Cost Benefit Analysis

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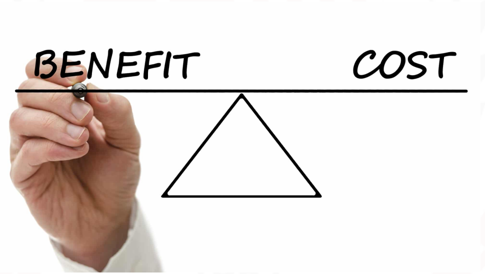


Environmental and Natural Resource Economics - **December 7, 2024**

Presentation Outline

What is Cost Benefit Analysis?

- Cost benefit analysis is about making an informed decision about
- Way of thinking seriously about positives and negatives of actions
- Often involves quantifying different types of costs and benefits and determining how to weigh them
- Extremely important in environmental economics

Economic Impact Analysis (EIA)

Definition:

- Economic Impact Analysis (EIA) evaluates the effects of a project, policy, or event on the economy of a specific region or sector.
- It measures changes in key economic indicators such as employment, income, business revenue, and GDP.

Key Components:

- **Direct Impacts:** Immediate effects (e.g., jobs created by a construction project).
- **Indirect Impacts:** Ripple effects through the supply chain (e.g., increased demand for materials).
- **Induced Impacts:** Effects of increased income on local spending (e.g., more retail activity).

Tools and Techniques:

- Input-output models (e.g., IMPLAN, RIMS-II).
- Econometric modeling and regional analysis.

Economic Impact Analysis

Applications:

- Evaluating infrastructure projects (e.g., highways, energy facilities).
- Assessing local impacts of business investments.
- Supporting grant applications and policymaking.

Output Example:

- Number of jobs created.
- Changes in regional GDP or tax revenue.
- Sector-specific economic growth.

Regulatory Impact Analysis (RIA)

Definition:

- Regulatory Impact Analysis (RIA) systematically evaluates the costs, benefits, and distributional effects of a proposed or existing regulation.
- It aims to assess whether the regulation achieves its objectives efficiently and equitably.

Key Components:

- **Problem Definition:** What issue does the regulation address?
- **Baseline Scenario:** What happens in the absence of regulation?
- **Cost-Benefit Analysis:** Quantifying the costs (compliance, administrative) and benefits (health, safety, environment).
- **Alternatives Assessment:** Comparing potential regulatory and non-regulatory solutions.

Regulatory Impact Analysis

Tools and Techniques:

- Discounting for cost-benefit analysis.
- Sensitivity analysis for uncertainty.
- Distributional analysis for equity impacts.

Applications:

- Environmental regulations (e.g., air quality standards).
- Financial sector regulations.
- Workplace safety and health standards.

Output Example:

- Net benefits of a regulation ($ millions).
- Emission reductions achieved (tons of CO_2).
- Cost per life saved or per unit of pollution abated.

Framework for Cost Benefit Analysis

1. Specify the project or program; specification, location, timing, groups involved, and connection to other programs.
2. Describe quantitative inputs and outputs of the program; typically monetary values.
3. Estimate the social costs and benefits of these inputs and outputs.
4. Determine the full range of consequences.
5. Compare the benefits and costs.

Definition: Marginal Abatement Curve (MAC)

What is a Marginal Abatement Curve (MAC)?

- A Marginal Abatement Curve represents the cost of reducing one additional unit of pollution or greenhouse gas (GHG) emissions.
- The curve is a graphical depiction of:
  - The cost (y-axis) of abating emissions.
  - The cumulative amount of abatement (x-axis).
- It is widely used to assess the cost-effectiveness of different mitigation strategies.

Key Features:

- Downward-sloping sections indicate negative or zero-cost abatement opportunities (e.g., energy efficiency improvements).
- Upward-sloping sections show progressively higher costs as cheaper options are exhausted.

Mathematical Explanation of a Marginal Abatement Curve

Mathematical Definition: The Marginal Abatement Cost (MAC) is the additional cost of reducing emissions by one unit:

$$MAC(E) = \frac{dC(E)}{dE}$$

where:

- $C(E)$: Total cost of abatement for emissions E,
- E: Emissions level after abatement.

Key Insights:

- MAC is increasing in E, reflecting that reducing emissions becomes more expensive as cheaper options are utilized.
- The curve integrates individual measures' costs, ordered from lowest to highest.

Definition: Marginal Damage Curve (MDC)

What is a Marginal Damage Curve (MDC)?

- A Marginal Damage Curve represents the additional damage caused by one more unit of pollution or greenhouse gas emissions.
- The curve is a graphical depiction of:
  - The damage (y-axis) caused by emissions.
  - The quantity of emissions (x-axis).
- Reflects the increasing marginal damage due to the nonlinear nature of environmental and social systems.

Key Features:

- Upward-sloping, indicating that marginal damage increases with higher levels of emissions.
- Represents externalities not captured in market prices.

Applications:

- Assessing the social cost of carbon (SCC).
- Setting optimal pollution taxes or emission caps.
- Evaluating trade-offs in environmental policy.

Mathematical Explanation of a Marginal Damage Curve

Mathematical Definition: The Marginal Damage (MD) is the additional damage caused by one unit of pollution:

$$MD(E) = \frac{dD(E)}{dE}$$

where:

- $D(E)$: Total damage caused by emissions E,
- E: Emissions level.

