Chapter 3 Lecture- Evaluating Trade-Offs: Benefit-Cost Analysis and Other Decision-Making Metrics

Econ 275 – Environmental Economics

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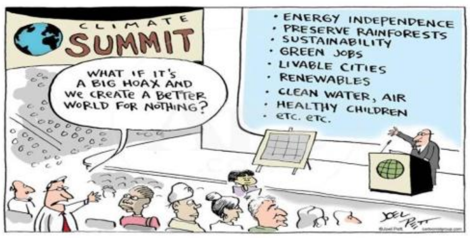

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Normative Criteria for Decision Making

- Benefit-cost analysis provides a method for determining whether or not an action should be supported.
- Most simply, if the benefits exceed the costs, then the action should be supported.

- Evaluating Predefined Options: Benefit-Cost Analysis
  - Let B be the benefits from a proposed action and C be the costs. Our decision rule would then be:
    - If B > C, support the action
    - Otherwise, oppose the action

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Normative Criteria for Decision Making

- Total benefits are the value of total willingness to pay, which is the area under the market demand curve from the origin to the allocation of interest.
- Opportunity cost is the net benefit lost when specific environmental services are forgone in the conversion to the new use.
- Total cost is the sum of marginal opportunity costs, which is the area under the marginal cost curve.

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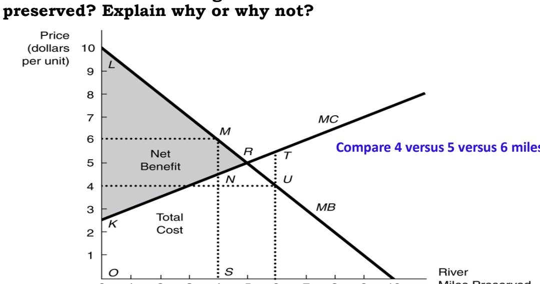
Normative Criteria for Decision Making

Consider the net benefits from preserving a stretch of river. Let's suppose that we are considering preserving a four-mile stretch of river and that the benefits and costs of that action are reflected in the figure below. Should that stretch be preserved? Explain why or why not?



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Chapter 3 Lecture- Evaluating Trade-Offs: Benefit-Cost Analysis and Other Decision-Making Metrics

Normative Criteria for Decision Making

- **Finding the Optimal Outcome**
  - **Use benefit-cost analysis to identify 'optimal'**
  - **Carry out normative analysis**
    - **Identify an optimal outcome**
    - **Discern the divergences between actual and optimal outcomes**
    - **Design appropriate policy solutions.**
  - **Examples include depleted fisheries, landfills, and waste.**

- **Relating Optimality to Efficiency**
  - **An allocation of resources is said to satisfy the static efficiency criterion if the economic surplus from the use of those resources is maximized by that allocation.**

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Normative Criteria for Decision Making

- **First Equimarginal Principle (the "*Efficiency Equimarginal Principle*"):**

  - **Net benefits are maximized when the marginal benefits from an allocation equal the marginal costs.**

- **Pareto optimality:**
  - **Allocations are said to be Pareto optimal if no other feasible allocation could benefit at least one person without any deleterious effects on some other person.**

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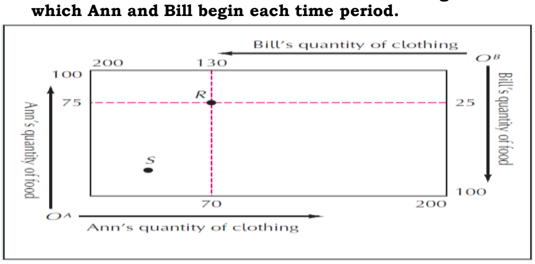
Pareto Optimality Explained

Simple economy in which there are only two consumers—Ann and Bill— and two goods, food and clothing.

