Lecture # 17 –Estimating Benefits

I. Estimating Benefits: General Principles

- Having discussed techniques for valuing environmental benefits, we now discuss how to determine what those benefits are.
    - We begin with general principles for determining benefits, then look at two examples: ecosystem services and climate change
- In principle, comprehensive analyses of all environmental effects of a policy are desirable.
    - However, this is difficult.
    - Thus, with some exceptions (such as the social cost of carbon calculations), benefit calculations are done using an “effect-by-effect” approach.
    - Need to avoid double-counting in these cases.
        - For example, stated value techniques get at non-use values, but may double count use values already included in revealed preference measures.
        - Thus, caution is needed when combining results from different methods.
- Steps to “effect-by-effect” approach to benefits analysis
    1. Identify benefit categories potentially affected
        - Need to understand how policy will affect the environment, so as to know what the benefits will be.
        - Research physical effects of pollutants
            - Often relies on interdisciplinary literature
        - Consider potential changes in these effects from policy
        - Determine which benefits to include
            - E.g. health benefits, recreation, non-use benefits
    2. Quantify significant endpoints
        - Focus on changes to the environment resulting from the policy.
            - Consultation with natural scientists important (e.g. to understand transport of pollution through the environment)
        - These are done relative to a baseline (further discussed below)
        - Role of economics in this step:
            - Ensure information provided useful for subsequent valuation
                - Are endpoints appropriate?
            - Consider behavioral changes that may affect results of risk assessment.
                - Will people change behavior to reduce risk (e.g. stay indoors to avoid air pollution)
    3. Estimate the value of these effects

- Because benefits analysis should capture *marginal* values, we need to properly define the baseline.
  - The baseline is "the best assessment of the world absent the proposed regulation or policy action." (EPA 2010, Chapter 5)
  - Note that the appropriate analysis of a policy is not *before* vs. *after*, but rather what happened compared to what would have happened without a policy intervention.
    - Because other factors in the economy will change whether or not the policy is enacted (e.g. changing demographics, economic activity, technology)
  - Usually use a single baseline, but multiple baselines used if policy is particularly complex (e.g. IEA energy projections)
- Examples of important variables for baseline consideration
  - Demographics
    - Population exposed to pollution matters.
    - Is the population changing?
      - Behavioral models needed if the policy may change demographic trends
  - Future economic activity
    - Is the regulated industry growing or in decline?
    - Is there increasing competition from abroad?
  - Changes in consumer behavior
    - Regulation may change prices
    - But would some behavior have changed anyway?
  - Technological change
    - Even without regulation, technology is changing
      - E.g. how will driverless vehicles affect energy demand?
- Example: estimating the direct benefits of reducing mercury from coal-fired power plants.
  - Background
    - The Supreme Court invalidated the rule in 2015 for not appropriately considering costs.
    - It is also the rule discussed in the *Economist* reading, where co-benefits dominate the direct benefits discussed here.
      - Thus, in identifying potential benefit categories, the EPA considered a wide range of benefits
  - Here, I focus on the EPA's estimate of the direct benefits of reduced mercury pollution focus on the effects of mercury on the IQ of children exposed.
    - First, project the number of pregnant mothers exposed to mercury from recreationally caught freshwater fish.
      - Used 2000 Census data to find the number of females aged between 15 and 44 in each state
      - # of pregnant women = # of females aged 15-44 * state's fertility rate

      - Second, estimate number of prenatally exposed children
        - Estimate number of households with angler fisherman using results of a survey on recreational activities
        - # potentially exposed children = # of pregnant women * (# of anglers/adult population in state)
          - Assumes fertility rate the same for angler and non-angler households
      - Third, estimate daily exposure for 32 different sub-populations (urban/rural, high or low income, distance to water, etc.)
        - average daily mercury ingestion rate = average mercury concentration in fish in each region * average daily self-caught freshwater fish consumption
        - Based on scientific literature, divide by 0.08 to get maternal mercury concentration
      - Fourth, convert maternal mercury concentration to IQ reduction
        - Multiply maternal mercury concentration by 0.18
          - Again, this is based on a scientific study
          - Assumes a linear relationship between mercury and IQ
      - Fifth, estimate monetary loss for each IQ point lost
        - Two measures, both based on outside studies:
          - Lost earnings: 1.76-2.379%
          - Decreased schooling costs:
            - Lower IQ => less time in school => cost savings of $13,453
        - Combining these two effects, each IQ point results in a lifetime income loss of:
          - $8,013-$11,859 with 3% discount rate
          - $893-$1,958 with 7% discount rate
      - Sixth, multiply change in IQ times monetary loss per IQ point to get benefits from reducing mercury
        - Estimate ranges from $0.5 million to $6.1 million
        - Depends no discount rate and net monetary loss per IQ point
  - Potential concerns:
      - Is IQ the best measure of effects of prenatal mercury exposure?
      - Is there a linear relationship between IQ loss and earnings
      - Uncertainties in calculation of exposure (e.g. # of fish consumed, demographics of angler population)
      - Note that the analysis uses scientific studies on different populations and applies them to this regulation
        - For example, the studies on mercury concentration come from New Zealand and the Seychelles Islands.
        - This is an example of *benefits transfer* described in the EPA reading

