COST-EFFECTIVENESS ANALYSIS

EE465/EE463 Project Evaluation

Semester 2/2014

Topics

- What is cost-effectiveness analysis (CEA)?
- CEA ratios
- Scale problems
- Cost-utility analysis (CUA)

What is Cost-Effectiveness Analysis (CEA)?

- CEA is an alternative to CBA. It is used when the impacts of the policy (eg. the value of a life saved) are difficult to be monetized.
- CEA compares (mutually exclusive) alternatives on the basis of the *ratio* of their costs and a single quantified but not monetized effectiveness measure.
  - Examples of 'effectiveness': the number of lives saved, the number of children receiving vaccine, tons of CO_2 reduced.
- The decision rule is based on *ranking*.
  - Programs that cost less per life saved are *more efficient* than other programs.

CEA Ratios

- Two alternatives:

1. Average cost per unit of effectiveness*:

$$CE_i = \frac{C_i}{E_i}$$ ➔ Lower is better

2. Average effectiveness per unit cost:

$$EC_i = \frac{E_i}{C_i}$$ ➔ Larger is better

➢As CEA computes the ratio of input to output (or vice versa), it is a measure of *technical efficiency* and is not necessarily a good measure of allocative efficiency.

Incremental CEA Ratios

- Consider two policies *i* and *j*, the cost-effectiveness ratio of policy *i* relative to policy *j* is given by:

$$CE_{ij} = \frac{C_i - C_j}{E_i - E_j}.$$

- This ratio is also called 'incremental cost-effectiveness ratio' (ICER).
- Simplest case: status quo is the basis for comparison.
- <u>Example</u>: Consider an additional highway safety program that would cost $2 million than the current program and avoid an additional 4 fatalities.
    - CE = ($2 million)/(4 avoided fatalities) = $500,000 per avoided fatality

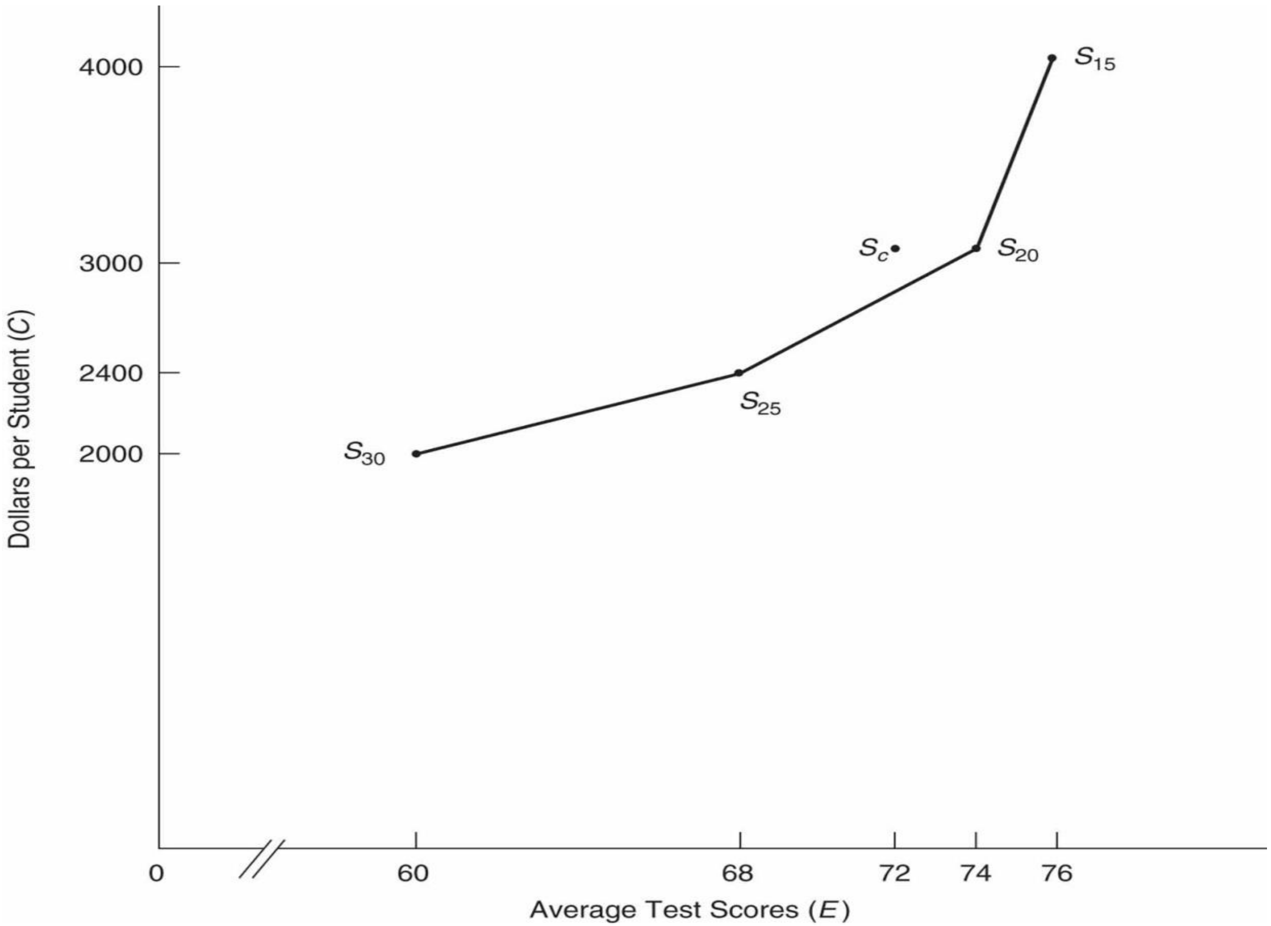
TABLE 18-1 Working with Cost-Effectiveness Ratios