Key Insights:

- $MD(E)$ increases with E due to the nonlinear effects of pollution.
- Reflects the environmental, health, and economic costs associated with emissions.

Equating Costs and Benfits Graphically

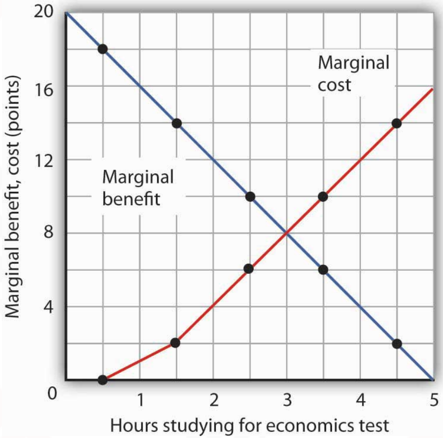


Figure 1: Better get studying...

Equating Marginal Damage and Marginal Abatement

FIGURE 6.1 Establishing the Size of a Public Program

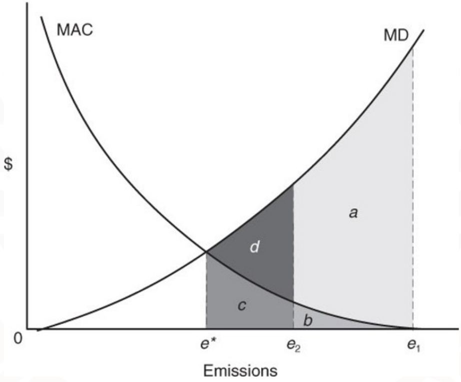


Figure 2: Total benefits=a+b, Total costs=b, Net benefits=a

Distributional Problems in Cost Benefit Analysis

- Who should get benefits and pay costs?
- Horizonal equity: How does the policy impact similar people with similar incomes?
- Vertical equity: How does a policy impact people with different incomes?
- Higher costs matter more to a poor person
- People paying costs might not be those receiving benefits

How should we deal with this situation?

	Person A	Person B	Person C
Reduced environmental damages ($/year)	60	80	120
Abatement costs ($/year)	40	60	80
Difference	20	20	40

Figure 3: Who should pay?

Comparison of Horizontal and Vertical Equity

Equity in Public Policy:

- Equity refers to fairness in the distribution of resources, benefits, and costs.
- Two key concepts:
  - **Horizontal Equity:** Equal treatment for equals.
  - **Vertical Equity:** Differentiated treatment based on ability to pay or need.

Vertical Equity

TABLE 6.2 Vertical Equity*

	Person A		Person B		Person C	
Income	5,000		20,000		50,000	
Program 1						
Reduced damages	150	(3.0)	300	(1.5)	600	(1.2)
Abatement costs	100	(2.0)	100	(0.5)	100	(0.2)
Difference	50	(1.0)	200	(1.0)	500	(1.0)
Program 2						
Reduced damages	150	(3.0)	1,400	(7.0)	5,500	(11.0)
Abatement costs	100	(2.0)	800	(4.0)	3,000	(6.0)
Difference	50	(1.0)	600	(3.0)	2,500	(5.0)
Program 3						
Reduced damages	700	(14.0)	2,200	(11.0)	3,000	(6.0)
Abatement costs	200	(4.0)	1,000	(5.0)	1,500	(3.0)
Difference	500	(10.0)	1,200	(6.0)	1,500	(3.0)

*Figures in this table show annual monetary values. Numbers in parentheses show the percentage of income these numbers represent.

Figure 4: Which program is best?

Comparing Horizontal and Vertical Equity

Comparison:

Aspect	Horizontal Equity	Vertical Equity
Definition	Equal treatment of individuals with the same characteristics.	Differentiated treatment to account for differences in income, ability to pay, or need.
Focus	Ensures fairness among equals.	Ensures fairness between different groups based on capacity or need.
Example in Taxation	Two individuals earning $50,000 should pay the same amount in taxes.	Higher-income individuals should pay a higher percentage of their income in taxes.
Application in Policy	Uniform access to public services, such as education or healthcare.	Means-tested programs or progressive taxation systems.
Challenges	Requires clear definitions of equality.	Balancing redistribution without discouraging economic productivity.

Risk Valuation in an Environmental Context

What is Risk Valuation?

- Risk valuation assesses the monetary value of uncertain future outcomes associated with environmental changes or hazards.
- Incorporates the probability of risks and their potential impacts into decision-making.

Components of Risk Valuation:

- **Probability:** Likelihood of an adverse event occurring (e.g., flooding, pollution).
- **Magnitude:** Scale of the damage or cost if the event occurs.
- **Time Horizon:** Long-term risks often require discounting future impacts.

Risk Valuation in an Environmental Context

Valuation Approaches:

- Expected monetary value (EMV):

$$EMV = \sum_i P_i \cdot C_i$$

  where P_i is the probability of event i, and C_i is the cost of event i.
- Willingness to pay (WTP) to reduce risk or avoid harm.
- Cost-benefit analysis incorporating risk factors.

