D. Economic Evaluation of Health Technology

D.1 Cost Benefit Analysis (CBA):
Sixth Stool Guaiac Example

D.2 Cost-effectiveness Analysis (CEA):
Sixth Stool Guaiac Example

D.3 Cost-effectiveness Analysis using QALY's:
Surgery Example with uncertainty & discounting

How do we decide whether a particular medical procedure is worth the cost?

CBA is the standard tool in public economics.

CEA is used especially in health economics.

Bhattacharya, Hyde and Tu Chapter 14: Health Technology Assessment

D.1 Cost Benefit Analysis (CBA) Overview

Demand and Supply Analysis

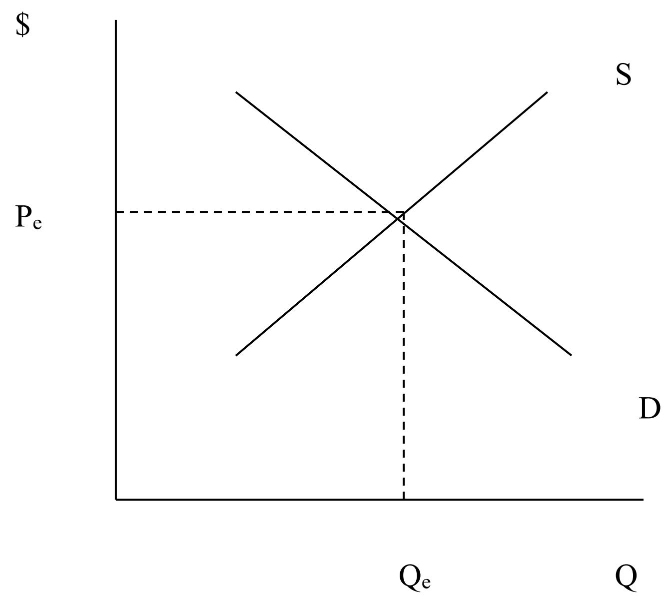
Usual way to determine, for example, optimal amount of Acetaminophen (either generic or Tylenol) for society.

Demand curve: amount that would be purchased at each price.

Supply curve: amount that would be supplied at each price.

Market equilibrium: quantity and associated price such that demand = supply.

Acetaminophen: price and # packets



Marginal Benefit and Marginal Cost Analysis

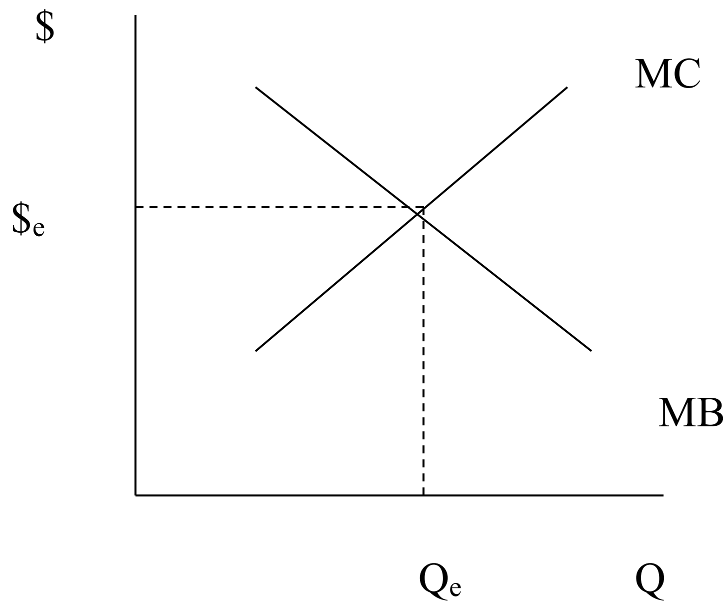
Problem: In health there may be no natural market.
e.g. How do we determine the optimal number of screening tests for colon cancer?

Solution: Recreate D and S curves using MB and MC curves.

Demand curve: maximum amount consumer will pay for each unit = **marginal benefit (MB) curve**.

Supply curve: minimum amount firm will sell each unit for = **marginal cost (MC) curve**.

Screening tests: MC / MB and number



MB and MC Analysis

Optimal Q is such that MB = MC.

This means that net benefit is maximized.
[Max (B-C) wrt Q ==> d(B-C)/dQ = 0 ==> dB/dQ = dC/dQ]

And it means that consumer + producer surplus is maximized.

