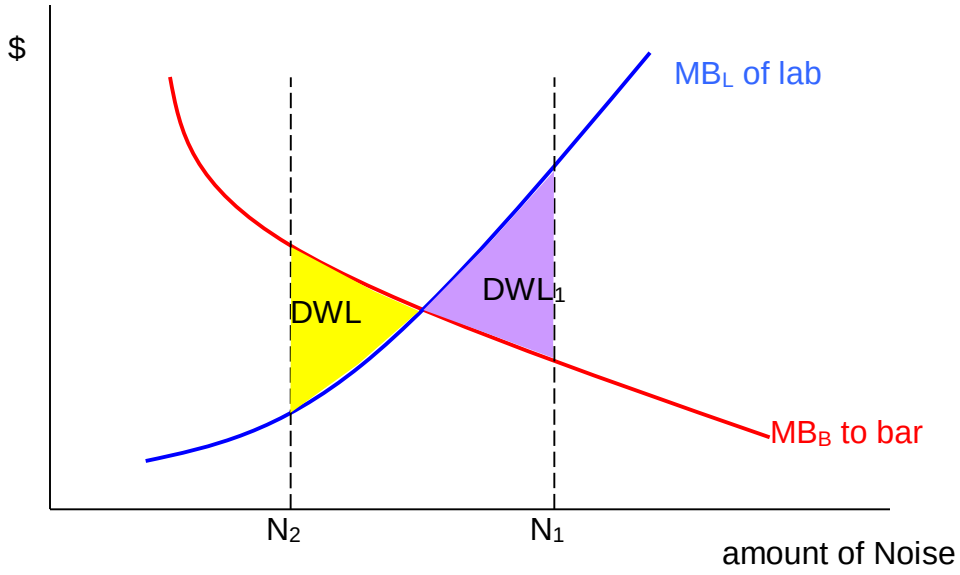


So there can be many complications but the central insight is that we should concentrate on transactions costs.

From the Coase viewpoint, transactions costs are equivalent to unclear (or insecure) property rights. What would happen if, in the above example of the lab and the bar, the noise were made by cars going by (ones tricked out with the bass speakers thumping, or Harley motorcycles with their distinctive roar)? The lab would have a difficult time either enforcing silence (if it had that right) or paying the passing vehicles (if they had a right to make noise). Similarly if there is one noisy bar annoying large numbers of adjacent apartment-dwellers then it would again be difficult either for the neighbors to get together to pay the bar to lower the noise (if the bar had the right to make noise) or for the bar to compensate them each.

In air pollution discussions, this is the difference between "point sources" and "non-point sources" since point sources of pollution (like large power plants) are easily identified while non-point sources (like every car) are much more difficult to effectively regulate.

With unclear property rights, if the noise level just happened to be at N_1 but there could not be trading, then there would be deadweight losses equivalent to the shaded triangle DWL_1; if the noise just happened to be at N_2 then without trade the deadweight losses would be the other shaded triangle, DWL_2.



If the government can assign property rights to one party or the other then there will no longer be deadweight losses – i.e. there will be Pareto-improving trades. Alternately if the government knew the marginal benefit schedules of the lab and the bar, then it could regulate the noise level to be precisely N*. In the current case it would seem implausible that the government could really know all of that information, however in other cases the informational asymmetry might not be as large.

Steve Levitt (in his Freakonomics blog) gives the simple example of web addresses. For a simple example, consider the web domain name "kevinfoster.com". There are various people who might value this address. Suppose I value the address at $100. Suppose that some business called "Kevin Foster" values the address at $120. If the property rule is "first come first served" and I was quick then I own that web site. So the business would offer me some price between $100 and $120, say $110, and we would both be better off – I would get $10 of surplus and the business would get $10 of surplus. Suppose instead that the property rule was "businesses get .com addresses" so that the business owns the web site. In that case they take it – I would not be willing to pay more than $100 for it; they would not sell for a price less than $120. Suppose that, instead, I valued the address at $150. In that case, if I originally owned the name then I would keep it; if the business originally owned the name then I would buy it from them, for some price between $120 and $150. In either case the entity that values the web address most highly will end up getting it – as long as they can make the transaction.