Risk Valuation Example

Example: Flood Risk in Coastal Areas

- **Scenario:** A coastal town faces annual flooding risks due to climate change.
- **Data:**
  - Probability of severe flooding = 5% per year ($P = 0.05$).
  - Estimated damage cost = \$1,000,000.
- **Expected Cost of Flooding:**

$$EMV = P \cdot C = 0.05 \cdot 1,000,000 = \$50,000 \text{ per year.}$$

- **Decision:** Evaluate whether investing \$200,000 in flood defenses (reducing P to 1%) is cost-effective.
- **Risk Reduction Benefits:**

$$\text{New EMV} = 0.01 \cdot 1,000,000 = \$10,000.$$

$$\text{Net Benefit} = (\$50,000 - \$10,000) \times \text{years} - \$200,000.$$

Statistical Value of Human Life (SVHL)

What is the Statistical Value of Human Life?

- The SVHL represents the monetary value society places on reducing the risk of death by one unit.
- It is not the intrinsic value of life but a measure used in cost-benefit analysis for policies that reduce mortality risk.

How is it Estimated?

- Derived from individuals' **Willingness to Pay (WTP)** to reduce small risks of death.
- Example: If 10,000 people each pay \$100 to reduce a risk of death by 1 in 10,000, the SVHL is:

$$\text{SVHL} = 10,000 \times 100 = 1,000,000\,\$.$$

Statistical Value of Human Life

Applications:

- Evaluating environmental regulations (e.g., air quality standards).
- Assessing safety improvements (e.g., vehicle safety standards).
- Determining health interventions' cost-effectiveness.

Typical Range:

- In the U.S., SVHL estimates range from $5 million to $10 million, depending on the context and methodology.

Example: Calculating the Statistical Value of Human Life

Scenario: A government agency is evaluating a policy to reduce air pollution, which is expected to lower the risk of death by 1 in 10,000 for 100,000 people.

Data:

- Willingness to pay (WTP) per person = \$200.
- Population affected = 100,000 people.

Example: Calculating the Statistical Value of Human Life

Calculation:

1. Total WTP for the risk reduction:

$$\text{Total WTP} = 100,000 \times 200 = 20,000,000\,\$.$$

2. Lives saved by the policy:

$$\text{Lives Saved} = \frac{\text{Population}}{\text{Risk Reduction Denominator}} = \frac{100,000}{10,000} = 10.$$

3. Statistical Value of Human Life:

$$\text{SVHL} = \frac{\text{Total WTP}}{\text{Lives Saved}} = \frac{20,000,000}{10} = 2,000,000\,\$.$$

Time Value of Money (TVM)

What is the Time Value of Money?

- The concept that money available today is worth more than the same amount in the future due to its earning potential.
- Based on the principle that money can earn interest or generate returns over time.

Key Components:

- **Present Value (PV):** Value of future money in today's terms.
- **Future Value (FV):** Value of current money at a future date.
- **Interest Rate (r):** Rate of return or growth over time.
- **Time Period (t):** Number of periods over which money grows or is discounted.

Basic Relationships

- Future Value:

$$FV = PV \times (1 + r)^t$$

- Present Value:

$$PV = \frac{FV}{(1 + r)^t}$$

Applications:

- Investment decisions.
- Loan repayment schedules.
- Environmental cost-benefit analysis (e.g., valuing future damages or benefits).

Discounting: Definition and Importance

What is Discounting?

- Discounting is the process of determining the present value of future cash flows or benefits by applying a discount rate.
- Reflects the time preference for money and opportunity costs of capital.

Formula:

$$PV = \frac{FV}{(1+r)^t}$$

where:

- PV: Present Value,
- FV: Future Value,
- r: Discount rate,
- t: Time in periods.

Discounting: Key Insights and Example

Key Insights:

- A higher discount rate (r) reduces the present value of future benefits or costs.
- Longer time horizons (t) result in lower present values.

Applications in Environmental Economics:

- Valuing future benefits of pollution reduction.
- Evaluating long-term climate change mitigation policies.
- Estimating the social cost of carbon.

Example:

- Future benefit = \$10,000 in 10 years, discount rate $r = 5\%$:

$$PV = \frac{10,000}{(1+0.05)^{10}} = 6,139.13\,\$.$$

Net Present Value (NPV): Definition and Formula

What is NPV?

- NPV measures the profitability of an investment by calculating the difference between the present value of cash inflows and outflows.
- It accounts for the time value of money, reflecting that money today is worth more than the same amount in the future.

Formula:

$$\text{NPV} = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

where:

- C_t: Net cash flow in period t,
- r: Discount rate or cost of capital,
- T: Total number of periods.

NPV Decision Rule

Decision Rule:

- If NPV > 0, the investment is profitable.
- If NPV < 0, the investment is unprofitable.
- If NPV $= 0$, the investment breaks even.

Applications:

- Capital budgeting.
- Evaluating renewable energy projects.
- Comparing alternative investment options.

Example: Calculating NPV

Scenario: A company considers investing in a project with the following cash flows:

Year (t)	Cash Flow ($)
0	-10,000
1	3,000
2	4,000
3	5,000

Discount Rate: $r = 8\%$.

Example: Calculating NPV

Steps:

1. Calculate present value (PV) for each year:

$$PV_t = \frac{C_t}{(1+r)^t}$$

2. Compute NPV:

$$\text{NPV} = \sum_{t=0}^{3} PV_t$$

NPV Calculation

Calculation:

$$PV_0 = \frac{-10,000}{(1+0.08)^0} = -10,000$$

$$PV_1 = \frac{3,000}{(1+0.08)^1} = 2,777.78$$

$$PV_2 = \frac{4,000}{(1+0.08)^2} = 3,429.36$$

$$PV_3 = \frac{5,000}{(1+0.08)^3} = 3,969.16$$

$$\text{NPV} = -10,000 + 2,777.78 + 3,429.36 + 3,969.16 = 176.30$$

Result: The project has a positive NPV of $176.30 and is profitable.