	C (dollars per student)	E (average test score)	C/E (relative to no schooling)	S_j (basis for comparison)	ΔC (relative to S_j)	ΔE (relative to S_j)	ΔC/ΔE (incremental cost-effectiveness ratio)
S_{30}	2000	60	33.3	–	–	–	–
S_{25}	2400	68	35.3	S_{30}	400	8	50
S_{20}	3000	74	40.5	S_{25}	600	6	100
S_{15}	4000	76	52.6	S_{20}	1000	2	500
S_c	3000	72	41.7	S_{30}	1000	12	83.3

- C/E = average cost-effectiveness ratio
- ΔC/ ΔE = ICER
- <u>Question</u>: Should S_c be chosen?
  - ➢ No, because it is strictly dominated by S_{20}.

➢ Still need more information to make a decision (e.g. shadow price of the average score)

Graphical Representation of Costs and Effectiveness



CEA Where Scale Problems Are Irrelevant

- The cost effectiveness ratios in CEAs do not take *different scales of projects* into account.
- This is not a problem if all alternatives have the same cost (fixed budget) or if all alternatives have the same level of effectiveness (fixed effectiveness),

TABLE 18-2 Cost-Effectiveness Analysis with Fixed (Identical) Costs

	Alternatives		
Cost and Effectiveness	***A***	***B***	***C***
Cost measure (budget cost)	\$10M	\$10M	\$10M
Effectiveness measure (number of lives saved)	5	10	15
CE ratio (cost per life saved)	\$2.0M	\$1.0M	\$0.67M[a]
EC ratio (lives saved per million dollars)	0.5 life	1.0 life	1.5 lives[a]

[a]CE ratio or EC ratio of the most cost-effective alternative.

CEA Where Scale Problems Matter

TABLE 18-3 The Problem with the CE Ratio When Scale Differs

Cost and Effectiveness	*Alternatives* A	*Alternatives* B
Cost measure (budget cost)	\$1M	\$100M
Effectiveness measure (number of lives saved)	4	200
CE ratio (cost per life saved)	\$250,000[a]	\$500,000
EC ratio (lives saved per million dollars)	4.0 lives[a]	2.0 lives

[a]CE ratio or EC ratio of the most cost-effective alternative.

Imposing Constraints to Deal with Scale Differences

Minimum acceptable level of effectiveness $(\bar{E})$ constraint:

- Rule 1: Minimize C_i subject to $E_i \geq \bar{E}$
  - Used when additional units of E are not valued much.
- Rule 2: Minimize CE_i subject to $E_i \geq \bar{E}$
  - Used when additional units of E matter.