In the internet name case, the property rights were unclear initially: people named "McDonald" grabbed mcdonalds.com and demanded money. At first, the hippies who set up the internet tried to restrict sales, which just led to confusion. Businesses tried to use existing trademark protection law to grab domain names, so it took lengthy legal proceedings to figure out just who owned it in the first place. Once initial ownership was decided, trade could flourish.

Of course there are differences in the flow of money – if I already own the name then either I get paid (if the business values it more) or I don't have to pay (if I already own it). The participants in the transactions care greatly about the initial property rights allocation. But, as you recall from our discussion of Pareto improvements, from the point of view of maximizing surplus these transactions are immaterial. Neither is a Deadweight Loss – they're losses to one side that are gains to another.

Coase originally made the analysis from thinking about the structure of the economy and seeing so few markets. When a business buys a supplier, it is stating that the free market for that input wasn't working as well as a planned economy would work. Consider the difference between freelance workers (who buy all sorts of their inputs in markets) versus employees of large firms (whose inputs are provided by planning not markets).

Tragedy of the Commons

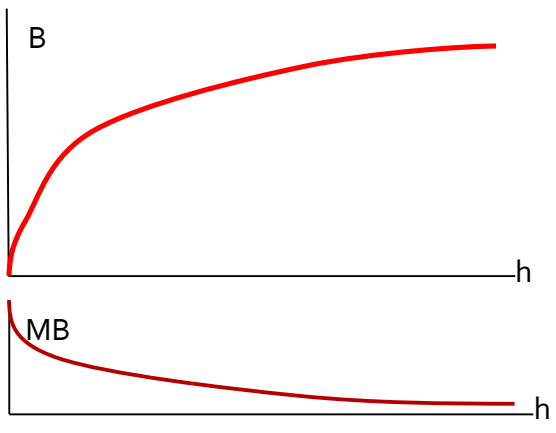
A particular case of an externality is called the **Tragedy of Commons**: when everyone can use a resource then they have incentive to over-use it. From the Coase perspective, the fact that "everyone" can use it creates substantial transaction costs.

Tim Harford, in his column *The Undercover Economist*, gives an example of popcorn during a movie. If a bunch of friends are all eating from the same bowl then the popcorn will disappear fast. If each person gets their own packet then they'll eat more slowly. I can save popcorn for the end of the movie if I have my own bowl/bag. But I can't save some if it's in the common bowl.

This was initially described as "Tragedy of the Commons" because in ancient times people grazed their animals on common land (a park in Boston is still called "Boston Common" from this). Since access was easy, the land was over-grazed. It has other applications but particularly in things like access to common areas – fishing or hunting, for example. The ocean off the eastern coast of North America was once bountiful with fish; New York City's teeming immigrants were fed on Newfoundland cod. But those areas were overfished and the stock of fish crashed. Now tight restrictions are trying to allow those fish populations to recover.

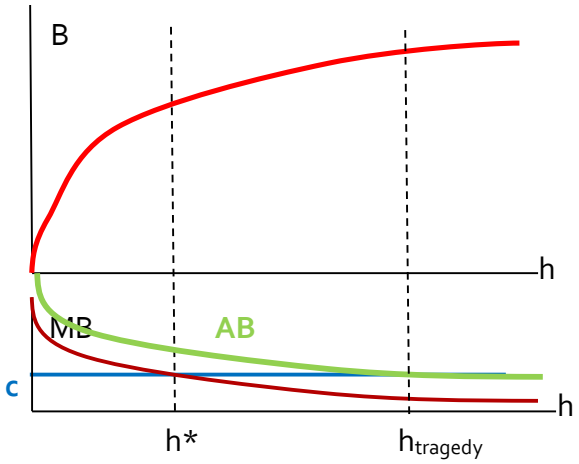
In winter, many neighborhoods have various informal property allocations regarding parking spaces, which are ordinarily common property. If I shoveled out a parking spot, do I get the future use of that space? Opinions differ.