Cost of Capital

Definition: The cost of capital is the rate of return required by investors or lenders to finance a project. It serves as the discount rate in NPV calculations.

Components of Cost of Capital:

- **Cost of Equity:** Return required by equity investors.
- **Cost of Debt:** Interest rate paid on borrowed funds, adjusted for taxes.

Weighted Average Cost of Capital (WACC):

$$\text{WACC} = \frac{E}{V} \cdot r_e + \frac{D}{V} \cdot r_d \cdot (1 - T)$$

where:

- E: Market value of equity,
- D: Market value of debt,
- V: Total value ($V = E + D$),
- T: Corporate tax rate.

Internal Rate of Return (IRR): Mathematical Definition

Definition: The Internal Rate of Return (IRR) is the discount rate (r) that makes the Net Present Value (NPV) of cash flows equal to zero:

$$\text{NPV} = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} = 0$$

where:

- C_t: Cash flow at time t,
- T: Total number of periods,
- r: IRR (unknown to solve for),
- t: Time period (0, 1, 2, ..., T).

Key Insight: The IRR represents the rate of return where the present value of inflows equals the present value of outflows.

Future Value and Interest Payments: A 30-Year Mortgage Example

Overview: Mortgages illustrate how interest payments accrue over time and how future value is impacted by compound interest.

Key Formula: The future value of a loan or investment with compound interest:

$$FV = P \cdot (1 + r)^n$$

where:

- P: Principal amount (initial loan).
- r: Interest rate per period.
- n: Number of periods.

Interest Rate Example: Mortgage

Example: A 30-Year Fixed-Rate Mortgage

- Loan amount (P): \$300,000
- Annual interest rate (r): 4% (0.04)
- Loan term (n): 30 years (360 monthly payments)

Monthly Payment Calculation: Using the formula for fixed monthly payments:

$$M = \frac{P \cdot r_m \cdot (1 + r_m)^n}{(1 + r_m)^n - 1}$$

where r_m is the monthly interest rate ($r/12$):

$$M = \frac{300,000 \cdot 0.003333 \cdot (1.003333)^{360}}{(1.003333)^{360} - 1} \approx \$1,432.25$$

Interest Rate Example: Mortgage

Total Interest Payments:

$$\text{Total Paid} = M \cdot 360 = 1,432.25 \cdot 360 = \$515,610$$

$$\text{Total Interest} = \text{Total Paid} - P = 515,610 - 300,000 = \$215,610$$

Conclusion: Over 30 years, the borrower pays $515,610 in total, with $215,610 as interest. Understanding interest compounding helps illustrate the long-term cost of borrowing.

Breakeven Point

What is the Breakeven Point?

- The level of sales or production at which total revenues equal total costs.
- Represents the point where a project or business becomes profitable.

Key Formula:

$$\text{Breakeven Point (Units)} = \frac{\text{Fixed Costs}}{\text{Price per Unit - Variable Cost per Unit}}$$

Types of Costs:

- **Fixed Costs:** Costs that do not change with production levels (e.g., rent, salaries).
- **Variable Costs:** Costs that vary directly with production (e.g., raw materials).

Discounted Payback Period

What is the Discounted Payback Period?

- The time it takes for a project to recover its initial investment, considering the time value of money.
- Accounts for discounting future cash flows rather than treating them equally, as in the traditional payback period.

Key Formula:

$$\text{Discounted Cash Flow (DCF)} = \frac{\text{Cash Flow}}{(1+r)^t}$$

where:

- r: Discount rate.
- t: Time period.

Discounted Payback period

Steps to Calculate:

1. Discount each cash flow using the chosen discount rate.
2. Cumulatively sum the discounted cash flows.
3. Identify the point where the cumulative discounted cash flows equal the initial investment.

Advantages:

- Accounts for the time value of money.
- Useful for assessing project risk and liquidity.

Limitations:

- Ignores cash flows beyond the payback period.
- Does not directly measure profitability.

Useful Excel Functions

- **SUM()**: Adds a range of numbers.
- **AVERAGE()**: Calculates the mean of a range.
- **IF()**: Returns different values based on a logical condition.
- **VLOOKUP()**: Searches for a value in the first column of a range and returns a value in the same row from another column.
- **HLOOKUP()**: Similar to VLOOKUP, but searches horizontally.
- **INDEX()**: Returns the value of a cell within a specific range.
- **MATCH()**: Returns the relative position of an item in an array.
- **COUNT()**: Counts the number of numeric values in a range.
- **COUNTIF()**: Counts values based on a condition.
- **CONCATENATE()/CONCAT()**: Combines text from multiple cells.

Useful Excel Functions for Finance

- **NPV(rate, values)**: Calculates the Net Present Value of an investment.
- **FV(rate, nper, pmt, pv)**: Calculates the Future Value of an investment.
- **PMT(rate, nper, pv)**: Calculates the payment for a loan based on constant payments and interest rates.
- **IRR(values)**: Calculates the Internal Rate of Return for a series of cash flows.
- **XIRR(values, dates)**: Calculates the IRR for a series of cash flows that are not periodic.
- **PV(rate, nper, pmt)**: Calculates the Present Value of an investment.

