Cost-Benefit Analysis & Chronic Disease

Why Do Cost-Benefit Analysis?

- Government resources are scarce
  - Note the projects debated in the stimulus package, such as aid to states, funding for the arts, etc.
  - Spend a dollar on one project, can't spend it on another
- Government should allocate these scarce resources to uses that provide most benefit
  - One measure is to compare costs and benefits of a government program
  - Not the only measure, as we will discuss later

The Basic Rule of CBA

- Devote resources to an activity until the last unit has a benefit just equal to the cost
  - Marginal Benefit = Marginal Cost
- We want to maximize "bang for the buck"

Costs

Quantity	Total Cost	Marginal Cost		Total Cost	Marginal Cost
1	5	5		5	5
2	10	5		12	7
3	15	5		20	8
4	20	5		29	9
5	25	5		39	10
6	30	5		50	11
7	35	5		62	12
8	40	5		75	13
9	45	5		89	14

Costs

- The 1st product has a *constant* marginal cost
  - Each unit increases total costs by $5
- The 2nd product has *increasing* marginal costs
  - Each additional units costs more to produce than the previous one
- We usually assume that marginal costs are increasing (sometimes constant)
  - The more you try to make/do, the more it costs for each additional unit

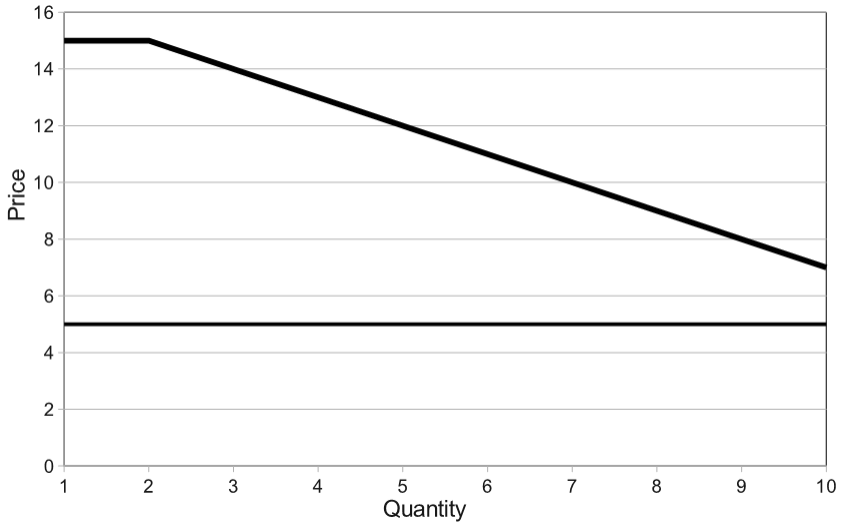
Benefits

Quantity	Total Benefit	Marginal Benefit		Total Benefit	Marginal Benefit
1	15	15		50	50
2	30	15		90	40
3	44	14		120	30
4	57	13		140	20
5	69	12		150	10
6	80	11		158	8
7	90	10		164	6
8	99	9		168	4
9	107	8		170	2