Numerical Example: suppose a forest is used for hunting and the benefit that accrues to a hunter depends on the number of other competing hunters, so for example, with h being the number of hunters and B the



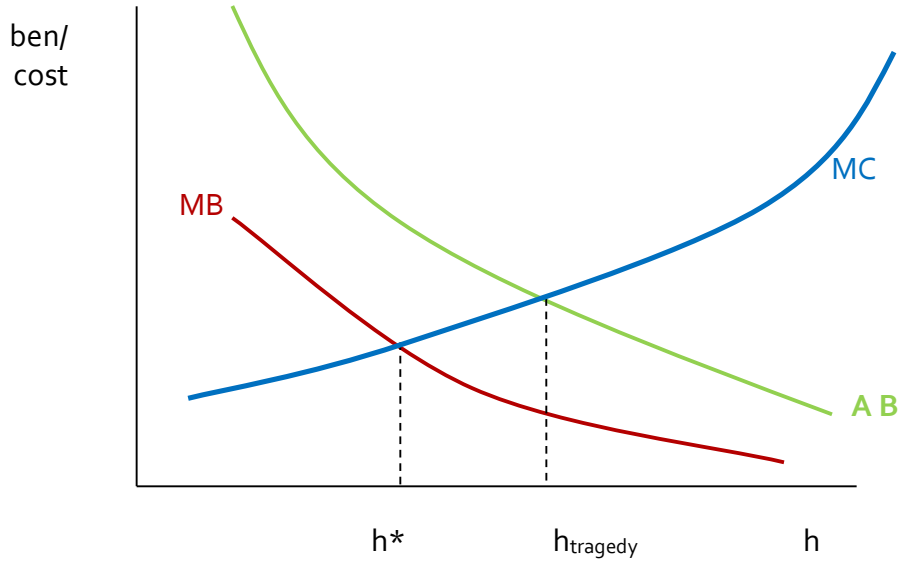
benefit to any one, $B = \sqrt{h}$ and the marginal benefit is $MB = \frac{1}{2}\frac{1}{\sqrt{h}}$. Graph is to the right.

If the marginal cost to each hunter is constant, say $MC = c$, then if the forest were managed by a single entity (person or corporation or government) then that person would allow hunting until $MB = MC$, $\frac{1}{2}\frac{1}{\sqrt{h}} = c$. However if there is no way of keeping hunters out then a hunter would enter as long as the average benefit (AB) per hunter, $\frac{B}{h} = \frac{\sqrt{h}}{h} = \frac{1}{\sqrt{h}}$, is greater than the cost, so hunters would enter until $\frac{1}{\sqrt{h}} = c$. Comparing the two results we clearly see that in the first case, where the forest is managed by a single entity, $h^* = \frac{1}{4c^2}$, while in the second case $h_{tragedy} = \frac{1}{c^2}$ -- four times the optimal amount!



From this it is straightforward to additionally note that, over time, the net increase or decrease in the available benefit is changed by different 'harvest' policies: over-hunting today (if $h_{tragedy}$ is greater than the breeding rate) leads to lower hunting possibilities tomorrow, until the animals are killed off entirely.

Taking a larger look at the graph,



Clearly if MC is upward sloping then the difference between the "Tragedy" level and the optimal level would not be quite as large, but there would still be a gap.

The Tragedy of Commons explains traffic, too. Clear roads are over-grazed – too many people hunt down the quick routes. Parking is over-grazed (there's an app for that).

