Methods of economic evaluation. Hurley, Chapter 4

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Review: efficient decision making.

- Rule (tautology?): if the benefits of X exceed the costs of X, it's efficient to do X.
- Suppose we are deciding on the level of some activity (number of hospital beds, number of Avatar BluRays, something).
- Increasing the level of the activity gives us benefits, but also imposes (opportunity) costs.
- (graph)
- MB=MC is just the Rule applied to incremental units.

Review: markets.

- As elaborated in the textbook, and Econ 103, and your other courses, under certain conditions the market outcome equates marginal benefits and marginal costs.
- Roughly, most economists think that markets do a pretty good job giving people the right incentives most of the time.
- But what about goods not provided by markets? e.g., in Canada, how should we decide whether to build a new hospital, or change the speed limit from 50kph to 60kph, or whether to provide an expensive medical treatment?
- Still want to equate MSC and MSB even though we do not have information revealed by the market.

Economic evaluation.

- An *economic evaluation* is a systematic, comparative analysis of the costs and consequences of two (or more) courses of action.
- Part of *evidence-based medicine*, which is turn a part of example of *evidence-based policy*.
- General idea: force analyst to be quantitatively explicit over the goals of the policy, the outcomes considered relevant, and how the policy is assumed to affect outcomes.

Cost–Benefit Analysis.

- One method to help governments make good decisions is CBA.
- Requires the analyst to explicitly write down all the costs and benefits of a project.
- Should evaluate those costs and benefits using best theory and evidence available.
- Benefits and costs should include all indirect and external effects.
- If benefits $>$ costs, suggests the project should go ahead, but not necessarily the only input policy makers should use.

Mortality in CBA.

- Many projects involve risks to life (# hospital beds, new highway divider, pollution abatement, smoking regulations, etc)
- We face a tradeoff between statistical lives saved and other ends.
- We have no choice but to explicitly or implicitly put a value on life!

Example.

- Building a new overpass is expected to avert five deaths per year.
- The overpass costs \$20,000,000. If you think we should not build the overpass, you implicitly think the value of a life is no greater than \$4M.
- How high would the costs have to be before you think we should not build the overpass? You are placing a value on life.
- Really, you are placing a value on the *cost of averting a statistical death.*
- (lives saved vs other outcomes PPF graph)

Measuring the value of statistical life (VSL).

- How NOT to think about the VSL: "A gun is put to your head. What would you pay to prevent the trigger from being pulled?"
- We are interested in the optimal provision of safety at a social level. More safety means less of other goals.
- One method: We can assess the *willingness to pay* some people place on their safety.
- For example, compare two (through statistical modeling) otherwise identical jobs, estimate the wage premium accruing to the more dangerous job.

Table 1
Average Probability of Death by Industry
(BLS: 1972-1982, NIOSH: 1980-1985)

Industries	Number of deaths per 100,000 workers	
	NIOSH	BLS
Mining	40.0	18.7
Construction	32.7	28.7
Manufacturing	4.4	1.5
Transportation, communication and utilities	20.2	10.7
Wholesale trade	2.2	2.7
Retail trade	3.2	2.0
Finance, insurance and real estate	2.3	4.0
Services	3.4	0.9

Source : Moore and Viscusi (1988a)

Inferring value of life: example

- probability of death per year for miners is $3/10{,}000$.
- probability of death per year for fishermen is $2/10{,}000$.
- miners earn \$62,000 per year. Fishermen \$60,000 per year.
- suppose miners and fishermen would earn exactly the same income if risk of death were the same.
- what do we infer for the value of life in this population?

Example, continued

- For every 10,000 miners, we have

$$\begin{aligned}\frac{\text{additional income}}{\text{additional deaths}} &= \frac{10,000(\$62,000 - \$60,000)}{10,000 * (3/10,000 - 2/10,000)} \\ &= \frac{\$62,000 - \$60,000}{1/10,000} \\ &= \$20,000,000.\end{aligned}$$

- Notice we multiplied and divided by the number of miners, so it doesn't matter. We need only calculate extra wages per worker divided by *change in* risk for each worker.

Measurement cont.

- Could also just ask people, e.g., "If you face X risk of a heart attack, what would you pay to reduce your risk to Y?" This is called *contingent valuation.*
- We can see how much people are willing to pay for safety devices, e.g., airbags, again statistically holding all else equal.
- All of these methods are problematic and produce highly variable estimates, but tend to recover estimates at least of similar magnitude.