Maximum acceptable cost $(\bar{C})$ constraint:

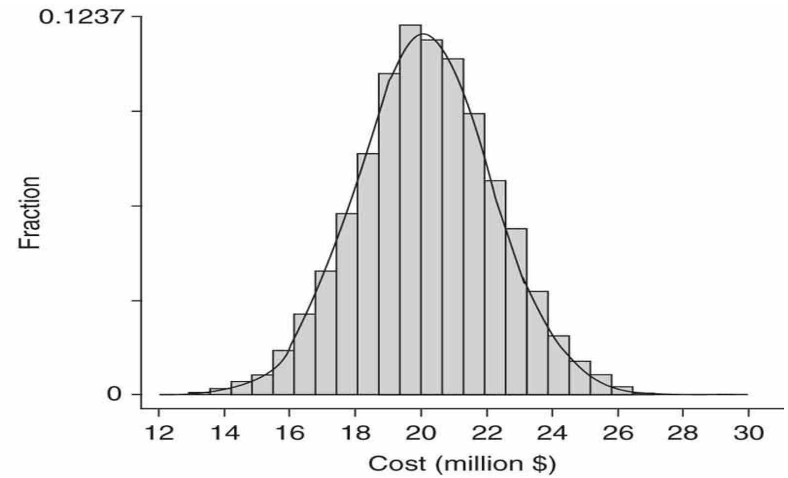
- Rule 3: Maximize E_i subject to $C_i \leq \bar{C}$
  - Used when incremental cost savings are ignored.
- Rule 4: Minimize CE_i subject to $C_i \leq \bar{C}$
  - Used when some weights are put on incremental cost savings.

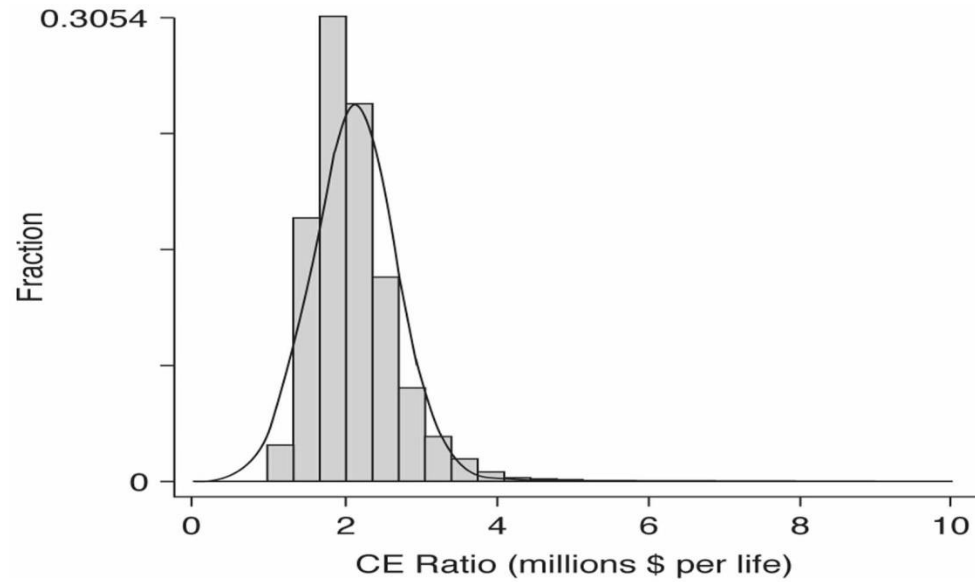
TABLE 18-4 Cost-Effectiveness Analysis with Constraints