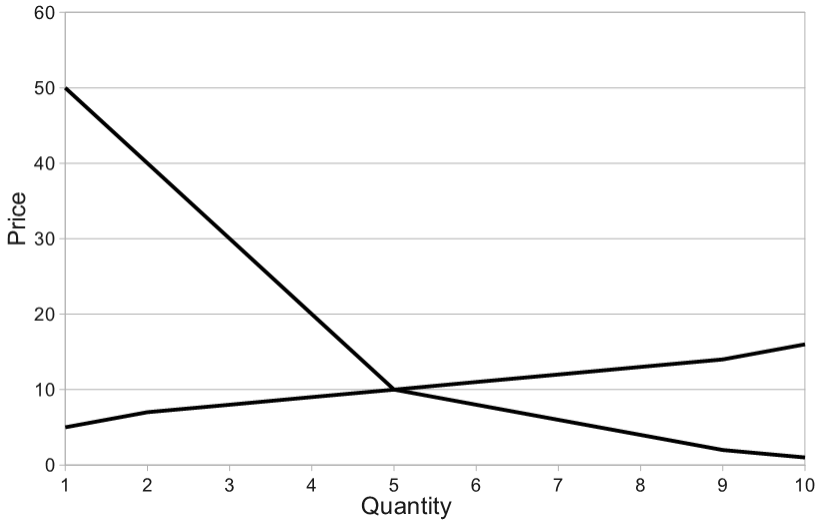
Benefits

- Both products have decreasing marginal benefits
  - The 1st has lower total benefits for all units, but decreases at a lower rate than the 2nd unit
  - The 2nd unit has higher total benefits for all units, but the marginal benefit decreases faster

Benefits vs Costs (1)



Benefits vs Costs (2)



What is the optimal amount?

- Consume where Marginal Benefits = Marginal Costs. Why?
- For the 1st product, marginal benefits are always greater than marginal costs over the given range
  - This implies we should consume/purchase more than 10 units
  - The benefits of an additional unit are greater than the costs
- For the 2nd product, MB = MC @ 5 units
  - If we purchase a 6th unit, we "over pay"
  - MC = 11, MB = 8 => a 6th unit makes us worse off

Measuring Benefits

- How do we value time?
  - Wages – the value of someone's time is what they are willing to work for
  - If they are willing to work for $10/hr, we should not assume their time is worth $20/hr when calculating benefits
  - Add up future earnings
  - Doesn't account for leisure time

Measuring Benefits

- Contingent Valuation – ask people what they think something is worth
  - People often try to tell surveyors what they think the person wants to hear
    - How much is a national park worth?
  - Incentive to lie if it will affect their taxes
  - People get confused
    - Order of issues matters – save seals and bears vs. save bears and seals
    - "embedding effects" – same value of saving 20k or 200k birds
    - How much is an extra year of life worth?

Measuring benefits

- Revealed preference – observe decisions people actually make to estimate how much they value something
  - 2 identical houses but 1 has 15 minute commute and other has 30 minute commute, observe difference in prices to determine value of time
  - Difficult in practice (impossible w/ health issues?)

Measuring costs

- Easy to do if there is a market
  - How much does a bottle of aspirin cost?
  - How much does a cure for cancer cost?
  - How much does an extra life cost?
- For many government projects, salaries are a large (largest) cost component
  - Easyto account for

Predicted Future Costs / Benefits

- If converting from past to present, use CPI
  - Adjust for Inflation
- How do we predict future costs / benefits?
- Use discount rate: predicted per-year increase in costs and benefits
- A dollar today is worth more than a dollar tomorrow
  - "A bird in hand is worth two in the bush"

Discount Rates

- Spend $20 per year for 5 years – PDV < $100
  - Depends on what discount (interest) rate used
- Large discount rate makes future cost look small
  - Pay $100k in 40 years, how much do you need in bank today?
  - Depends on interest rate
    - r = .03 => PV=$30,655, r = .10 => PV=$2,209
  - Where do these numbers come from?

Basic Defintions

- Present Value – money now
- Future Value – money later
- Interest rate – "exchange rate" between money now and money later
  - Cost of capital (borrowing money)
  - Discount rate

Future Value: Formula

- FV = PV(1 + r) ^t
  - FV = future value
  - PV = present value
  - r = period interest rate, expressed as a decimal
  - t = number of periods

Example

- Invest $1000 for one year at 5% per year.
  - What is the future value in one year?
  - FV = PV(1 + r) ^t
  - FV = 1,000(1 + .05) = 1,050
- How much will you have two years from now?
  - FV = 1,000(1.05)(1.05) = 1,000(1.05) ^2 = 1,102.50

- Future costs – need to use present discounted value
  - Spend $20 per year for 5 years – PDV < $100
    - Depends on what discount (interest) rate used
  - Large discount rate makes future cost look small
    - Pay $100k in 40 years, how much do you need in bank today?
    - r = .03 => PV=$30655, r = .10 => PV=$2209

Compounding

- Simple versus compound interest
- Previous example
  - FV with simple interest = 1000 + 50 + 50 = 1100
  - FV with compound interest = 1102.50
  - Interest on first interest payment = .05 * 50 = 2.50

