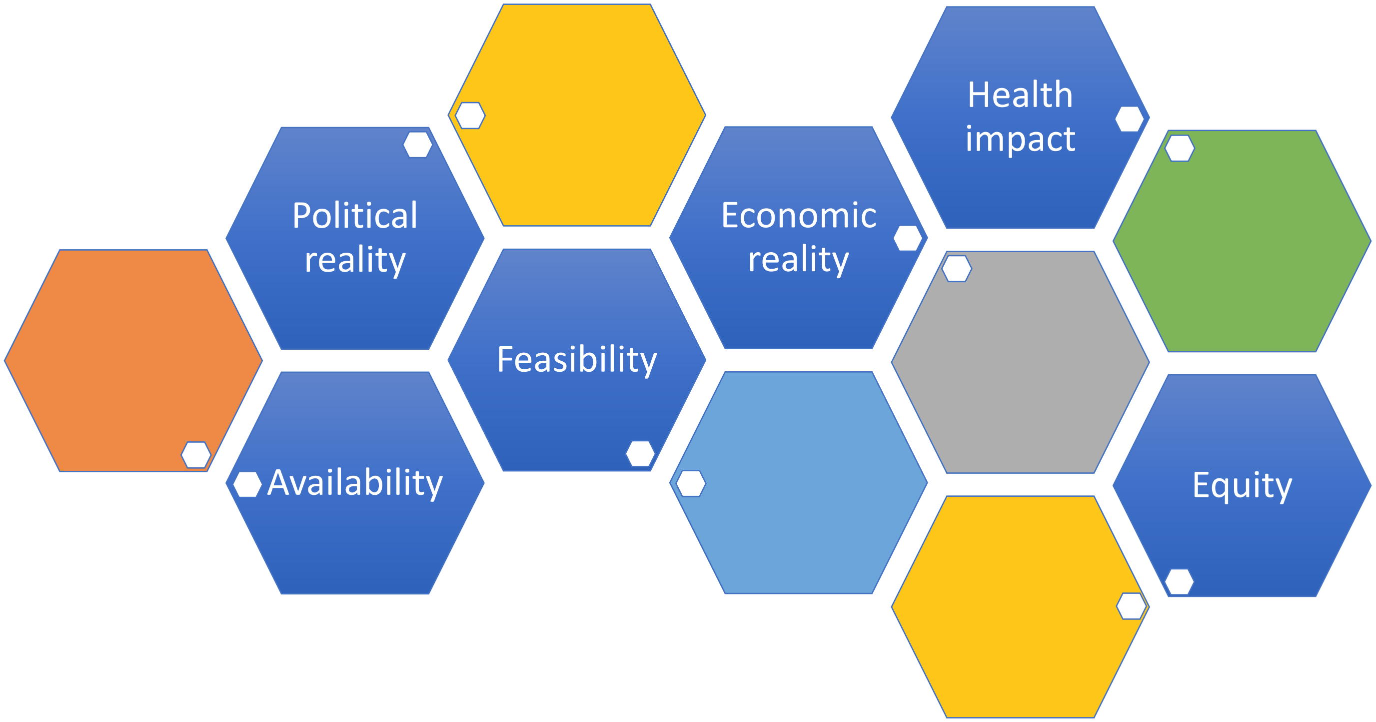
Introduction to Economic Evaluation

Presented by Dr. Chrispus Mayora

TVEE
TEACHING VACCINE ECONOMICS EVERYWHERE

Choice of Whether to Invest In Vaccines is a Complex Dynamic

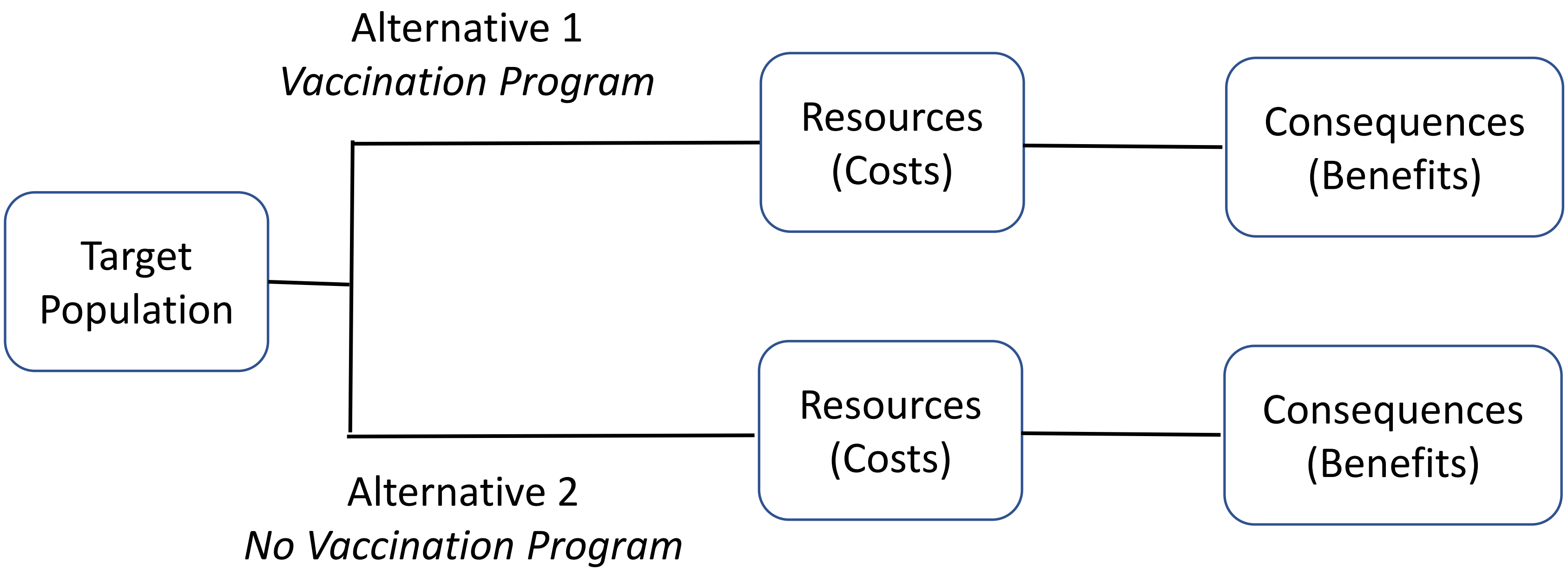


Recap: Central Debate during COVID-19 Pandemic

- Production capacity of vaccine (Supply-side issues)
  - Will global production output of the vaccine be enough to sustain demand?
- Price of vaccine and cost of immunization (Financing issues)
  - With shrinking economies, how will funds be reallocated towards COVID-19 immunization and vaccine procurement from – other vaccine/immunization efforts? From other public health interventions? From other social programs?
- Storage of vaccine (Logistic and Operational issues)
  - If the vaccine requires specialized cold-chain equipment, are EPI programs able to reallocate funding towards acquiring the equipment?
  - Decrease inventory of other vaccines to make space for COVID-19 vaccine?
- Uptake of the vaccine (Demand-side issues)
  - How to obtain high coverage despite recent rumors and false information in media about COVID-19 vaccine?
  - At what cost will mass immunization campaigns affect the risk of being infected?
  - If supply of vaccine is low, which population sub-group to target?

Economic Evaluation In Health Care

Resources are scare – choices must be made!