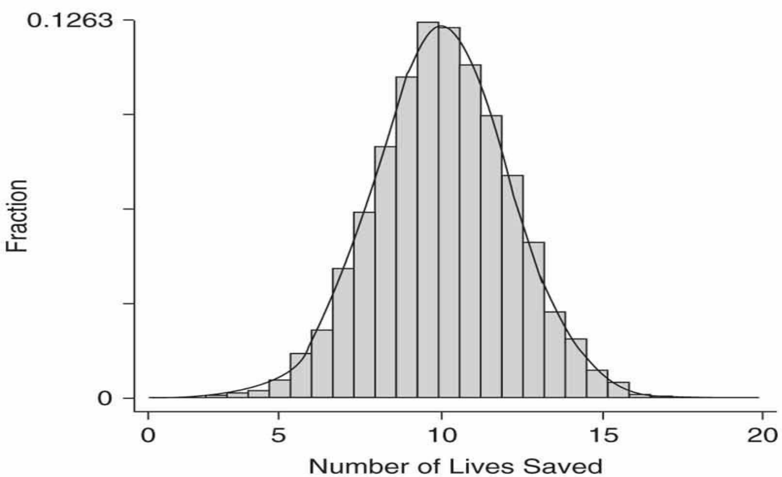
				$E \geq 50$		$C \leq 250$	
Projects (1)	*Lives Saved (2)*	*Budget Cost ($M) (3)*	*CE Ratio (cost per life saved) ($M/life saved) (4)*	*Budget Cost of Projects That Save at Least 50 Lives (5)*	*CE Ratio of Projects That Save at Least 50 Lives (6)*	*Lives Saved of Projects That Cost No More than $250M (7)*	*CE Ratio of Projects That Cost No More than $250M (8)*
A	100	250	2.5	250	2.5[a]	100[a]	2.5
B	20	44	2.2	—	—	20	2.2
~~C~~	~~100~~	~~300~~	~~3.0~~	~~300~~	~~3.0~~	—	—
~~D~~	~~50~~	~~300~~	~~6.0~~	~~300~~	~~6.0~~		
E	10	20	2.0[a]	—	—	10	2.0[a]
~~F~~	~~100~~	~~900~~	~~9.0~~	~~900~~	~~9.0~~	~~—~~	~~—~~
G	60	210	3.5	210	3.5	60	3.5
H	50	200	4.0	200[a]	4.0	50	4.0
I	40	100	2.5	—	—	40	2.5
J	45	110	2.4	—	—	45	2.4

[a]CE ratio, budget cost, or effectiveness of the most preferred alternative.

Monte Carlo Analysis of a Cost- Effectiveness Ratio







- Even if both costs and effectiveness are normally distributed, there is no guarantee that their ratio will be normally distributed.
- Monte Carlo sensitivity analysis is particularly useful in CEA because it reveals the distribution of the ratio.

Omitted Costs and Benefits

Measurement of Costs

- Costs often, and most narrowly, consist of the cost of medication.
- However, more broadly, costs might include other treatment costs, such as the doctors' time or hospitalization.
- Costs might also include waiting time or time lost from work, which are borne by patients or employers.
- It is preferable to include all social costs (or opportunity costs).
- Costs that are constant across all alternatives can be omitted because this will not change the CE rankings, but it will change the CE ratios.

Omitted Costs and Benefits

Omitted Impacts: Technical versus Allocative Efficiency

- CEA considers only one measure of effectiveness. In practice, however, projects often have *multiple benefits*.
- Examples:
  - Regulations that save lives may also reduce injuries or illnesses.
  - New drugs may effectively cure a disease and also have fewer side effects than current drugs.
- To measure allocative efficiency, all costs and benefits should be taken into consideration.
- One solution is to compute the following *adjusted CE* ratio:

$$\widetilde{CE} = \frac{\text{social costs - other social benefits}}{\text{effectiven ess}}$$

Cost-Utility Analysis (CUA)

- CUA is used most in the area of health care. The measure of effectiveness is usually quality-adjusted life years (QALY).
- CUA is most useful when alternative programs or treatment embody a trade-off between quality of life (morbidity) and length of life (mortality).
- *Quality-adjusted life-years* (QALY) combines both the number of additional years of life and the quality of life during those years.
- Programs are compared on the basis of dollars per quality-adjusted life-year ($/QALY).