Standard tool to use for
- Public good [use social MB equals sum of individual MB's]
- Externality [replace MC by social MC or MB by social MB]
- Health applications where construct SMC and SMB.

D.1 Cost Benefit Analysis (CBA): Sixth Stool Guaiac

Test Details

Example from Neuhauser and Lewicki (NEJM, 1975).
Here use rounded numbers in Getzen (2^{nd} ed., 2004, p.48-52).
[This example is not in subsequent editions of Getzen].

Screening program for colon cancer:
Complication: test is imperfect.
Question: what is the optimal number of tests?

Test accuracy:

- Only 90% of cancer cases are detected
- And 20% of tests detect cancer when there is none.

Test costs:

- $4 for first stool test and $1 for each additional stool test.
- $100 for confirmatory enema test given to each person who test positive on stool test.

Test Benefits:

Early treatment of colon cancer.

Difficult to estimate the benefit.

Suppose worth $100,000 per case diagnosed.

Screening Program: 100,000 screened when 720 have undiagnosed colon cancer.

First Test

Detects 90% of true cases:

0.9 x 720 = 648.

+ false positives 20% of time: 0.2 x 100,000 = 20,000.

Costs

Stool tests	100,000 x $4	= $400,000
Enema tests	(20,000 + 648) x $100	= $2,064,800
Total		**$2,464, 800**

Benefits

Total	648 x $100,000	= **$64,800,000**

[Variation: false positives are 20% of (100,000–720)=19,856
Costs are $400,000 + (19,856 + 648) x $100 =$2,450,400]

Second Test

Detects 90% of remaining cases:

0.9 x (720-648) = 0.9 x 72 = 64.8.

+ additional false positives 20% of time:

0.2 x (100,000 – 20,000) = 16,000.

Marginal Costs

Stool tests	100,000 x $1	= $100,000
Enema tests	(16,000 + 65) x $100 =	$1,606,500
Total		**$1,706,500**

Marginal Benefits

Total	64.8 x $100,000	= **$6,480,000**

[Variation: false positives 20% of (100,000–19,856–720)=15,884.8
Costs are $100,000 + (15,884.8 + 64.8) x $100 =$1,694,960]

Third Test

Detects 90% of remaining cases:

0.9 x (720-648 – 64.8) = 0.9 x 7.2 = 6.48.

+ additional false positives 20% of time:

0.2 x (100,000 – 20,000 – 16,000) = 12,800.

Marginal Costs

Stool tests	100,000 x $1	= $100,000
Enema tests	(12,800 + 6) x $100	= $1,280,600
Total		**$1,380,600**