Study Design

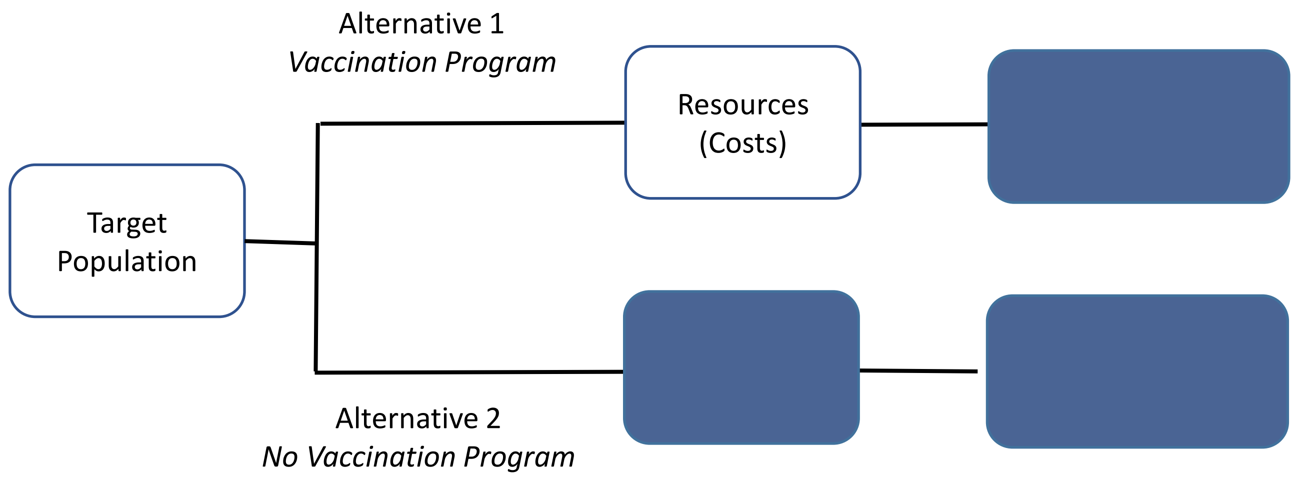
- Characteristics of the target population
- Specification of alternative programs/interventions
- Quantify resources consumed – valuation of resources
- Identification of consequences – measurement of benefit

Economic Evaluation Methods For Immunization

Economic Evaluation Methods

- Cost Finding
- Cost-minimization
- Cost (burden) of Illness
- Cost-Consequence
- Cost-Effectiveness
- Cost-Benefit

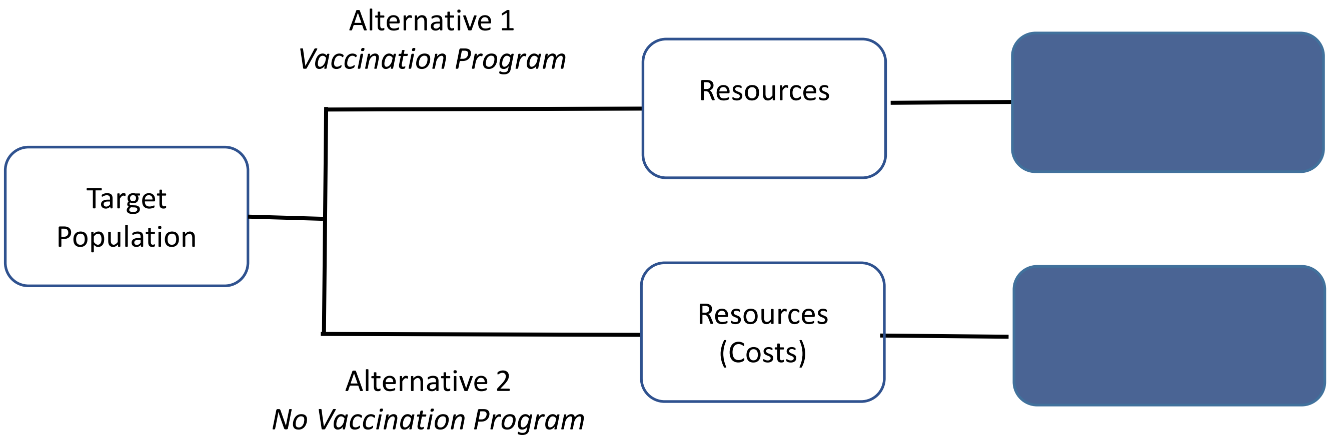
Economic Evaluation Methods
Cost Finding



Objectives:

- Identify resources consumed in the provision of a specific program or intervention
- Estimate the monetary value of these resources

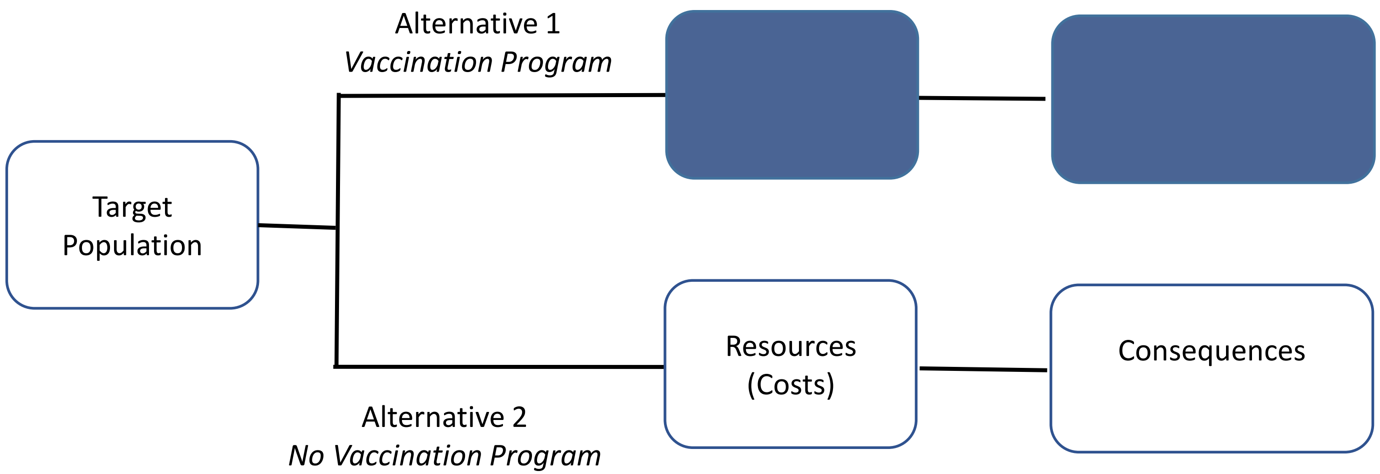
Economic Evaluation Methods
Cost-Minimization Analysis (CMA)



Objectives:

- Identify resources consumed in the provision of alternative interventions
- Estimate the monetary value of these resources
- Compare the cost of the alternative interventions
- ***Identify the least costly alternative***

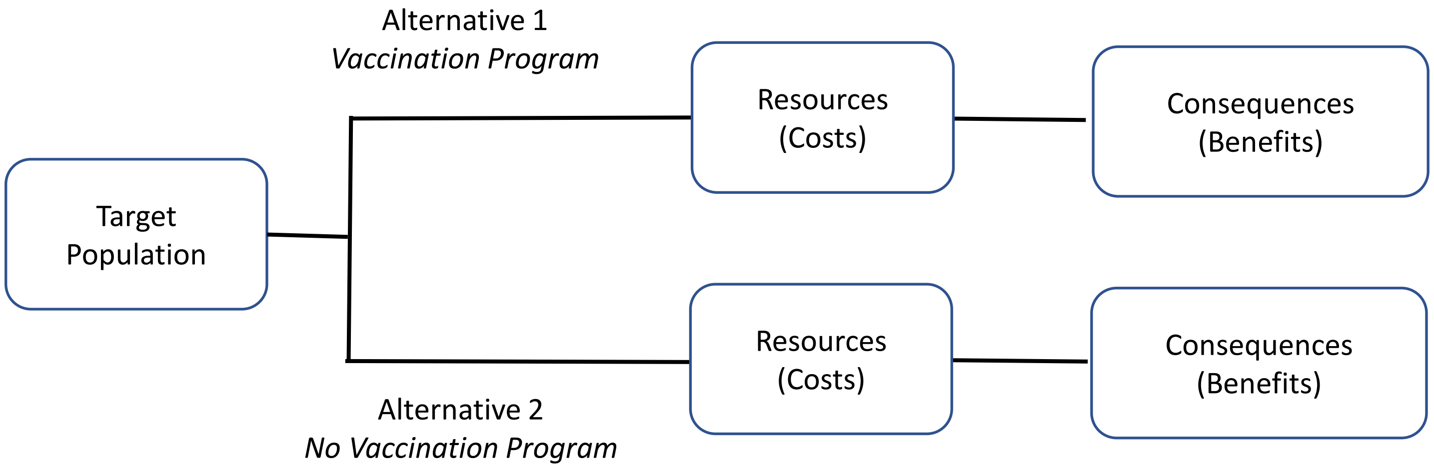
Economic Evaluation Methods
Cost (Burden) of Illness Analysis (COI)