- ***Allocation:* an assignment of these total amounts between Ann and Bill.**
- ***Initial endowments:* the amounts of the two goods with which Ann and Bill begin each time period.**



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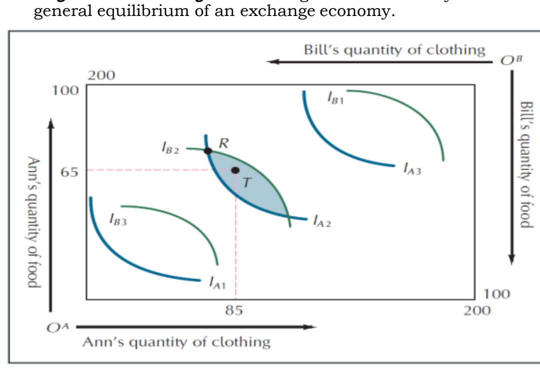
Edgeworth Exchange Box – Gains from Exchange

- ***Edgeworth exchange box:*** a diagram used to analyze the general equilibrium of an exchange economy.



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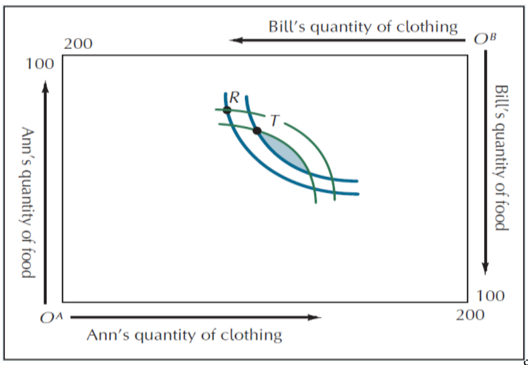
Further Gains from Exchange



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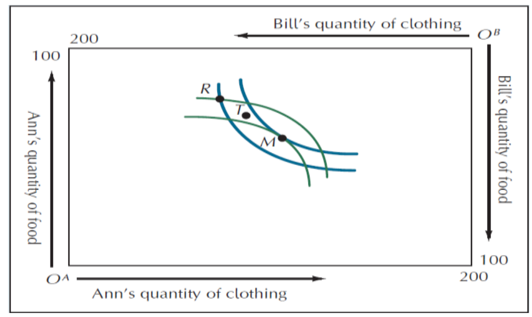
A Pareto-Optimal Allocation



Pareto optimal: **the term used to describe situations in which it is impossible to make one person better off without making at least some others worse off.**

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Back to Normative Criteria for Decision Making

Comparing Benefits and Costs Across Time

- **Present Value of a *one-time* net benefit (B_n) received n years from now is**

$$PV[B_n] = \frac{B_n}{(1+r)^n}$$

Where r is the interest rate and B_0 is the amount of net benefits received immediately

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Normative Criteria for Decision Making

- **The present value of a stream of net benefit {B_0,…, B_n) received over a period of n years is**

$$PV[B_0, \ldots, B_n] = \sum_{i=0}^{n} \frac{B_i}{(1+r)^i}$$

Where r is the interest rate and B_0 is the amount of net benefits received immediately.

- **The process of calculating the present value is called discounting, and the rate r is referred to as the discount rate.**

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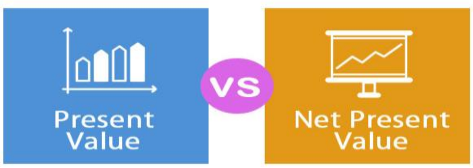
Demonstrating Present Value Calculations

Year	1	2	3	4	5	Sum
Annual Amounts	$3,000	$5,000	$6,000	$10,000	$12,000	$36,000
Present Value (r = 0.06)	$2,830.19	$4,449.98	$5,037.72	$7,920.94	$8,967.10	$29,205.92



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Normative Criteria for Decision Making

- As looked at earlier, an allocation is efficient or has achieved **static efficiency** if the net benefit from the use of those resources is maximized by that allocation.
- Thus, an efficient allocation will be achieved when marginal benefit and marginal cost are equal.

- **Dynamic Efficiency**
  - An allocation of resources across *n* time periods satisfies the dynamic efficiency criterion if it maximizes the present value of net benefits that could be received from all the possible ways of allocating those resources over the *n* periods.

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Applying the Concepts

- **Pollution Control**
  - Benefits include, but are not limited to, reduced death rate, lower incidences of chronic bronchitis and other diseases, better visibility, improved agricultural productivity
  - Costs include
    - higher costs passed to consumers such as installing, operating, and maintaining pollution control equipment
    - administrative costs such as designing, implementing, monitoring relevant policies.