Useful Excel Functions for Finance

- **RATE(nper, pmt, pv)**: Calculates the interest rate per period of an annuity.
- **SLN(cost, salvage, life)**: Calculates straight-line depreciation.
- **DB(cost, salvage, life, period)**: Calculates declining balance depreciation.
- **CUMIPMT(rate, nper, pv, start, end)**: Calculates cumulative interest paid on a loan between two periods.

Example: NPV Function

Problem: Calculate the Net Present Value (NPV) of an investment with the following cash flows:

Year	Cash Flow ($)
0	-10,000
1	3,000
2	4,000
3	5,000

Solution:

- Use the formula `=NPV(0.08, B2:B4) + B1`.
- Here:
  - `0.08` is the discount rate (8%).
  - `B2:B4` contains cash flows for years 1-3.
  - `B1` is the initial investment.
- Result: $923.22 (approx.).

Example: Calculating IRR in Excel

Problem: Find the IRR for the following cash flows:

Year	Cash Flow ($)
0	-10,000
1	3,000
2	4,000
3	5,000

Steps in Excel:

1. Enter cash flows in a column (e.g., cells `A1:A4`).
2. Use the formula:

   `=IRR(A1:A4)`

3. Excel will iterate to find the rate (r) that makes NPV $= 0$.

Result:

- IRR $= 11.79\%$ (approximately).
- Interpretation: This is the annualized rate of return for this investment.

The Perils of Excessive Discounting

- Often economists use a discount factor of 95%
- This feels right in macro and most finance

The Perils of Excessive Discounting

- Often economists use a discount factor of 95%
- This feels right in macro and most finance
- However, consider that this implies the welfare of people 100 years down the road basically does not matter
- Creates problems when thinking about long-term issues like global warming
- Should we even be discounting the future? Don't our children matter as much as we do?

What are the Benefits?

- A curious fact about environmental economics is that the benefits are generally avoided costs of environmental degradation
- The benefits actually come from the decrease in the damage function
- Environmental damage may seem nebulous, but there is a cost of carbon someone puts out

How can we Measure these?

- Cost to to repair to initial environment
- Cost of sickness and lost productivity
- Loss of beauty
- Consideration of other factors: animals, intrinsic values

Estimating Damage Functions

Steps to Estimate a Damage Function:

1. **Identify the Impact Pathway:**
   - Link pollution sources (e.g., emissions) to endpoints (e.g., health outcomes, crop yields).
2. **Collect Data:**
   - Pollution levels, affected outcomes, and economic costs.
3. **Specify the Functional Form:**
   - Linear, logarithmic, or nonlinear forms to capture relationships.
4. **Quantify the Damage:**
   - Use empirical methods or models to estimate the relationship.
5. **Validate and Test:**
   - Test robustness and account for uncertainty.

Econometric Example: Estimating a Damage Function

Example: Impact of Air Pollution on Worker Productivity

- Research Question: How does air pollution (e.g., $PM_{2.5}$) affect worker productivity?

Econometric Model:

$$Y_{it} = \beta_0 + \beta_1 PM_{2.5\,it} + \beta_2 X_{it} + \alpha_i + \epsilon_{it}$$

where:

- Y_{it}: Worker productivity for individual i at time t,
- $PM_{2.5\,it}$: Level of particulate matter,
- X_{it}: Vector of control variables (e.g., temperature, hours worked),
- α_i: Individual fixed effects,
- ϵ_{it}: Error term.

Estimation of Damage Function Steps

Estimation Steps:

1. Collect panel data on worker productivity, pollution levels, and controls.
2. Estimate the model using fixed effects regression to control for unobserved heterogeneity.
3. Interpret β_1 as the marginal damage of pollution on productivity.

Result Example:

- $\beta_1 = -0.02$: A 1-unit increase in $PM_{2.5}$ reduces productivity by 2%.
- Total economic damage = Productivity Loss × Wages × Affected Workers.

Cost of Illness Approach

What is the Cost of Illness (COI) Approach?

- The COI approach estimates the economic damages associated with adverse health outcomes caused by pollution or other environmental factors.
- It focuses on direct and indirect costs related to illness or injury.

Key Components:

- **Direct Costs:**
  - Medical expenses (e.g., hospitalization, medication, treatment).
- **Indirect Costs:**
  - Productivity losses due to illness or premature mortality.
- **Intangible Costs (optional):**
  - Pain, suffering, or reduced quality of life (harder to monetize).

COI Example

- Health outcome: Asthma exacerbations due to air pollution.
- Direct costs: \$500 per hospital visit, \$100 for medication.
- Indirect costs: \$200 lost productivity per day.
- If 1,000 cases occur annually, total cost:

$$\text{Total COI} = (500 + 100 + 200) \times 1,000 = \$800,000.$$

Production Cost Effects of Pollution

What Are Production Cost Effects of Pollution?

- Pollution can increase production costs by damaging inputs like labor, capital, or raw materials.
- These effects are particularly significant in industries reliant on natural resources, such as agriculture, fishing, and forestry.

Key Mechanisms:

- **Labor Productivity:** Health impacts on workers can reduce efficiency.
- **Capital Costs:** Pollution can cause wear and tear on equipment (e.g., corrosion from acid rain).
- **Raw Material Quality:** Environmental degradation can reduce the availability or quality of natural inputs.