- Muller and Mendelsohn provide an example of marginal damage, showing how marginal damages can vary across geography.
    - Use the Air Pollution Emissions Experiments and Policy model (APEEP), which they introduce in a 2007 paper.
    - Damages depend on where they are released.
    - Population exposed matters
        - APEEP models transport of pollutants from the source to affected populations.
    - Their model considers how an efficient pollution control system could establish an exchange rate for pollution across different regions.
        - Calculate the marginal damages for 10,000 sources measured by the EPA for six pollutants:
            - particulate matter (<= 10 micrometers)
            - fine particulate matter (<= 2.5 micrometers)
            - nitrogen oxides (NOX)
            - sulfur dioxide (SO2)
            - volatile organic compounds (VOC)
            - ammonia
    - Research steps
        - Collect data on emission from EPA
            - Non-point sources measured at the county level
            - Point sources modeled individually
        - Calculate marginal damages
            - First, estimate total damages from all reported emissions in the model
            - Next, add one ton of one pollutant at one source and recompute
                - The difference in total damages is marginal damage.
                - Damage calculations in APEEP include:
                    - health effects
                    - reduced crop and timber yields
                    - lost recreation services
                    - reduced visibility
                - Use research on mortality rates from recent scientific studies to link changes in emissions to mortality
            - Repeat for each pollutant and each source (60,000 combinations)
            - Use value of life studies (to be discussed later in the semester) to assign dollar values to changed mortality rates
                - Assume a value of statistical life (VSL) of $2 million.

- Results
    - Table 1 shows the range of marginal damages for each pollutant
        - Note that there is much spatial variation.
        - For example, marginal damages from ammonia range from \$100/ton to \$59,450/ton
    - Figures 1 and 2 show variation across the US
        - Lowest in rural western US
        - Median sources near suburban areas
        - Highest MD near large metro areas
    - Table 2 shows the various quantiles for SO_2 and the trading ratios implied
        - For example, damages from a source in Hudson, NJ are 49.4 times worse than a source in Klamath, OR
        - Implies a trading scheme would require a reduction of nearly 50 tons of SO_2 in Klamath to offset one ton SO_2 in Hudson
        - Note that such a policy would discourage, for example urban polluters buying permits from rural sources

II. Estimating Damages from Climate Change

- There are three main methods for estimating damages from climate change
    - Expert interviews
        - Often used to make projections about things that have yet to happen (e.g. future impacts, technological change)
    - Enumerative method
        - Begin by estimating physical effects from natural science research
        - Give each physical effect a price and add up
            - E.g. calculate effects of agriculture by modeling how crop prices change as crop outputs change
            - Advantage
                - Based on literature from natural science
            - Disadvantage
                - Concerns about extrapolation
                    - Studies from limited areas extrapolated to rest of word
                    - Results from recent past extrapolated to distant future
                - Are assumptions about adaptation realistic?
                    - Additional adaptation would lower costs
    - Statistical approach
        - Direct estimates of welfare impacts using observed variations in prices and expenditures
        - Done for selected countries, added up, and extrapolated.
        - Advantages
            - Based on real-world observation
        - Disadvantages
            - Differences in values across places attributed to climate.
                - Might there be other unobserved variables that matter?
            - Much of the research looks at cross-section variation
                - Appropriate because climate is about long-term trends, not year to year variation.
                    - Thus, cross-section variation gives you variation in climates
                - However, some important aspects, such as sea level rise, do not have much spatial variation.

- Dell *et al*. (2012) provide an example of a statistical study. They examine the effect of temperature shocks on economic growth
  - Their earlier work (cited in one of the *Economist* articles) finds income falling 8.5% per degree Celsius.
    - But, this is from a cross section of countries in a single year
    - If poorer countries in tropical regions, is temperature causing lower growth, or are their other factors at work.
  - This study uses panel data for each country from 1950-2003
  - Looks at how changes in temperature and precipitation *within a country* affect growth
  - Key findings
    - Higher temperature reduces growth rates, but only in poorer countries
      - 1 degree Celsius rise in temperature => 1.3 percentage points reduced growth
      - Appears to reduce growth *rates*, not just levels of income
      - Changes in precipitation have lower effects
    - What about the long run? Will people adapt?
      - Short-run economic impacts are larger than cross-sectional relationship
        - With no adaptation, cross-country differences in temperature would lead to 8.5% lower growth in just 7 years
        - But this sample includes over 50 years of data. Thus, adaptation is likely mitigating some of the effect of higher temperature.
- Results of damage studies such as these are then put into climate models to simulate the effect of climate change (e.g. the social cost of carbon)
  - These models integrate knowledge from multiple fields, including natural and social sciences, to generate estimates of the social cost of carbon

III. The Value of Ecosystem Services: Water

- What makes estimating a social cost of water pollution challenging?
  - Role of place matters
    - Where pollution occurs matters for water
      - Some pollution may be highly concentrated locally, but not impact other areas
      - Pollution near major drinking sources more harmful
      - Compare to carbon emissions, whose impacts are global
  - Characteristic of the area where pollution occurs matters
    - E.g. population, presence of endangered species
  - As a result, Kling *et al*. argue that a social cost of water pollution is important conceptually, but a single estimate is not possible
- Four things needed to estimate a social cost of water:
  - Identify the source of pollution
  - Identify how pollutants move through the environment
  - Estimate the impact of pollutants on ecosystem services
    - Many current studies focus on recreation.
    - What else matters
      - Access to drinking water
        - Not just about municipal systems, which can be treated. About 15% of Americans get drinking water from wells
      - Commercial uses
        - Fisheries
        - Transportation (e.g. on rivers)
        - Industrial uses of water
  - Estimate how these services are valued by people
- Note the importance of estimating *marginal* values of a specific resource.
  - Without any ecosystem services, life could not be sustained
    - But, this implies that the *total value* of ecosystem services is infinite!
    - Also note that marginal benefits will increase as more ecosystems are destroyed
  - Early studies often gave implausibly high values, because they focused on total benefits.
    - This led to the work being discredited.