Natural Resource Economics & Management

Οικονομικά και διαχείριση φυσικών πόρων

Lecture 4

Cost Benefit Analysis

Normative Criteria for Decision Making

- 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
- How do we measure benefits and costs?

Defining the subject

- CBA is a process of quantifying costs and benefits of a decision, program, or project (over a certain period), and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation.

  A CBA calculates net social benefits (*NSB*) for each policy alternative: net social benefits equal social benefits (*B*) minus social costs (*C*): ***NSB = B - C***

CBA measures the aggregate change in individual well-being resulting from a policy decision. Individual welfare is assumed to depend on the satisfaction of individual preferences, and monetary measures of welfare change are derived by observing how much individuals are willing to pay, i.e., willing to give up in terms of other consumption opportunities.

This approach can be applied to nonmarket "public goods" like environmental quality or environmental risk reduction as well as to market goods and services, although the measurement of nonmarket values is more challenging.

Defining the subject

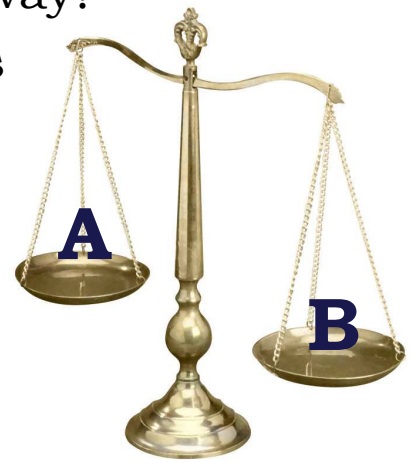
- There is no problem, public or personal, to which the Cost-Benefit analysis' broad ideas could not be applied.

- However, Cost-Benefit analysis is usually used as a tool to compare policy alternatives.

Some typical questions on which cost-benefit analysis has something to say are:

Should Thessaloniki expand its airport, or improve its water supply?
Should higher education expand, or invest on the subway?

How fast should we consume non-renewable resources and what are the costs and benefits of protecting the environment?



Policy A is more efficient than policy B if the net benefits are greater under policy A.

Why Value the Environment?

DEBATE:
Should Humans Place an Economic Value on the Environment?

Arne Naess, the late Norwegian philosopher, used the term *deep ecology* to refer to the view that the nonhuman environment has "intrinsic" value, a value that is independent of human interests. Intrinsic value is contrasted with "instrumental" value in which the value of the environment is derived from its usefulness in satisfying human wants.

Two issues are raised by the Naess critique: (1) What is the basis for the valuing of the environment? and (2) how is the valuation accomplished? The belief that the environment may have a value that goes beyond its direct usefulness to humans is in fact quite consistent with modern economic valuation techniques. As we shall see in this chapter, economic valuation techniques now include the ability to quantify a wide range of "nonuse" values as well as the more traditional "use" values.

Controversies over how the values are derived are less easily resolved. As described in this chapter, economic valuation is based firmly upon human preferences. Proponents of deep ecology, on the other hand, would argue that allowing humans to determine the value of other species would have no more moral basis than allowing other species to determine the value of humans. Rather, deep ecologists argue, humans should only use environmental resources when necessary for survival; otherwise, nature should be left alone. And, because economic valuation is not helpful in determining survival necessity, deep ecologists argue that it contributes little to environmental management.

Those who oppose all economic valuation face a dilemma: when humans fail to value the environment, it may be assigned a default value of zero in calculations designed to guide policy. A value of zero, however derived, will tend to justify a great deal of environmental degradation that could not be justified with proper economic valuation. As a 1998 issue of *Ecological Economics* demonstrated, a number of environmental professionals now support economic valuation as a way to demonstrate the enormous value of the environment to modern society. At the very least, support seems to be growing for the proposition that economic valuation can be a very useful means of demonstrating when environmental degradation is senseless, even when judged from a limited anthropomorphic perspective.

Sources: R. Costanza et al., "The Value of Ecosystem Services: Putting the Issues in Perspective." ECOLOGICAL ECONOMICS, Vol. 25, No. 1 (1998), pp. 67–72; and Gretchen Daily and Katherine Ellison, THE NEW ECONOMY OF NATURE: THE QUEST TO MAKE CONSERVATION PROFITABLE (Washington, DC: Island Press, 2003).

Why Value the Environment?

DEBATE:
Should Humans Place an Economic Value on the Environment?

Inderst, R., Sartzetakis, E. and Xepapadeas, A. (2021) Technical Report on Sustainability and Competition

Individuals view the environment from many different perspectives. Consider, for example, the value of a wild animal. To humans it may have instrumental value[1] because it provides value as an exploitable resource (as food or labor), and/or as a source of emotional, recreational, aesthetical, or spiritual experience. In addition to the value it creates for others, a wild animal may also have value unto itself – that is, intrinsic value[2] – that needs to be recognized and respected. It has been argued that if an entity possesses intrinsic value, it "generates a prima facie direct moral duty on the part of moral agents to protect it or at least refrain from damaging it."[3] A substantial literature on environmental ethics that arose in the early 1970s[4] challenges a purely anthropocentric approach, positing new directions such as enlightened anthropocentrism, biocentrism, new animism, and deep ecology. An important point that differentiates these approaches concerns the attribution of intrinsic value – that is, whether only humans, or only animals,[5] or all natural entities including flora, mountains, and rivers, have intrinsic value. Another important point is whether comparisons between these values are permitted, that is, whether hunting or using animals in experiments should be allowed when the results of these actions provide value to humans.

[1] Defined as the value of an entity as means to achieve an end.
[2] Defined as the value of an entity as an end in itself.
[3] See Brennan and Lo (2020, p. 2). On the issue of intrinsic value, see also Nash (1989) and Jamieson (2002).
[4] Building on the classic works of Rachel Carson's *Silent Spring* (1963), Paul Ehrlich's *The Population Bomb* (1968) and Dennis Meadows et al. *The Limits to Growth* (1972).
[5] Those that can experience happiness and pain, including all animal species.

Why Value the Environment?

- Valuing Environmental Services: Pollination as an Example
  - Multiple benefits including nonmarket impacts

- Some 1,000,000 honeybee hives, or more than 40% of all the beehives in the US are required for crosspollination of the $2 billion almond crop in California. When the almond trees flower, managed honeybee hives are moved by flatbed trucks to the San Joaquin Valley to provide sufficient bees to pollinate the crop (Ratnieks and Carreck, 2010). Unfortunately this important ecosystem service may be in jeopardy. In 2006, the popular press began reporting on what has been called Colony Collapse Disorder, an unexplained disappearance of honeybee colonies. Beekeeper surveys suggest that 33 percent of honeybee colonies in the United States died in the winter of 2010. While the exact causes are, as of yet, unknown, multiple causes are likely to blame.

Valuation

- Economists have decomposed the total economic value conferred by resources into three main components:
  - Use Value
    - the willingness to pay for direct use of the environmental resource
  - Option Value
    - the willingness to pay for the *future* ability to *use* the environment
  - Nonuse Value
    - individuals' willingness to pay to preserve a resource that he or she will never use

- These categories of value can be combined to produce the total willingness to pay (TWP)

  - Total willingness to pay (TWP)

    TWP = Use Value + Option Value + Nonuse Value

Valuation

- Use Value
  - Examples include fish harvested from the sea, timber harvested from the forest, water extracted from a stream for irrigation, even the scenic beauty conferred by a natural vista (*passive-use values or nonconsumptive use values*).
- Option Value
  - Example: Are you planning to visit Valia *Calda* next summer? Perhaps not, but would you like to preserve the option to go someday?
- Nonuse Value
  - Bequest value is the willingness to pay to ensure a resource is available for your children
  - Existence value is measured by the willingness to pay to ensure that a resource continues to exist in the absence of any interest in future use.

Valuation

- Classifying Valuation methods
  - ➢ Revealed preference
    - Methods which are based on actual observable choices and from which actual resource values can be directly inferred
  - ➢ Stated preference
    - Methods to elicit respondents' willingness to pay when the value is not directly observable
- In summary:

Methods	Revealed Preference	Stated Preference
Direct	Market price	Contingent valuation
	Simulated markets	
Indirect	Travel cost	Attribute-based models
	Hedonic properties	Conjoint analysis
	Hedonic wages	Choice experiment
	Avoiding cost	Contingent Ranking

Source: Modified by the author from Mitchell and Carson, 1989.