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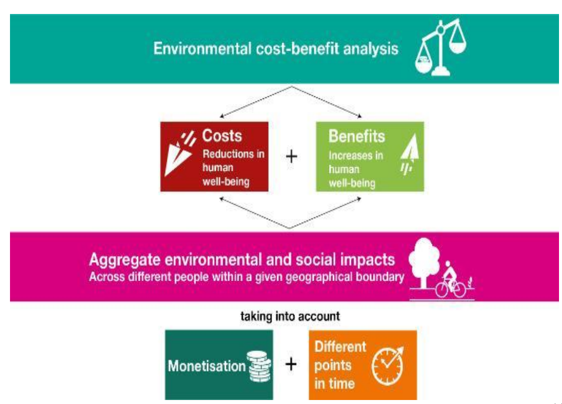

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Does Reducing Pollution Make Economic Sense? Evidence from the Clean Air Act

In its 1997 report to Congress, the EPA presented the results of its attempt to discover whether the Clean Air Act had produced positive net benefits over the period 1970–1990. The results suggested that the present value of benefits (using a discount rate of 5 percent) was $22.2 trillion, while the costs were $0.523 trillion. Performing the necessary subtraction reveals that the net benefits were therefore equal to $21.7 trillion. According to this study, US air pollution control policy during this period made very good economic sense.

Soon after the period covered by this analysis, substantive changes were made in the Clean Air Act Amendments of 1990 (the details of those changes are covered in later chapters). Did those additions also make economic sense?

In August of 2010, the US EPA issued a report of the benefits and costs of the Clean Air Act from 1990 to 2020. This report suggests that the costs of meeting the 1990 Clean Air Act Amendment requirements are expected to rise to approximately $65 billion per year by 2020 (2006 dollars). Almost half of the compliance costs ($28 billion) arise from pollution controls placed on cars, trucks, and buses, while another $10 billion arises from reducing air pollution from electric utilities.

These actions are estimated to cause benefits (from reduced pollution damage) to rise from roughly $800 billion in 2000 to almost $1.3 trillion in 2010, ultimately reaching approximately $2 trillion per year (2006 dollars) by 2020! For persons living in the United States, a cost of approximately $200 per person by 2020 produces approximately a $6,000 gain in benefits from the improvement in air quality. Many of the estimated benefits come from reduced risk of early mortality due to exposure to fine particulate matter. Table 3.3 provides a summary of the costs and benefits and includes a calculation of the benefit/cost ratio.

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Summary Comparison of Benefits and Costs from the Clean Air Act 1990–2020 (Estimates in Million 2006$)

	Annual Estimates			Present Value Estimate
	2000	2010	2020	1990–2020
Monetized Direct Costs:				
Low[1]				
Central	$20,000	$53,000	$65,000	$380,000
High[1]				
Monetized Direct Benefits:				
Low[2]	$90,000	$160,000	$250,000	$1,400,000
Central	$770,000	$1,300,000	$2,000,000	$12,000,000
High[2]	$2,300,000	$3,800,000	$5,700,000	$35,000,000
Net Benefits:				
Low	$70,000	$110,000	$190,000	$1,000,000
Central	$750,000	$1,200,000	$1,900,000	$12,000,000
High	$2,300,000	$3,700,000	$5,600,000	$35,000,000
Benefit/Cost Ratio:				
Low[3]	5/1	3/1	4/1	4/1
Central	39/1	25/1	31/1	32/1
High[3]	115/1	72/1	88/1	92/1

[1]The cost estimates for this analysis are based on assumptions about future changes in factors such as consumption patterns, input costs, and technological innovation. We recognize that these assumptions introduce significant uncertainty into the cost results; however, the degree of uncertainty or bias associated with many of the key factors cannot be reliably quantified. Thus, we are unable to present specific low and high cost estimates.

[2]Low and high benefit estimates are based on primary results and correspond to 5th and 95th percentile results from statistical uncertainty analysis, incorporating uncertainties in physical effects and valuation steps of benefits analysis. Other significant sources of uncertainty not reflected include the value of unquantified or unmonetized benefits that are not captured in the primary estimates and uncertainties in emissions and air quality modeling.