Steps to Estimate Costs

1. Identify the impact of pollution on inputs (e.g., crop yields, worker absenteeism).
2. Quantify changes in productivity or quality.
3. Monetize these changes by estimating the increased production costs.

Production Function Approach Example

Example: Agricultural Impacts

- **Scenario:** A 10% reduction in crop yields due to increased ground-level ozone.
- **Baseline:** A farm produces 1,000 tons of crops annually at \$100/ton.
- **Impact:** Pollution reduces yields by 100 tons, requiring additional fertilizer to compensate.
- **Costs:**

$$\text{Additional Fertilizer Cost} = 100\,\text{tons} \times 20\,\$/\text{ton} = 2,000\,\$.$$

- **Total Cost:** \$2,000 annually in added expenses.

Chinatown

Figure 5: Forget it Jake, it's Chinatown

Willingness to Pay

What is Willingness to Pay (WTP)?

- WTP is the maximum amount an individual is willing to pay for a good, service, or improvement, or to avoid a negative outcome.
- It reflects the value individuals place on changes in welfare or utility.

Applications:

- Environmental economics (e.g., valuing clean air or water).
- Health economics (e.g., valuing life-saving treatments).
- Marketing and pricing strategies.

Methods to Estimate WTP:

- **Revealed Preferences:** Based on observed behavior (e.g., hedonic pricing, travel cost methods).
- **Stated Preferences:** Based on survey data (e.g., contingent valuation, discrete choice experiments).

Key Insight: WTP serves as a monetary measure of how much individuals value changes in their well-being.

Deriving WTP from a Utility Function

Using Utility Functions to Calculate WTP:

- WTP is derived from the compensating variation that equates initial and post-change utility levels.
- **Utility Function:** $U = U(Y, Q)$
  - Y: Income,
  - Q: Quantity/quality of the good or service.

Formula for WTP:

$$U(Y, Q_0) = U(Y - \text{WTP}, Q_1)$$

where:

- Q_0: Initial quantity/quality,
- Q_1: Improved quantity/quality.

Steps:

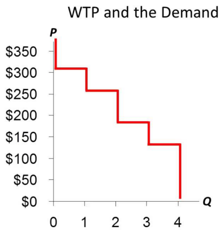
1. Specify the utility function (e.g., $U = \ln(Y) + \alpha Q$).
2. Solve for WTP by equating utilities before and after the change.

Willingness to Pay Linear Utility

Example: Linear Utility Function

$$U = Y + \alpha Q \quad \Rightarrow \quad \text{WTP} = \alpha(Q_1 - Q_0)$$

Willingness to Pay Graphically



P	*Q^d*
$301 & up	0
251 – 300	1
176 – 250	2
126 – 175	3
0 – 125	4

Figure 6: Demand curves are different people.

Estimating WTP Using Discrete Choice Modeling

Discrete Choice Models and WTP:

- WTP is estimated in discrete choice models by analyzing how individuals trade off money for changes in attributes of a good or service.
- Common models include:
    - Multinomial Logit (MNL),
    - Mixed Logit,
    - Conditional Logit.

Estimating WTP Using Discrete Choice Modeling

Utility Function:

$$U_{ij} = V_{ij} + \epsilon_{ij} \quad \text{where } V_{ij} = \beta X_{ij} - \lambda P_j$$

- U_{ij}: Utility of individual i for alternative j,
- X_{ij}: Attributes of alternative j,
- P_j: Price of alternative j,
- β, λ: Coefficients to estimate.

Calculating WTP

Calculating WTP:

$$\text{WTP} = \frac{\beta_k}{\lambda}$$

- β_k: Coefficient of the attribute of interest,
- λ: Coefficient of price (negative marginal utility of income).

Example:

- $\beta_k = 2.5$, $\lambda = -0.5$,
- $\text{WTP} = \frac{2.5}{0.5} = 5.0$.
- Interpretation: The individual is willing to pay $5 for a 1-unit improvement in the attribute.

Practical Issues of Using Willingness to Pay (WTP) in Environmental Contexts

Challenges in Measuring WTP:

- **Non-Market Goods:**
  - Environmental goods (e.g., clean air, biodiversity) lack direct market prices.
  - Requires stated preference methods (e.g., surveys) or revealed preference techniques.
- **Bias in Survey-Based Methods:**
  - **Hypothetical Bias:** Respondents may overstate or understate WTP in contingent valuation surveys.
  - **Strategic Bias:** Participants might misreport WTP to influence outcomes.
  - **Embedding Effect:** WTP may change depending on how the question is framed or scoped.

Practical Issues of Using Willingness to Pay (WTP) in Environmental Contexts

- **Distributional Concerns:**
  - WTP depends on income, leading to equity issues.
  - Wealthier individuals may have higher WTP, biasing results against low-income communities.
- **Aggregation Problems:**
  - Aggregating individual WTP to a societal level can be contentious.
  - Requires assumptions about population size and representativeness.

Environmental Context-Specific Issues:

- **Long Time Horizons:** Environmental benefits often accrue over decades, complicating discounting.
- **Intergenerational Equity:** WTP of future generations is hard to capture.
- **Non-Use Values:** Difficult to estimate WTP for intangible benefits (e.g., existence of endangered species).