Multiple programs.

- Suppose you allocate x_1 dollars on program 1 and x_2 dollars on program 2. You have a fixed budget.
- (graphs)
- Rule: health is maximized when marginal health benefit per dollar is equalized across programs.
- Otherwise, you could take a dollar away from a marginally ineffective program and give it to a marginally effective program and increase health without changing the budget.
- Equivalently: if we're not allocating resources well, we could save more lives with any given amount of money.

Full Implementation

	People Affected	Total Annual Cost	Total Annual Life-Years Saved	Cost/ Life-Year Saved
1. Smoking cessation advice for pregnant women who smoke	Many	-$72,237,187	6,568.0	≤$0
2. Sickle cell screening for black newborns	Many	$226,876	961.0	$236
3. Ban asbestos in brake blocks	Few	$311,781	10.8	$28,869
4. Heart transplants	Some	$460,048,544	2,915.0	$157,821
5. Arsenic emission control at glass manufacturing plants	Few	$4,785,532	3.563	$1,343,119
6. Seat belts, auto center back seat	Few	$101,602,435	52.0	$1,943,893
7. Seat belts for school buses	Many	$52,995,773	19.2	$2,760,197
8. Radionuclide emission control at surface uranium mines	Few	$940,645	0.23976	$3,923,277
9. Radionuclide emission control at elemental phosphorus plants	Few	$2,821,935	0.5184	$5,443,547
10. Ban asbestos in automatic transmission components	Few	$22,112	0.000333	$66,402,402

The three cells marked with a tick indicate results which show that a program is unambiguously economically efficient. Where the net cost of the program is zero, an increase in health outcomes is being obtained at no change in health care costs. Where costs decrease, then if health outcomes either remain unchanged or increase, the program improves economic efficiency. In these last two situations, the program is described as being dominant in comparison with the alternative and a cost-effectiveness ratio is not calculated because the cost per unit of health effect is negative.

In contrast to the three cells marked with a tick, the three cells marked with a cross show that a

Table 3
Cost per life-year saved for a sample of screening programs (US dollars, 1993 prices)

Life-saving intervention	Cost per life-year saved
Breast cancer screening	
Mammography for women age 50 years	\$810
Mammography every 3 years for women age 50–65 years	\$2,700
Annual mammography and breast exam for women age 40–49 years	\$62,000
Annual mammography for women age 55–64 years	\$110,000
Cervical cancer screening	
Cervical cancer screening every 3 years for women age 65 + years	≤ \$0
Cervical cancer screening every 9 (vs. 10) years for women age 30–39 years	\$410
One time cervical cancer screening for women age 65 + years	\$2100
Cervical cancer screening every 5 years for women age 35 + years with 3 + kids	\$32,000
Annual cervical cancer screening for women beginning at age 20 years (study 1)	\$82,000
Annual cervical cancer screening for women beginning at age 20 years (study 2)	\$220,000
Annual (vs. every 2 years) cervical cancer screening for women age 20 years	\$1,500,000
Cholesterol screening	
Cholesterol screening for boys age 10 years	\$6500
Colorectal screening	
Annual stool guaiac colon cancer screening for people age 55 + years	≤ \$0
One stool guaiac colon cancer screening for people age 40 + years	\$660
Colonoscopy for colorectal cancer screening for people age 40 + years	\$90,000
HIV / AIDS screening	
Screen blood donors for HIV	\$14,000
Screen donated blood for HIV with an additional FDA-licensed test	\$880,000
Hypertension screening	
Hypertension screening every 5 years for men age 45–54 years	\$36,000
Hypertension screening for asymptomatic women age 60 years	\$17,000
Hypertension screening for asymptomatic women age 20 years	\$87,000
Newborn screening	
PKU genetic disorder screening in newborns	≤ \$0

VSL in Canada and the U.S.

- The U.S. and Canadian governments usually use a value of about $7M as the value of a statistical life when evaluating programs.
- This means that, ignoring other effects of the program, a program is considered desirable if it costs no more than ($7,000,000)*(expected number of lives saved).
- Hopefully the effective cost of averting a death is, therefore, around $7M.

Examples.

- A new hospital is expected to save 50 lives per year and costs \$200M per year. The hospital has no other effects. We should build it, because the cost per life saved is \$4M.
- A new workplace safety regulation is expected to have a social cost of \$100M per year and save 5 lives per year, and has no other effects. We should not implement the regulation, as the cost per life saved is \$10M, so the opportunity cost of implementing the regulation is more than 10 lives.