[3]The low benefit/cost ratio reflects the ratio of the low benefits estimate to the central costs estimate, while the high ratio reflects the ratio of the high benefits estimate to the central costs estimate. Because we were unable to reliably quantify the uncertainty in cost estimates, we present the low estimate as "less than X," and the high estimate as "more than Y," where X and Y are the low and high benefit/cost ratios, respectively.

Sources: U.S. Environmental Protection Agency, THE BENEFITS AND COSTS OF THE CLEAN AIR ACT, 1970 to 1990 (Washington, DC: Environmental Protection Agency, 1997), Table 18, p. 56;. and the U.S. Environmental Protection Agency Office of Air and Radiation, THE BENEFITS AND COSTS OF THE CLEAN AIR ACT, 1990 to 2020 – Summary Report, 8/16/2010 and Full Report available at http://www.epa.gov/oar/sect812/prospective2.html (accessed on 12/31/2010).

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The 1990 Clean Air Act Amendments prevent:

	Year 2010 (cases)	Year 2020 (cases)
Adult Mortality - particles	160,000	230,000
Infant Mortality - particles	230	280
Mortality - ozone	4,300	7,100
Chronic Bronchitis	54,000	75,000
Acute Myocardial Infarction	130,000	200,000
Asthma Exacerbation	1,700,000	2,400,000
Emergency Room Visits	86,000	120,000
School Loss Days	3,200,000	5,400,000
Lost Work Days	13,000,000	17,000,000

This chart shows the health benefits of the Clean Air Act programs that reduce levels of fine particles and Ozone.

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Applying the Concepts

Issues in Benefit Estimation

- **Primary versus secondary effects**
  - **Consider both primary and secondary consequences while implementing environmental projects.**
- **Accounting stance**
  - **Who benefits? The accounting stance refers to the geographic scale at which the benefits are measured.**
- **Aggregation**
  - **Estimations of benefits and costs must be aggregated to some level.**

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Applying the Concepts

With and without principle

- **The "with and without" principle states that only those benefits that would result from the project should be counted, ignoring those that would have accrued anyway.**

Tangible versus intangible benefits

- **Tangible benefits can reasonably be assigned a monetary value.**
- **Intangible benefits cannot be assigned a monetary value.**

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Applying the Concepts

Approaches to Cost Estimation

- **The survey approach**
  - **Involves asking polluters about their control costs**
- **The engineering approach**
  - **Using engineering information to estimate the technologies available and the costs of purchasing and using those technologies**
- **The combined approach**
  - **Combining both survey and engineering approaches**

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Applying the Concepts

- **Distribution of Benefits and Costs**
  - **Economic impact analysis**
    - **A broad characterization of who gains and who loses from a given policy**
  - **Equity analysis**
    - **Impacts on disadvantaged groups or sub-populations**
- **Choosing the Discount Rate**
  - **The appropriate rate to use will depend on the nature and expected lifetime of the project, who is doing the financing, and the level of risk.**

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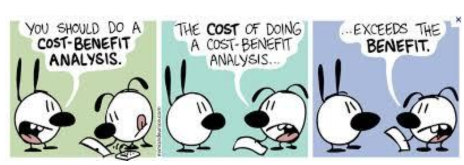
Divergence of Social and Private Discount Rates

A Critical Appraisal

- **When correctly implemented, benefit-cost analysis is a very useful tool in decision making.**
- **Concerns exist on the reliability of benefit-cost analysis when benefits or costs are difficult or impossible to quantify.**



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Cost-Effective Analysis

Second Equimarginal Principle (the Cost-Effectiveness Equimarginal Principle):

- **The least-cost means of achieving an environmental target will have been achieved when the marginal costs of all possible means of achievement are equal.**
- **In the case of pollution control, cost-effectiveness can be used to find the least-cost means of meeting a particular standard and its associated cost.**

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Pollution Damages

- **People have a willingness to pay to avoid damages caused by pollution**
- **We examine the Marginal Damages – additional damage caused by additional units of pollution (or higher ambient or surrounding concentrations)**
- **Marginal Damages tend to rise exponentially**
  - **A little pollution causes little or no damage**
  - **A safe 'threshold' level of emissions without damages may exist**
  - **At higher concentrations, damages increase at an increasing rate**
  - **For some, highly toxic pollutants, any emissions may cause large damages**

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Marginal Damages: Explain Why?