The problem can be seen as unclear property rights: if I don't eat fast (or don't go hunting or don't go fishing or don't drive) then how do I keep a claim on the un-eaten popcorn (or un-killed game or un-caught fish or space on the road)? We will often return to the problem of unclear property rights (Coase transaction costs).

This simple analysis can be unduly pessimistic; in the analysis of Elinor Ostrom (who won the Nobel prize in economics in 2009) there is more optimism for the ability of communities to properly use common resources. Viewed by a political scientist there is more scope for the policies of a community to have an effect, compared with what simple game theory predicts.

In Ostrom's view (see her Nobel lecture for an overview), "humans have a more complex motivational structure and more capability to solve social dilemmas than posited in earlier rational-choice theory." Many public goods are provided by "polycentric" organizations (multiple government and non-government entities) that interact with other entities, individuals, and companies in complex and diverse settings, which end up often being more efficient than a single monopoly government. Her research focuses on "common pool resources" which are non-excludable but rival (although she does not like that terminology). She also distinguishes "toll goods" that are non-rival but excludable; these can be provided as for example toll roads or bridges or private clubs.

Ostrom rebukes economic theory for being myopic, "The classic models have been used to view those who are involved in a Prisoner's Dilemma game or other social dilemmas as always trapped in the situation without capabilities to change the structure themselves. … Public investigators purposely keep prisoners separated so they cannot communicate. The users of a common-pool resource are not so limited." Only in common pool resource "dilemmas where individuals do not know one another, cannot communicate effectively, and thus cannot develop agreements, norms, and sanctions, aggregate predictions derived from models of rational individuals in a noncooperative game receive substantial support." In more realistic and complex cases, property rights are not so clear-cut. Identifies at least 5 property rights to common-pool resources: access, withdrawal (harvest), management, exclusion, alienation (selling previous 4 rights to another).

Results from behavioral economics also show that people do not in general behave as the Coase Theorem would specify – the "endowment effect" notes that people get attached to the stuff that they initially have (Kahneman, Knetch, & Thaler 1990; Kahneman's *Thinking Fast and Slow* book is terrific).

In many respects the problem of Global Climate Change is a tragedy of commons: the atmospheric capacity to absorb CO_2 is a common resource available to every person on the earth. Can governments work together to " develop agreements, norms, and sanctions"?

Sustainability

It is difficult enough to figure out how some impartial policy analyst might measure social marginal cost or social marginal willingness to pay, when they differ from the private analogs, or what tax/subsidy would cure it. But that presumes that policymakers want to maximize social surplus. To what extent is that a good assumption? Is that sufficient?

First, how exactly do we (ought we) as economists define Sustainability?

Sustainability and Sustainable Development

Principal definition from the 1987 Brundtland Commission, Sustainable Development is development that meets the needs of present generations without compromising the ability of future generations to meet their own needs.

At the American Museum of Natural History here in New York, the entrance rotunda has the following words carved into the wall:

> Nature
>
> There is a delight in the hardy life of the open.
>
> There are no words that can tell the hidden spirit of the wilderness, that can reveal its mystery, its melancholy and its charm.

> The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased; and not impaired in value.
>
> Conservation means development as much as it does protection.

Theodore Roosevelt, 26th President of the United States (the youngest ever) and also a winner of Nobel Peace Prize, was a prominent advocate of conservation, wilderness, and the AMNH. The last two sentences on the wall can be seen as inconsistent or at least as implying different varieties of what we would now call "sustainability".

But Teddy Roosevelt's further quotes reveal more, "Conservation means development as much as it does protection. I recognize the right and duty of this generation to develop and use the natural resources of our land; but I do not recognize the right to waste them, or to rob, by wasteful use, the generations that come after us." "Defenders of the short-sighted men who in their greed and selfishness will, if permitted, rob our country of half its charm by their reckless extermination of all useful and beautiful wild things sometimes seek to champion them by saying the 'the game belongs to the people.' So it does; and not merely to the people now alive, but to the unborn people. The 'greatest good for the greatest number' applies to the number within the womb of time, compared to which those now alive form but an insignificant fraction. Our duty to the whole, including the unborn generations, bids us restrain an unprincipled present-day minority from wasting the heritage of these unborn generations. The movement for the conservation of wild life and the larger movement for the conservation of all our natural resources are essentially democratic in spirit, purpose, and method." (Again, TR, *A Book-Lover's Holidays in the Open*, 1916.)