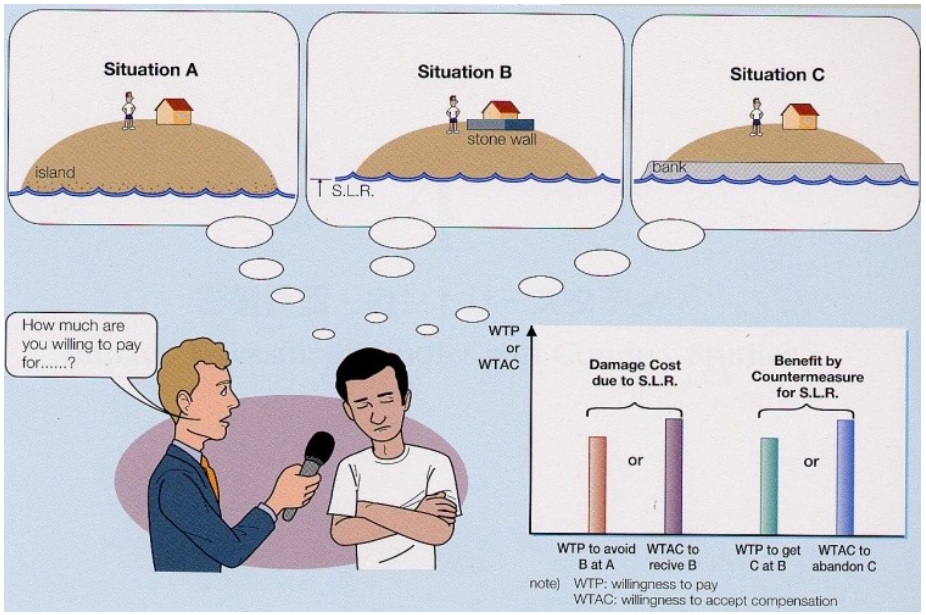
Valuation

I: Methods for environmental valuation using case-specific data	
Methods based on market choices (potentially in surrogate markets)	Examples: Discrete choice analysis of preferences revealed from actual purchases (e.g. of products that are more or less environmentally friendly) – Hedonic prices derived from surrogate markets, e.g. real estate prices
Methods based on hypothetical choices or stated preferences	Examples: Contingent valuation analysis based on surveys of stated preferences over hypothetical scenarios Conjoint analysis of (pairwise) choice between different scenarios Subjective well-being valuation based on correlating stated well-being with observable (environmental) variables and monetary values
II: Valuation methods for estimating and aggregating case-specific impact	
Dose-response approaches	Example: Estimating welfare through the impact on life expectancy or morbidity
Averting and defensive behavior	Example: Estimating avoided costs of defensive expenditures
III: Valuation using data from existing studies and databases	
Benefit transfer within a calibrated model	Example: Adjusting willingness-to-pay (e.g. obtained from contingent valuation) to different socioeconomics and demographics
Environmental prices databases	Example: Using environmental prices aggregating all health-related costs from the emission of a particular substance in a specific country
IV: Valuation derived from stated policy objectives	
Using market prices for permits or taxes on emissions	Example: CO_2 prices from the EU Emissions Trading System
Use of avoided abatement costs under a cost effectiveness analysis	Example: CO_2 prices based on an analysis and ranking of the costs of alternative abatement methods

Inderst, R., Sartzetakis, E. and Xepapadeas, A. (2021) Technical Report on Sustainability and Competition

I. Stated Preferences Methods

- Stated Preferences Methods
  - Contingent Valuation Method
    - It is to elicit people's willingness-to-pay (WTP) in a hypothetical market
    - Major concerns include strategic bias, information bias, starting-point bias, hypothetical bias and discrepancy between WTP and willingness-to-accept (WTA)
    - A NOAA panel (1993) legitimized the use of contingent valuation.
    - Benefit transfer methods
      - Value transfers, benefit function transfer, meta-analysis



Contingent Valuation Method

- The most common (direct) stated preference method is the contingent valuation method (CVM). It is a survey where respondents are asked what value they would place on some level of environmental change.

- Steps in a CVM:
  - Preparing a questionnaire
  - Choosing a survey technique
  - Choosing the sample
  - Analyzing the collected data to get the WTP and aggregate

Contingent Valuation Method

- Preparing a questionnaire

  Guidelines to be followed when preparing a questionnaire:

  - ❑ Conservative design
  - ❑ Accurate description on the environmental problem
  - ❑ Accurate description of the program/policy
  - ❑ Reminder of undamaged substitute commodities
  - ❑ Ask WTP instead of WTA
    - o Open-ended: ask respondents for maximum WTP.
    - o Close-ended: ask respondents whether they are WTP a certain amount, or ask them to choose between different ranges. This amount (or, these ranges) canvary across respondents.
    - o Bidding games: ask respondents whether they are WTP a certain amount. If yes, ask them about a higher amount, until the highest WTP is reached.
  - ❑ Referendum format when possible
  - ❑ Follow-up questions
  - ❑ Specify a believable and non-controversial payment mechanism
  - ❑ Collect demographic data about the respondent

Contingent Valuation Method

- Choosing a survey technique
  - ❑ Mail and Telephone surveys (voluntary response surveys).

Advantages	Disadvantages
Relatively inexpensive method	Self-selection bias Low response rate Demographic characteristics of the respondent cannot be verified Limited number of questions to be asked

  - ❑ Personal interviews:
    - o Better than voluntary response surveys BUT very expensive.

Contingent Valuation Method

- Choosing the sample
  - ❑ Identify the population to be affected by the program/policy
  - ❑ Sample size of 1,000 or more (when "yes-no" questions asked, according to NOAA guidelines)
  - ❑ A simple random sample (SRS) must be used
  - ❑ If the SRS selected is not representative of the population use stratified SRS

Contingent Valuation Method

- Analyzing the responses

  Once the data are collected there are two main categories econometric models to be used:

  - Parametric models
    - Logit
    - Probit
  - Non-parametric models
    - Turnbull estimation

Contingent Valuation Method

Example: bidding questions and Turnbull estimation

- The mayor of a small town wants to get an estimate about the value people (population of 2.000) place on the quality of the potable water. Upon the results of the estimation, the mayor will decide to undertake a public investment on placing new pipes and filters. The researchers selected to prepare a study, have randomly selected 24 people. Assume that the WTP of the individuals in the sample are given in the table below:

Individual	WTP	Individual	WTP	Individual	WTP
1	$5	**9**	$24	**17**	$37
2	$10	**10**	$26	**18**	$38
3	$12	**11**	$27	**19**	$42
4	$12	**12**	$28	**20**	$43
5	$13	**13**	$30	**21**	$44
6	$15	**14**	$31	**22**	$47
7	$17	**15**	$35	**23**	$49
8	$20	**16**	$36	**24**	$67

Contingent Valuation Method

Example continued..

- The researches randomly distribute questionnaires on the 24 individuals with the question being:
  - "Are you willing to pay $10 for the installation of new pipes and filters in the public water system?
  - If yes, are you willing to pay $20 for the installation of new pipes and filters in the public water system?...
  - ... If yes, are you willing to pay $50 for the installation of new pipes and filters in the public water system?"

- The responses they get are

Question	No
WTP up to $10	1
WTP up to $20	6
WTP up to $30	5
WTP up to $40	6
WTP up to $50	5
WTP more than $50	1

Contingent Valuation Method

Example continued..

- Turnbull estimator
  - Step 1: Using the data derive the counts of individuals for every WTP interval. Derive the probability of individual being on a specific interval.
  - Step 2: Derive the Cumulative Distribution. Check that it is increasing. If not you will have to "pool" the intervals between which the CDF is decreasing.
  - Step 3: Multiply each lower bound of a WTP by the probability and add up all the weighted WTP (lower-bound Turnbull estimator).
  - Step 4: Multiply each upper bound of a WTP by the probability and add up all the weighted WTP (upper-bound Turnbull estimator).

WTP	Counts	Prob.	CDF	Lower bound x Pr.	Upper bound x Pr.
$0 ≤ WTP < $10	1	0.042	0.042	0 x 0.042= $0.00	9.99 x 0.042 = $0.42
$10 ≤ WTP < $20	6	0.250	0.292	10 x 0.250 = $2.50	19.99 x 0.250 = $5.00
$20 ≤ WTP < $30	5	0.208	0.500	20 x 0.208 = $4.16	29.99 x 0.208 = $6.24
$30 ≤ WTP < $40	6	0.250	0.750	30 x 0.250 = $7.50	39.99 x 0.250 = $10.00
$40 ≤ WTP <$50	5	0.208	0.958	40 x 0.208 = $8.32	49.99 x 0.208 = $10.40
$50 ≤ WTP	1	0.042	1.000	50 x 0.042 = $2.10	80 x 0.042 = $3.36
				$24.58	**$35.42**

What's this???
For those who answer "yes" to all questions we must make an assumption about their maximum WTP. In this example the assumption is that maxWTP = $80

Contingent Valuation Method

Example continued..

- Assuming that the sample is representative of the population of 2.000, the total willingness to pay (total benefits) for the public project is

- Conservative estimation:

Total Benefits = 2000 x 24.58 = €49.160

- Aggressive estimation:

Total Benefits = 2000 x 35.42 = €70.840

Contingent Valuation Method

- Issues with CVMs: Cost
  - CVM is an expensive method. Possible alternatives include
  - meta-analysis. Meta-analysis utilizes a cross section of contingent valuation studies for determining non-use values.
  - benefits transfer. It involves the use of estimates from other places and other times being used for similar analysis elsewhere

- Issues with CVMs: Bias
  - Strategic bias is the tendency to overstate or understate WTP in order to affect policy.
  - Information bias occurs when respondents are forced to evaluate goods/attributes for which they have little or no experience.
  - Starting point bias is the tendency for reference points for bidding games to induce higher or lower responses.
  - Hypothetical bias is the tendency for hypothetical payments to differ from actual payments due to a difficulty in picturing the situation.
  - WTP versus WTA bias

Attribute-based methods

- Stated Preferences Methods (contd.)
  - Attribute-based methods
    - Choice-based, conjoint analysis, choice experiments
    - Contingent ranking

II. Revealed Preferences Methods

- Revealed Preferences Methods

  Revealed preference methods are those that are based on actual observable choices and/or goods that have market prices. Loss in value can be calculated easily if prices are directly observable. Indirect revealed preference methods utilize surrogate markets to infer a value. These techniques utilize spending on other goods in other markets in order to extract out the environmental value of that good.

  – Travel Cost Models infer values of recreational resources by determining how much visitors spent getting to a site and then using this information to estimate a demand curve for that site.

  – Hedonic property value and hedonic wage approaches use regression analysis to infer environmental values from spending on goods which include those values.

  – Averting Expenditures are designed to reduce the damage caused by pollution by taking some kind of averting action.