Discounting.

- Almost always the costs and benefits of a project will be distributed over time, usually unequally.
- How much are you willing to pay to get \$1 with certainty in exactly one year?
- Your answer is your *discount rate*.
- If a dollar in a year is worth b today, then dollar n years from now is worth b^n.

Discounting cont.

- We can express the same concept in terms of interest rates.
- How much would you have to save right now to have \$1 in a year?

$$S + rS = 1$$
$$S = \frac{1}{1+r} = b$$

- That is, if you think a dollar in a year is worth \$b today, that's equivalent to an interest rate of $\frac{1}{1+r}$.

Discounting cont.

- Example: you are willing to pay \$90 today for \$100 in one year.
- Then your discount rate is $b = 0.9$, or the equivalent interest rate is

$$\begin{aligned} 90 + r90 &= 100 \\ (1 + r) &= 100/90 \\ r &\approx 0.11 \end{aligned}$$

Discounting cont.

- If a dollar in a year is worth b to you today, then a dollar in two years is worth b one year from now.
- Something worth b in one year is worth b^2 today.
- Then a dollar in n years is worth b^n today.
- Expressed as an interest rate, A dollars n years from now is worth $(\frac{1}{1+r})^n$ dollars today.

Discounting cont.

- Suppose a project has a sequence of benefits and costs over time.
- In the t^{th} year, the project has net benefits of $(B_t - C_t)$.
- We discount those benefits and costs back to the present to determine the **net present value** of the project:

$$NPV = \sum_{t=1}^{\infty} \frac{B_t - C_t}{(1+r)^t} \tag{1}$$

Discounting cont.

- We can and should discount outcomes even when we are not measuring in dollars.
- Example: Intervention 1 saves 10 lives per year for 10 years. Intervention 2 saves no one for 10 years, but 100 people exactly 10 years from now.
- Then for any positive discount rate, all else equal, intervention 1 is preferable.

Example

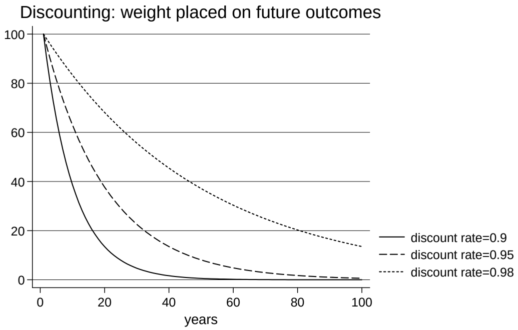
- New medical imaging software costs \$100,000 today plus \$20,000 per year in licensing fees, due at the end of each year, and is expected to last two years.
- If the software generates B of benefits per year and the interest rate is r, its net present value is:

$$NPV = -100,000 + \frac{B - 20,000}{1+r} + \frac{B - 20,000}{(1+r)^2} \quad (2)$$

Discounting cont.

- What rate to choose for r? For various reasons, the (real) market rate of interest is often chosen.
- Notice that $(1/(1+r)^t)$ goes to zero as t rises for any $r > 0$.
- Does this mean we're discriminating against future generations?

graph.pdf


Discounting: weight placed on future outcomes
100
80
60
40
20
0
0
20
40
60
80
100
years
discount rate=0.9
discount rate=0.95
discount rate=0.98

Discounting cont.

- e.g.: $d = 0.10$: $\{$ 1, 0.909, 0.826, 0.751, ... $\}$, after 100 years: 0.0000798, that is, \$1 in 100 years is worth about (7/1000) of one penny.
- At $d = 0.10$, \$1 today is equivalent to about \$6,230,000,000,000,000,000,000,000,000,000,000,000,000, about 27 orders of magnitude more than current world GDP, after 923 years.
- Discounting over long time periods is problematic!

Discounting cont.

- Many interesting ethical and theoretical issues.
- As time frames get large, discounting essentially zeros future costs and benefits.
- But not discounting also leads to strange conclusions.
- Most economists think the relevant discount rate is not zero but less than the market interest rate.

Alternatives to CBA.

- Recall CBA is a method that tells us whether to do something or not: if $B > C$, do it.
- But we have seen that measurement is a serious problem, particularly when risks to health are involved.
- We can use weaker variants of CBA which don't yield as forceful results but do not require (as) severe assumptions to work.

