Weighted Benefit-Cost Analysis

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Evaluation of transportation projects & policies

- Transportation projects & policies affect multiple people
  - How should projects be evaluated?
- Individuals are assumed to have a preference relation over consequences (bundles of personal consumption, safety, travel time, etc.)
  - Policies that all individuals weakly prefer (and some strictly prefer) produce a Pareto improvement
- Other policies benefit some people & harm others
- Central question:
  - When is it justified to harm some people in order to benefit others?
  - How can we rank outcomes on the efficient frontier?
    - Which is best?
  - Useful to compare magnitudes of benefit and harm to different people
    - No objective method for comparing utility changes or levels between people

Policy preferences depend on level & distribution of wellbeing

- No objective method to compare changes in wellbeing between people
  - Who benefits more from
    - $1000 ?
    - Saving an hour of travel time ?
    - Preventing a painful injury ?
- BCA & CEA assume an interpersonally comparable "numeraire"
  - Money → Benefit-cost analysis (BCA)
  - QALYs → Cost-effectiveness analysis (CEA)
    - Numeraire can be weighted based on individual characteristics
- Social welfare functions
  - $W = f(u_1, u_2, \ldots, u_n)$
    - u_i = wellbeing of individual i (often lifetime)
  - Assumes an interpersonally comparable measure of wellbeing
  - Can mimic policy evaluation by SWF using weighted BCA
    - Locally, i.e., for small changes in wellbeing
    - SWF provides justification for choice of weights

Benefit-cost analysis

- Evaluate all (significant) effects on all individuals
  - With standing (i.e., those whose preferences count)
- Quantify effects on wellbeing as monetary values
- Sum monetary values across individuals
  - Kaldor-Hicks compensation test
    - If sum > 0, in principle:
      - Winners can compensate losers to adopt policy
      - Losers cannot compensate winners to forgo policy
    - Policy is a “potential Pareto improvement” on the status quo
    - Policy + compensation is Pareto superior to the status quo
- One dollar of benefit or cost has same effect on total net benefits, independent of who receives or bears it
  - Pure transfers have no effect on evaluation

Justifications for BCA

- Recognizing there is no objective way to compare wellbeing (levels or changes) interpersonally
- using individuals' monetary values is a practical approach and (either):
  - BCA yields an adequate approximation to a desired (utilitarian) calculus
    - Marginal utility of wealth is sufficiently close to equal across individuals
  - Distribution of wellbeing can be improved at lower cost by directed programs (e.g., tax and transfer)
    - Separate evaluation of efficiency (maximize social pie) from distribution (allocation of social pie)