Objectives:

- Focus on current status of the target population without intervention
- Estimate health care resources consumed and associated costs
- Quantify "burden of Illness" with metrics such as
    - mortality (years of life lost)
    - disability (limitations on daily activity)
    - lost productivity

Economic Evaluation Methods
Cost – Consequence Analysis



Objectives:

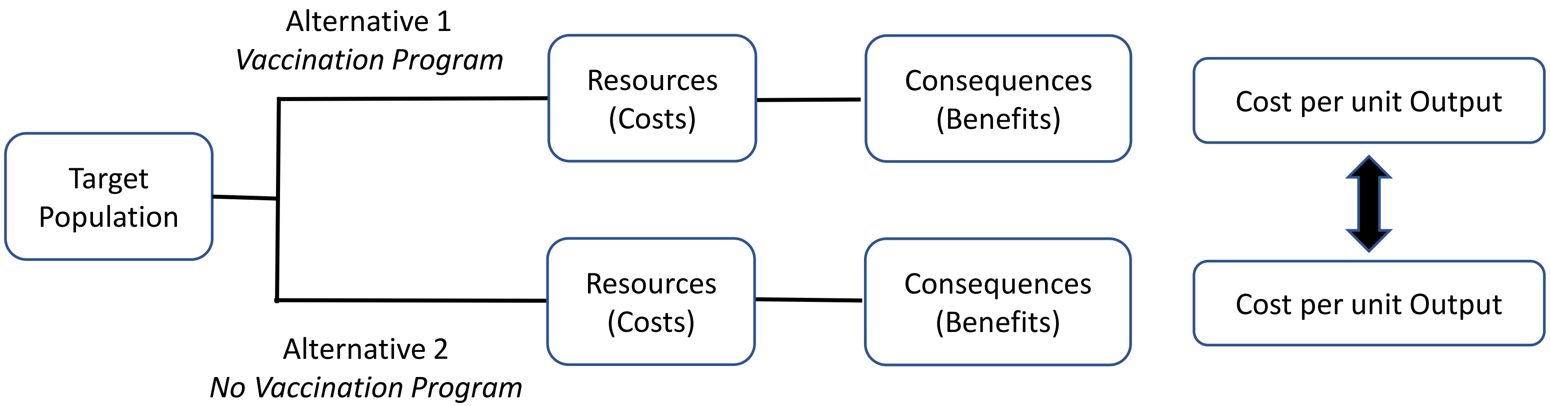
- Identify resources consumed in the provision of alternative interventions
- Estimate the cost of each alternative intervention
- Identify and quantify effects of each intervention
    - Patient and Family
    - Community
    - Health Care System
    - Nation

Potential Economic Consequences (Benefits) of A Vaccine Program

Benefit	Category	Definition
Health gains	Direct	Reduction in mortality/morbidity
Health care cost savings	Direct	Averted medical expenditures (outpatient visits, hospitalizations, diagnostics and treatments, transport to the facility)
Care related productivity gains	Indirect	Savings of parents' productive time and lost wages
Outcome-related productivity gains	Broader	Improves cognition and physical development, as well as school enrollment, attendance and educational attainment
Behavior-related productivity gains	Broader	Improves child health and survival and thereby changes household choices, such as fertility and consumption choices
Community externalities	Broader	Improves health among unvaccinated community members, general economic improvement

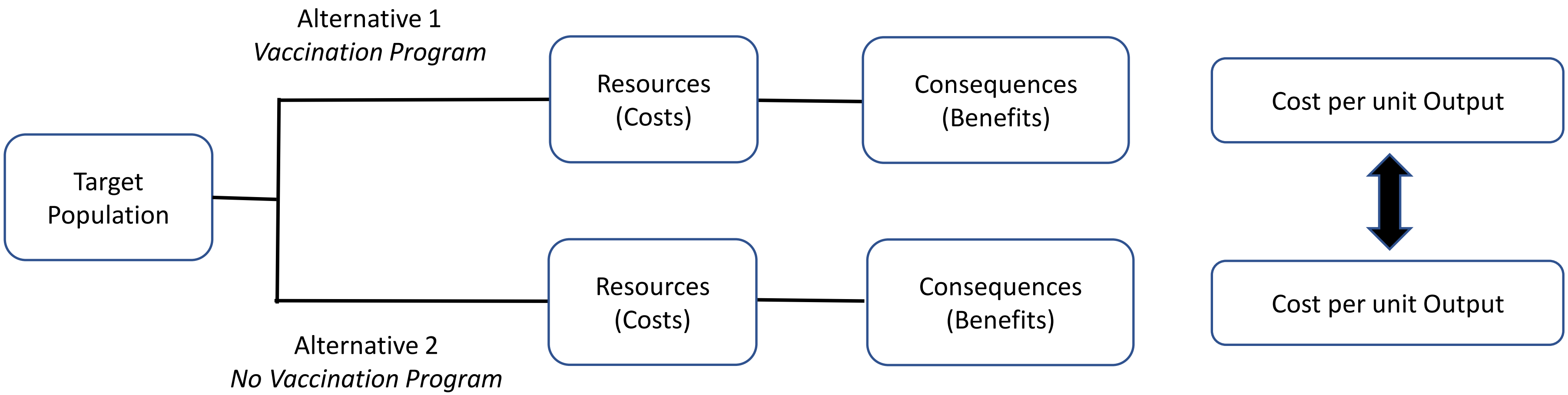
Barnighausen T, et al. Rethinking the benefits and costs of childhood vaccination: the example of the Haemophilus influenzae type b vaccine. Vaccine 2011; 29(13): 2371-80.

Measuring the "Output" of a Vaccine Program or Intervention



- Ideal metric combines both the *quantity* and *quality of life* as a result of the program or intervention
- ***Quality adjusted life-year*** *(QALY)* - duration of survival weighted by a factor representing consumer strength of preference for state of health during this period – more common in Western countries, recommended by U.S. cost-effectiveness panel
- ***Disability-adjusted life-year*** *(DALY)* - years lost relative to optimum survival weighted by a factor representing level of impairment – more commonly used in Vaccine economics, recommended by WHO

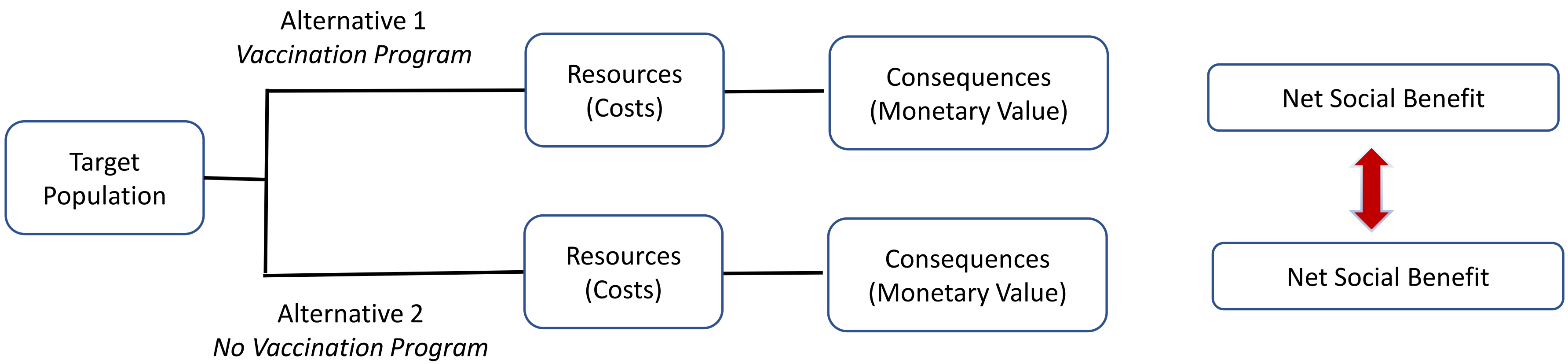
Economic Evaluation Methods
Cost - Effectiveness Analysis