- **Location Matters**
  - **Damages may be higher in urban areas than rural areas**
- **Knowledge Matters**
  - **The more you know about the impacts of pollution, the more you are willing to pay to avoid it**
- **Tastes and Preferences Matter**
  - **If my child has asthma, I may be willing to pay more to reduce pollution**
- **Ability to Pay Matters**
  - **Pollution damages may be lower in low income areas**

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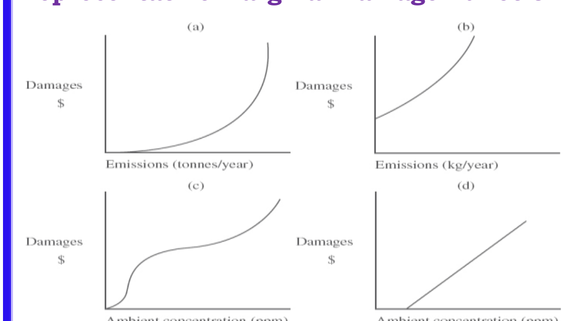
Representative Marginal Damage Functions



Ambient Concentration: Measure of environmental quality indicating the amount of pollutants found per unit volume in different environmental media.

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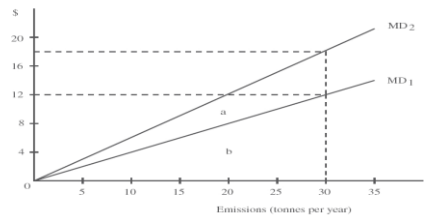
Marginal versus Total Damages



- Area b on the graph represents the Total Damages for curve MD_1.
- Area a + b on the graph represents the Total Damages for curve MD_2
- Which curve might represent an urban area and which might represent a rural area? Explain why.

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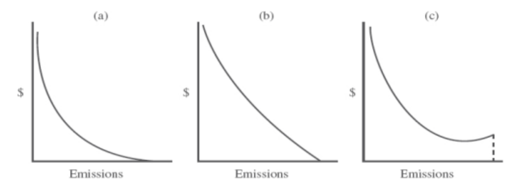
Abatement Costs

The Marginal Abatement Cost (MAC) Curve

- The cost of abating the next unit of emissions
- Rises exponentially as the amount of emissions to be abated increases
- The more pollution you abate, the higher the cost of abating the next unit of emissions because you have already abated the lowest cost units



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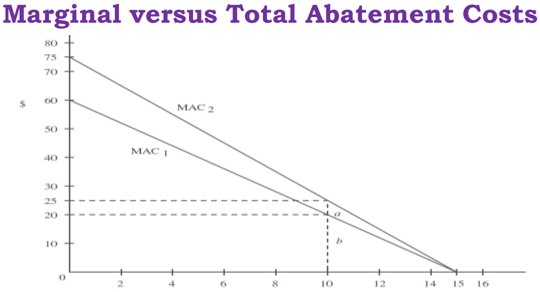
Marginal versus Total Abatement Costs



- The area under the Marginal Abatement Cost curve represents the Total Abatement Cost
- If technology to reduce abatement improves, the MAC curve will shift lower (MAC_1 versus MAC_2)

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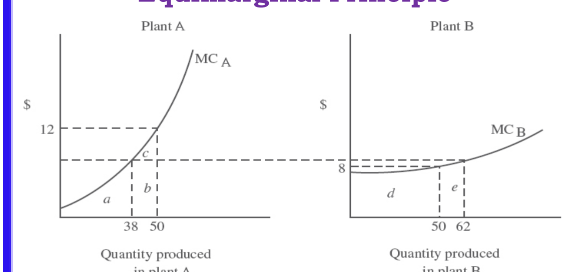
Equimarginal Principle



- The equimarginal principle requires that the total production be distributed among sources so that their marginal cost of production are equalized