Opportunity Costs

- You can't just judge by observed costs and benefits

Opportunity Costs

- You can't just judge by observed costs and benefits
- You must also think about opportunity costs
- If two projects are not mutually exclusive, choose projects until rate of return is below cost of capital
- If two projects are mutually exclusive, focus on NPV and maximize total NPV
- Time horizon considerations may matter

Levelized Avoided Cost of Energy

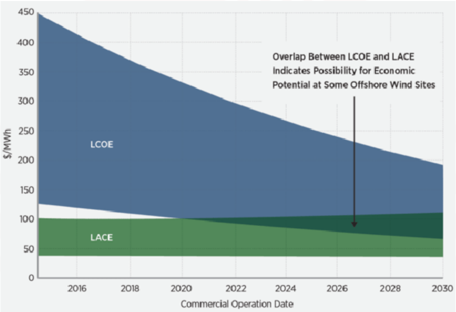


Figure 7: Benefits and Costs Offshore Wind

What are the Costs of Environmental Policies

- Loss of innovation
- Loss of economic activity
- Cost of abatement
- Harms to people lived in areas, particularly with land reclamation and some green energy

With and Without Principle

- Cannot simply consider current costs versus costs after policy
- Must consider costs in a world with the policy versus costs in a world without
- If costs are 100 now but will increase to 150 with the regulation but 120 without the regulation, the cost of the regulation is 30

Types of Costs

- Social costs of regulation
- Regulatory costs
- Cost to innovation and loss of efficient outcome

How to get cost data

- Costs surveys
- Historical data
- The representative firm approach.
- Issues?

How to get cost data

- Costs surveys
- Historical data
- The representative firm approach.
- Issues?
- Regulated firms have private information about their costs and incentive to lie
- Costs estimated may not represent minimum abatement costs.

Distribution of Costs

- When regulation affects the costs of one industry this can impact the employment and costs of several other industries as well as overall GDP.
- There may be important regional differences in what groups benefit and what groups are burdened with the costs.
- It is important to not only examine the total costs but how these costs are distributed.

Environmental Costs of Environmental Protection

- Reducing untreated domestic waste outflows into rivers leaves quantities of solid waste that need disposal.
- Reducing airborne SO_2 emissions from power plants leaves highly concentrated sludge that needs disposal.
- The mitigation costs must be included as part of the total costs of overall pollution reduction.
- Enforcement costs must also be included.

Social Costs of Regulation

- Loss of jobs
- Shrinking of lower markets
- Resources move to lower value uses

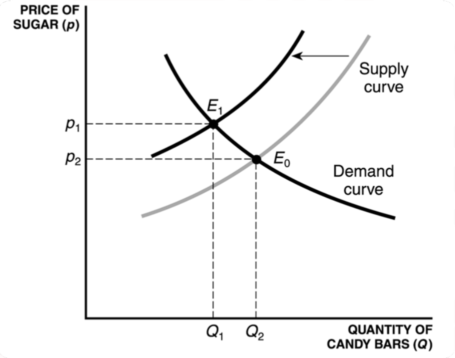


Figure 8: Poor sugar farmers. LOL

Levelized Cost of Electricity (LCOE): Definition and Formula

Definition: LCOE represents the average cost per unit of electricity generated over the lifetime of a project.
Formula:

$$\text{LCOE} = \frac{\sum_{t=1}^{T} \frac{I_t + O_t + F_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{E_t}{(1+r)^t}}$$

Where:

- I_t: Investment costs in year t,
- O_t: Operation and maintenance costs in year t,
- F_t: Fuel costs in year t,
- E_t: Electricity generated in year t,
- r: Discount rate,
- T: Project lifetime.

Example: LCOE Calculation

Problem: Calculate the LCOE for a power plant with the following parameters:

Year (t)	Investment ($)	O&M ($)	Fuel ($)	Electricity (MWh)
1	1,000,000	50,000	100,000	20,000
2	0	50,000	100,000	20,000
3	0	50,000	100,000	20,000
4	0	50,000	100,000	20,000
5	0	50,000	100,000	20,000

Assumptions:

- Discount rate (r) = 8% (0.08).
- Project lifetime = 5 years.

LCOE Calculation

1. Calculate **Discounted Costs** for each year:

$$\text{Discounted Cost}_t = \frac{\text{Investment}_t + \text{O\&M}_t + \text{Fuel}_t}{(1+r)^t}$$

Example for Year 1:

$$\frac{1,000,000 + 50,000 + 100,000}{(1+0.08)^1} = 1,111,111.11$$

2. Calculate **Discounted Electricity** for each year:

$$\text{Discounted Electricity}_t = \frac{\text{Electricity}_t}{(1+r)^t}$$

Example for Year 1:

$$\frac{20,000}{(1+0.08)^1} = 18,518.52$$

3. Sum the Discounted Costs and Electricity:

5

Calculating LCOE in Excel

Steps to Calculate LCOE:

1. Create columns for I_t, O_t, F_t, and E_t over the lifetime of the project.
2. Add a column for the discount factor: $(1 + r)^t$.
3. Calculate discounted costs for each year:

$$\text{Discounted Costs} = \frac{I_t + O_t + F_t}{(1 + r)^t}$$

4. Calculate discounted electricity for each year:

$$\text{Discounted Electricity} = \frac{E_t}{(1 + r)^t}$$

5. Sum the discounted costs and electricity over all years.
6. Use the formula:

$$\text{LCOE} = \frac{\text{Total Discounted Costs}}{\text{Total Discounted Electricity}}$$

LCOE in Excel Formula

Excel Formula Example:

- Discounted Cost (e.g., cell B2): `=(A2 + B2 + C2)/POWER(1 + r, t)`
- Repeat for all rows and sum.
- Use total discounted values to compute LCOE.