Present Value

- How much do I have to invest today to have some amount in the future?
  - FV = PV(1 + r) ^t
  - PV = FV / (1 + r) ^t
- Discounting - PV of some future amount

New Savings Account

- Invest $500 today and $600 in one year
- Earn 9% annually
- How much will you have in two years?
  - Yr 1 FV = 500(1.09) ^2 = 594.05
  - Yr 2 FV = 600(1.09) = 654.00
  - Yr 1 + Yr 2 FV = 1248.05
- How much will you have in 5 years if you make no further deposits?
  - FV = 1248.05(1.09) ^3 = 1616.26

Government projects

- Spend today, but the benefits accrue tomorrow
- Spend $1,000 today to get benefits of $1,100 in the future (1 year). Is this a good deal?
  - Depends on discount rate
  - If interest rate is 5% (r = .05) then this is a good deal
    - PV of $1,100 is $1,048 (PV= 1,100/1.05)
  - If interest rate is 15% (r = .15) then this is a bad deal
    - PV of $1,100 is $956
- Spend $1,000 today to get benefits of $1,300 in the future (10 years). Is this a good deal?
  - 5% => PV = 1,300/1.63 => $798
  - 2% => PV = 1,300/1.22 => $1,066

Choosing a Discount Rate

- Future costs/benefits are very sensitive to the choice of discount rate
- Should use multiple discount rates when doing cost/benefit analysis
- Example: recent study of benefits of expanding Kentucky's community college system used discount rates from 1 to 4 %

Quiz

- Suppose you had a choice between spending money today for future benefits, or getting benefits today and paying in the future.
- Which would you prefer?

Is a flu shot worth it?

- Costs of flu: time (missed work), $, dr visit
  - How much is this?
    - 1 week of work = $1000, suffering = $500
    - Total = $1500
  - What is probability of flu? Assume 1%
  - Expected cost of flu = .01 x $1500 = $15
- Benefit of shot: suppose no chance of flu w/shot
- Costs of shot: 1 hour ($25), cost of shot ($10)
- Should you get a shot? Costs > benefits => no

Flu shots

- What if you are over 65? Probability of flu = .1
  - Expected cost = .1 x $1500 = $150
- Over 65 doesn't work => no cost of missing work but higher probability of hospital
  - Shots probably make sense for over 65
- Benefits to society of flu shots (large benefit?)
  - When you have shot, you benefit everyone else
    - How to measure this benefit
    - Positive externality
    - Why old and young get shots?

Cost Effectiveness

- Government has limited resources
- Cannot fund all possible programs
- Needs to choose among programs, especially in current budget climate
- How can government choose among programs where benefits exceed costs?

Cost Effectiveness Analysis

- Sometimes it is impossible to put a dollar value on the benefits of a program
  - Value of life problems
  - Difficult to estimate future savings or benefits
    - High school graduation rates in 18 years
- Cost effectiveness analysis compares the costs of achieving a particular non-monetary outcome
  - Reducing premature births
  - Increasing graduation rates

Cost Effectiveness Analysis

- We don't have to calculate a dollar value of benefits, but we still need to calculate costs
- We calculate CEA ratios as
  - (C1 – C0) / (E1 – E0)
  - The change in costs divided by the change in outcomes

Example

- 2 possible programs to reduce premature births
  - A costs $10,000 for each premature birth prevented
  - B costs $3,000 for each premature birth prevented
  - B is more cost effective than A
- Suppose a 3rd program prevents SIDS
  - Costs $5,000 for each SIDS death prevented
- Can't compare Apples to Oranges

Cervical Cancer Screening

- Screen every 4 years vs. no screening
  - Increase in life expectancy = 94 days
  - Cost increase = $300
  - Spend ~$100/month or $1200/year increase
- Screen every 3 years vs. every 4 years
  - Increase in life expectancy = 2 days
  - Cost increase $100
  - Spend ~$100 to add 2 days or ~$18,000/year
- 365/2 = 182*100 => $18,200
- Not cost effective to increase screening from every 4 years to every 3 years

What about health interventions?