Example: QALY

TABLE 18-5 The Basic QALY Format

		Additional Years of Life (Y)				
Health Status (H)		**Y_1**	**Y_2**	**Y_3**	**Y_4**	**Y_5**
H_1	worst	$\boxed{Y_1H_1^{SQ}}$	Y_2H_1	Y_3H_1	Y_4H_1	Y_5H_1
H_2		Y_1H_2	Y_2H_2	Y_3H_2	$\boxed{Y_4H_2^{B}}$	Y_5H_2
H_3		Y_1H_3	Y_2H_3	$\boxed{Y_3H_3^{A}}$	Y_4H_3	Y_5H_3
H_4		Y_1H_4	Y_2H_4	Y_3H_4	Y_4H_4	Y_5H_4
H_5	best	Y_1H_5	Y_2H_5	Y_3H_5	Y_4H_5	Y_5H_5

- Status quo – worst health status and only 1 additional year
- Alternative A – 3 extra years with moderate health status
- Alternative B – 4 extra years with more serious health problems.

➔ Clearly, the status quo is dominated. But should we choose alternatives A or B?

Formulating a Health Status Index and Measuring QALYs

- To construct QALYs, we need to assess health-related quality of life (HRQoL).

  QALYs = HRQoL x Life Years

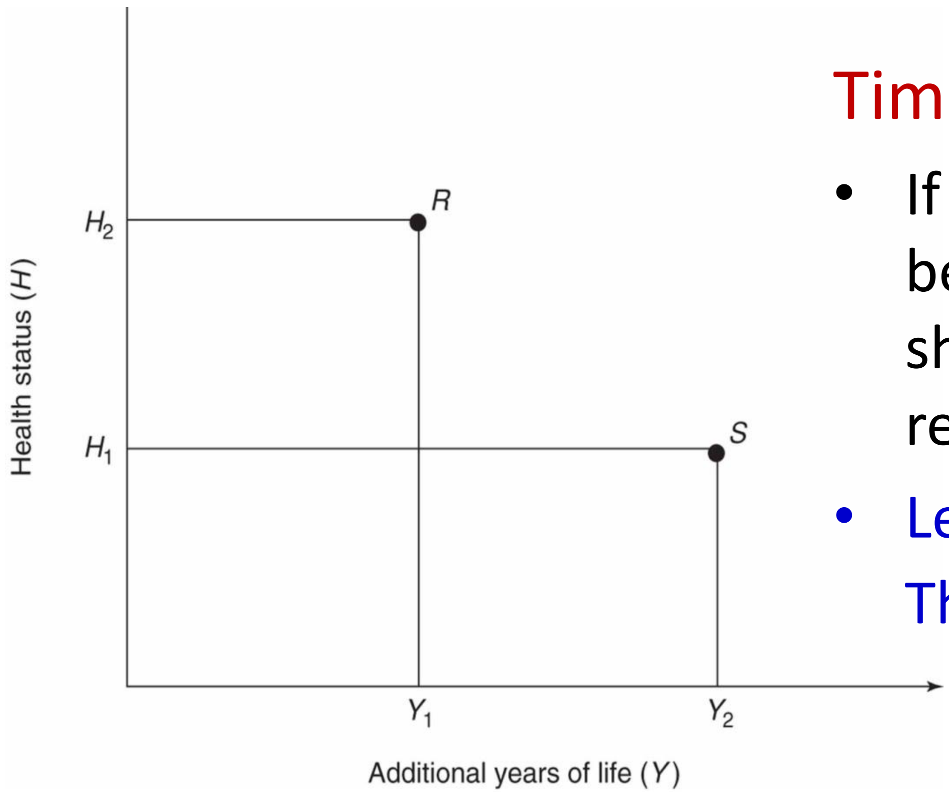
- HRQoL is usually measured on a scale from 0 (*death*) and 1 (*perfect health*).
- There are 4 common approaches to assess HRQoL:
  1. Health rating method
  2. Time trade-off method
  3. Standard gamble method
  4. Health index method

Method 1: Health Rating Method

- This derives health ratings from questionnaires with health experts, potential subjects of treatment, or members of society in general. Individuals are asked to assign values between 0 and 1 to various (well-described) health states.
- Respondents asked to compare different combinations of length and quality of life. The trade-offs in the responses provide a basis for ranking various states (in quality and years)

Method 2: Time Trade-off Method

- Respondents asked to compare different combinations of length and quality of life. The trade-offs in the responses provide a basis for ranking various states (in quality and years)