Travel Cost Models

- Travel-cost methods infer values of recreational resources by determining how much visitors spend getting to a site (for instance a park or a river) and then using this information to estimate a demand curve for that site.
- Example:

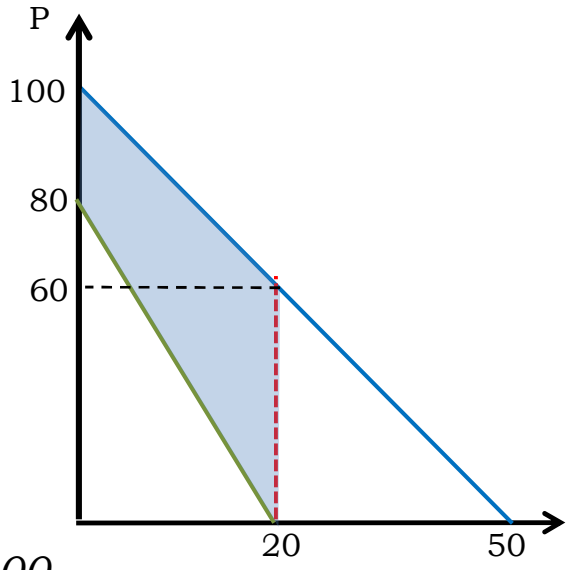
Using the travel cost method, some economists have estimated the demand for visiting two Ontario lakes, Ahmic Lake and Eagle Lake. Ahmic Lake is contaminated by seaweed. The demands for trips to these two lakes are:

$$P_E = 100 - 2Q_E$$

$$P_A = 80 - 4Q_A$$

What is the WTP to clean Lake Ahmic?

Assuming that one is considering going 20 times to each lake, the difference in the willingness to pay is the resulting trapezoid shape between the two demands. This can be a good proxy of the amount people are willing to pay in order to clean up Lake Ahmic.



Therefore:

$WTP = (100 + 60)(20)/2 - (80)(20)/2 = 800$

Hedonic Values & Averting Cost

- Hedonic property value and hedonic wage methods use regression analysis to infer environmental values from spending on goods that include those values. For example, property values are typically lower in areas with higher levels of air or water pollution. Houses near open space or with nice views will likely be more expensive than similar houses without those amenities. Similarly, workers in high-risk occupations receive higher wages for taking on that risk.

- The averting expenditure method identifies the actions and expenditures needed to reduce the damage caused by pollution. These expenditures can be used as a lower bound estimate of damages.

Hedonic Values & Averting Cost

Example:

- Smog has become a serious problem for the people in Hamilton, Ontario. To deal with the negative consequences of smog, some people in Hamilton buy air purifiers. The (inverse) demand for air purifiers in Hamilton has been estimated to be

$$P = 400 - 0.125Q_H$$

- People buy air purifiers for other reasons too (e.g., to clean up the air due to the presence of a smoker in the family). For example, people in Winnipeg, Manitoba, despite enjoying a smog free atmosphere, they have an inverse demand for air purifiers given by

$$P = 240 - 0.2Q_W$$

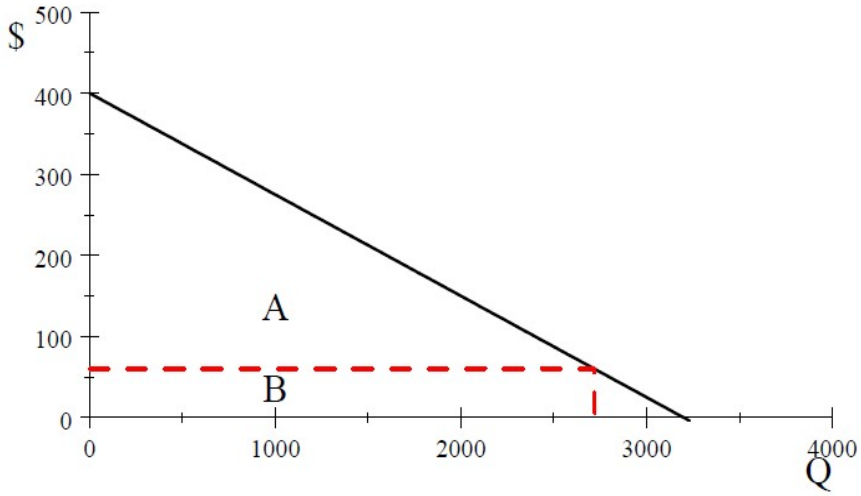
  - Currently the world price of an air purifier is $60. What is the value that people of Hamilton place on clean air?

Hedonic Values & Averting Cost

Example:

- The total willingness to pay for 2720 air purifiers equals the sum of areas A and B. One can think of this WTP as the amount of money people of Hamilton would be willing to pay in order to avert the damage caused from smog. Calculating this area, we get:

$$TWTP = (400+60)(2720)/2 = 625.600$$



When P=\$60 the quantity of air purifiers demanded is:

$60=400-0.125Q_H \Longrightarrow Q_H = 2720$

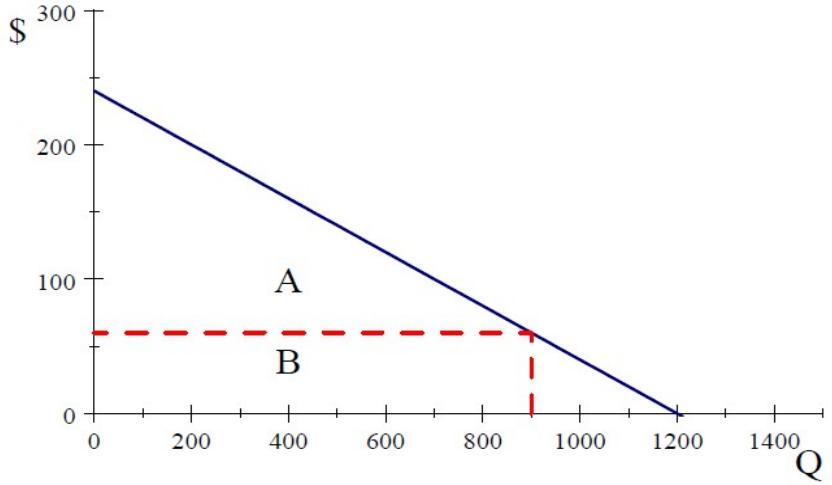
- However, the above amount represents the WTP for purifiers for ANY reason. To figure out what's the WTP ONLY because of smog we have to subtract from the above amount an amount equal to the WTP for purifiers to clean up smoke! We can interpret the WTP for air purifiers of people of Manitoba as the amount of money Hamiltonians would have been willing to pay for air purifiers IF they had no problem with smog (since the two cities are similar in their characteristics).

Hedonic Values & Averting Cost

Example:

- The total willingness to pay for 900 air purifiers equals the sum of areas A and B. Calculating this area, we get:

$$TWTP = (240+60)(900)/2 = 135.000$$



When P=\$60 the quantity of air purifiers demanded is:

$$60=240-0.2Q_W \Longrightarrow Q_W = 900$$

- Therefore, the actual willingness to pay for smog-clean air is the difference of what we have found in the two cases. That is,

$$WTP = 625.600 - 135.000 = 490.600$$

Valuing Human Life

- Valuing Human Life
  - Controversial subject
    - Focusing on calculating the change in the probability of death resulting from a reduction in some environmental risk and then placing a value on that change

Valuing Human Life

- It is common to take the "heroic" view that life is sacred and cannot be monetised.
- However, individuals make decisions everyday which involve undertaking health and mortality risks
  - Driving a car
  - Smoking a cigarette
  - Eating a medium-rare hamburger

- Also, we collectively have to make decisions in many fields – transport policy, health, environment, etc. that require to place a monetary value on life, or changing the average expectation of duration of life.

- Value of a Statistical Life (VSL) is **not about immortality** (how much one person could pay to avoid death)

- But rather, how much a great number of people should pay to avoid the probability that one of them would die prematurely.

Valuing Human Life

- The dominant benefit identified in benefit/cost analysis of the Clean Air Act (1970-90) was reduced premature mortality due to reductions in particulate matter, which contributed $16.6 trillion of the estimated mean benefits of $22.2 trillion (in constant 1990 dollars), or approximately 75% of the total economic benefit.

- But how do researchers go from risk assessment of a pollutant such as particulate matter to the economic value of premature mortality prevented by regulation?

- The main method used is the **value-of-statistical-life (VSL) approach**.

Valuing Human Life

- The value of statistical life is often used to estimate the benefits of reducing the risk of death (Viscusi 2003).
- The value of statistical life is an estimate of the financial value society places on reducing the average number of deaths by one.
- A related concept is the value of statistical life year, which estimates the value society places on reducing the risk of premature death, expressed in terms of saving a statistical life year.
- The value of statistical life is most appropriately measured by estimating how much society is willing to pay to reduce the risk of death.
- Therefore, it could be interpreted as the **demand for risk reductions**

Viscusi, W. Kip, and Joseph E. Aldy. 2003. The value of a statistical life: A critical review of market estimates throughout the world. *Journal of Risk and Uncertainty* 27:5–76.

