Lecture # 20 – Benefit-Cost Analysis

I. Discounting

- The costs and benefits we've discussed often occur at different times. To compare them fairly, it is important to discount costs and benefits that occur in the future.
    - The idea is to compare a flow of benefits and costs into a single value.
- The present value of a future amount of money is the maximum amount you would be willing to pay today for the right to receive that money in the future.
    - Present value accounts for the opportunity cost of not investing the money elsewhere.
    - Example:
        - You have \$100 now
        - If you put it in the bank, you will get 5% interest
        - Next year, that money is worth (1 + 0.05)x100 = \$105
        - After two years, it is worth (1.05)(1.05)(100) = $(1.05)^2(100)$ = \$110.25
    - General rule:
        - FV = future value, PV = present value, r = interest rate
        - $FV = PV(1 + r)^t$
    - As a result, you wouldn't give up \$100 now for \$100 next year, because you could invest the money and get \$105 next year.
        - The present value of \$100 next year is the most you would give up today to get \$100 next year
        - FV => PV(1.05) = \$100(1.05)
        - PV = FV/r = 100/1.05 = \$95.24
    - General rule
        - PV = FV/(1 + r)
    - For a stream of payments:
        - $PV = x + X/(1+r) + X/(1+r)^2 + \ldots + X/(1+r)^t$
        - Please see the spreadsheet from class for additional examples.

- To proceed, we need to know what value to use for r. This is the discount rate.
- The discount rate reflects the relative value a person places on future consumption compared to current consumption.
    - Lower values show a greater preference for future consumption.
        - If your discount rate is greater than the interest rate, you will be willing to borrow money.
            - A high discount rate says that current consumption is important to you.
        - If your discount rate is lower than the interest rate, you will be willing to loan money.
            - A low discount rate says that future consumption is important to you.
    - Since the market interest rate reflects an equilibrium of lenders and borrowers, we can use the market interest rate as a measure of the discount rate.
- There are several market interest rates. Which should we use?
    - Typically, economists use a risk-free rate.
        - Investors looking for a safe return invest in U.S. Treasury bills. Thus, the return on T-bills is a measure of the nominal risk-free rate.
        - To purchase assets that are riskier, investors need to be compensated with a higher rate of return.
            - This additional return is known as a risk premium.
        - The most commonly used rates in government reports are 3% and 7%
            - 3% represents the risk-free rate
                - It is the average real rates on US Treasury bills from 1973-2003
            - 7% represents the returns on private capital, which are higher due to taxes and increased risk.
- Why the discount rate matters
    - Discounting affects the value placed on future benefits and costs.
    - Higher discount rates place less importance on future returns.
    - Note, for example, how this is a particular problem for long-term problems such as climate change.
    - Because the benefits of climate protection extend far into the future, calculations of the social cost of carbon are very sensitive to the choice of discount rates
        - 2%: $121/ton
        - 3%: $51/ton
        - 7%: $6/ton

- Prest *et al*. give three reasons why a 3% rate is no longer appropriate for climate change
  - Since 2003, average real rates on US Treasury bills have fallen. Would suggest a discount rate of 2%
  - Uncertainty about future discount rates suggests using lower rates for longer time horizons
  - A 7% rate assumes costs of climate protection fall on private capital. But benefits of protection can also help private capital
- Because we use higher discount rates when growth is higher, uncertainty about future economic growth (e.g. because damages may reduce growth), discount rates also become uncertain
  - E.g. future discount rates should be linked to future growth

- Note also how the discount rate relates to economic growth theory
  - discount rate = pure rate of time preference + growth rate of income x elasticity of marginal utility for income
    - Represented as $r = a + bg$.
    - The first term, *a*, captures the relative weight placed on the future versus today
      - Involves ethical judgments
    - The second term acknowledges that, due to economic growth, we expect future generations to be richer
      - If the marginal utility of income falls as we get richer, than additional money is less valuable when we are richer
- How to choose the parameters *a* and *b*
  - Descriptive approach
    - Find parameters that match observed market rates
    - But note that different combinations of *a* and *b* can yield the same rate
    - Thus, theory also matters
  - Prescriptive approach
    - Based on:
      - ethical decisions (e.g. is a positive *a* appropriate)
      - surveys