Objectives:

- Compare alternative programs in terms of efficiency
- ”Benefit” is defined as units of output
  - example: output for an intervention that reduces mortality could be specified as “years of survival”
  - Same metric must be used for each alternative to enable comparison
- Efficiency of each alternative calculated as ”cost per unit of benefit”

Economic Evaluation Methods
Cost - Benefit Analysis (CBA)



Objectives:

- Compare alternative programs in terms of net social cost
- ”Benefit” is defined as the monetary value
  - All relevant consequences for each intervention must be given a specific monetary value
  - Requires assumptions for monetary value of years of survival gained, days of disability avoided
- Net social cost of a program = value of benefit – cost
- Assess a single program: worthwhile if net social benefit >0
- Compare alternative programs: which has greater net benefit?

Types of Analysis

Type of Analysis	Input/Cost	Outcomes
Cost Minimization	Monetary terms ($)	Not considered
Cost-Effectiveness	Monetary terms ($)	Natural units (e.g. child mortality/morbidity)
Cost-Utility	Monetary terms ($)	Utility measures (QALYs, DALYs, etc.)
Cost-Benefit	Monetary terms ($)	Monetary terms ($) (capture wider range of benefits)

Economic Evaluation Methods
Other Methods

- Budget Impact
  - Cost of a Vaccine absorbed over a pooled risk
  - Commonly interpreted by government or vaccine payers
  - Measure of cost of intervention for all those in need to entire population in terms of "Per member per month" or "Per member per year"

- Return on Investment (ROI)
  - Long-term outlook of costs recouped from benefit
  - Vaccine cost tradeoff to medical expenses
  - Generally measured over: 5 or 10 years

Summary

Role of economic evaluation of vaccines in health policy

Efficiency

Cost-effectiveness

Affordability

Budget Impact

Equity

Return on Investment

Understanding the ICER Plane

Cost-Effectiveness Analysis: "ICER"

"ICER" – Incremental Cost-effectiveness Ratio

$$\text{ICER} = \frac{\text{Cost}_{\text{NEW PROGRAM}} - \text{Cost}_{\text{ALTERNATIVE}}}{\text{Output}_{\text{NEW PROGRAM}} - \text{Output}_{\text{ALTERNATIVE}}}$$

Example - Hib conjugate vaccination in India (versus no vaccination)
"From a government perspective, cost-effectiveness ranged from \$192 to \$1033 per discounted DALY averted. With the inclusion of household healthcare costs, cost-effectiveness ranged from \$155 to \$939 per discounted DALY averted."

Clark et al, J Pediatrics 2013;163:S60-S72

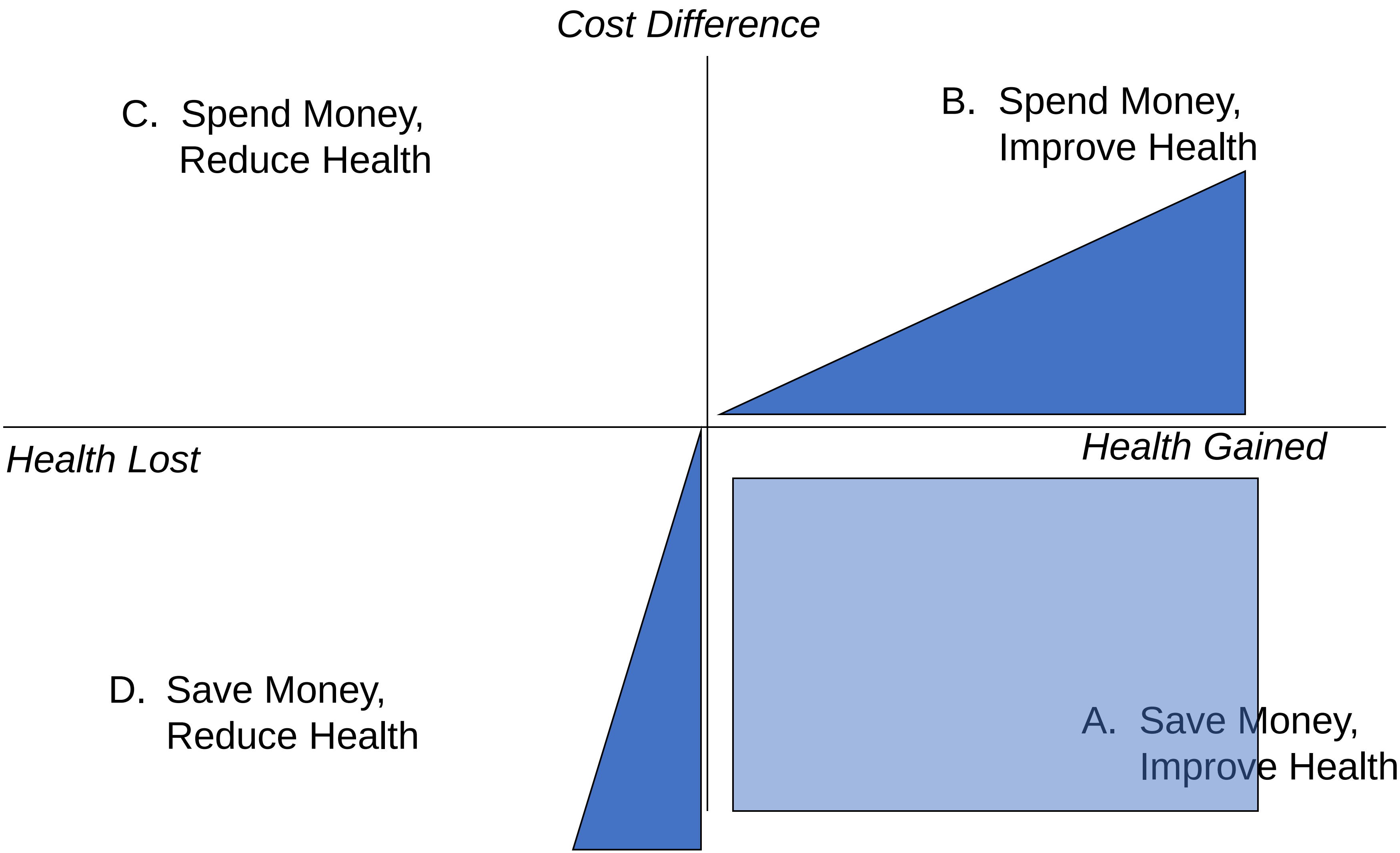
Example: Clark et. al, Hib Vaccine

Table IV. Hib vaccine impact and cost-effectiveness by state: aggregate estimates over the period 2012-2031