The concern with subsequent generations is not new, of course. Read Edmund Burke, *Reflections on the French Revolution*, 1790, "Society is indeed a contract. ... it is not a partnership in things subservient only to the gross animal existence of a temporary and perishable nature. It is a partnership in all science; a partnership in all art; a partnership in every virtue, and in all perfection. As the ends of such a partnership cannot be obtained in many generations, it becomes a partnership not only between those who are living, but between those who are living, those who are dead, and those who are to be born." (Earlier in the same, he noted, "the age of chivalry is gone. That of sophisters, economists, and calculators, has succeeded; and the glory of Europe is extinguished for ever." http://www.bartleby.com/24/3/)

Sustainability, in whatever conception, is not straightforward to analyze within an economic framework. We need to work out the details of the definition farther.

Sustainability and Economic Growth

> From J.C.V. Pezzey & M.A. Toman, (2008) "Sustainability and its Economic Interpretations," draft chapter in *Scarcity & Growth in the New Millenium*, ed R.U. Ayres, D. Simpson, & M.A. Toman.

Big question: can economy grow forever?

Sustainability in general is about equity between generations. Could either define it as equity of outcomes (utility) or equity of opportunities. If look at outcome, then ask: can future generations' utility continue without declining? If look at opportunity, then does wealth (broadly defined) never decline? Amartya Sen considers human capabilities.

Economic problem: in many analyses we assume that people discount the future – find the present discounted value of costs & benefits. We do this in analyzing investments by private companies as well as governments. But this discounting means that the welfare of future generations may not be highly valued.

Early papers on economic growth provide boundaries of the problem. If there is a depletable natural resource, then rational choice (discounting the future) by current generations implies declining consumption over time. (People do this just for themselves: many people don't save enough for their own retirement!)

If, on the other hand, technological growth is rapid enough, then the discounting dilemma is solved: consumption can grow over time. But the discounting dilemma shows that, even if there are no externalities and every good is 'properly' priced, the economy might still be unsustainable. Adding in externalities and tragedy of the commons might make it even less sustainable.

First question: so what? If every current person likes the unsustainable path, then is there a moral basis to limit current choice? If so, who will limit current choices? Can we distinguish between people acting as 'homo economicus' in markets but as 'Good Citizen' in government? For a good review of how important is economic growth to basic human welfare watch Hans Rosling's TED talk – spoiler: most measures of health and human welfare are positively correlated with GDP.

Do people act rationally anyway? Do they discount in that way? How do we deal with the uncertainty inherent in some of these models? No easy answers.

Sometimes hear criticism that economists are crazy to believe in the possibility of infinite growth since physical energy and material are limited. This ignores the reality of value creation which is not limited by energy inputs – as the virtual economy grows, there are an increasing number of goods which are valued in ways unrelated to inputs. This is technological growth.

Technology can allow growth but still there remains a fundamental question: if future generations will be much richer, then why must we now sacrifice for them? Why should the poor (us today) sacrifice for the rich (future generations)? (But note that ethical statement that rich should get less and poor should get more, is widely seen as having different answers whether the comparisons are intertemporal or at a single time.) Many countries and societies

have developed by first exploiting natural resources to get rich, then only later remediating environmental harm (e.g. the USA).

This question of discounting arises often in policy disputes. We will come back to it (esp. in climate change) but for now note that there is no simple answer.

Social Welfare

How can we, as economists, say much about which outcomes are better than others, with a minimum imposition of our own particular ethics and morals? Some outcomes might deliver high income inequality; some might constrain inequality but with a lower average level of consumption. How can we say which is better?