Valuing Human Life

- In economic terms (VSL) is explained as a marginal rate of substitution between mortality risk and money (i.e., other goods and services).

$$VSL = \frac{\text{marginal utility of a small reduction in mortality risk}}{\text{marginal utility of a small change in income}}$$

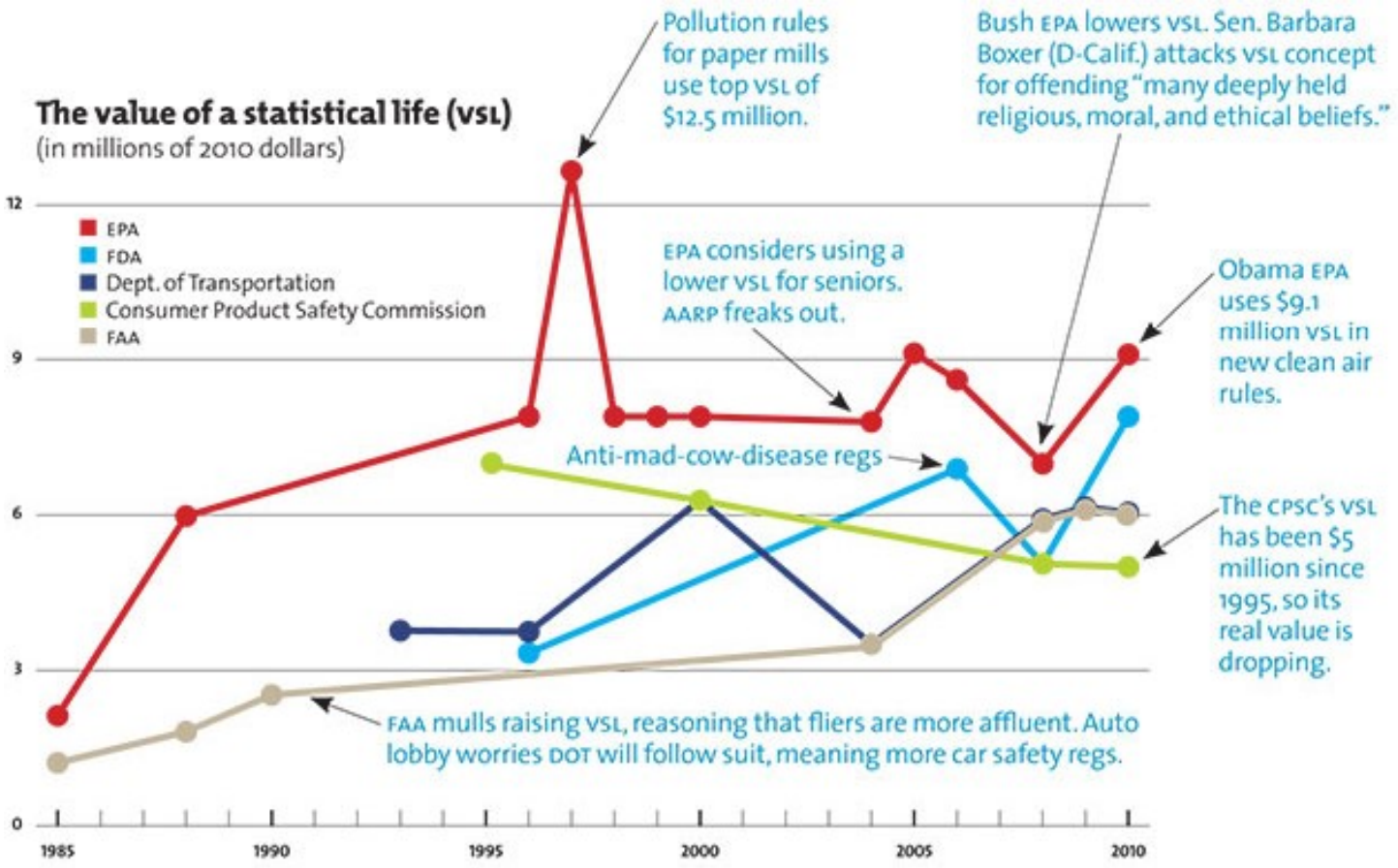
- While the WTP for an incremental risk change will be small, the numerical value of this ratio is very large.
  - For mortality risks (typically the risk of sudden death in the current period), empirical data on the tradeoffs that real people are willing to make often indicate a middle-of-the-road estimate of around $7,000,000.

Valuing Human Life

- Estimates of VSL that various agencies in the USA have used during the period 1985-2000, to estimate C-B in millions of dollars (in constant prices of 2000).

Food and Drug Administration (FDA)

Federal Aviation Administration (FAA)



Valuing Human Life

DEBATE:
Is Valuing Human Life Immoral?

In 2004 economist Frank Ackerman and lawyer Lisa Heinzerling teamed up to write a book that questions the morality of using benefit–cost analysis to evaluate regulations designed to protect human life. In *Priceless: On Knowing the Price of Everything and the Value of Nothing* (2004), they argue that benefit–cost analysis is immoral because it represents a retreat from the traditional standard that all citizens have an absolute right to be free from harm caused by pollution. When it justifies a regulation that will allow some pollution-induced deaths, benefit–cost analysis violates this absolute right.

Economist Maureen Cropper responds that it would be immoral not to consider the benefits of lifesaving measures. Resources are scarce and they must be allocated so as to produce the greatest good. If all pollution were reduced to zero, even if that were possible, the cost would be extremely high and the resources to cover that cost would have to be diverted from other beneficial uses. Professor Cropper also suggests that it would be immoral to impose costs on people about which they have no say—for example, the costs of additional pollution controls—without at least trying to consider what choices people would make themselves. Like it or not, hard choices must be made.

Cropper also points out that people are always making decisions that recognize a trade-off between the cost of more protection and the health consequences of not taking the protection. Thinking in terms of trade-offs should be a familiar concept. She points out that people drive faster to save time, thereby increasing their risk of dying. They also decide how much money to spend on medicines to lower their risk of disease or they may take jobs that pose morbidity or even mortality risks.

In her response to Ackerman and Heinzerling, Cropper acknowledges that benefit–cost analysis has its flaws and that it should never be the only decision-making guide. Nonetheless, she argues that it does add useful information to the process and throwing that information away could prove to be detrimental to the very people that Ackerman and Heinzerling seek to protect.

Sources: Frank Ackerman and Lisa Heinzerling, PRICELESS: ON KNOWING THE PRICE OF EVERYTHING AND THE VALUE OF NOTHING (New York: The New Press, 2004); Frank Ackerman, "Morality, Cost-Benefit and the Price of Life." ENVIRONMENTAL FORUM, Vol. 21, No. 5 (2004), pp. 46–47; and Maureen Cropper, "Immoral Not to Weigh Benefits Against Costs." ENVIRONMENTAL FORUM, 21, No. 5 (2004): 47–48.

Valuing Human Life

TABLE: The Cost of Risk-Reducing Regulations

	Agency Year and Status	Initial Annual Risk	Annual Lives Saved	Cost Per Life Saved (Millions of 1984 $)
Unvented Space Heaters	CPSC 1980 F	2.7 in 10^5	63.000	$.10
Cabin Fire Protection	FAA 1985 F	6.5 in 10^8	15.000	.20
Passive Restraints/Belts	NHTSA 1984 F	9.1 in 10^5	1,850.000	.30
Seat Cushion Flammability	FAA 1984 F	1.6 in 10^7	37.000	.60
Floor Emergency Lighting	FAA 1984 F	2.2 in 10^8	5.000	.70
Concrete and Masonry Construction	OSHA 1988 F	1.4 in 10^5	6.500	1.40
Hazard Communication	OSHA 1983 F	4.0 in 10^5	200.000	1.80
Benzene/Fugitive Emissions	EPA 1984 F	2.1 in 10^4	0.310	2.80
Radionuclides/ Uranium Mines	EPA 1984 F	1.4 in 10^4	1.100	6.90
Benzene	OSHA 1987 F	8.8 in 10^4	3.800	17.10

(continued)

Valuing Human Life

TABLE: The Cost of Risk-Reducing Regulations

	Agency Year and Status	Initial Annual Risk	Annual Lives Saved	Cost Per Life Saved (Millions of 1984 $)
Asbestos	EPA 1989 F	2.9 in 10^5	10.000	104.20
Benzene/Storage	EPA 1984 R	6.0 in 10^7	0.043	202.00
Radionuclides/ DOE Facilities	EPA 1984 R	4.3 in 10^6	0.001	210.00
Radionuclides/ Elemental Phosphorous	EPA 1984 R	1.4 in 10^5	0.046	270.00
Benzene/ Ethylbenzenol Styrene	EPA 1984 R	2.0 in 10^6	0.006	483.00
Arsenic/ Low-Arsenic Copper	EPA 1986 R	2.6 in 10^4	0.090	764.00
Benzene/ Maleic Anhydride	EPA 1984 R	1.1 in 10^6	0.029	820.00
Land Disposal	EPA 1988 F	2.3 in 10^8	2.520	3,500.00
Formaldehyde	OSHA 1987 F	6.8 in 10^4	0.010	72,000.00

Note: In the "Agency Year and Status" column, R and F represent Rejected and Final rule, respectively. "Initial Annual Risk" indicates annual deaths per exposed population; an exposed population of 10^3 is 1000, 10^4 is 10,000, and so on.

Source: Data from Tables 1 and 2 from "Economic Foundation of the Current Regulatory Reform Efforts" by W. Kip Viscusi, from JOURNAL OF ECONOMIC PERSPECTIVES, 10 (3) summer, 1996, pp. 119–134. Copyright © 1996 by W. Kip Viscusi. Reprinted with permission of American Economic Association.

CBA: advantages and criticism

- Advantages of CBA:
  - Transparency;
  - accountability;
  - framework for consistent data collection;
  - the ability to aggregate dissimilar effects (such as those on health, visibility, and crops) into one measure of net benefits (money metric).