Cost–effectiveness analysis (CEA)

- Compare programs which generally have different costs and different amounts of the desired outcome, but do not place a monetary value on the benefits.
- e.g. Program 1 costs \$100M and is expected to save 5 lives. Program 2 costs \$100M and is expected to save 10 lives. If these programs have no other effects, then program 2 is more cost-effective than program 1.
- Notice that it might be the case that neither program has positive net benefits.

CEA cont.

- Suppose a program raises health output from E_0 to E_1, and raises costs from C_0 to C_1. Then the *incremental cost-effectiveness ratio* for this program relative to business as usual is

$$\text{ICER} = \frac{C_1 - C_0}{E_1 - E_0}. \tag{3}$$

Example

- Treatment A saves 2,000 life years and costs \$18,000,000.
- Treatment B saves 1,000 life years and costs \$10,000,000.
- Then

$$\text{ICER} = \frac{18M - 10M}{2,000 - 1,000} = \frac{8M}{1,000} = \$8,000$$

so switching to treatment A incurs additional costs of \$8,000 per life year saved.

CEA cont.

- Notice that it must be possible to express outputs in the same units to use CEA.
- If one program costs more (less) and is less (more) effective, then choice is easy. Otherwise, a judgement call must be made.

Cost-utility analysis.

- Most programs that affect health will not just affect mortality, they will affect length and quality of life.
- We must make a tradeoff between length and quality of life.
- There are many methods analysts use to try to bring evidence to bear on this tradeoff.

QALYs

- A common method is to weight the life–years a program creates by a measure of the quality of those years.
- QALY idea: A year in some ill-health state is worth a proportion q of a year in perfect health, where q is (usually) between 0 and 1.
- e.g., if you live 10 more years in perfect health, $q = 1$ for all those years and you enjoy 10 QALYs (ignoring discounting).
- if you live 10 more years in a poor health such that, say, $q = 0.4$, then you have 10 more years but only 4 more QALYs (ignoring discounting).

QALYs over time.

- An outcome in which a person will live for T more years in a health state "worth" a fraction q_t in the t^{th} year is then evaluated

$$QALY = \sum_{t=1}^{T} \frac{q_t}{(1+d)^t} \tag{4}$$

where d is the discount rate.

QALYs cont

- Example. A treatment produces a health state worth $q_1 = 0.7$ QALYs after one year, $q_2 = 0.4$ QALYs after two years, and $q_3 = 0.1$ QALYs after three years. The present discounted value of the stream of QALYs is, at discount rate $d = 0.1$,

$$\begin{aligned} QALY =& \frac{1}{(1+0.1)}(0.7) + \frac{1}{(1+0.1)^2}(0.4) + \frac{1}{(1+0.1)^3}(0.1) \\ \approx& 1.04. \end{aligned}$$

Incorporating life expectancy.

- We also want to take into account that different programs will generally have different effects on life expectancy.
- Suppose in the t^{th} year from now, under the program the probability the person is still alive is F_t. Then the expected number of QALYs under this program is

$$QALY = \sum_{t=1}^{T} \frac{F_t q_t}{(1+d)^t} \tag{5}$$

- Notice F_t is indistinguishable from the discount factor $b^t = (\frac{1}{(1+r)})^t$.

QALYs cont

- Example: A patient will live one year with certainty in health state $q_1 = 0.5$. She will live another year with probability 0.9 in health state $q_2 = 0.3$. There is a 70% probability she will live another year in health state $q = 0.2$. The discount rate is $d = 0.05$. Then the expected present discounted value of her QALYs is

$$
\begin{aligned}
QALY =& \frac{1}{(1+0.05)}0.5 + \frac{1}{(1+0.05)^2}(0.9)(0.3) + \frac{1}{(1+0.05)^3}(0.7)(0.2) \\
=& 0.84
\end{aligned}
$$

QALYs cont

- How do we determine the q_t?
- Commonly, just ask people ("contingent evaluation" again).
- But this is done in clever ways.

Standard gamble

- Suppose the utility of living in some poor health state is $U(\text{disease})$.
- Consider a hypothetical treatment with two outcomes: with probability q the treatment returns the person to full health, and with probability $(1-q)$ the treatment kills the person instantly.
- Elicit q^*, the value of q which makes the person indifferent to taking treatment.

Standard gamble cont.

- We have

$$U(\text{disease}) = q^* U(\text{full health}) + (1 - q^*) U(\text{death})$$

- If we set ("normalize") the utility of death to zero and full health to 1.0, we have $q^* = U(\text{disease})$.
- For this respondent, one year in the disease state is deemed to be equivalent to a fraction q^* of a year in full health.
- Simple demonstration online app: click here

Standard Gamble example.