I'll use the general term "government" but this refers to any joint decision making body. People get together to form various organizations, which then promulgate rules that bind the members – any of these organizations can be considered a 'government' from the view of social welfare analysis. A building coop is a 'government' of a sort: it makes rules that (hopefully) help the people who live there. Business Improvement Districts join up local merchants. There are unions and farmer marketing boards. Then there are myriad levels of government in the conventional sense of the word including "quangos," quasi-governmental agencies like Fannie Mae or Port Authority. These are Elinor Ostrom's polycentric organizations.

So how can any such government or group choose its goals? One of the very minimal items that we might propose, is that we ought not to omit any movements in allocations that are "Pareto improving." A Pareto improving trade gives something for nothing – someone gets more utility without anyone else getting less utility. Certainly these sorts of trades ought to be made, right? So a "Pareto optimal" economy has eliminated all of these possible trades and has no more possibility of getting something for nothing.

This is what kids do after getting Halloween candy: the one who likes chocolate best will trade away the Starbursts and gummi bears to friends who like those more than chocolate. Everyone wins.

The First Welfare Theorem of Economics tells that every (frictionless) market equilibrium is Pareto optimal. This tells us that, based on the rather meager definition of "optimal" that we just gave, that each market equilibrium meets this low criterion. This is nearly by definition: if there were some trade that would make both parties happier, then they would make it in a market economy (unless constrained by some friction; e.g. the whole Coase discussion).

The Second Welfare Theorem of Economics is more interesting. We just said that "Pareto optimal" is a weak condition – a dictatorship where one person has nearly all of the wealth, while the others toil in peonage, could be Pareto optimal. There are many possible Pareto optimal equilibria. Suppose society had some idea of which particular one it wanted – could a market economy get us there? The Second Welfare Theorem tells that every Pareto optimal

allocation is a market equilibrium that started from some initial endowment. So this makes a lovely separation: if policymakers want to change which allocation they desire, then they ought to change the initial endowments. The market system is not the reason for inequalities or injustices – these mirror inequities in the original allocations.

But, as we said, there are many Pareto Optimal allocations – this is one consideration but not the sole consideration. How can society choose the "best" outcome? The Second Welfare Theorem said that, if we had something to aim for, we know how to hit it. But what do we aim for?

Not every Pareto Optimal allocation is very good: if we start from an aristocratic society with 1% of people getting nearly all of the wealth while the other 99% live at subsistence level, then there is no Pareto improvement that will help the 99% who are peasants without taking something away from the aristocrats.

We would like to have some sort of society utility function, analogous to an individual utility function, so that we could use the rational choice apparatus to look at social choices. Call this a "Social Welfare Function," denoted W( ).

One idea for a Social Welfare function is Utilitarianism, originally due to Jeremy Bentham, which holds that we should just add up the utilities of the people in the society, u_1, ... u_N. This sets

$W\left(u_1,...,u_N\right)=\sum_{i=1}^{N}u_i$, or, with slightly more generality,

$W\left(u_1,...,u_N\right)=\sum_{i=1}^{N}a_iu_i$,

where the a_i are weights. This has problems, chiefly being the impossibility of measurement, as well as the impositions upon human rights.

From the definition of utility functions, these are just arbitrary functions which represent preferences; any monotonically increasing function of a utility function is itself a utility function. One person's utility of chocolate could be 1,000,000,000; another's could be -1 but we CANNOT conclude that the first person likes chocolate better. How can we compare happiness levels?

Then there is the problem of human rights: if we believe that people have "certain inalienable rights" then the utilitarian framework could justify, say, selling one person into slavery if the money raised can make others happy enough.

The philosopher John Rawls proposed a minimax function,

$W\left(u_1,...,u_N\right)=\min\left\{u_1,...,u_N\right\}$.