- A Quality Adjusted Life Years (QALY) is a probability weighted average of the expected quality of life estimates associated with each possible health state
- Essentially, life expectancy with a quality weight for each year
  - Weight = 0 if dead, =1 if perfect health

Where do QALYS come from?

- Time-trade off: respondents are asked to choose between remaining in a state of ill health for a period of time, or being restored to perfect health but w/ shorter life expectancy
- Standard gamble: respondents are asked to choose between remaining in a state of ill health for a period of time, or choosing a medical intervention which has a chance of either giving perfect health or killing them

Where do QALYS come from?

- Visual analogue scale: respondents are asked to rate a state of ill health on a scale from 0 to 100
- Those who do not suffer from the affliction in question will overestimate the detrimental effect on quality of life, compared to those who are afflicted. (paralysis, amputation, blindness…)
- "hand waving"

QALY example

- 55 years old with diabetes
- Life expectancy of 70 => 15 years w/ diabetes
- Suppose patient assigns a weight of .4 to a year of diabetes => QALY = 6 (15 x .4)
- 15 years with diabetes = 6 years perfect health

Use of QALYs

- We can use QALYs to determine the benefits of a drug
- Suppose a drug costs $10,000 and extends a person's life (perfect health) for 1 year and then they die => cost per QALY is $10,000
- A drug costs $50,000 and extends a person's life for 20 years with a weight of .5
  - QALY = .5 x 20 = 10
  - Cost per QALY = $5,000
  - Worth it?

Value of life

- Imagine you're the mayor of a small town. The hot line rings, and you learn that both the town nursing home and the nursery school are in flames. Eleven octogenarians are trapped in the home, and 10 toddlers are trapped in the school. The fire chief needs to know where to send the town's only fire truck.
- 11 > 10 => save old people?
- What if everyone in nursing home is >90?

Measuring Value of Life

- Individuals make decisions every day that provide implicit information on value of life
  - Driving behavior (speed, seat belt, aggressiveness, talking on cell phone, etc.)
  - Lifestyle (diet, exercise, sleep, stress, etc.)
  - Leisure activities (skiing, sky diving, hunting, scrabble, etc.)
  - Occupation (working conditions, stress level, safety of workplace, etc.)

Measuring Value of Life (Cont'd)

- Many government projects and regulations result in increases or decreases in the number of deaths:
  - Seat belt requirements, helmet laws
  - Children's sleepwear flammability
  - Lead restrictions in toys
  - Lead restriction in gasoline
- In order to do cost/benefit analyses, government needs to assign dollar amount to value of life

Value of life

- Compensating wage differentials
  - One profession is compensated more than a similar one due to danger
  - Police vs fire fighters vs dog catcher
- Wage replacement
  - How much money is a person going to make over the rest of their life?
  - Stock broker worth more than a busboy? Retired?
- How much will you pay to avoid risk?

Value of life - example

- Airbags reduce fatality rate by 50%
- Suppose accidents kill people 4 times in every 1000 accidents
  - w/ airbags kill people 2 times every 1000 accidents
- Airbags cost $500, what does this imply about the value of a life?
  - Every 1000 people who buy airbags leads to 2 lives saved => $500 x 1000 = $500k for 2 lives
  - $250,000 per life

Value of life - example

- Smoke detectors in home cost $10
- Put detector in each bedroom costs $30
- With detectors, no chance of death
- Without detectors, 1 in 10,000 chance of death
- Spend $3,00,000 to save 1 life
  - 10,000 x $30 = $3,00,000
- What if a detector costs $50 and no one purchases? Value of life < $15 million

Estimates of Value of Life
(1990 dollars)

- Labor Market Studies - $1.6 - $10.4 million
- Fire fatality risks - $2 million
- Automobile accident risks - $4 million
- Cigarette smoking - $700,000
- Air pollution - $800,000

Why So Much Variation in VSL?