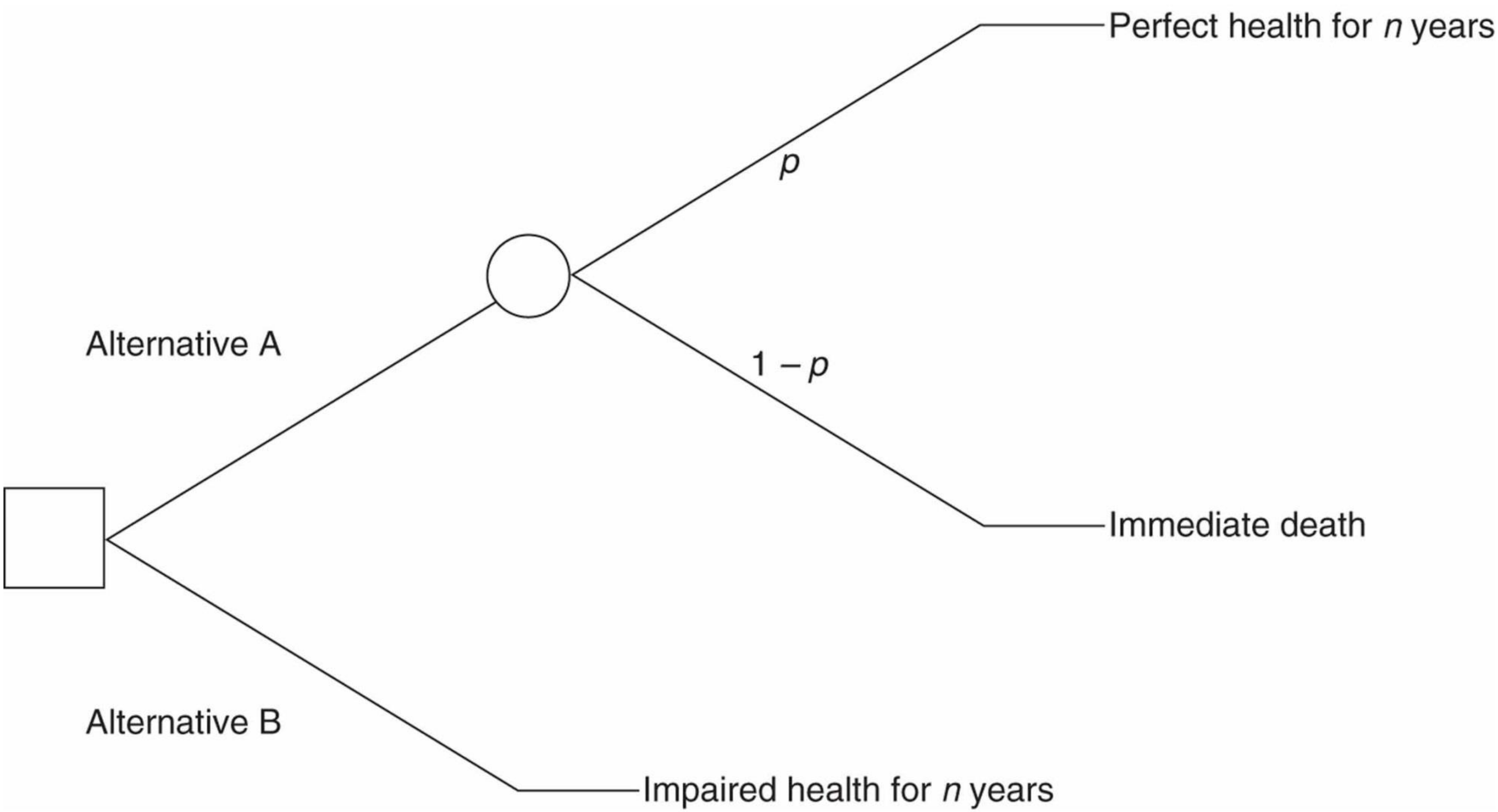
Time Trade-Off Example

- If the respondent is indifferent between points R and S, then she is willing to give up H_2-H_1 in return for Y_2-Y_1.
- Let $U(H_2) = 1$.
  Then, $U(H_1) = Y_1/Y_2$

Method 3: Standard Gamble Method

- Respondents are presented with a decision tree with two alternatives like the following:
  - one alternative is impaired health for *t* years
  - the other alternative is normal health for *n* years with probability *p* or immediate death with probability *1-p*.
- The probability *p* at which an individual is indifferent can be interpreted as the respondent's utility of the former alternative (impaired health status).
- Two approaches to find p:
  1. Ask the respondent to state the probability
  2. Offer an initial probability, and then raise or lower it until the respondent expresses indifference.