Sensitivity Analysis of LCOE in Excel

Goal: Analyze how changes in key parameters (e.g., discount rate, fuel costs, or electricity generation) affect LCOE.

Steps:

1. Identify variables to test for sensitivity (e.g., discount rate r, investment costs I_t, or electricity generated E_t).
2. Create a table with rows for the variable values to test and columns for the corresponding LCOE.
3. Use Excel's `Data Table` feature:
   - Input a range of values for the chosen variable.
   - Reference the LCOE calculation cell in the table.
   - Excel recalculates LCOE for each input value.
4. Analyze results using graphs (e.g., line charts) to visualize sensitivity.

LCOE Sensitivity Analysis

Example: Discount Rate Sensitivity Table

Discount Rate (%)	LCOE ($/MWh)
5	50.00
6	52.50
7	55.10

LCOE Sensitivity Visualization

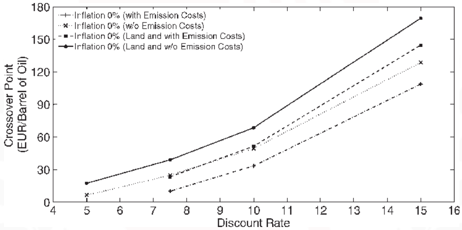


Figure 9: How confident are you in your assumptions?

Overview of the CREST Tool (NREL)

What is CREST?

- The **Cost of Renewable Energy Spreadsheet Tool (CREST)** is a free financial modeling tool developed by the National Renewable Energy Laboratory (NREL).
- It is designed to evaluate the economic feasibility of renewable energy projects, including wind, solar, and geothermal.
- CREST is Excel-based and allows users to assess the impact of key financial and policy parameters on project economics.

Overview of the CREST Tool (NREL)

Key Features:

- Calculates Levelized Cost of Energy (LCOE).
- Models cash flows, tax credits, and depreciation.
- Tailored to specific renewable technologies.
- Designed for use by policymakers, project developers, and analysts.

Supported Technologies:

- Solar PV and Solar Thermal
- Wind (onshore and offshore)
- Biomass and Geothermal

Using the CREST Tool

Steps to Use the CREST Tool:

1. **Download the Tool:**
   - Visit the NREL website to download the CREST spreadsheet tool.
   - Ensure Excel macros are enabled for full functionality.
2. **Input Project Parameters:**
   - Specify technology type (e.g., solar PV, wind).
   - Enter system size, capacity factor, and project lifetime.
   - Provide detailed financial inputs such as capital costs, O&M costs, and financing structure.
3. **Input Policy and Incentive Information:**
   - Include tax credits, grants, and renewable energy credits.
   - Model depreciation schedules (e.g., MACRS) if applicable.

Using the CREST Tool

- **Analyze Results:**
  - Review LCOE, cash flow projections, and return on investment (ROI).
  - Perform sensitivity analysis by adjusting key variables.

Output Example:

- LCOE breakdown (capital, O&M, fuel costs).
- Financial indicators (IRR, NPV, payback period).
- Graphs and summary tables for visualization.

Overview of the SLOPE Tool (NREL)

What is SLOPE?

- The **State and Local Planning for Energy (SLOPE)** tool is an integrated, free, and publicly available online platform developed by the National Renewable Energy Laboratory (NREL).
- Designed to support state and local decision-makers in energy planning and policy development.
- Provides data and analysis on energy efficiency, renewable energy, and sustainable transportation options.

Key Features:

- Combines data from NREL and other organizations (e.g., DOE, EPA).
- Supports energy scenario modeling and goal setting.
- Enables comparison of energy opportunities at state, county, and city levels.

Using the SLOPE Tool

Steps to Use the SLOPE Tool:

1. **Access the Tool:**
   - Visit the SLOPE platform on NREL's website.
   - No installation required; it is entirely web-based.
2. **Explore the Data:**
   - Choose a geographic area (state, county, or city).
   - Browse data layers such as renewable energy potential, energy consumption, and costs.
3. **Create Scenarios:**
   - Input targets for energy efficiency or renewable energy deployment.
   - Model the impacts of various policy or investment decisions.

Using the SLOPE Tool

- **Analyze Results:**
  - View charts and maps showing energy use, emissions reductions, and costs.
  - Compare different regions or scenarios.
- **Download Reports:**
  - Export data, charts, and reports to share with stakeholders.
  - Use results for policy proposals and grant applications.

Applications:

- Strategic energy planning.
- Evaluating renewable energy investment potential.
- Supporting decarbonization initiatives.

SLOPE

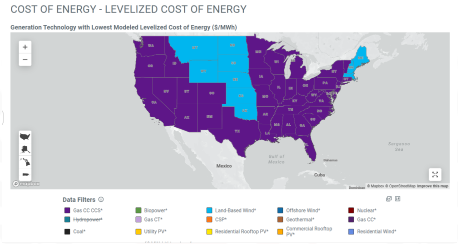


Figure 10: Hydropower is cheap but so are wind and solar...

Enviro-tech Industry

- Firms producing goods and services used by other firms to reduce their emissions and environmental impact
- Environmental clean-up
- New pollution control technology and practices
- Instrumental in lowering future marginal abatement costs
- Huge potential employer for people in this room!!!

Thank You So Much!

List of References