- Might the social discount rate deviate from the market rate?
    - The above estimates use market data to determine the discount rate. Are their reasons to believe that the market rate is flawed?
    - Some economists argue that the opportunity cost of foregone future consumption might differ from the opportunity cost revealed in the markets.
        - In this case, it might make sense to use a social discount rate which is lower than the rates observed in the marketplace.
            - The <u>social discount rate</u> represents the willingness of society to trade off present and future consumption.
                - If there are market failures, this may differ from discount rates observed from market behavior.
        - Why might market rates not be appropriate?
            - Long term projects involve benefits or costs for future generations.
                - However, future generations are not represented in the market.
            - People may be myopic, and thus not save sufficiently.
            - There may also be other externalities that cause the market rate of return on investments to deviate from the social discount rate, such as positive externalities from research and development.
            - Uncertainty may be a concern
                - Therefore, risk aversion may justify using a lower discount rate. However, uncertainty is not an excuse to do nothing.
- Drupp *et al*. (2018) survey economists on the social discount rate.
    - They asked economists who have published on the topic.
        - Survey had 262 responses
    - They ask about each component of $r = \delta + g\eta$.
    - Also asked what social discount rate they would recommend for a global public project with intergenerational consequences.
        - Mean risk-free rate: 2.38
        - Mean social discount rate: 2.27
            - 68% of responses between 1 & 3 percent
            - Most common response: 2%
        - Mean rate of time preference 1.1%
        - Mean elasticity of marginal utility 1.35%
        - Should normative weights be used for SDR?
            - 80% think both normative and positive matter, and that normative matters should get more weight

II. Including Environmental Justice in Benefit-Cost Analysis

- E.O. 14008 (2021) calls on federal agencies to secure environmental justice for communities that have been "historically marginalized and overburdened by pollution and under-investment in housing, transportation, water and wastewater infrastructure and health care."
  - How might this be done?

- Because EJ acknowledges historical record of injustice contributes to existing vulnerabilities, analysis considers how preexisting vulnerabilities may interact with new policies
  - Puts focus on cumulative exposure, instead of simply changes in impacts across households
  - Environmental justice analysis focuses on:
    - low-income populations
    - minority populations
    - indigenous peoples

- EPA technical guidance on EJ (2016) suggests three questions:
  - Are there preexisting EJ concerns absent the regulatory action (i.e., in the baseline)?
  - Are there potential EJ concerns for the regulatory option(s) under consideration?
  - Do the regulatory option(s) under consideration exacerbate, create, or mitigate potential EJ concerns relative to the baseline?

- Ways to address equity in benefit-cost analysis
  - Distributional weights assign different weights to the net benefits of each group.
    - For example, to evaluate EJ, could apply greater weight to outcomes of low-income groups.
    - But this doesn't provide information on *how* different groups are affected – still provides just net benefits and costs.
  - Provide analysis for different subgroups
    - Here, we must distinguish between benefits, costs, and transfers
    - <u>Transfer payments</u> are shifts of resources from one group to another that do not involve a net change in the value of resources available to society as a whole.
    - Since there is no net change in the value to society, no resources are used, and no new value is created.
      - However, all of the transfers that we have discussed have important equity considerations.
      - A project that passes whose benefits exceed the costs may nonetheless be rejected if the distribution of benefits and costs is seen as unfair.

        - Examples of transfer payments:
            - Taxes paid (such as emissions fees)
            - Benefits provided to specific groups (e.g. welfare payments)
        - Two principles for identifying and measuring transfer payments:
            - At the level of particular groups, transfer payments resemble conventional benefits and costs.
                - That is, resources they are willing to pay to acquire, or resources expended by the group represent a loss of opportunity value to the group.
            - However, for society as a whole, the sum of transfer payments to particular groups must sum to zero.
                - Since no value is created or destroyed, one group's benefit is another group's cost.
                - Transfer payments merely represent shifts of resources.
        - Guidelines for defining groups
            - Groups should not overlap, and should add up to comprise the total society affected by the program.
                - Overlapping groups lead to double counting costs and benefits.
            - The sum of transfer payments across groups should be zero.

- How often does the EPA consider EJ analysis?
    - Emphasis tends to be on health risks or impacts, rather than monetized benefits or costs
    - No recent studies consider how *costs* of regulation vary for different groups

- Examples
  - Lead dust hazard and lead dust clearance
    - Would reduce the amount of lead dust considered a hazard and lower the allowed amount of lead dust remaining after remediation
    - EJ analysis centered on the extent to which low-income children and children of color are exposed to higher levels through lead dust from paint in older housing.
    - EPA linked predicted blood levels from risk modeling with data on housing to predict changes in exposure for different groups
  - Baseline assessment of hydrofluorocarbon (HFC) phase-down (2021)
    - Incentivized switch to new chemicals
    - Potential EJ effects
      - No local health impacts, but because vulnerability to climate change differs for different groups, benefits may affect marginalized communities more
      - Production of HFCs uses toxic chemicals.
        - Those living near plants producing HFCS will benefit
        - But those near plants producing substitutes for HFCs could be harmed
      - Trading allowed to meet reduction targets could change distribution of local impacts.
    - How the analysis addressed EJ
      - Qualitatively discussed evidence on vulnerability of specific populations to climate change
      - Quantitatively characterized changes in local effects relative to baseline
        - Used Toxics Release Inventory to get facility-level data on chemicals released
        - Conducted analysis to understand characteristics of population near these plants, relative to national averages
          - Higher percentage of people of color near HFC facilities.
        - More difficult to make projections about substitutes, since don’t know where those will be produced