		Vaccine impact, undiscounted					Cost-effectiveness, discounted at 3%					
State	Region	Pneumonia lives saved	Meningitis lives saved	NPNM lives saved	Total lives saved	Percent of U5MR averted	Vaccine costs (millions)	Gov cost savings (millions)	Family cost savings (millions)	Total DALYs averted	US$ per DALY averted (government perspective)	US$ per DALY averted (societal perspective)
Delhi	North	278	807	34	1119	0.6%	$36	$0.6	$3.2	34470	1033	939
Haryana	North	472	1038	42	1552	0.3%	$43	$0.3	$4.9	47096	903	800
Himachal Pradesh	North	253	506	13	773	1.0%	$10	$0.3	$1.0	20314	500	453
Jammu and Kashmir	North	262	662	19	943	0.3%	$20	$0.5	$1.2	25620	777	728
Punjab	North	364	1048	41	1453	0.4%	$45	$0.4	$3.7	44145	1017	934
Rajasthan	North	2942	5492	140	8575	0.4%	$118	$3.0	$9.9	220070	524	479
Chhattisgarh	Central	6050	2315	59	8424	1.0%	$51	$2.8	$11.3	197709	245	188
Madhya Pradesh	Central	21 415	7010	152	28 578	1.1%	$133	$5.6	$24.4	661798	192	155
Uttar Pradesh	Central	30 054	12 112	364	42 531	0.5%	$432	$24.6	$82.6	1 040354	392	312
Bihar	East	19 200	6431	179	25 810	1.0%	$169	$2.4	$24.4	617964	269	229
Jharkhand	East	7482	2493	68	10 043	1.2%	$62	$2.5	$7.8	237934	252	219
Orissa	East	4820	1995	60	6876	0.7%	$58	$4.7	$4.9	169599	315	286
West Bengal	East	12 577	5468	147	18 191	1.5%	$130	$8.3	$8.9	439363	276	256
North East*	North East	614	1170	23	1807	0.9%	$19	$0.3	$0.4	43599	420	411
Gujaret	West	2419	3793	94	6305	0.6%	$83	$1.1	$7.0	161467	506	463
Maharashtra	West	6073	7993	233	14 299	1.0%	$204	$4.6	$22.2	374003	533	474
Andhra Pradesh	South	6019	7979	188	14 186	1.0%	$147	$2.2	$7.7	351765	411	389
Karnataka	South	3645	4636	127	8408	0.9%	$104	$1.7	$7.1	216132	474	441
Kerala	South	662	1403	58	2123	2.0%	$51	$1.3	$3.2	64781	775	725
Tamil Nadu	South	2266	3490	107	5863	0.8%	$90	$3.1	$4.4	156945	555	526
India		127 869	77 840	2150	207 859		$2006	$70	$240	5 125128	378	331

*The North East region includes Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, and Assam.

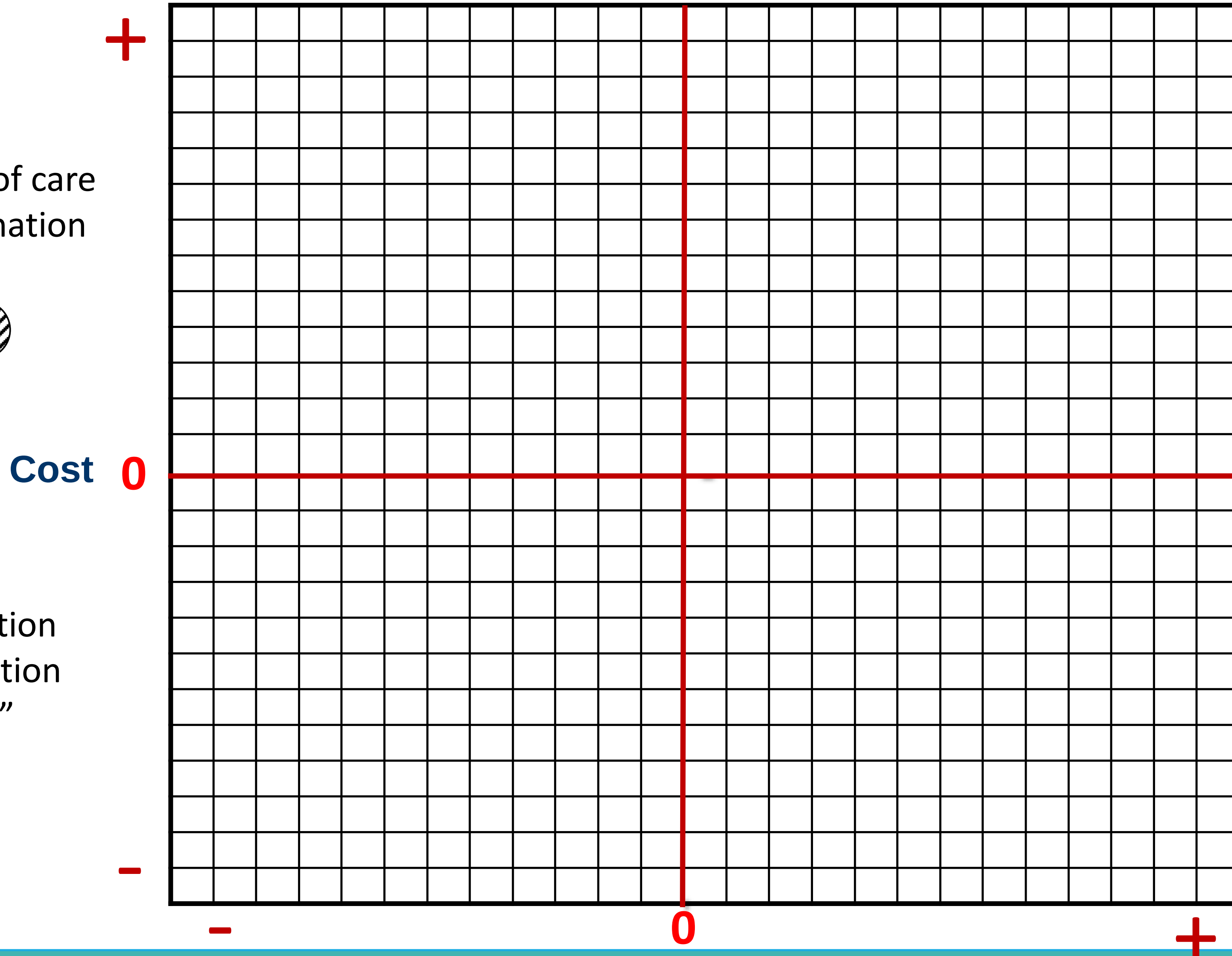
Four Regions in Space



Cost-Effectiveness Plane

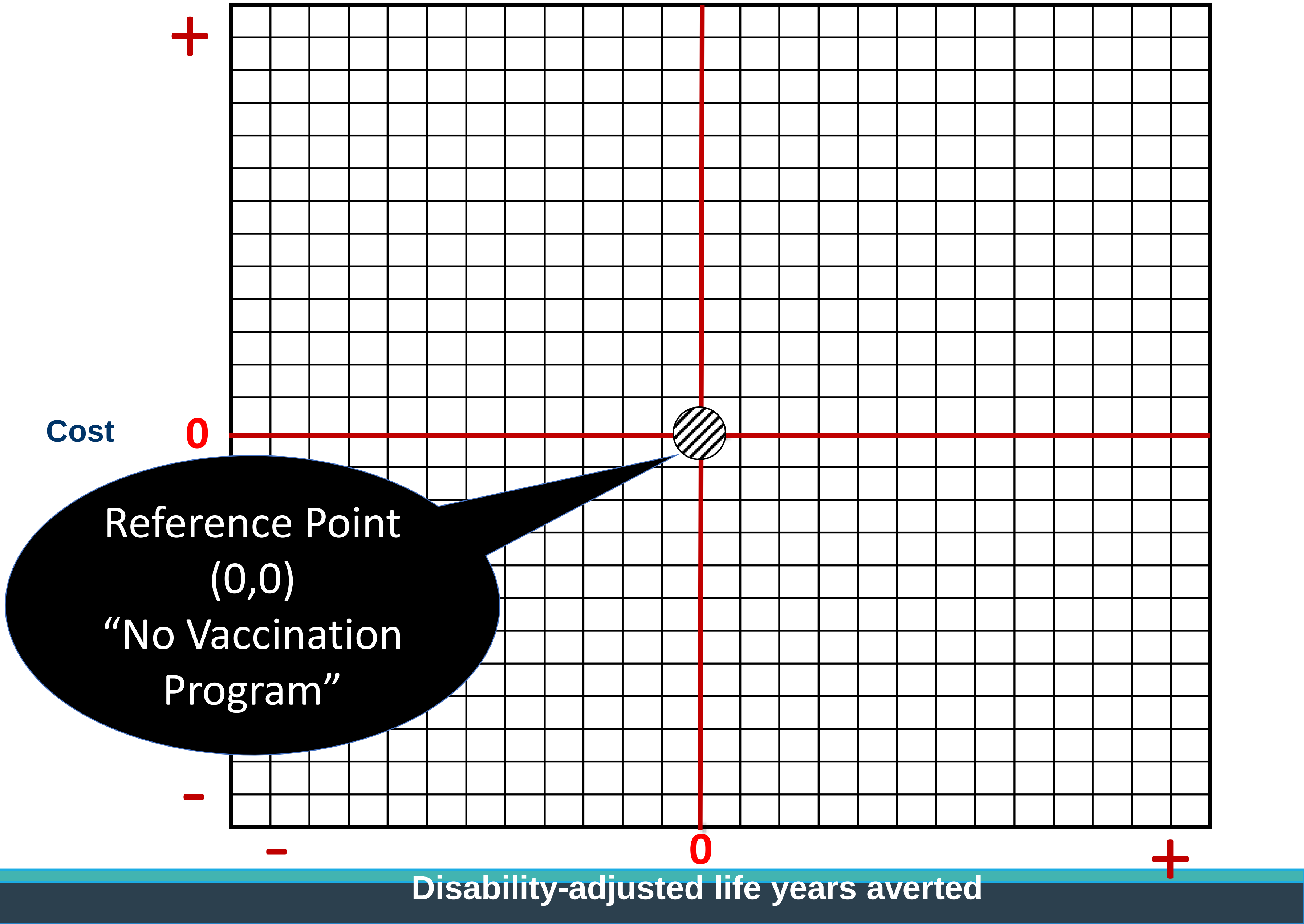
Standard of care
“No vaccination
program”