- Different populations served
  - Variation by age, gender, race/ethnicity
- Different techniques
  - Varying quality of estimates
- More than just wages
  - Need to value time not at work
- Discount rates really matter

Measuring benefits

- Absolute risk reduction (ARR) – the difference in the probabilities of an event between the control and treatment group
- Relative risk reduction (RRR) – the absolute risk divided by the probability of an event in the control group
- Number Needed to Treat (NNT) – 1/RRR

Absolute vs Relative Risk

- Suppose there is a drug that treats high-blood pressure and heart attacks, we have to decide who we should provide this drug to.
- Scientists have determined that this drug is effective in reducing the probability of heart attacks
  - High risk patients have a risk of 40% w/o drug
  - High risk patients have a risk of 30% w/ drug
  - => drug reduces probability of a heart attack by 25% (40-30/40) = .25

Absolute vs Relative Risk – con't

- Same drug is given to people with a lower risk of a heart attack
  - Low risk patients have a risk of 10% w/o drug
  - Low risk patients have a risk of 7.5% w/ drug
  - The drug reduces the probability of a heart attack by 25% (10-7.5/10) = .25
- Should we purchase this drug for both types of patients?
  - The relative risk reduction is the same (25%), but the absolute risk reduction is very different (10 vs. 2.5%)

Number Needed to Treat (NNT)

- The relative risk reduction is 25% for both groups
- The absolute risk reduction is different
  - High risk = 10%
  - Low risk = 2.5%
- The NNT tells us how many people we need to treat in order to "save" one person
  - NNT for high risk = 1/.1 = 10
  - NNT for low risk = 1/.025 = 40
  - We need to treat 4 times as many low risk people vs. high risk in order to save 1 person

NNT

- How many patients would require treatment with a form of medication to reduce the expected number of cases by one
- The reciprocal of the Absolute Risk Reduction
- Ex: probability of death for control = .25 & treatment = .15
  - ARR = .25 - .15 = .10 => NNT = 1/.1 = 10
  - Need to give the drug to 10 people in order to save one person

Example

	Stroke in 5 Years		Risk Reduction		Number Needed to Treat (NNT) 1/(Pc-Pt)
Hypertension	Control Group	Treatment Group	Relative (Pc-Pt)/Pc	Absolute (Pc-Pt)	
Moderate (diastolic </=115)	.30	.20	.33	.10	10
Mild (diastolic </=110)	.03	.02	.33	.01	100

Benefits and harms

- What if a drug could cause harm?
- Risk of stroke (5 years)
  - High risk – 30% w/ drug vs. 20% w/o drug
  - Low risk – 3% w/ drug vs. 2% w/o drug
  - Relative risk reduction is the same for both (33%)
  - Absolute risk reduction is different (10% vs. 1%)

Benefits and Harms

- Risk of gastric bleeding w/ drug
  - Same for both – 9% w/ drug vs. 3% w/o drug
  - Relative Adverse event risk is tripled w/ drug
  - Absolute risk increase = 6%
- Number needed to harm is calculated the same way
  - 1/absolute risk increase => 1/6 = 16.7
- Who should get this drug?
  - Low risk group has large NNT (1/.01 = 100)
  - High risk group has small NNT (1/.1 = 10)
  - Both groups have same risk of harm (NNH = 1/6 = 16.7)
  - 1 person harmed for every 16 people taking drug

Put it all together

- Suppose you are hired to evaluate a new cancer drug for the FDA that on average "saves" 1 person out of every 30 it is administered to. Without this drug, the person will die within 2 months. Suppose this drug costs $1,000.
  - What is the NNT?
  - How would you evaluate this drug?
- The Number Needed to Treat (NNT) is 30
- The cost to save one life is $30,000 (30 x $1,000).

- Suppose, if the new drug is successful (NNT = 30), it leads to 8 years of life with a quality of life weight of .60.
  - How much does a QALY cost?
- If this drug costs $1,000, the QALY is 4.8, and the cost per QALY is $6,250.
  - 30 x $1,000 = $30,000 & 8 x .6 = 4.8
  - $30,000/4.8 = $6,250

- If a similar drug when successful (NNT = 40) leads to 8 years of life with a quality of life weight of .75, and the drug costs $2,000, how much is a QALY?
- the QALY is 6 and the cost per QALY is $13,333.
  - 40 X $2,000 = $80,000. 8 x .75 = 6
  - $80,000/6 = $13,333
- Which drug should you (gov't) purchase?