III. Example: Benefit-Cost Analysis of Hybrid Delivery Vehicles

- We finished class discussing Krutilla and Graham's article in the *Journal of Policy Analysis* as an example of benefit-cost analysis.
- As a reminder, these are the steps to benefit-cost analysis that we discussed earlier. Note how the work in this article matches up with each of these steps.
    1) Specify clearly the project or program.
    2) Determine quantitatively the inputs and outputs of the program.
    3) Estimate the social costs and benefits of these inputs and outputs.
    4) Compare these costs and benefits.

- **Specify the project or program**: What is the project and/or policy analyzed?
    - In 2011, the National Highway Traffic Safety Administration (NHTSA) and Environmental Protection Agency (EPA) implemented new rules on fuel consumption and CO_2 emissions from medium- and heavy-duty trucks.
    - This analysis does a cost-benefit analysis of diesel-electric hybrid technology as a potential response to the new rules.
        - Specifically consider technology to propel urban pickup and delivery vehicles (PUADs).
        - PUADs operate at low speeds and stop-and-start frequently, making them good candidates for hybrid technology.
            - Companies such as FedEx and UPS use them
            - Hybrids have larger up-front costs and battery replacement costs, but save money on fuel
                - Incremental cost of about $33,000 in 2012 for hybrid purchase.
                - Note that discounting is thus important!

- **What are the inputs and outputs of using this technology?** What are the benefits and costs?
  - What are the benefits of hybrid technology?
    - Value of fuel savings
      - Depends on market adjustments to reduced diesel demand
      - Paper assumes diesel prices set in global market, and thus not affected by increased hybrid usage
      - Value is thus market price of diesel net fuel taxes
        - Taxes are a transfer Ignores scarcity rents lost by domestic suppliers
    - Externalities
      - Environmental damages from CO_2
      - Tailpipe emissions that affect local air pollution
        - Function of miles traveled and fuel economy
      - National security issues with imported oil
      - Congestion, accidents, and roadway maintenance
        - Function of miles traveled
        - Not included, since occur even if a hybrid not used
          - Note importance of *marginal analysis* here
          - Assumes little rebound effect for delivery vehicles
  - What are the costs of hybrid technology?
    - Incremental technology costs
      - Additional capital costs
        - May improve over time, since the technology is immature
      - Cost of eventual battery replacement
      - Other changes in operating and maintenance costs
        - May be positive or negative

- **Estimate social costs and benefits:** How do the authors estimate social costs and benefits of these inputs and outputs?
    - Operational performance and fuel savings
        - Begin with a reference hybrid model
            - Assume both it and the conventional model would be driven for 20 years
        - Assumptions
            - Fuel efficiency: Hybrid gets 9.8 MPG, compared to 7.5 for conventional
                - Assume 1% improvement over time for hybrid
                - But, model future MPG probabilistically
                - Future MPG of conventional expected to improve in response to new regulations
                    - 7.85 MPG in 2014
                    - 8.2 MPG in 2017
                - Note that *Business as Usual (BAU)* (e.g. what happens with no intervention) is different than simply assuming the status quo continues forever
            - Miles driven: Assume driven 20,000 miles/year
                - Leads to fuel savings of 639 gallons per year
                - Assume mileage increase to 20,267 in 2017, because of rebound effect due to new fuel economy standards
                    - Increases fuel savings
            - Fuel prices
                - Use projections from Annual Energy Outlook
                    - Extend projections to 2050 for hybrids purchased in 2030
                    - **Table 1** shows projections
    - Externality valuation (#s in **Table 1**)
        - Global climate benefit
            - Develop CO_2 equivalents for all emissions saved
            - Use social cost of carbon to monetize
                - Assumes SCC increases over time as CO_2 emissions increase over time
                - Include uncertainty analysis using a lognormal distribution based on Interagency Working Group on the Social Cost of Carbon report (2010)
        - Energy security
            - Costs of imports include potential disruptions and military costs with securing imported oil
            - Use Oak Ridge National Laboratory estimate of energy security benefits
        - Local air pollution
            - Includes reduction of NO_X, CO, and PM
            - Use an EPA study on the benefits of new air quality standards to get benefits