New
intervention
“Vaccination
program”

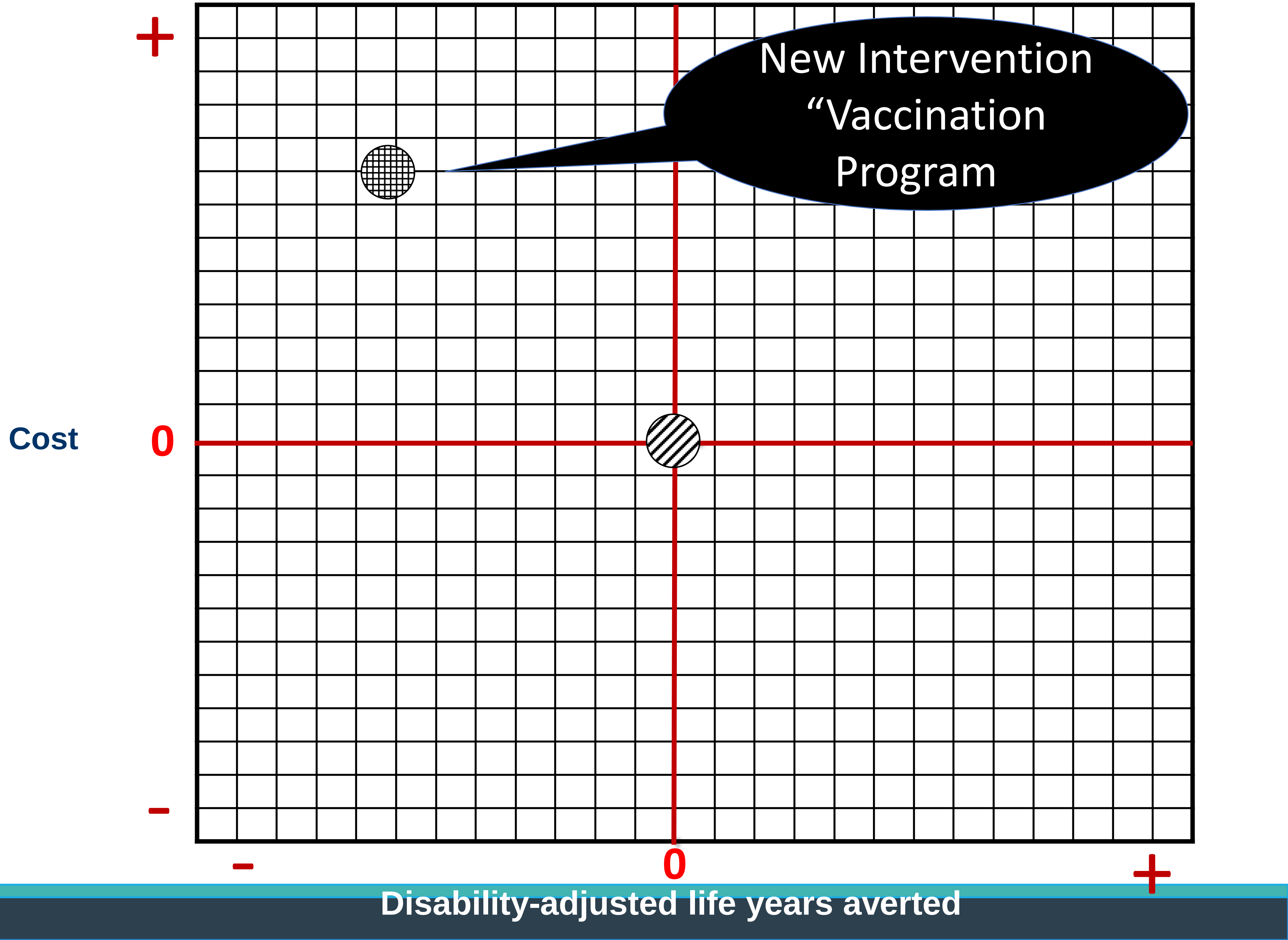


Disability-adjusted life years averted

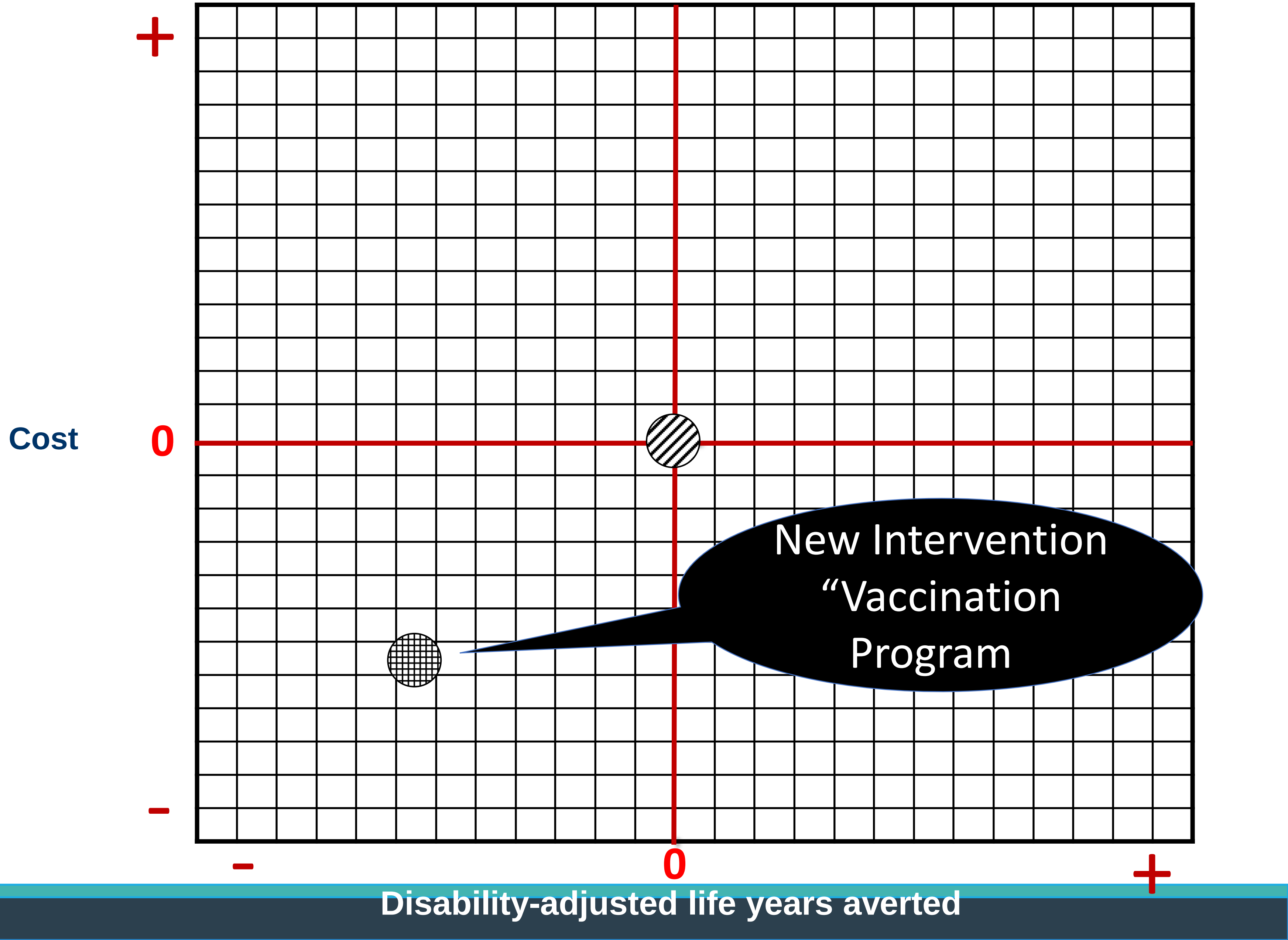