Social welfare functions

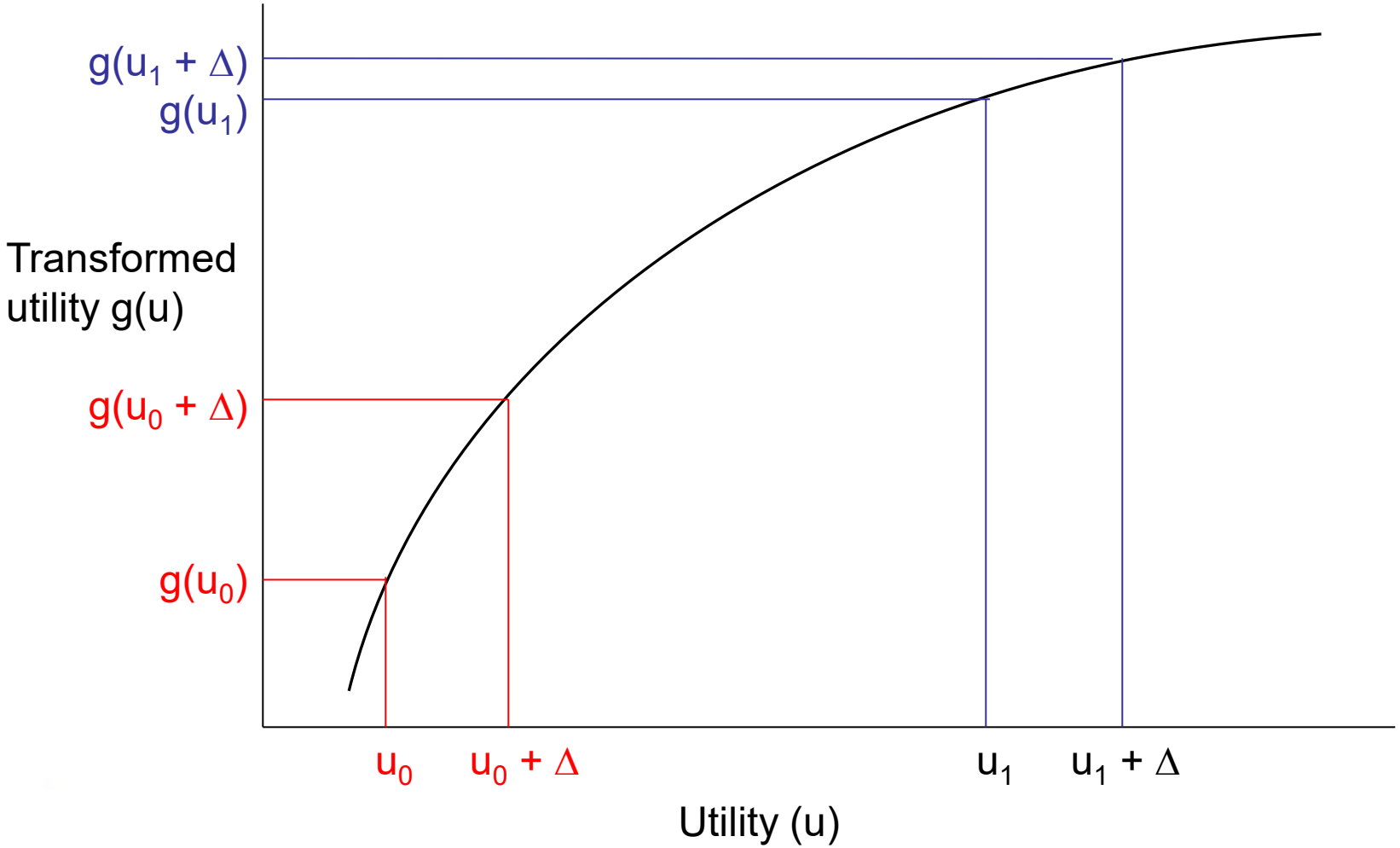
- $W = f(u_1, u_2, \ldots, u_n)$
  - u_i = utility of individual i
    - Or other measure of wellbeing (e.g., capabilities, subjective wellbeing = 'happiness', etc.)
  - Ranks population distributions of wellbeing
    - Integrates efficiency & equity
  - Requires interpersonal comparability (levels and/or differences)
    - Judgments about how utility varies with consumption & other factors
  - Can summarize W by 'equally distributed equivalent'
    - E.g., common income level producing same social welfare
- Common applications
  - Tax policy
  - Climate change (integrated-assessment models)
  - Intergenerational discounting (Ramsey rule)

Social welfare functions (generalized utilitarian)

- Utilitarian
  - $W^U = \sum u_i$
    - (Requires interpersonal comparability of differences but not levels)
- Prioritarian
  - $W^P = \sum g(u_i)$
    - g' > 0, g" < 0
    - Averse to mean-preserving spreads of individuals' utility
    - (Requires interpersonal comparability of differences & levels)
- Maximin (Rawls)
  - $W^M = min_i\{u_i\}$
    - (Requires interpersonal comparability of levels but not differences)
- Utilitarian & maximin are limiting cases of prioritarian

- Alternative SWFs can take account of other individual characteristics (in addition to wellbeing)
  - Anonymity axiom (SWF does not depend on individual identities)

Prioritarian transformation function g(u)



Mimic SWF using weighted BCA

- $W = \sum g[u_i(c_i)]$
  - $u_i' > 0$, $u_i'' < 0$
  - $g' > 0$, $g'' \leq 0$ (prioritarian or utilitarian SWF)
- Policy changes u_i to $u_i + \Delta_i$
- BCA: Net benefits = $\sum v_i$
  - v_i = monetary value of utility increment Δ_i
  - $u_i(c_i) = u_i(c_i - v_i) + \Delta_i$
  - $\Delta_i \approx v_i u'_i(c_i)$
- SWF: Change in social welfare = $\sum \Delta W_i$
  - $\Delta W_i = g(u_i + \Delta_i) - g(u_i)$
  - $\approx \Delta_i g'(u_i) \approx [v_i u'_i(c_i)] g'(u_i)$
  - $\Delta W_i = v_i w_i$
    - Weight $w_i = u'_i(c_i) g'(u_i)$