Marginal Benefits

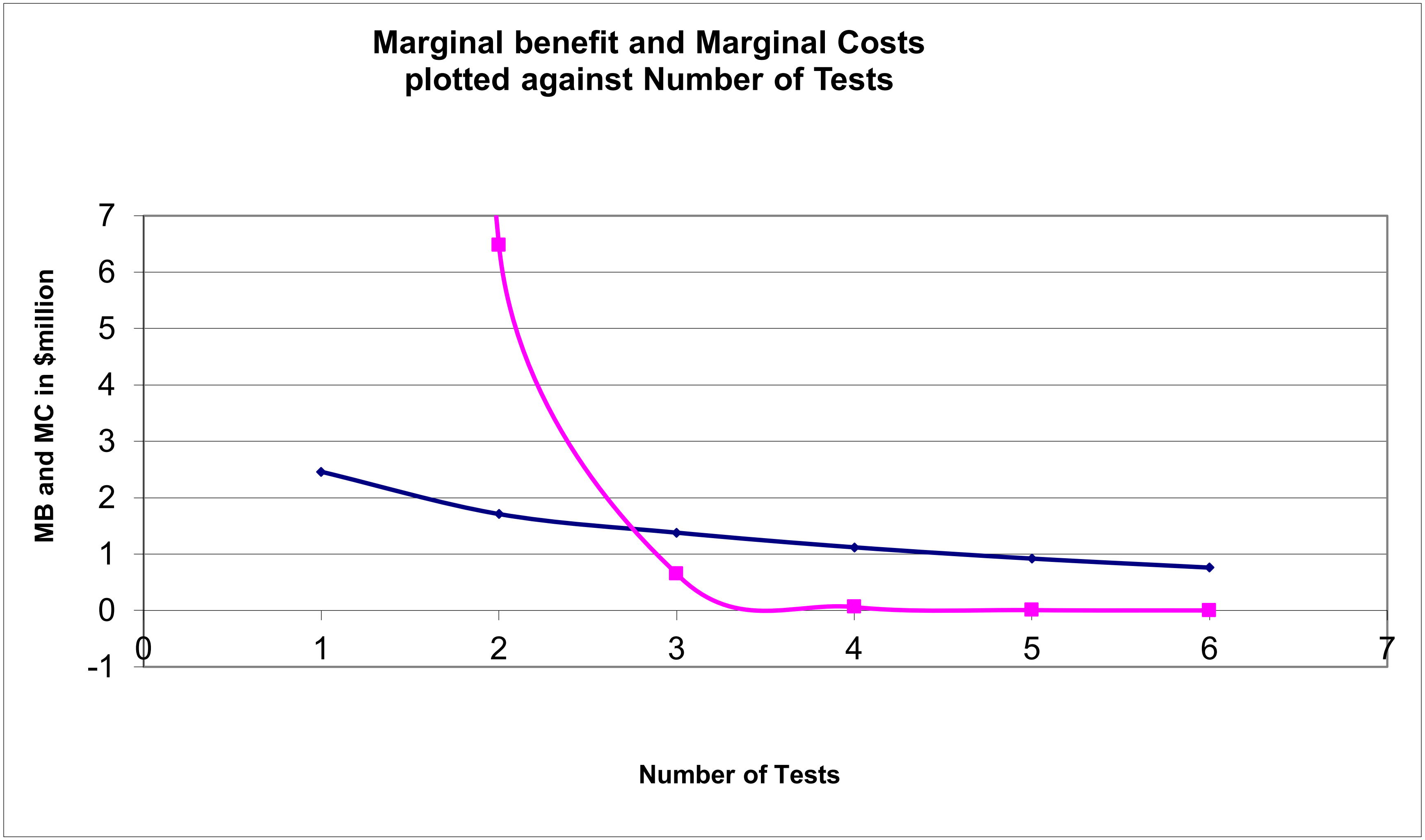
Total	6.48 x $100,000	= **$648,000**

Up to Six Tests

Number of Tests	Cases Detected	Marginal Cost	Marginal Benefit
0	0	-	-
1	648	$2,464,800	$64,800,000
2	712.8	$1,706,500	$6,480,000
3	719.28	$1,380,600	$648,000
4	719.928	$1,124,100	$64,800
5	719.9928	$919,200	$6,480
6	719.99928	$755,400	$648

MB = MC between two and three tests.

If early treatment is worth $100,000 per case of early detection, then two tests are optimal, as on the third test we lose
MC – MB = $1,380,600 - $648,000 = $731,400.


Marginal benefit and Marginal Costs
plotted against Number of Tests
MB and MC in $million
7
6
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
Number of Tests

D.2 Cost-effectiveness Analysis (CEA): Sixth Stool Guaiac

Cost-effectiveness analysis (CEA) determines the **cost per standardized objective**, most notably life-year saved.

For comparing treatment A to B:

Incremental Cost-effectiveness ratio (ICER)

= incremental costs / incremental benefits

= [Costs(A) – Costs(B)] / [Benefits(A) – Benefits(B)]

(One of the treatments may be no treatment).

For the sixth stool Guaiac test we do cost-effectiveness analysis for each test, using early detection as the objective.

We ask what is the **marginal cost per case of early detection** as the number of tests increases?

Number of Tests	Extra Cases Detected	Marginal Cost	MC per extra case detected
1	648	$2,464,800	$3,804
2	64.8	$1,706,500	$26,335
3	6.48	$1,380,600	$213,056
4	.648	$1,124,100	$1,734,722
5	.0648	$919,200	$14,185,185
6	.006488	$755,400	$116,430,000

Four or more tests are exceptionally expensive.

Even the third test is costing a lot per case detected, and money could be better used in some other way.

D.2 CEA: Life-years Saved Example

Common objective for CEA is life-years saved.

Suppose that a person with terminal cancer has the following options

1. No treatment: Spend nothing and live two more years.

2. Treatment: Spend $40,000 and live five more years.

Then cost-effectiveness analysis computes the **incremental cost of a year of life saved** through treatment (versus no treatment) as:

($40,000 - $0) / (5 – 2)

= $40,000 / 3

= $13,333 per year of life saved.

D.3 CEA Using QALY's

Cost-utility analysis (CUA) is a variation of CEA that adds an adjustment for quality of the outcome.

[A back-door way to bring in valuation].