- Time savings in refueling
  - Apply a gallon pumped per minute value to fuel savings
  - Value time savings at relevant wage rate
  - Data from both taken from NHTSA (2011)
    - Comes to 3.8 cents/gallon saved
- Costs of hybrids
  - Current difference in costs is $33,085
    - But future hybrid costs expected to fall
      - Use NRC report for the new rulemaking as a guide
  - Batteries replacement
    - Battery lifetime is 7 years
      - Sensitivity analysis showed little impact on results
    - Batteries currently cost $10,353, assumed to improve over time at same rate as other hybrid technology
  - Assume O&M costs will be similar for hybrids and other vehicles
- Taxes
  - While taxes are transfers, they do impact private returns
    - Moreover, there are potential changes to revenues for different levels of governments (e.g. state vs. federal)
  - Consider fuel taxes, sales taxes, and corporate income taxes
    - E.g. value of fuel savings is after tax
    - Capital costs can be depreciated
      - There are thus additional tax savings for purchasers
      - The federal government loses tax revenues
- Discount rate
  - Use both 3% and 7%
    - 7% recommended by Office of Management and Budget (OMB)
      - Represents before-tax rate of return on private capital
    - 3% as example of social discount rate

- How do the authors address uncertainty?
  - Simulate NPV annually for hybrids purchased each year between 2012-2030
    - Account for fuel price, environmental, and technology trends
  - What assumptions must be made?
    - Assume a distribution of possible values for uncertain values, including:
      - Future fuel economy
      - Future fuel price
      - Future costs of hybrids
    - For these variables, the distribution includes minimum, maximum, and most likely values
      - These are the PERT distributions discussed on page 506
    - For other variables, they parameterize a wider distribution of potential values
      - Social cost of carbon (Weibull distribution, p. 509)
      - Air quality benefits
    - They run simulations using different vales of these variables from each of their distributions
      - **Table 2** shows the combinations for three key variables using PERT
      - For each combination in Table 2, they run multiple simulations based on other uncertain variables.
        - These are the Monte Carlo simulations they describe on page 514.
  - What information do they use to inform their assumptions?
    - Used an expert panel to make projections, then used probabilistic modeling to characterize key variables

- **Compare costs and benefits:** What are their results?
  - Present results for four different stakeholders:
    - Private hybrid purchaser
    - State government
    - Federal government
    - Parties impacted by external costs
      - Net society includes all of these
  - **Tables 3 & 4** shows results for a single year – a hybrid purchased in 2014
    - Using a 7% discount rate (**Table 3**), the NPV is negative
    - Using a 7% discount rate for private costs and benefits, and 3% for social costs and benefits (**Table 4**), the NPV is positive
      - The column “Evaluator adjustor for differential discounting” converts the 7% discounted private costs and benefits into 3% discounted values for the social returns.
        - It is the extra benefit or cost if discounted at 3%, so that the total in Net Society is a total discounted at 3%
      - Why do results change?
        - Value of external benefits increase
        - Adjustment for fuel savings is also large ($9,141). Why might it make sense to consider social value of this, and not just the private value?
          - Could be that more fuel is available for other uses.
  - **Figures 1 & 2** show the path of NPV over time
    - Show the most and least optimistic assumptions
    - Can see when NPV becomes positive for each group and for society
      - Preregulation Societal 3% represents a counterfactual simulation on baseline assumptions of the fuel efficiency of medium duty and heavy duty trucks
      - In early years, benefits smaller because new fuel economy standards implemented in 2014 & 2017
        - These reduce the relative gains from diesel-electric hybrids, as other vehicles become more efficient
          - NPV of Diesel-electric hybrid for society at 3% is around $1,196, but would be $17,773 without new fuel economy regulations on medium- and heavy-duty trucks
      - Expected NPV increases after 2017 for all scenarios because of projected technology improvements

        - Key results
            - NPV for society at 3% always positive with optimistic assumptions (Figure 1), but is negative until 2025 with low assumptions (Figure 2)
            - For private investors, NPV doesn't become positive until 2024 in Figure 1, and never becomes positive in Figure 2
        - Private and social diverge over time because of changes in taxes over time (p. 520-521).
    - *Is the long-term benefit worth the short term costs?* E.g. should early hybrid development be subsidized to encourage future cost savings?
        - Discount the NPV of a purchase in each year back to the initial year
        - Tables show mean of each simulation, as well as the probability that NPV is positive for each set of assumptions. Note standard deviations and 90% confidence intervals also included.
        - **Table 5** shows societal perspective
            - mean NPV never positive with 7% discount rate
            - mean NPV positive for 5 of 8 cases with 3% social discount rate
        - **Table 6 & 7** show effect on state and federal revenues
            - States gain money (presumably sales taxes), federal government loses money (corporate income taxes)
        - **Table 8** shows total fiscal impact

- Conclusions
    - The authors argue that most studies ignore tax distortions, but that they do matter
        - Changes in sales and corporate income tax revenue dominate effect on fuel taxes
    - Given that NPV only positive for social returns when using 3% rate, and isn't positive for private citizens, does this justify policy to support hybrid-diesel technology?