- The first drug (NNT = 30) is financially better in that it is less expensive per quality adjusted life year.
- However, the similar drug (NNT = 40) gives the person a better quality of life in the person's daily functioning over the 8 years. (6 > 4.8)
- We would probably want the gov't to buy the 2nd drug even though it is more expensive.

Annual Age-Adjusted Ambulatory Care Visits And Hospital Discharges Per 10,000 Adults, Selected Years 1995–2006

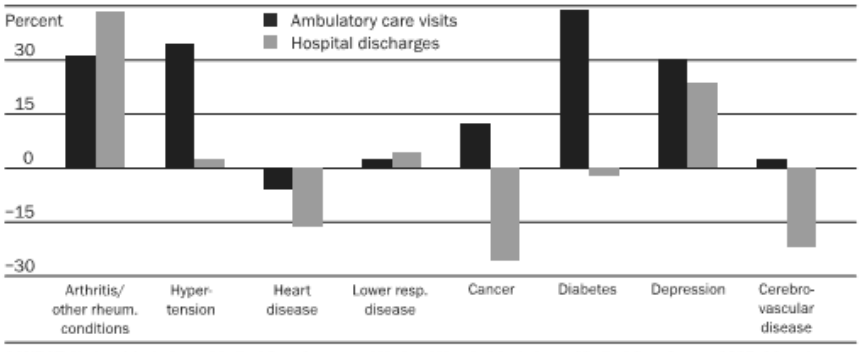
	Ambulatory care visits			Hospital discharges		
	1995–96	2005–06	Percent change	1996	2006	Percent change
All conditions	35,836	41,531	16**	1,427	1,423	0
All eight chronic conditions below	8,694	10,508	21**	481	439	–9**
Arthritis and other rheumatic conditions	1,786	2,344	31**	33	48	43**
Hypertension	1,568	2,108	34**	23	23	2
Heart disease	1,273	1,195	–6	216	181	–16**
Lower respiratory disease	1,119	1,145	2	34	36	4
Cancer	1,094	1,228	12	70	52	–26**
Diabetes	898	1,290	44**	25	25	–2
Depression	783	1,018	30**	30	37	23
Cerebrovascular disease	176	180	2	50	39	–22**

SOURCES: National Ambulatory Medical Care Survey and National Hospital Ambulatory Medical Care Survey, 1995–96 and 2005–06; and National Hospital Discharge Survey, 1996 and 2006.

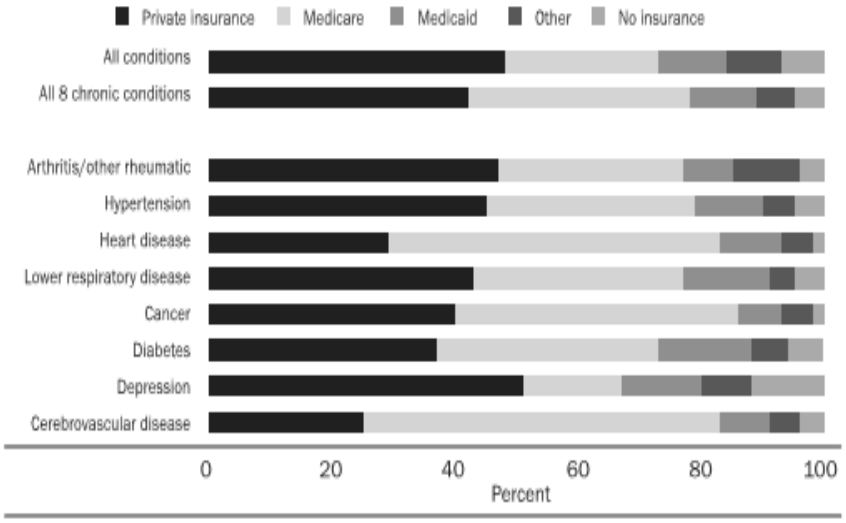
NOTE: Statistical significance indicates that the *p* value associated with a t-test of the difference in the age-adjusted visit rate for 1995–96 and 2005–06 or the discharge rate for 1996 and 2006 is significant.