- Criticism of CBA
  - can individual well-being be characterized in terms of preference satisfaction?
  - can aggregate social well-being be expressed as an aggregation (usually just a simple summation) of individual welfare?
    - can (should) we make trade-offs between one person's benefits and another person's costs?
  - empirical problems encountered in quantifying economic value and aggregating measures of individual welfare
    - how to monetize costs and benefits, what impacts are (especially over time), whether an impact is a cost or a benefit, and how to make trade-offs between the present and the future

CBA: Dependence on Wealth Distribution

The WTP of a person depends on the wealth of the individual. So, if the distribution of wealth of society changes, then individual WTP changes, and perhaps, the ranking of alternatives could change. Dependence of net benefits on distribution of wealth is not a problem if losers are actually compensated (*a la* Pareto principle). In the potential Pareto principle, however, it is possible that the policy could lower the sum of utilities if people with different levels of wealth have different marginal utilities of money (since the benefits and costs would be valued differently by different income groups). Therefore, the potential Pareto principle weakens for policies with costs and benefits concentrated on different wealth groups. However, if the potential Pareto principle is applied consistently, winners and losers would even out and the overall effect would be an increase in aggregate utility for everyone.

Critics of CBA question the validity of Pareto efficiency because it depends on the present distribution of wealth. They advocate creation of a social welfare function that maps utility, wealth, or consumption of society into an index ranking alternative distribution of goods. An efficient policy is then one that maximizes the value of the social welfare function. The social welfare function, in practice, must be provided by the analyst. The analyst can either:

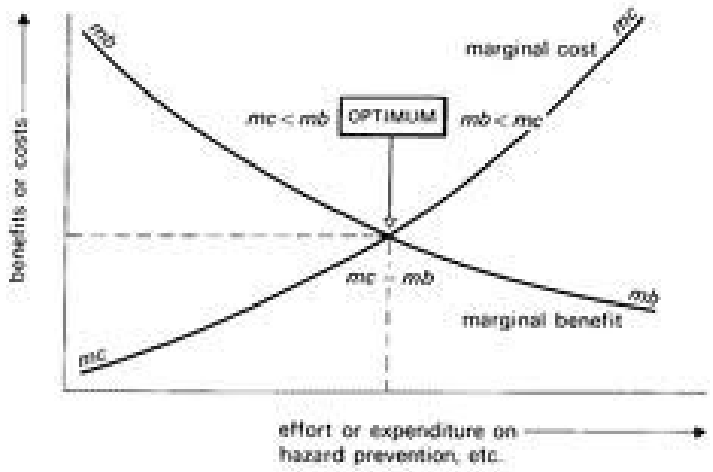
- Compare policies in terms of both efficiency and distributional criteria.
- Report net benefits by wealth or income group as well as for society as a whole.

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 costs is the sum of marginal opportunity costs, which is the area under the marginal cost curve.



EXAMPLE

Valuing Ecological Services from Preserved Tropical Forests

As Chapter 12 makes clear, one of the main threats to tropical forests is the conversion of forested land to some other use (agriculture, residences, and so on). Whether economic incentives favor conversion of the land depends upon the magnitude of the value that would be lost through conversion. How large is that value? Is it large enough to support preservation?

A group of ecologists investigated this question for a specific set of tropical forest fragments in Costa Rica. They chose to value one specific ecological service provided by the local forest: wild bees using the nearby tropical forest as a habitat provided pollination services to aid coffee production. While this coffee (*C. arabica*) can self-pollinate, pollination from wild bees has been shown to increase coffee productivity from 15 to 50 percent.

When the authors placed an economic value on this particular ecological service, they found that the pollination services from two specific preserved forest fragments (46 and 111 hectares, respectively) were worth approximately $60,000 per year for one large, nearby Costa Rican coffee farm. As the authors conclude:

> *The value of forest in providing crop pollination service alone is . . . of at least the same order [of magnitude] as major competing land uses, and infinitely greater than that recognized by most governments (i.e., zero).*

These estimates only partially capture the value of this forest because they consider only a single farm and a single type of ecological service. (This forest also provides carbon storage and water purification services, for example, and these were not included in the calculation.) Despite their partial nature, however, these calculations already begin to demonstrate the economic value of preserving the forest, even when considering only a limited number of specific instrumental values.

Source: Taylor H. Ricketts et al., "Economic Value of Tropical Forest to Coffee Production." PNAS (Proceedings of the National Academy of Science), Vol. 101, No. 34, August 24, 2002, pp. 12579–12582.

Normative Criteria for Decision Making

- Consider the net benefits from preserving a stretch of river using Figure 3.1. 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 Figure 3.1

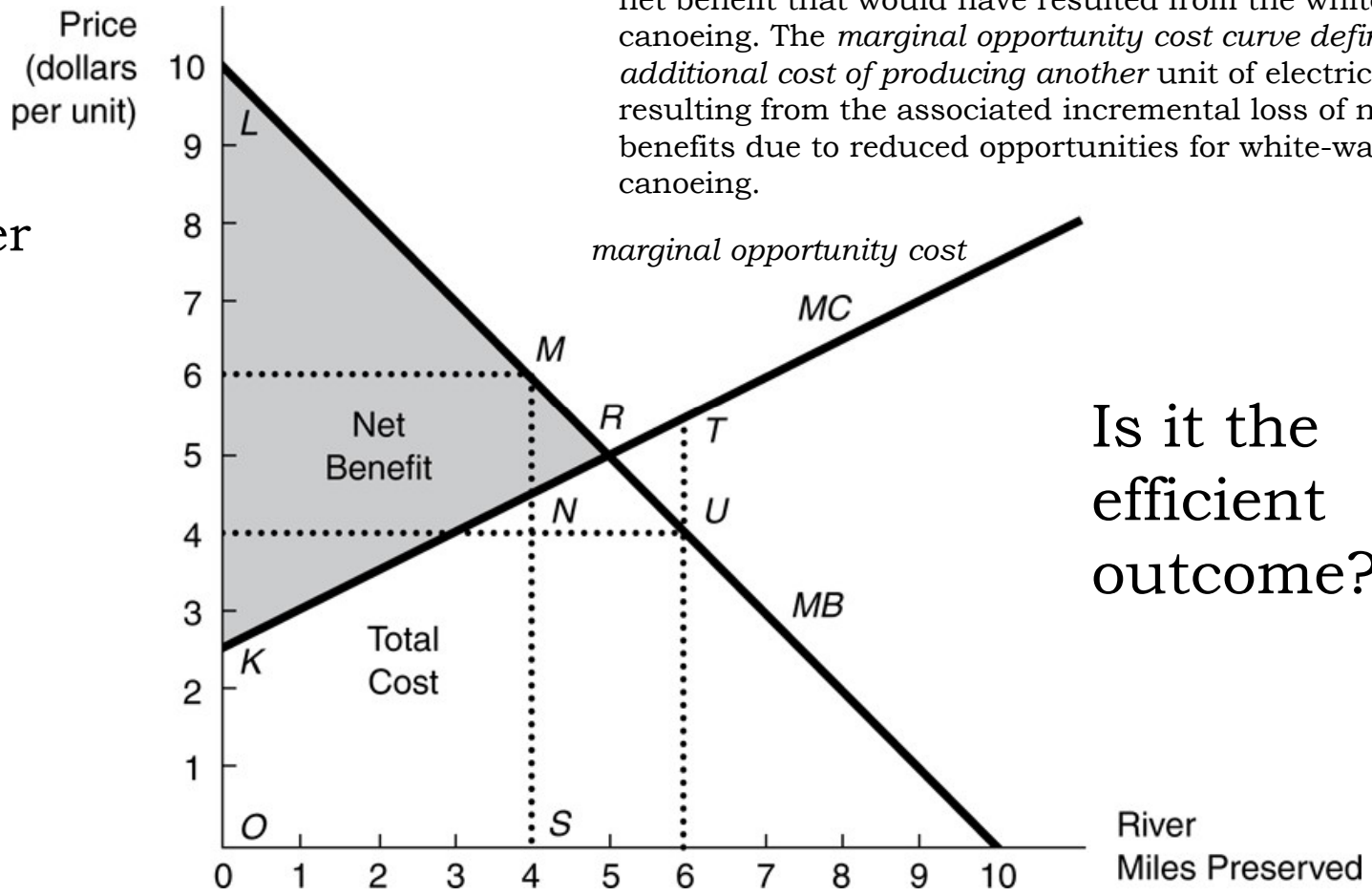
  – This part of the river can be used either for white-water canoeing or to generate electric power. Since the dam that generates the power would flood the rapids, the two uses are incompatible.

- Should that stretch be preserved? Explain why or why not?