The Standard Gamble Method



Example of SG Question
(Adapted from Exhibit 1 in Boardman ch. 18)

- The following alternatives were presented to patient with a history of heartburn.
  - *Alternative 1 is that you know for certain that you will live for another 10 years in your current health state. During these 10 years, your heart-burn as well as symptoms of any other health problems that you may have will be exactly as you have experienced them over the last 12 months. After these 10 years you will die.*
  - *Alternative 2 is that there is a treatment that either is successful or fails. If the treatment is successful, you will recover perfect health and remains perfectly healthy during 10 years, that is the same period of time as in alternative 1. Perfect health means that you are free from all health problems, that is, you are free from heart-burn as well as symptoms of any other health problems that you may have. After these 10 years you will die. If treatment fails, you will die immediately.*
- Respondents are randomly given starting points of either 0.97 or 0.7 for the probability of success. After that, probabilities were raise or lowered until the respondent was indifferent between the two alternatives.

Method 4: Health Index Method

- Health status is assessed in terms of a health index with various dimensions of well-being, such as mobility, absence from pain, etc.
- For example, the Short Form Health Survey (SF-36) provides eight dimensions of assessment .
- With several levels of well being on each dimension, the index can distinguish among thousands of health status.
- Researchers use the standard gamble or time trade-off method to elicit respondents' utilities for a subset of the statuses and then statistically estimate weights that can be used to assign utilities to any of the statuses.

Example of A Modified SF-36 Form

The following questions are about activities you might do during a typical day. In the past 1-week does your health limit you in these activities? If so, how much?

(Please circle one number on each line)

	ACTIVITIES	Yes Limited A lot	Yes Limited A little	No, Not Limited At All
3a:	Vigorous activities, such as running, lifting heavy Objects, participating in strenuous sports	1	2	3
3b:	Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
3c:	Lifting or carrying groceries	1	2	3
3d:	Climbing several flights of stairs	1	2	3
3e:	Climbing one flight of stairs	1	2	3
3f:	Bending, kneeling, or stooping	1	2	3
3g:	Walking more than one kilometre	1	2	3
3h:	Walking half a kilometre	1	2	3
3i:	Walking 100 metres	1	2	3
3g ww:	Wheeling more than one kilometre	1	2	3
3h ww:	Wheeling half a kilometre	1	2	3
3i ww:	Wheeling 100 metres	1	2	3
3j:	Bathing or dressing yourself	1	2	3

[a]Modified from SF-36[1]: Items 3 (a to j) are the original SF-36 questions, while 3g ww to 3i ww (shaded area) comprise the supplementary SF-36ww modification.

Source: http://www.nature.com/sc/journal/v47/n1/fig_tab/sc200865b1.html

Some Caveats on CUA

- Discounting is somewhat problematic as one cannot trade off near years of health for far years of health (and vice versa).
- Methods are based on questionnaires, so the following problems might occur:
  - *hypotheticality problems* (respondents simply haven't thought about the issues very much)
  - *sample selection problems* (potential treatment candidates might exaggerate the "utility" they would receive from a better health state following treatment)
  - *framing effects* (i.e. how questions are asked).

WHEN IS CEA CLOSE TO CBA?

- CEA measures technical efficiency, not allocative efficiency. The most cost-effective alternative is not necessarily worth doing (i.e. it may not be allocatively efficient).
- If all social costs are measured, there is only one benefit (effectiveness) and projects are of similar scale, then the rankings by CBA and CEA will be the same.
- If the above conditions do not apply (ie. CEA is not close to CBA), the analyst could:
  - Try to incorporate significant non-budgetary social costs and other categories of benefits into an adjusted cost-effectiveness measure.
  - Do CBA if effectiveness can be monetized.
  - Move to a more qualitative evaluation method, such as multi-goal analysis.