Cost-Effectiveness Plane



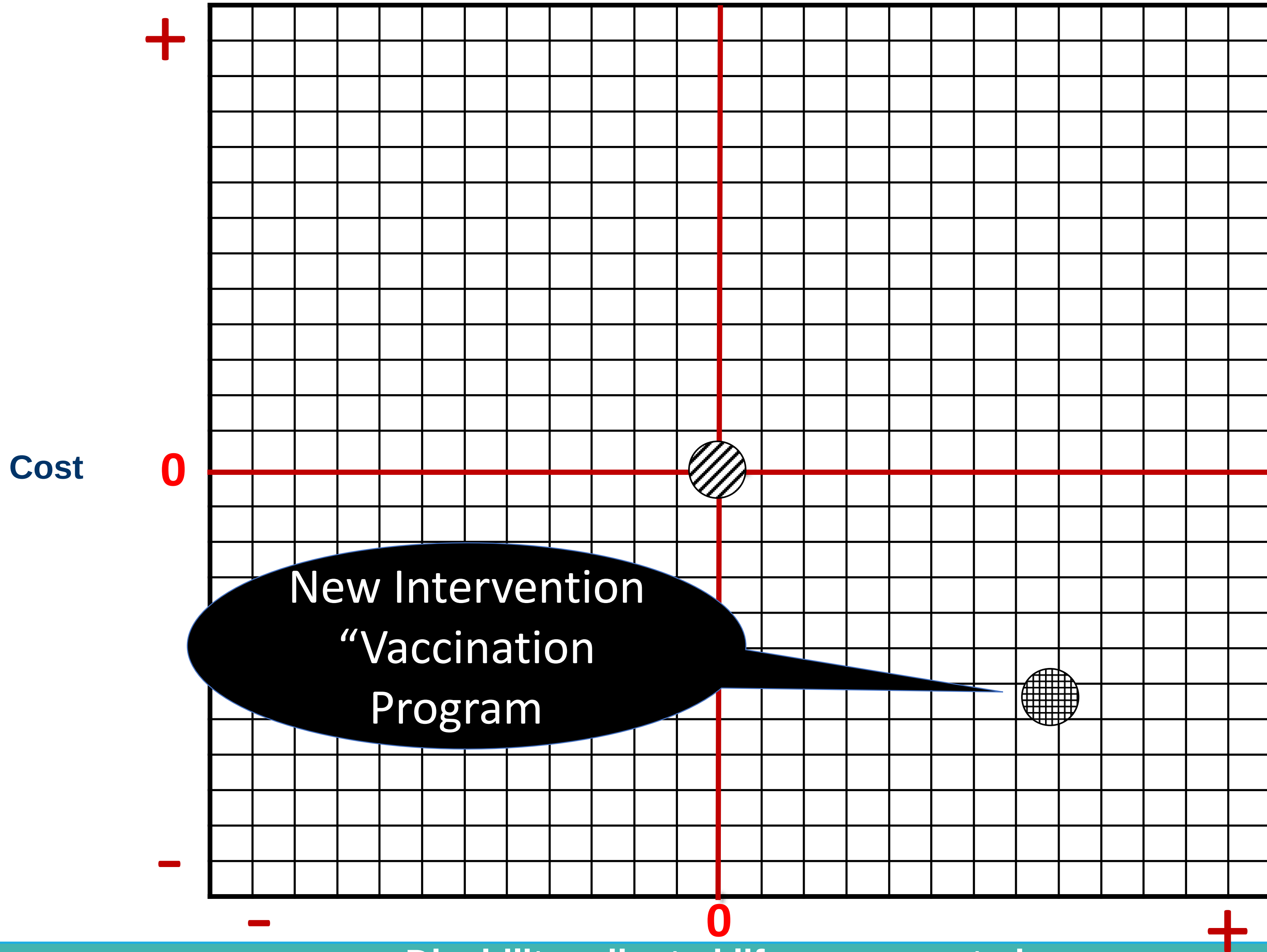
Interpreting the ICER (1)



Interpreting the ICER (2)