$^{**}p < 0.05$

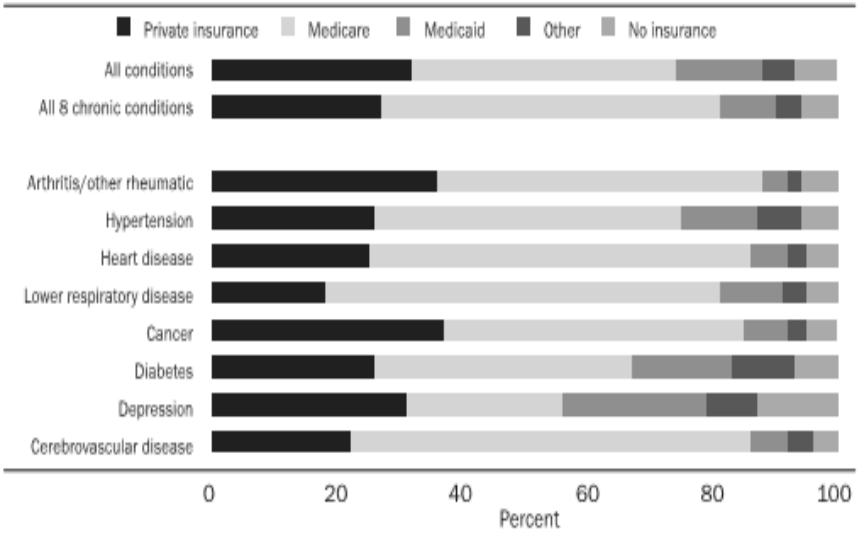
Percentage Change In Age-Adjusted Ambulatory Care Visit (1995–96 And 2005–06) And Hospital Discharge (1996 And 2006) Rates



Percentage Distribution Of Primary Expected Sources Of Payment For Ambulatory Care Visits, 2005–2006



Percentage Distribution Of Primary Expected Sources Of Payment For Hospital Discharges, 2006



Socioeconomic Characteristics Of Medical Expenditure Panel Survey (MEPS) Respondents, By Number Of Chronic Conditions, 2005

Characteristic	Number (millions)	Number of chronic conditions			
		None	One	Two	Three or more
Total population	292	56.3%	19.7%	10.7%	13.3%
Age (years)					
0–19	81	78.6	16.5	3.7	1.2
20–44	102	67.6	19.7	8.4	4.4
45–64	74	36.9	24.0	16.7	22.4
65–79	26	13.1	20.2	21.5	45.3
80+	9	10.8	14.8	20.2	54.2
Sex					
Male	143	60.1	19.9	9.4	10.7
Female	149	52.6	19.7	12.0	15.8
Race					
White	234	54.4	20.2	11.3	14.1
Black	37	62.8	18.2	8.5	10.6
Other	21	65.9	17.3	8.0	8.9
Hispanic ethnicity					
Hispanic	43	73.2	14.9	5.9	5.9
Non-Hispanic	249	53.3	20.6	11.5	14.5
Insurance status[a]					
Age 65 and older					
Medicare only	13	13.7	18.5	21.5	46.2
Medicare/private	19	11.7	19.5	21.3	47.4
Medicare/Medicaid	4	11.8	15.8	19.7	52.7
Under age 65					
Private	167	58.2	22.3	10.5	9.1
Medicaid	41	65.9	17.5	7.3	9.4
Other public	6	49.1	18.6	11.7	20.6
Uninsured	35	78.3	12.5	5.3	3.9
Poverty status[b]					
Poor	37	63.0	15.8	8.2	13.1
Near-poor	13	59.0	16.6	9.4	15.0
Low income	40	58.9	17.2	9.6	14.2
Middle income	92	57.5	19.9	10.0	12.6
High income	111	51.7	22.2	12.7	13.4

Socioeconomic Characteristics And Mean Annual Out-Of-Pocket Spending Per Person, By Number Of Chronic Conditions, 2005