In particular **quality-adjusted life years (QALY's)** adjust life years saved by multiplying by a quality factor.

[Aside: QALYs can also be used to compute

Quality-adjusted life expectancy (QALE) from age $t=t_0$

$= \sum_{t=t0}^{END} q_t p_t$

where q_t quality adjustment factor and p_t = probability survive to t

In some cases we may use discounted QALE $\sum_{t=t0}^{END} \delta^t q_t p_t$.]

QALY Computation

Several methods are used

- Time trade-off: x years of condition H versus y years of perfect health
- Visual analogue scale: rate condition H on scale of 0 (worst possible health) to 100 (best possible healthy)
- Standard gamble: compare condition H with certainty to a gamble with perfect health (probability p) and death (probability 1-p)

Bhattacharya et al. Table 14.5 gives QALY factors from a 2004 study with a range depending on method used

e.g. 1 year in depression = 0.27 – 0.61 years in perfect health.

e.g. 1 year blind = 0.36 – 0.72 years in perfect health.

e.g. 1 year watery diarrhea = 0.75–0.92 years in perfect health.

CEA using life-years saved in practice

Realistic problems have three complications:

- The outcome of treatment is **uncertain**, so we need to weight the probabilities of different outcomes.
- The analysis is over several years, so we need to **discount** future years costs and benefits to the present
  - the discount rate is typically 3% to 5%.
- The quality of life differs under different treatment and outcomes, so we need to use **QALY**'s.

CEA Example

The following example uses data in Getzen (2004, p.65).

1. No treatment: Outcome is certain and is the following

Live 2 years
No additional costs
QALY adjustment factor 0.50.

2. Treatment: Outcome is uncertain with two possibilities

a. Treatment is a success (with probability 0.85):

Live 4 years
$100,000 additional costs initially plus $10,000 each year
QALY adjustment factor 0.80.

b. Treatment is a failure (with probability 0.15):

Live 0 years
$100,000 additional costs
QALY not relevant

1: Analysis with just uncertainty
(but no time discounting or quality of life adjustment)

The main complication is that two outcomes are possible with treatment. Use **expected values**.

Treatment

Benefits:

Expected life years with transplant

$= 0.15 \times 0 + 0.85 \times 4$
$= 3.40$

Costs:

Expected costs with transplant

$= 0.15 \times 100{,}000 + 0.85 \times 140{,}000$

$= 134{,}000.$

No Treatment

Benefits: 2.0 years

Costs: $0

Treatment Cost-effectiveness:

Expected cost per additional expected life year

= ($134,000 - $0)/ (3.40 – 2.0)

= **$95,714.**

2: CEA Analysis with uncertainty, time discount and QALYs

Year	Year 1	Year 2	Year 3	Year4	Total
Time Discount Factor	1.00	1/1.05 =.9524	$1/1.05^2$ =.9070	$1/1.05^3$ =.8638	1.00
Baseline (no surgery)					
LY (no discount)	1.00	1.00	0.00	0.00	2.00
QALY (no discount)	0.50	0.50	0.00	0.00	1.00
QALY discounted	0.50	0.4762	0.00	0.00	0.9762
Cost (no discount)	0	0	0	0	0
Cost discounted	0	0	0	0	0
Surgery Succeeds (prob 0.85)					
LY (no discount)	1.00	1.00	1.00	1.00	4.00
QALY (no discount)	0.80	0.80	0.80	0.80	3.20
QALY discounted	0.80	0.7619	0.7256	0.6911	2.979
Cost (no discount)	110,000	10,000	10,000	10,000	140,000
Cost (discount)	110,000	9,524	9,070	8,638	137,232
Surgery Fails (prob 0.15)					
LY (no discount)	0.0	0.0	0.0	0.0	0.0
QALY (no discount)	0.0	0.0	0.0	0.0	0.0
QALY discounted	0.0	0.0	0.0	0.0	0.0
Cost (no discount)	0	0	0	0	0
Cost (discount)	100,000	0	0	0	100,000

Use the previous table, weighting by the probabilities.

Treatment:

Benefits: Expected discounted QALYs with transplant

$= 0.15 \times 0 + 0.85 \times 2.9786 = 2.532.$

Costs: Expected costs with transplant

$= 0.15 \times 100{,}000 + 0.85 \times 137{,}232 = 131{,}647.$

No Treatment:

Benefits: Discounted QALYs without transplant = 0.976.