The Derivation of Net Benefits

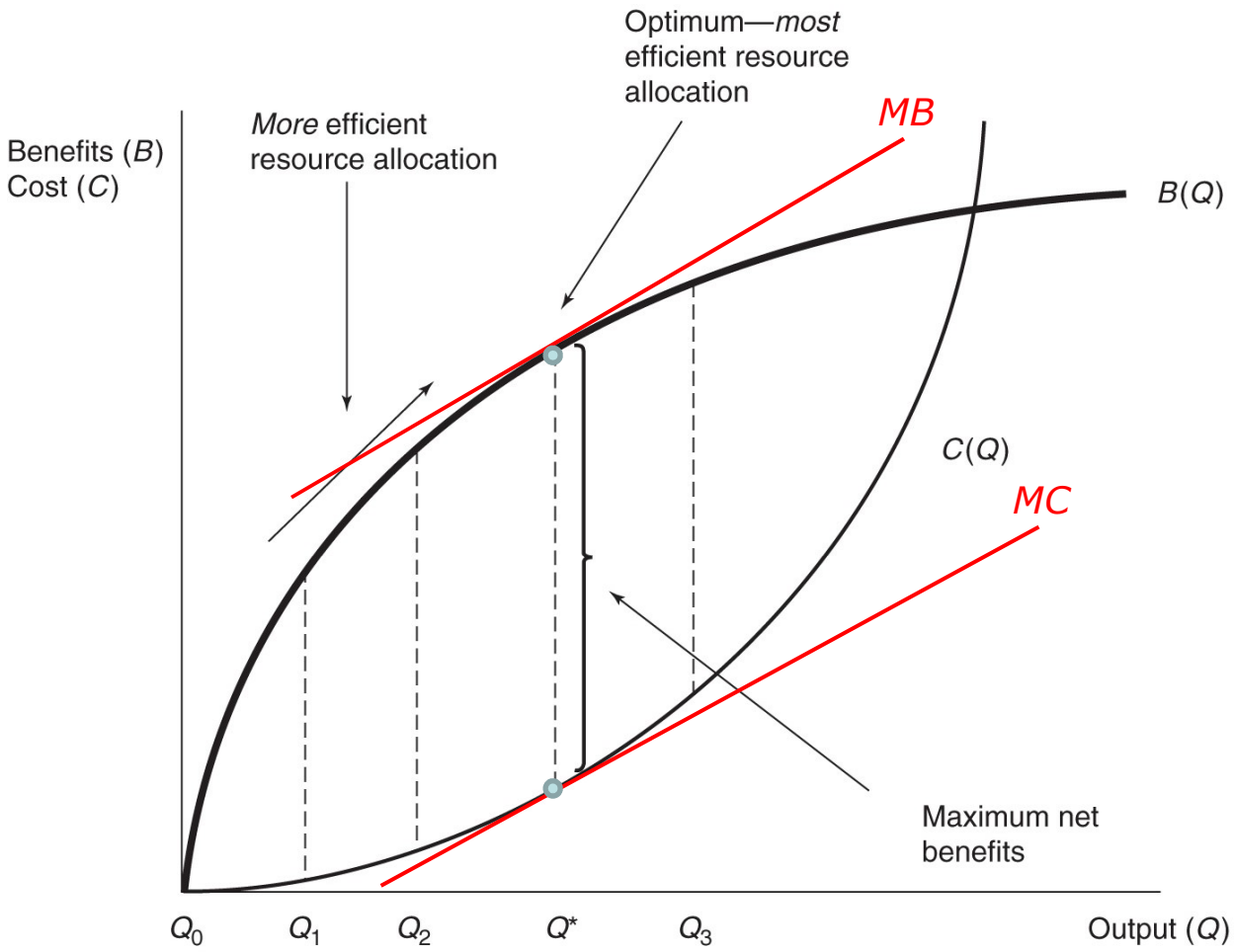
The opportunity cost of producing power is the foregone net benefit that would have resulted from the white-water canoeing. The *marginal opportunity cost curve defines the additional cost of producing another* unit of electricity resulting from the associated incremental loss of net benefits due to reduced opportunities for white-water canoeing.

The answer was yes (preserve the 4-mile stretch) because the net benefits from that action are positive.



Is it the efficient outcome?

Efficient outcome



Moving from Q_0 toward Q^* increases efficiency; that is: $NPV(Q^*) > NPV(Q_2) > NPV(Q_1) > NPV(Q_0)$

Moving beyond Q^* reduces efficiency, but Q_3 is more efficient than Q_0: $NPV(Q^*) > NPV(Q_3) > NPV(Q_0)$

Diagrammatical illustration of the highest NPV

Optimality and efficiency

Static efficiency, requires us to ask a rather different question, namely, what is the optimal (or efficient) number of miles to be preserved? (maximize net benefits)

First Equimarginal Principle (the "Efficiency Equimarginal Principle"): *Social net benefits are maximized when the social marginal benefits from an allocation equal the social marginal costs.*

It is efficient, but is it fair?

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.*

Optimality and efficiency

Efficient allocations are Pareto optimal. Since net benefits are maximized by an efficient allocation, it is not possible to increase the net benefit by rearranging the allocation.

Therefore, even if you have some losers, it is possible for the gainers to compensate the losers sufficiently;

The gains to the gainers would necessarily be larger than the losses to the losers.

Dependence on Wealth Distribution

The WTP of a person depends on the wealth of the individual. So, if the distribution of wealth of society changes, then individual WTP changes, and perhaps, the ranking of alternatives could change. Dependence of net benefits on distribution of wealth is not a problem if losers are actually compensated (*a la* Pareto principle). In the potential Pareto principle, however, it is possible that the policy could lower the sum of utilities if people with different levels of wealth have different marginal utilities of money (since the benefits and costs would be valued differently by different income groups). Therefore, the potential Pareto principle weakens for policies with costs and benefits concentrated on different wealth groups. However, if the potential Pareto principle is applied consistently, winners and losers would even out and the overall effect would be an increase in aggregate utility for everyone.

Critics of CBA question the validity of Pareto efficiency because it depends on the present distribution of wealth. They advocate creation of a social welfare function that maps utility, wealth, or consumption of society into an index ranking alternative distribution of goods. An efficient policy is then one that maximizes the value of the social welfare function. The social welfare function, in practice, must be provided by the analyst. The analyst can either:

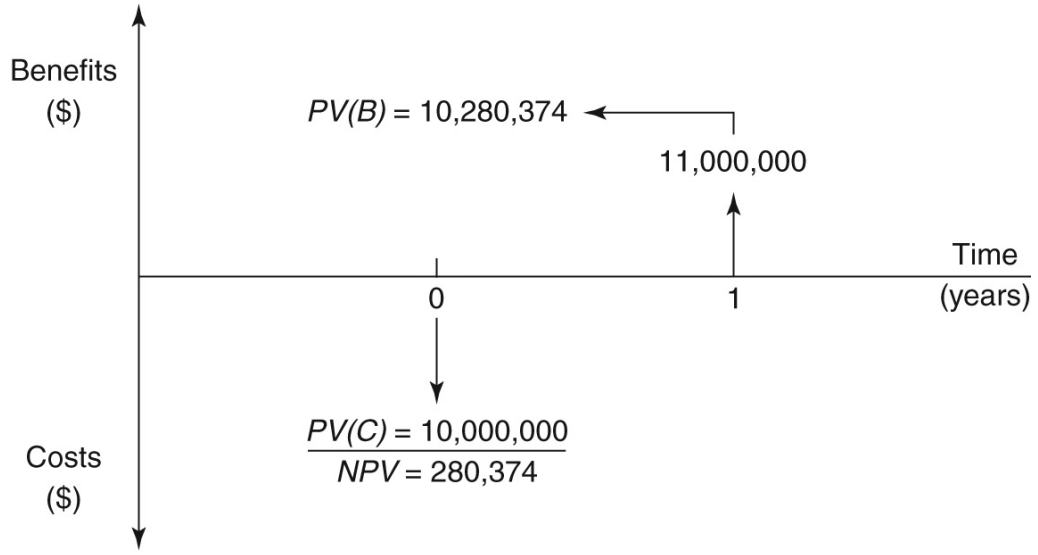
- Compare policies in terms of both efficiency and distributional criteria.
- Report net benefits by wealth or income group as well as for society as a whole.

Basics of discounting

- **Net Present Value Analysis** – Choose the project with the largest net present value, which calculates the sum of the present values of all the benefits and costs of a project (including the initial investment):

$$NPV = PV(benefits) - PV(costs) \qquad (3)$$

Usually projects are evaluated relative to the status quo. If there is only one new potential project and its impacts are calculated relative to the status quo, it should be selected if its NPV > 0, and should not be selected if its NPV < 0. If the impacts of multiple, mutually exclusive alternative projects are calculated relative to the status quo, one should choose the project with the highest NPV, as long as this project's NPV > 0. If the NPV < 0 for all projects, one should maintain the status quo.



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

Normative Criteria for Decision Making

However, many of the decisions made now have consequences that persist well into the future. Time is a factor.

How can we make choices when the benefits and costs may occur at different points in time?

The present value of a stream of net benefit $\{B_0,\ldots, B_n\}$ 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

Compounding & discounting

- **Future Value over Multiple Years** – Interest is compounded when an amount is invested for a number of years and the interest earned each period is reinvested.
- Interest on reinvested interest is called compound interest.
- The future value, *FV*, of an amount *X* invested for *n* years with interest compounded annually at rate *i* is:

$$FV = X(1+i)^n \qquad (4)$$

Year	*Beginning of Year Balance ($ millions)*	*Annual Interest ($ millions)*	*End of Year Balance ($ millions)*
1	10.000	0.700	10.700
2	10.700	0.749	11.449
3	11.449	0.801	12.250
4	12.250	0.858	13.108
5	13.108	0.918	14.026

Increases over time

The government invests 10 mil. with interest compounded annually at a rate 7% for 5 years