He propelled this function by arguing that most people's definitions of a fair allocation depend upon their knowledge of their own situation: someone who is intelligent might happily agree to a society where smart people are well rewarded; someone else with different advantages would argue for a different allocation. He proposed a thought experiment: what allocation would be chosen, if the members of society could get together before they knew what their own situation would be – whether they would be fortunate or unlucky, healthy or sick, endowed with which talents? They would have to make a decision from behind a "veil of ignorance" over their future endowments. Rawls argued that, from this perspective, a person would give a great weight to the worst possibility – extreme risk aversion – that a society with substantial inequality would not be appealing because even a small chance of being utterly destitute would be too large. Therefore he proposed a minimax principle, that every change in allocation, away from perfect equality, must help the worst-off person. So he would allow greater rewards to, say, doctors, in order to give them incentive to help the sick and the most fragile members of society.

Societies make these tradeoffs with policies like patents: these award monopoly power (which is short-run inefficient) for invention (which is long-run efficient). So, for example, pharmaceuticals are more expensive today in order to be more available to future generations. Figuring the optimal patent length is complicated.

These social welfare functions so far allow people's utilities to depend on anything and everything. We might further restrict that people's utilities depend only on their own consumptions, in which case we would have a Bergson-Samuelson welfare function. But this is not generally realistic.

Rights-based social welfare functions run into difficulties since these generally do not allow tradeoffs – a slight diminution in some right might make everyone better off. But rights-based are generally "lexicographic" preferences where no positive benefit can possibly compensate ("lexicographic" since Azzz is alphabetized before Baaa). Yet different people have different ideas about which rights are most important (in the US, the Supreme Court must adjudicate when there are competing rights clashing). Many people voluntarily surrender certain rights in order to gain other benefits (e.g. a coop or condo association restricts property rights but is beneficial to property values); it is unclear why a social welfare function should not do so.

We might hope for an answer like "democracy". But Ken Arrow (CCNY alumnus and Nobel Prize winner) showed that a democracy does not guarantee rational orderings of choices.

Arrow's Theorem states that if we desire:

1. Completeness: The social welfare function, W( ), is defined for all allocations,
2. The social welfare function is responsive to individual preferences,
3. It is independent of irrelevant alternatives (so if W(X)>W(Y) then adding a choice Z, if W(X)>W(Z), does not change the original ordering) (like Transitivity)
4. It is not an imposed dictatorship.

Then, if there are more than 3 choices, there is NO POSSIBLE Social Welfare function can be guaranteed to satisfy all four conditions.

People care about justice and fairness and other considerations. Too many policy debates result from arguing about proposals, where each side uses radically different definitions of these terms – what do justice and fairness mean? Economists have proposed some definitions.

The Second Welfare Theorem got us focused upon initial allocations, so we might wonder if that will help. Is a symmetric distribution, where everyone gets exactly the same bundle of goods, fair? If people's utility functions are not perfectly uniform then people will voluntarily trade among themselves, and we will move away from perfect equality. Is this desirable? Would someone envy another person's allocation? Define **envy** that person *i* would prefer *j*'s bundle rather than her own. An allocation is **equitable** if none of the bundles are envied. Define a **fair** allocation as one that is equitable and Pareto efficient (i.e. nothing is wasted). Now it can be proved that if society starts from a symmetric distribution then the outcome of market trading will be fair, under this definition. (But the symmetric outcome is not generally fair.)

From the definitions of Pareto optimality, economists have often backed off to the measure, "Possibly Pareto Improving" (or Potentially Pareto Improving), to indicate that some policy could generate enough surplus to compensate the losers and still leave the winners with something. For example, a policy that gave A $100 while costing B just $40 would be Possibly Pareto Improving since A could compensate B the $40 lost and A would still be $60 ahead. This is the theory behind the general introductory lesson on Deadweight Loss (DWL) – that social surplus could be increased by enough to compensate the losers and still leave the winners ahead.