Costs: $0

Treatment Cost-effectiveness:

Expected discounted cost per additional expected QALY saved

= ($131,647 - $0)/ (2.532 – 0.976)

= **$84,600.**

In practice this would be used to compare the cost-effectiveness of alternative treatments.

QALY League Tables

From Getzen (2013, Table 3.8) from a 1995 U.K. study

Present value of extra cost per QALY versus no treatment

$450	Physician advice to stop smoking
$1,900	Pacemaker implant for heart block
$2,000	Hip replacement
$2,800	CABG for severe angina left main disease (coronary artery bypass graft)
$8,200	Kidney transplant
$9,500	Breast cancer screening
$14,000	Heart transplant

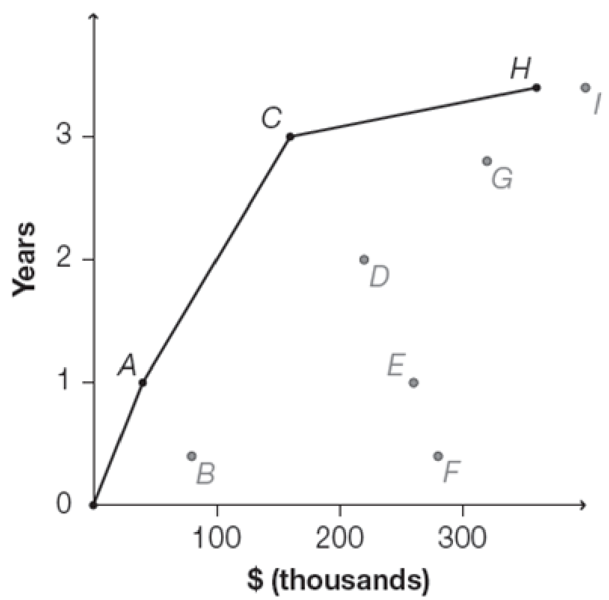
Comparing Multiple Treatments for a given problem

For each treatment get cost and benefits (e.g. life-years saved).

Draw graph with **benefit on y axis** and **cost on x axis**.

Drop dominated treatments (below the line) for which there is another treatment that has lower cost and higher benefit.

Cost-effectiveness frontier (CEF) links nondominated treatments.



Incremental cost-effectiveness ratio (ICER) between any two treatments is the inverse slope of CEF.

Complications of CBA, CEA and CUA in health applications

Measuring Costs (CBA, CEA and CUA)

- Medical costs are below medical charges ("posted price")
- Follow-up costs (can exceed treatment costs)
- Time and Pain of Patient and Family
- Time and Inconvenience of Provider

Measuring Benefits (CBA)

- What is $ benefit of improved health?
- Measuring productivity benefit in workplace by wages earned treats different people differently.
- How to value life saved?

The Value of a Life Saved

1. Constructive method: use PDV of future earnings.
This is used for damages to individual in legal cases.

2. Indirect methods

- called value of a statistical life

- marginal consideration for small changes in mortality risks

a. Willingness to pay (WTP)

This uses consumer behavior to avoid risk of death.

e.g. 0.00001 ↓ in death costs $10 for home fire detectors
then life worth $10/.00001 = $1 million.

b. Willingness to accept uses compensating wage differential for exposure to death.

e.g. 0.0001 ↑ in death means $240 ↑ in salary
then life worth $240/.0001 = $2.4 million.

Indirect methods are appropriate for health policy.

- measure value of small changes in mortality risks and then scales up to one life.
- called the value of a statistical life, a marginal consideration of willingness to pay for a small reduction in mortality risks
- relevant metric as health policy costs are also marginal.

They give a big range for the statistical value of a life.
Examples used by U.S. federal agencies are the following.

Environmental Protection Agency (EPA) used $9.1 million in 2010.

Food and Drug Administration (FDA) used $9.3 million in 2015.

U.S. Department of Transportation used $9.2 million in 2014.

Disability-Adjusted Life Expectancy and Life-Years

QALYs are used to measure gains in health due to treatment.

An alternative weighting scheme is used to measure health lost due to disease and disability. This uses **disability weights**, that are computed for thousands of diseases and disabilities.

Disability-adjusted life-year (DALY)
= Number of years lost due to ill-health, disability or early death
= Years of Life Lost due to premature death (YLL)
+ Years Lived with disability (YLD) weighted by disability weight

The weights can also be used to compute disability-adjusted life expectancy (DALE).

QALY and DALY are examples of health-adjusted life-years (HALY).