		Number of chronic conditions			
Characteristic	All	None	One	Two	Three or more
Total population	$ 741	$343	$ 655	$1,039	$1,865
Age					
0–19	288	232	385	590	952
20–44	550	377	621	869	1,416
45–64	1,014	514	783	1,128	1,772
65–79	1,479	575	872	1,247	2,049
80 or older	1,807	519	1,300	1,326	2,319
Sex					
Male	624	291	569	900	1,733
Female	841	389	739	1,143	1,950
Race					
White	793	368	686	1,085	1,938
Black	490	207	491	725	1,390
Other	550	296	544	892	1,554

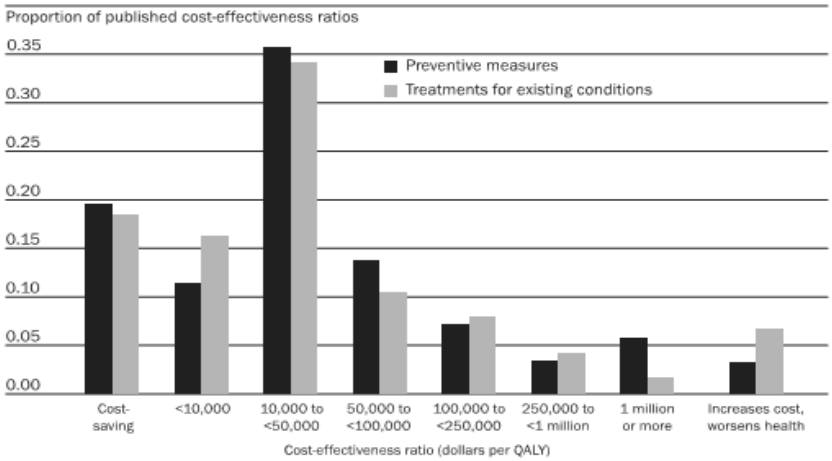
Percentage Using Services And Mean Out-Of-Pocket Spending Per Person, By Type Of Medical Service And Number Of Chronic Conditions, 2005

	Percent using services							
Number of chronic conditions	Rx drugs	Home health	Dental services	Office visits	Hospital inpatient	Hospital outpatient and ED	Medical equipment	Vision aids
Age 65 or older	95%	10%	47%	96%	17%	47%	15%	21%
0	64	2	55	84	5	27	7	24
1	93	4	45	92	9	37	7	17
2	100	8	48	97	11	40	11	21
3 or more	100	15	45	98	24	59	22	22
Under age 65	71	1	51	83	7	27	4	19
0	52	0	51	75	4	20	2	16
1	91	1	50	88	7	28	4	19
2	98	2	52	94	10	36	5	22
3 or more	100	4	49	98	17	52	14	27

Socioeconomic Characteristics Of Medical Expenditure Panel Survey (MEPS) Respondents, Differences In The Percentage Of People With Chronic Conditions Between 1996 And 2005

	Number of chronic conditions			
Characteristic	**None**	**One**	**Two**	**Three or more**
Total population	-3.0%	-4.0%	1.1%	5.9%
Age (years)				
0–19	2.2	-2.5	-0.2	0.5
20–44	0.0	-3.6	2.0	1.7
45–64	-4.8	-5.7	0.8	9.7
65–79	-9.2	-6.0	-2.3	17.6
80 or older	-3.9	-12.0	-0.7	16.6
Sex				
Male	-2.8	-3.6	1.2	5.3
Female	-3.4	-4.2	1.1	6.5
Race				
White	-3.4	-4.0	1.1	6.3
Black	-2.9	-3.2	1.4	4.7
Other	-1.2	-4.4	2.0	3.7

Distribution Of Cost-Effectiveness Ratios For Preventive Measures And Treatments For Existing Conditions



SOURCE: Data from the Tufts–New England Medical Center Cost-Effectiveness Registry, as published in J.T. Cohen, P.J. Neumann, and M.C. Weinstein, "Does Preventive Care Save Money? Health Economics and the Presidential Candidates," *New England Journal of Medicine* 358, no. 7 (2008): 661–663
NOTE: QALY is quality-adjusted life-year.