Issues in application

- Quantifying distributions of effects
- Lifetime v time-slice evaluation
- Choice of weights
- Standing
- Comparing weighted with equal-weighted net benefits

  — Acknowledgment: some of my thoughts have been stimulated by advising Chris Behr's work applying weighted BCA to transportation infrastructure

Quantifying distribution

- Weighted BCA or SWFs should apply to the net effect of a policy on each individual
  - Highly unequal distribution of benefits may be equitable if costs are distributed in parallel
    - Need to account for joint distribution of benefits & costs
  - Common approach to BCA that estimates total benefits and total costs is inadequate
- Often difficult to quantify distribution of effects when agents can respond (inside or outside markets)
  - New or improved transportation infrastructure may induce reallocation of trips, affecting users of other transportation modes
  - Compliance costs imposed on firms may be born by consumers, workers, firm owners, plus consumers & producers of competing or complementary products, plus government (tax revenue)

Lifetime v time-slice evaluation

- SWFs generally depend on lifetime wellbeing
  - Priority to individuals with short life expectancy or bad childhoods
- Conventional BCA (in practice) evaluates project during a typical year, or over a finite duration

Choice of weights

- Weights are ethical judgment (as are equal weights in conventional BCA), not measurable
  - Some population surveys, but is does not imply ought
- Wellbeing
  - Often individual utility, assume constant elasticity of marginal utility (power function), e.g., u(c) = log(c)
    - UK Green Book specifies elasticity = 1.2 based on relationship of subjective wellbeing ('happiness') to income
- Transformation function g
  - Depends on how wellbeing is measured
  - Often Atkinson (power) or Kolm-Pollack (exponential) function of utility
  - Single-parameter that measures inequality aversion informed by leaky-bucket thought experiments

Standing (whose benefits & costs count?)

- Transportation infrastructure has local/regional consequences but is often funded by federal and state sources
- Conventional BCA (in this context) usually restricted to local population
  - Allocation of costs between federal taxpayers and local funding (sales taxes, user fees, etc.) does not affect net benefits
  - Federal taxes generally more progressive than local sources
    - Shifting costs from local to federal sources increases weighted net benefits, independent of project
    - Pure transfer from federal sources to local population has zero net benefits but positive weighted net benefits

Possible solutions to problem of standing

- Need to compare project with counterfactual
- Counterfactual 1: federal contribution could go to other policies (perhaps tax cuts, debt reduction)
  - Federal taxes could be different, need to account for effect on federal taxpayers
  - Including full "society" (national population?) in analysis should always be valid
- Counterfactual 2: federal contribution would go to other transportation-infrastructure projects
  - Decision problem is choice of which projects to fund
  - Welfare effect of federal funding is the same, can be ignored

Comparing weighted & equal-weighted results

- Useful to present conventional (equal-weight) and weighted results side by side
  - Provides information about how incorporating distributional concerns alters the assessment
- Problem: weights are relative, scale is arbitrary
  - Utilitarian SWF: weight = marginal utility of consumption but units & scale of utility are arbitrary

Possible solutions to comparing weighted & equal-weighted BCA

- Normalize weights so weighted net benefits if policy effects were distributed equally would equal unweighted net benefits
  - Requires different normalizations for different projects
    - Hard to compare projects
  - Weighted net benefits quantifies change in welfare due to unequal distribution of policy effects
- Choose a standard normalization
  - 1 weighted dollar = 1 US dollar for individual at reference income (reference = median, mean, etc.)
  - Calculate benchmark net benefits assuming everyone has reference income
    - Distribution of effects does not affect benchmark net benefits
  - Weighted net benefits given real income distribution quantifies change in welfare relative to benchmark

Conclusions

- Distribution of policy effects within a population can be important for evaluation
- Conventional BCA is based on questionable ethical judgments
  - Often, differences in monetary values between individuals are ignored (because they are ethically unattractive)
- Weighted BCA (or social welfare functions) can incorporate more appealing ethical judgments
  - Weights, SWF and transformation function g are ethical choices, not measurable (as is choice of equal-weight BCA)
  - Requires being explicit about judgments that are currently implicit
    - Interpersonal comparison of policy effects on utility
    - Aversion to inequality
      - Of opportunity, of outcome?
      - Role of individual responsibility
  - Requires estimating individual net benefits
    - Not total benefits and total costs
    - Lifetime rather than limited period