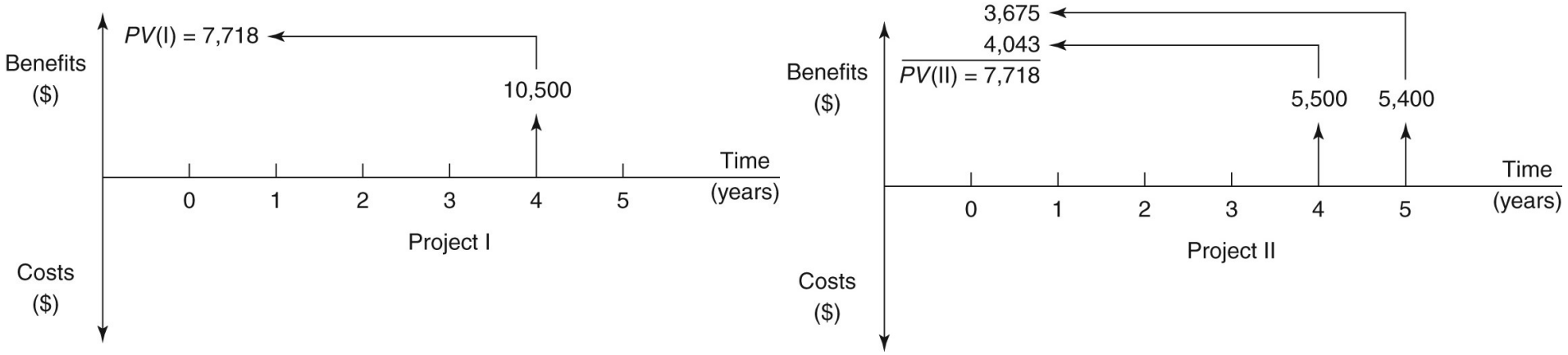
Compounding & discounting

- **Present Value over Multiple Years** – The present value, *PV*, of an amount Y received in *n* years, with interest compounded annually at rate *i* is:

$$PV = \frac{Y}{(1+i)^n}$$

- The present value for a stream of benefits or costs over *n* years *is*:

$$PV(B) = \sum_{t=o}^{n} \frac{B_i}{(1+i)^t} \qquad PV(C) = \sum_{t=o}^{n} \frac{C_i}{(1+i)^t}$$



Example: Compare the above two alternative projects:

PV(I) = 7,718 *PV(II) = 7,718*

Demonstrating Present Value Calculations

Suppose you were investigating an allocation that would yield the following pattern of net benefits on the last day of each of the next five years: $3,000, $5,000, $6,000, $10,000, and $12,000. If you use an interest rate of 6 percent (*r = 0.06) and the above formula, you will discover that this stream has a present value* of $29,205.92.

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

Interpreting Present Value Calculations

What does that number mean? If you put $29,205.92 in a savings account earning 6 percent interest and wrote yourself checks, respectively, for $3,000, $5,000, $6,000, $10,000, and $12,000 on the last day of each of the next five years, your last check would just restore the account to a $0 balance

Year	1	2	3	4	5	6
Balance at Beginning of Year	$29,205.92	$27,958.28	$24,635.77	$20,113.92	$11,320.75	$0.00
Year-End Fund Balance before Payment ($r = 0.06$)	$30,958.28	$29,635.77	$26,113.92	$21,320.75	$12,000.00	
Payment	$3,000	$5,000	$6,000	$10,000	$12,000	

Thus, you should be indifferent about receiving $29,205.92 now or in the specific five-year stream of benefits totaling $36,000; given one, you can get the other. Hence, the method is called present value because it translates everything back to its current worth.

Normative Criteria for Decision Making

- 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.

Applying the Concepts

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

EXAMPLE

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, U.S. 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 U.S. 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.

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

	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).

Applying the Concepts

- One of the most basic conflicts faced by environmental policy occurs when a currently underdeveloped but ecologically significant piece of land becomes a candidate for development.
- Preservation Versus Development
  - Benefits include improved economic welfare from increasing employment, rise of income and etc
  - Costs include degradation of ecosystem.
  - Example of mining in Chalkidiki or Kozani

EXAMPLE

Choosing between Preservation and Development in Australia

The Kakadu Conservation Zone, a 50-square-kilometer area lying entirely within the Kakadu National Park (KNP), was initially set aside by the government as part of a grazing lease. The current issue was whether it should be mined (it was believed to contain significant deposits of gold, platinum, and palladium) or added to the KNP, one of Australia's major parks. In recognition of its unique ecosystem and extensive wildlife as well as its aboriginal archeological sites, much of the park has been placed on the U.N. World Heritage List.

Mining would produce income and employment, but it could also cause the ecosystems in both the KCZ and KNP to experience irreversible damage. What value was to be placed on those risks? Would those risks outweigh the employment and income effects from mining?

To provide answers to these crucial questions, economists conducted a benefit–cost analysis using a technique known as contingent valuation. (We shall go into some detail about how this technique works in Chapter 4, but for now it can suffice to note that this is a technique for eliciting "willingness-to-pay" information.) The value of preserving the site was estimated to be A$435 million, while the present value of mining the site was estimated to be A$102 million.

According to this analysis, preservation was the preferred option and it was the option chosen by the government.

Source: Richard T. Carson, Leanne Wilks, and David Imber, "Valuing the Preservation of Australia's Kakadu Conservation Zone." OXFORD ECONOMIC PAPERS, Vol. 46, Supplement (1994), pp. 727–749.

Applying the Concepts

- Issues in Benefit Estimation
  - Primary Versus Secondary Effects

(Ex.: the primary effect of cleaning a lake will be an increase in recreational uses of the lake. This primary effect will cause a further ripple effect on services provided to the increased number of users of the lake.

Are these secondary benefits to be counted? In general, they should be counted in high unemployment areas or when the particular skills demanded are underemployed)

- Considering 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.

Applying the Concepts

- Issues in Benefit Estimation (contd.)
  - 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. (How are intangible benefits to be handled? One answer is perfectly clear: They should not be ignored.)

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

Applying the Concepts

- The Treatment of Risk
- Suppose we have a range of policy options *A, B, C, D and a range of possible* outcomes *E, F, G for each of these policies depending on how the economy evolves* over the future (example: low, medium, or high demand growth).
- Thus, if we choose policy *A*, we might end up with outcomes *AE, AF, or AG. Each of the other policies has three* possible outcomes as well, yielding a total of 12 possible outcomes.
- Even if we examine all 12 possibilities, the policy that maximizes net benefits for E may be different from that which maximizes net benefits for F or G. Thus, if we only knew which outcome would prevail, we could select the policy that maximized net benefits; the problem is that we do not. Furthermore, choosing the policy that is best if outcome E prevails may be disastrous if G results instead.
- How do we choose the optimal policy?

Applying the Concepts

- The Treatment of Risk
  - A dominant policy is one which confers the higher net benefits in every outcome.
  - The expected value of net benefits is the sum over the possible outcomes of the present value of net benefits of that outcome weighted by its probability of occurrence.

$$EPVNB_j = \sum_{i=0}^{I} P_i PVNB_{ij}, \quad j = 1,\ldots,F \quad (3.1)$$

where

$EPVNB_j$ = expected present value of net benefits for policy j

P_i = probability of the ith outcome occurring

$PVNB_{ij}$ = present value of net benefits for policy j if outcome i prevails

$\mathcal{J}$ = number of policies being considered

I = number of outcomes being considered

  - The policy selected should be the one with the highest expected present value of net benefits.

Applying the Concepts

- The Treatment of Risk
- *Risk-neutrality:* You are given the choice between a definite $50 or entering a lottery with 50% chance of winning $100 and a 50% chance of winning nothing. (EV = $50 = 0.5($100) + 0.5($0)). If you are indifferent between the two you would be said to be risk-neutral, if you view the lottery as more attractive, you would be exhibiting *risk-loving behavior, while a preference for the definite $50 would* suggest *risk-averse behavior.*

- Using the EPVNB approach implies that society is risk-neutral. Is it?
- "when the risks of a public investment are publicly borne, the total cost of risk-bearing is insignificant and, therefore, the government should ignore uncertainty in evaluating public investments." (Arrow and Lind, 1970)

- When the decision is irreversible, considerably more caution is appropriate. Irreversible decisions may subsequently be regretted, but the option to change course will be lost forever. (Arrow and Fisher, 1974)

Applying the Concepts

- Distribution of Benefits and Costs
- We should also consider the distributional impacts of costs and benefits as part of any economic analysis.
- Distributional analysis can take two forms:
  - Economic impact analysis
    - a broad characterization of who gains and who loses from a given policy
  - An equity analysis
    - Impacts on disadvantaged groups or sub-populations

Applying the Concepts

- Choosing the Discount Rate
- The discount rate can be defined conceptually as the social opportunity cost of capital.

- The choice of *r* is extremely important
  - Ex.: a project imposes an immediate cost of $4,000,000 (today's dollars), and derives $5,500,000 benefits in 5 years.
  - For $r=5\%$: $5{,}500{,}000/(1+0{,}05)^5 = 4{,}309{,}393{,}9$ (C<B)
  - For $r=10\%$: $5{,}500{,}000/(1+0{,}1)^5 = 3{,}415{,}067{,}3$ (C>B)
- 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

Does the choice of the discount rate matter?

- Yes – choice of the rate can affect policy choices.

  Generally, low discount rates favor projects with the highest total benefits, while high SDRs rates favor projects where the benefits are front-end loaded.

- Example: The government has a budget of 100.000 to be spend on one of the following 3 projects with the net yearly benefits presented in the Table. As you can see the ranking of the projects depends on the value of the discount rate. Low discount rates favor projects with great value regardless of the timing, while high discount rates favor front-end loaded projects

Year	*Project A*	*Project B*	*Project C*
0	−80,000	−80,000	−80,000
1	25,000	80,000	0
2	25,000	10,000	0
3	25,000	10,000	0
4	25,000	10,000	0
5	25,000	10,000	140,000
NPV ($i = 2\%$)	37,836	35,762	46,802
NPV ($i = 10\%$)	14,770	21,544	6,929

Theory of the discount rate choice

- To understand the theoretical foundation of discounting, one must recognize that it is rooted in the preferences of individuals.

marginal rate of time preference

Individuals tend to prefer to consume a given amount of benefits immediately, rather than in the future.