This sneaks back a bit of Utilitarianism into the argument – now we're comparing utilities but using the measure of dollars (marginal willingness to pay). This implicitly weights utility by wealth since rich people can pay more.

The problem with "Possibly Pareto Improving" policies is obvious: the "Possible" does not mean that it actually does occur! A policy that made Bill Gates $100 wealthier while making the poorest person $90 poorer would likely be condemned by a variety of social welfare functions. But it is "**Possibly** Pareto Improving" (even if it is improbable that it actually will be). Policymakers could justify a progressive tax on the theory that it distributes some of these Possible Pareto gains from the winners to the losers, but the connection between this progressive tax and other policies is often lost.

The typical economist's tool of "Cost-Benefit Analysis" (CBA) has this same shortcoming. This would add up the marginal costs of some policy, add up the marginal benefits, and then make the change if the benefits outweighed the costs. Again this avoids all questions of who gets the net (social) profit! Cost-Benefit Analysis is the same as Possible Pareto Improving. A policy that provides $100 of benefits to the rich while imposing $90 of costs on the poorest would

pass a CBA even though it might be considered inequitable. (And if the benefits are in the future while costs are in present then compensation is difficult. Government deficits can be thought of as shifting consumption from future generations to the present.)

> "From Angus Deaton's superb new book, The Great Escape: Health, Wealth, and the Origins of Inequality: Economists — my own tribe — think that people are better off if they have more money — which is fine as far as it goes. So if a few people get a lot more money and most people get little or nothing, but do not lose out, economists will usually argue that the world is a better place. And indeed there is enormous appeal to the idea that, as long as no one gets hurt, better off is better; it is called the Pareto criterion. Yet this idea is completely undermined if wellbeing is defined too narrowly; people have to be better off, or no worse off, in wellbeing, not just in material living standards. If those who get rich get favorable political treatment, or undermine the public health or education systems, so that those who do less well lose out in politics, health, or education, then those who have done less well may have gained money but they are not better off. One cannot assess society, or justice, using living standards alone. Yet economists routinely and incorrectly apply the Pareto argument to income, ignoring other aspects of wellbeing." Bill Gardner, *http://theincidentaleconomist.com/wordpress/quote-inequalities-in-income-health-and-wellbeing/*
>
> Also see this on cost-benefit assumptions
> http://econospeak.blogspot.com/2014/11/numeraire-shmoo-meraire-nature-doesnt.html

It is not clear how a society would choose sustainability over other social desires. Nevertheless, suppose it were – could we measure how sustainable a society is, or is becoming? (On old theory that what isn't measured can't be managed.)

Measuring Sustainability

Define "Total Capital" as man-made capital (machines) plus human capital (knowledge and expertise) plus natural capital (from the ecosystem). Write

$$K_{total} = K_{made} + K_H + K_{Natural} .$$

Often distinguish between "strong" and "weak" sustainability

- *weak sustainability* implies that total capital does not decline – but this can include cases where natural capital is used to increase human or man-made capital. This assumes that each type of capital is a perfect substitute for the other. Also assumes that there is some metric to convert all of the types of capital into a single unit (usually present-value money) – otherwise how to add up machinery and university degrees with coal fields, biodiversity, and clean water?
- *strong sustainability* implies that at least some component of K_N cannot fall below some critical value – there are threshold effects. Precautionary Principle follows. The Stern Report on Climate Change ended up using this sort of argument to overcome the disagreements about measurement that are inherent in the previous definition.
- *Green Net National Product* (GNNP) proposed to supplement GNP to offset the depreciation of $K_{Natural}$. Augmented National Income takes Green but adds in

technological progress. Related is *Genuine Savings*, which gives net investment after depreciation of all of the capital amounts. So if Augmented National Income is not rising then economy is unsustainable.

- if economy has endogenous growth then this might be fast enough to overcome environmental degradation
- Other measures include "carbon footprint" (or other footprints) but these lack clear justification