- Example. Suppose you are a blind person. You have the option of taking a pill which will completely restores your sight with probability 0.8, otherwise it will kill you instantly. Do you take the pill?
- If you would, then your QALYs per year in with your health condition are less than 0.8. If you would not, they are greater than 0.8.
- We elicit from people the probability which makes them *just indifferent* to taking the pill.
- So if you would take the pill at a probability of , say, 0.66 but not at 0.64, then we estimate your QALYs per year in this health state at $q = 0.65$.

Using QALYs

- Once we have established QALY values for various health states, we can use them in a CEA to find the policies which yield the greatest QALYs for a given cost.
- We can also use them in CBA if we're willing to put a dollar value on a QALY.
- When using CBA, values of up to about $75,000 per QALY are used as thresholds.

Evaluating QALYs

- It is difficult to reconcile these approaches with standard welfare economics, even if we could perfectly measure preferences.
- We cannot perfectly measure preferences. (e.g., method discussed above confounds risk preference and preferences over health states).
- Applied analysis in this area is often of poor quality.
- Discriminates against elderly, possibly against poor. Usually does not consider distributional effects (either on income or on health).

An example of a real evaluation.

- Sander *et. al.*, 2009.
- *Objectives*: To project the potential economic impact of pandemic influenza mitigation strategies from a societal perspective in the United States.
- *Methods*: We use a stochastic agent-based model to simulate pandemic influenza in the community. We compare 17 strategies: targeted antiviral prophylaxis (TAP) alone and in combination with school closure as well as prevaccination.

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VALUE IN HEALTH

Economic Evaluation of Influenza Pandemic Mitigation Strategies in the United States Using a Stochastic Microsimulation Transmission Model

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ABSTRACT

Objectives: To project the potential economic impact of pandemic influenza mitigation strategies from a societal perspective in the United States.
Methods: We use a stochastic agent-based model to simulate pandemic influenza in the community. We compare 17 strategies: targeted antiviral prophylaxis (TAP) alone and in combination with school closure as well as prevaccination.
Results: In the absence of intervention, we predict a 50% attack rate with an economic impact of $187 per capita as loss to society. Full TAP (FTAP) is the most effective single strategy, reducing number of cases by 54% at the lowest cost to society ($127 per capita). Prevaccination reduces number of cases by 48% and is the second least costly alternative ($140 per capita). Adding school closure to FTAP or prevaccination further improves health outcomes but increases total cost to society by approximately $2700 per capita.
Conclusion: FTAP is an effective and cost-saving measure for mitigating pandemic influenza.
Keywords: computer simulation, cost–benefit analysis, economics, human disease outbreaks, influenza, pharmaceutical models, theoretical.

Table I Description of interventions

Intervention	Description
No intervention	No prevaccination, prophylaxis or treatment with antivirals
HTAP25	Household targeted antiviral prophylaxis, stockpile for 25% of population
HTAP50	Household targeted antiviral prophylaxis, stockpile for 50% of population
HTAP	Household targeted antiviral prophylaxis, stockpile unlimited
FTAP25	Full targeted antiviral prophylaxis (household contacts and 60% of work/school contacts), stockpile for 25% of population
FTAP50	Full targeted antiviral prophylaxis (household contacts and 60% of work/school contacts), stockpile for 50% of population
FTAP	Full targeted antiviral prophylaxis (household contacts and 60% of work/school contacts), stockpile unlimited
Prevaccination	Prevaccinating 70% of population with low-efficacy vaccine
School closure	Closing all schools for 26 weeks
HTAP25 + school closure	Household targeted antiviral prophylaxis, stockpile for 25% of population, plus closing all schools for 26 weeks
HTAP50 + school closure	Household targeted antiviral prophylaxis, stockpile for 50% of population, plus closing all schools for 26 weeks
HTAP + school closure	Household targeted antiviral prophylaxis, stockpile unlimited, plus closing all schools for 26 weeks
FTAP25 + school closure	Full targeted antiviral prophylaxis (household contacts and 60% of work/school contacts), stockpile for 25% of population, plus closing all schools for 26 weeks
FTAP50 + school closure	Full targeted antiviral prophylaxis (household contacts and 60% of work/school contacts), stockpile for 50% of population, plus closing all schools for 26 weeks
FTAP + school closure	Full targeted antiviral prophylaxis (household contacts and 60% of work/school contacts), stockpile unlimited, plus closing all schools for 26 weeks
Prevaccination + school closure	Prevaccinating 70% of population with low-efficacy vaccine, plus closing all schools for 26 weeks
Treatment only	Treating all cases with antivirals