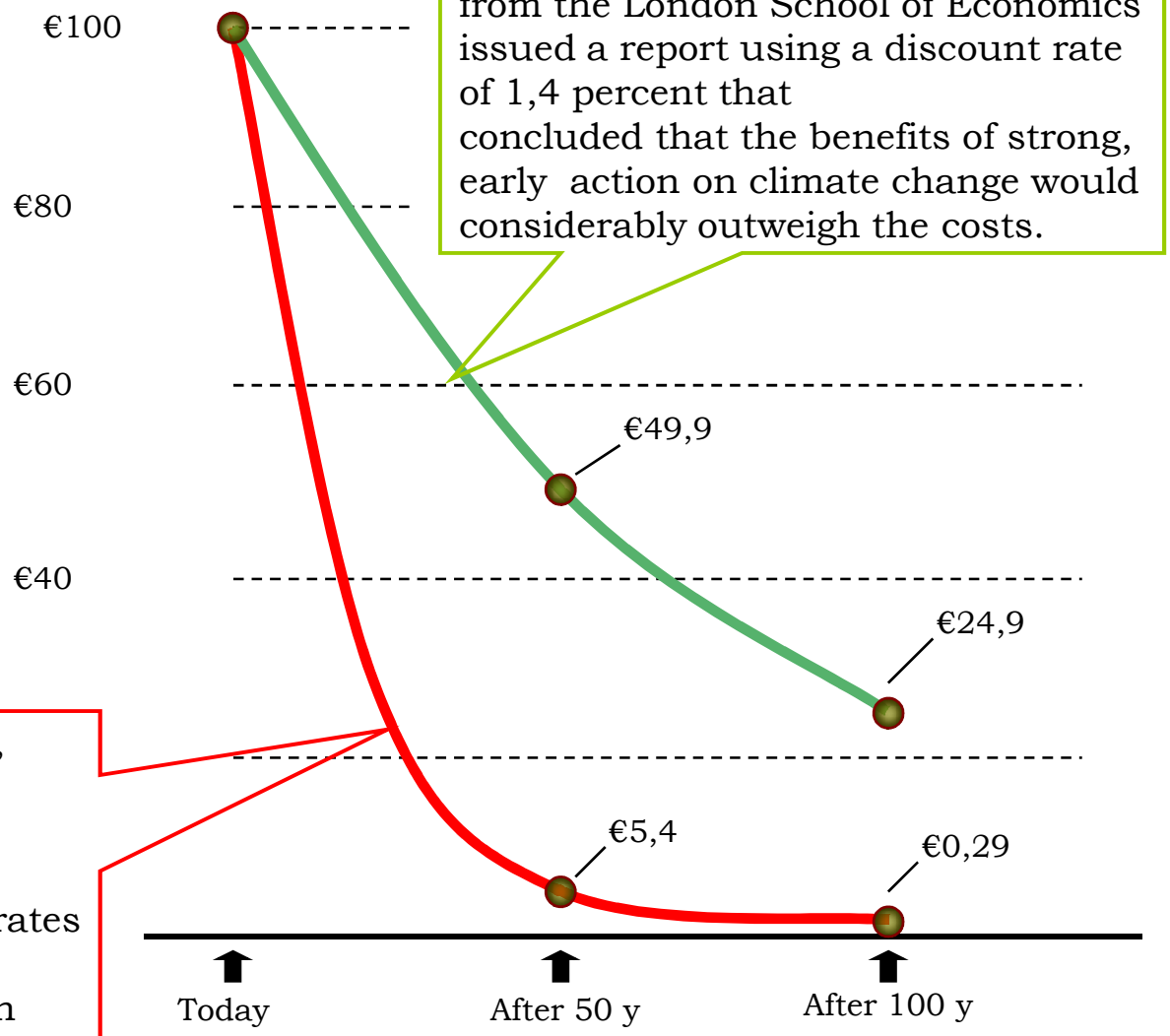
marginal rate of private investment

Individuals also face an opportunity cost of forgone interest if they postpone receiving a given amount of funds until later because they could potentially invest these funds once they are received.

These two considerations of importance to individual decisions -- the *marginal rate of time preference* and the *marginal rate of return on private investment* -- provide a basis for deciding how costs and benefits realized by society in the future should be discounted so that they are comparable to costs and benefits realized by society today.

Choosing the discount rate

- A recent very interesting example is the debate of whether we should take action concerning climate change



Divergence of Social and Private Discount Rates

- If resources are to be allocated efficiently, firms must use the same rate to discount future net benefits as is appropriate for society at large.
  - If firms were to use a higher rate, they would extract and sell resources faster than would be efficient.
  - Conversely, if firms were to use a lower-than-appropriate discount rate, they would be excessively conservative.

- Why might private and social rates differ?

- The social discount rate is equal to the social opportunity cost of capital.

Divergence of Social and Private Discount Rates

- The social opportunity cost of capital can be divided into two components:
  - Risk-free cost of capital
    - The rate of return is earned when there is absolutely no risk of earning more or less than the expected return.
  - Risk premium
    - It is the amount required to compensate capital owners for potential differences between expected and actual returns.
- If the risk of certain private decisions is different from the risks faced by society as a whole, then the social and private risk premiums may differ.
- Another divergence in discount rates may stem from different underlying rates of time preference.
    - It affects both private and social discount rates, as well as across countries.

EXAMPLE

The Importance of the Discount Rate

Let's begin with an historical example. For years the United States and Canada had been discussing the possibility of constructing a tidal power project in the Passamaquoddy Bay between Maine and New Brunswick. This project would have heavy initial capital costs, but low operating costs that presumably would hold for a long time into the future. As part of their analysis of the situation, a complete inventory of costs and benefits was completed in 1959.

Using the same benefit and cost figures, Canada concluded that the project should not be built, while the United States concluded that it should. Because these conclusions were based on the same benefit–cost data, the differences can be attributed solely to the use of different discount rates. The United States used 2.5 percent while Canada used 4.125 percent. The higher discount rate makes the initial cost weigh much more heavily in the calculation, leading to the Canadian conclusion that the project would yield a negative net benefit. Since the lower discount rate weighs the lower future operating costs relatively more heavily, Americans saw the net benefit as positive.

In a more recent illustration of why the magnitude of the discount rate matters, on October 30, 2006 economist Nicholas Stern from the London School of Economics issued a report using a discount rate of 0.1 percent that concluded that the benefits of strong, early action on climate change would considerably outweigh the costs. Other economists, such as William Nordhaus of Yale University, who prefer a discount rate around 6 percent, believe that optimal economic policies to slow climate change involve only modest rates of emissions reductions in the near term, followed by sharp reductions in the medium and long term.

EXAMPLE *(cont.)*

In this debate the desirability of strong current action is dependent (at least in part) on the size of the discount rate used in the analysis. Higher discount rates reduce the present value of future benefits from current investments in abatement, implying a smaller marginal benefit. Since the costs associated with those investments are not affected nearly as much by the choice of discount rate (remember that costs occurring in the near future are discounted less), a lower present value of marginal benefit translates into a lower optimal investment in abatement.

Far from being an esoteric subject, the choice of the discount rate is fundamentally important in defining the role of the public sector, the types of projects undertaken, and the allocation of resources across generations.

Sources: Edith Stokey and Richard Zeckhauser. *A Primer for Policy Analysis* (New York: W. W. Norton, 1978): 164–165; Raymond Mikesell. *The Rate of Discount for Evaluating Public Projects* (Washington, DC: The American Enterprise Institute for Public Policy Research, 1977): 3–5; the Stern Report: http://webarchive.nationalarchives.gov.uk/ and /http://www.hm-treasury.gov.uk/sternreview_index.htm; William Nordhaus. "A Review of the Stern Review on the Economics of Climate Change," *Journal of Economic Literature* Vol. XLV (September 2007): 686–702

Divergence of Social and Private Discount Rates

- A Critical Appraisal
  - Concerns exist on the reliability of benefit/cost analysis.
    - *A study found bias incorporated into agency ex ante evaluation procedures, resulting in persistent overstatement of expected benefits.*
    - Another shortcoming of benefit–cost analysis is that it does not really address the question of who reaps the benefits and who pays the cost.
- Thus, there are positives and negatives in using cost-benefit analysis

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.

EXAMPLE

NO_2 Control in Chicago: An Example of Cost-Effectiveness Analysis

In order to compare compliance costs of meeting a predetermined ambient air quality standard in Chicago, Seskin, Anderson, and Reid (1983) gathered information on the cost of control for each of 797 stationary sources of nitrogen oxide emissions in the city of Chicago, along with measured air quality at 100 different locations within the city. The relationship between ambient air quality at those receptors and emissions from the 797 sources was then modeled using mathematical equations. Once these equations were estimated, the model was calibrated to ensure that it was capable of re-creating the actual situation in Chicago. Following successful calibration, this model was used to simulate what would happen if EPA were to take various regulatory actions.

The results indicated that a cost-effective strategy would cost less than one-tenth as much as the traditional approach to control and less than one-seventh as much as a more sophisticated version of the traditional approach. In absolute terms, moving to a more cost-effective policy was estimated to save more than $100 million annually in the Chicago area alone. In Chapters 15 and 16 we shall examine in detail the current movement toward cost-effective polices, a movement triggered in part by studies such as this one.

Impact Analysis

- What can be done when the information needed to perform a benefit–cost analysis or a cost-effectiveness analysis is not available? The analytical technique designed to deal with this problem is called *impact analysis.*

- An impact analysis attempts to quantify the consequences of various actions.

- Impact analysis places a large amount of relatively undigested information at the disposal of the policy-maker.