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Equimarginal Principle

- **An aggregate MAC function (such as for several firms or factories) will <u>always</u> represent the minimum MAC achievable**
- **The aggregate level of emissions will be distributed among different sources in a way that equalizes MAC**
- **Under the equimarginal principle, abate the cheapest unit of pollution first, no matter which factory emits it**

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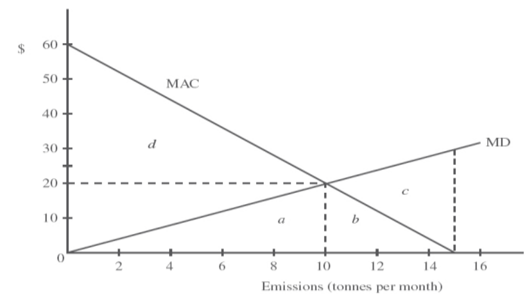
The Socially Efficient Level of Emissions

The socially efficient level of emissions is found where the MAC and the MD functions are equated



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Proving Social Efficiency Yields the Lowest Social Cost

- **Total social costs [the total costs of damages (area a) plus the total costs of abatement (area b)] are minimized at the level of emissions where MAC=MD (At 10 units of emissions)**
- **If emissions levels are higher or lower than the efficient level, the sum of the total costs of damages plus the total costs of abatement is higher than at the efficient level**
- **For example, at 15 units of emission, total social costs equal total damages (a + b + c). There are no abatement costs at this point, but the damages to society are very high. Emissions that cause high damages can be abated at low cost, improving social welfare**

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Impact Analysis

- **An impact analysis attempts to quantify the consequences of various actions.**
  - **A pure impact analysis does not convert all consequences into a one-dimensional measure, such as dollars, to ensure comparability.**
  - **Also, impact analysis does not necessarily attempt to optimize.**
  - **Impact analysis places a large amount of relatively undigested information at the disposal of the policy-maker.**
- **Impact analysis is useful when the data needed for either a benefit-cost analysis or a cost-effectiveness analysis is unavailable.**

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Future Uncertainty

Uncertainty may exist when anticipating future values of benefits and costs.

- **For example we are uncertain when and where an earthquake may strike. Therefore it is hard to estimate how much we extra we should spend today to make buildings strong to withstand an earthquake that may or may not occur in our lifetimes**
- **Probabilities can be created based on previous data or expert advice to help gauge the likelihood of future occurrences to better understand the risks involved.**

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Future Uncertainty

Scenario Analysis

- **We may want to create future scenarios to address uncertainty**
- **For example, calculating a benefit-cost analysis of reducing CO_2 emissions to lessen the greenhouse effect requires estimations of future energy saving technologies. As a result, scenarios can be presented based on "slow," "moderate," or "fast" advancement rate. Economic Efficiency and equitable distribution of cost and benefits must be taken into account when government introduces programs and policies.**

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TYPES OF ECONOMIC ANALYSIS

- **Economic impact analysis (EIA) --** What is the contribution of tourism activity to the economy of the region?
- **Benefit Cost analysis (B/C) –** Which policy will generate the highest net benefit to society over time?
- **Environmental Impact assessment –** What are the impacts of an action on the surrounding environment?
- **Fiscal impact analysis –** Will government revenues from tourism activity (taxes, direct fees, etc.) cover the added costs for infrastructure and government services
- **Demand analysis –** How will the number or types of tourists change due to changes in prices, promotion, competition, quality,etc.?
- **Feasibility study –** Can/should this project or policy be undertaken?
- **Financial analysis –** Can we make a profit from this activity?

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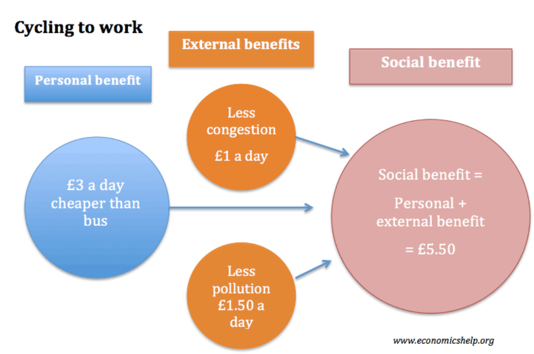
Looking at Benefits



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