Table 3 Base-case results (ranked by expected QALYs)

Intervention	Illness attack rate (%)	Deaths per 1000	QALYs* per 1000	Incremental QALYs† per 1000	Courses per 1000	Total cost in million $ per 1000
No intervention	50	13	21,141	—	—	0.19
FTAP25	48	12	21,157	16	246	0.18
FTAP50	45	11	21,175	34	481	0.18
HTAP25	48	11	21,181	40	250	0.19
School closure	39	10	21,210	69	—	2.72
HTAP50	42	8	21,239	98	498	0.17
Treatment only	49	8	21,241	100	243	0.19
HTAP	41	7	21,264	123	651	0.17
Prevaccination	26	6	21,271	130	—	0.14
HTAP25 and school closure	31	7	21,273	132	204	2.70
FTAP25 and school closure	23	6	21,300	159	150	2.66
FTAP50 and school closure	22	5	21,310	169	279	2.66
HTAP50 and school closure	27	5	21,316	175	374	2.68
HTAP and school closure	24	4	21,330	189	395	2.67
FTAP	23	5	21,351	210	2,447	0.12
FTAP and school closure	6	1	21,403	262	640	2.61
Prevaccination and school closure	4	1	21,403	262	—	2.62

*Expected average quality-adjusted life expectancy.
†Compared with no intervention.
Note: QALY ranking differs slightly from illness attack rate ranking because QALYs take into account the differences in morbidity and mortality (life expectancy) across age groups, i.e., it is important in which age groups cases and deaths occur.
HTAP, household targeted antiviral prophylaxis; FTAP, full targeted antiviral prophylaxis; QALY, quality-adjusted life-year.

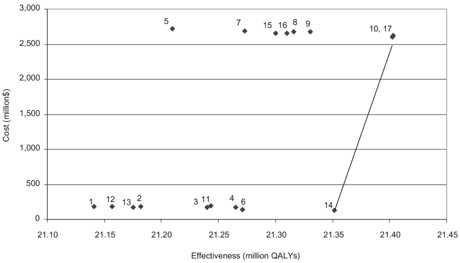

Figure 2 Cost-effectiveness frontier base-case. 1 = no intervention; 2 = HTAP25; 3 = HTAP50; 4 = HTAP; 5 = school closure; 6 = prevaccination; 7 = HTAP25 and school closure; 8 = HTAP50 and school closure; 9 = HTAP and school closure; 10 = prevaccination and school closure; 11 = treatment only; 12 = FTAP25; 13 = FTAP50; 14 = FTAP; 15 = FTAP25 and school closure: 16 = FTAP50 and school closure.
HTAP = household targeted antiviral prophylaxis; FTAP = full targeted antiviral prophylaxis; QALYs = quality-adjusted life-year.

Table 4 Incremental cost utility for noneliminated strategies (pandemic occurs within 1 year)

Intervention	Total cost in million $ per 1000	Incremental cost in million $ per 1000	QALYs per 1000	Incremental QALYs per 1000	Incremental cost-utility ratio ($)
FTAP	0.12	—	21,352	—	—
FTAP and school closure	2.73	2.48	21,403	51	48,472
Prevaccination and school closure	2.73	2.50	21,403	51	48,638

Note: FTAP plus school closure and prevaccination plus school closure are individually compared to the same baseline (FTAP).
FTAP, full targeted antiviral prophylaxis; QALY, quality-adjusted life-year.

Recap: three methods

1. CBA: requires evaluation of dollar value of benefits, allows analyst to say whether a project is worth undertaking or not.
2. CEA: assumes objective is already specified, determines least-cost method of achieving that objective.
3. CUA: variant of CEA puts varied health outcomes into same units (QALYs or similar).

Controversy over WTP

- Often CBA measures outcomes using willingness-to-pay as the measure of benefit.
- This assumption usually means that health benefits accruing to richer people are deemed to provide greater benefits.
- This is turn raises ethical conundrums.
- Possible to "fudge" CBA by using distributional weights (e.g., one QALY accruing to young, poor parent equal to two QALYs accruing to elderly, wealthy single person).