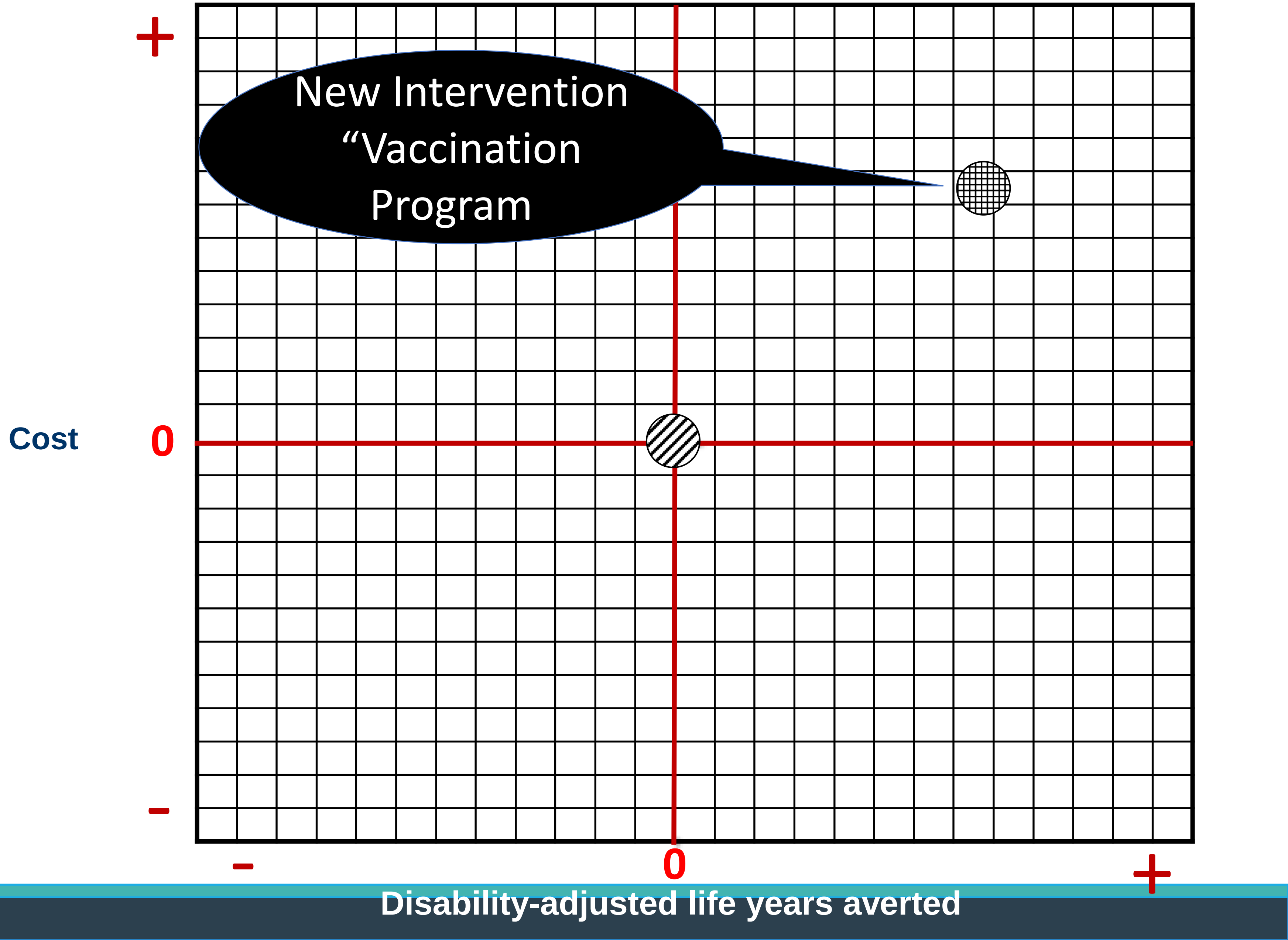


Interpreting the ICER (3)

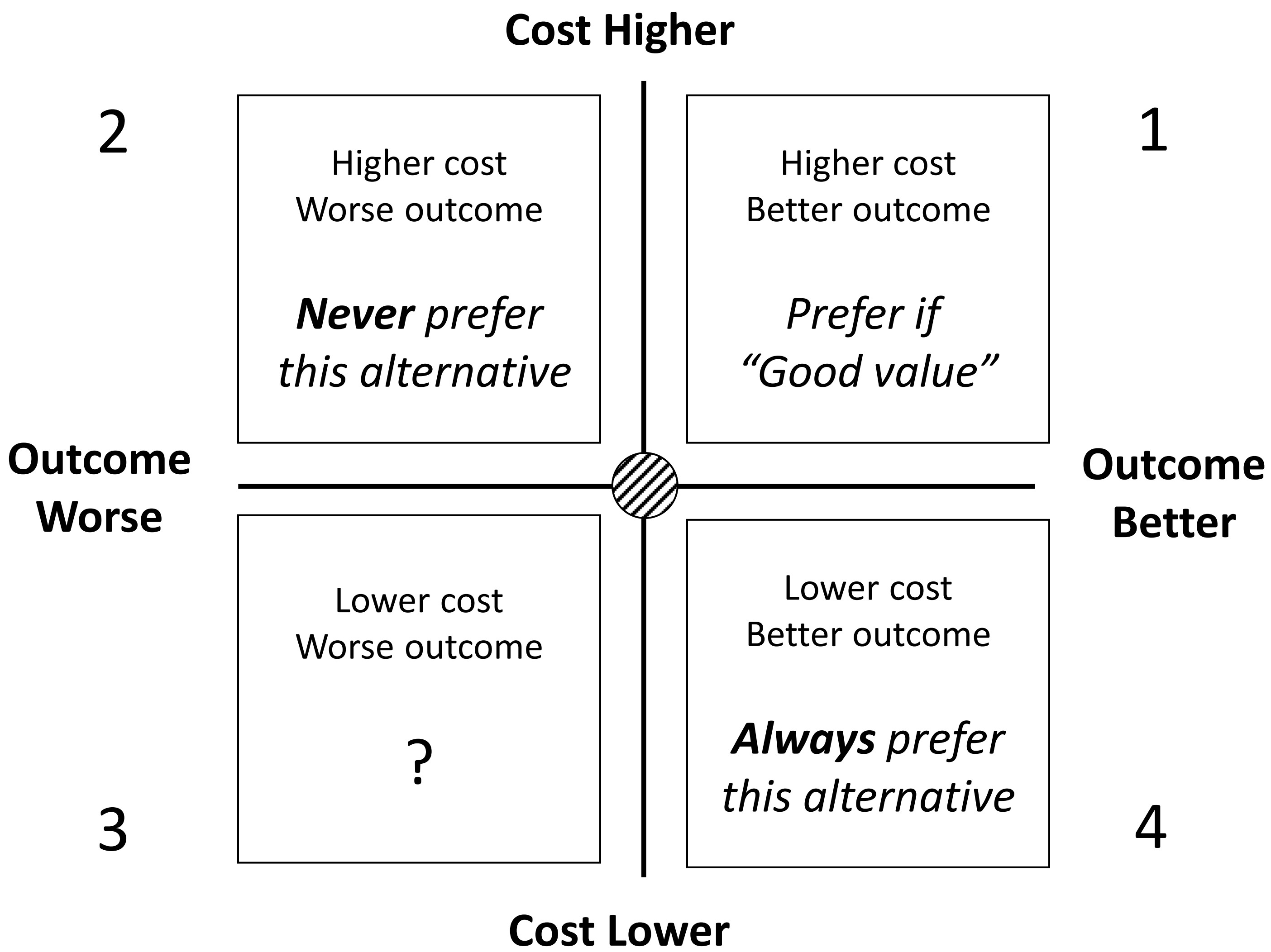


Disability-adjusted life years averted

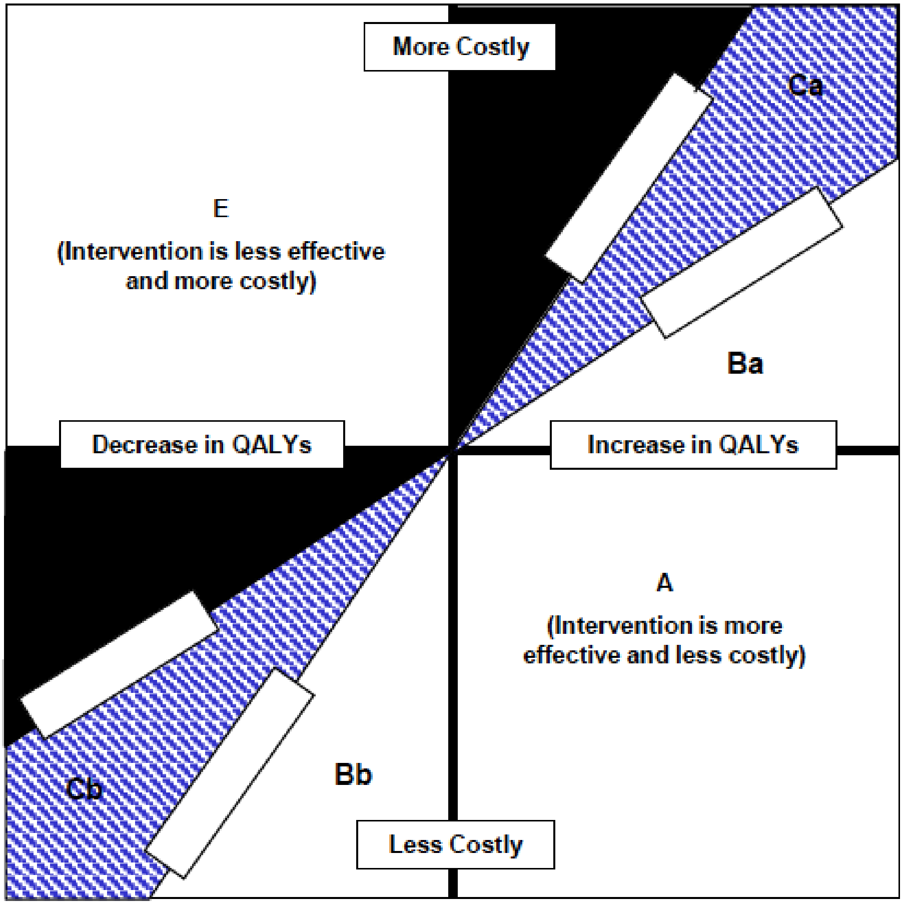
Interpreting the ICER (4)



Decision Rules for Vaccine CEA



Grades for Adoption of New Vaccines



A: Compelling evidence for adoption

B: Strong Evidence

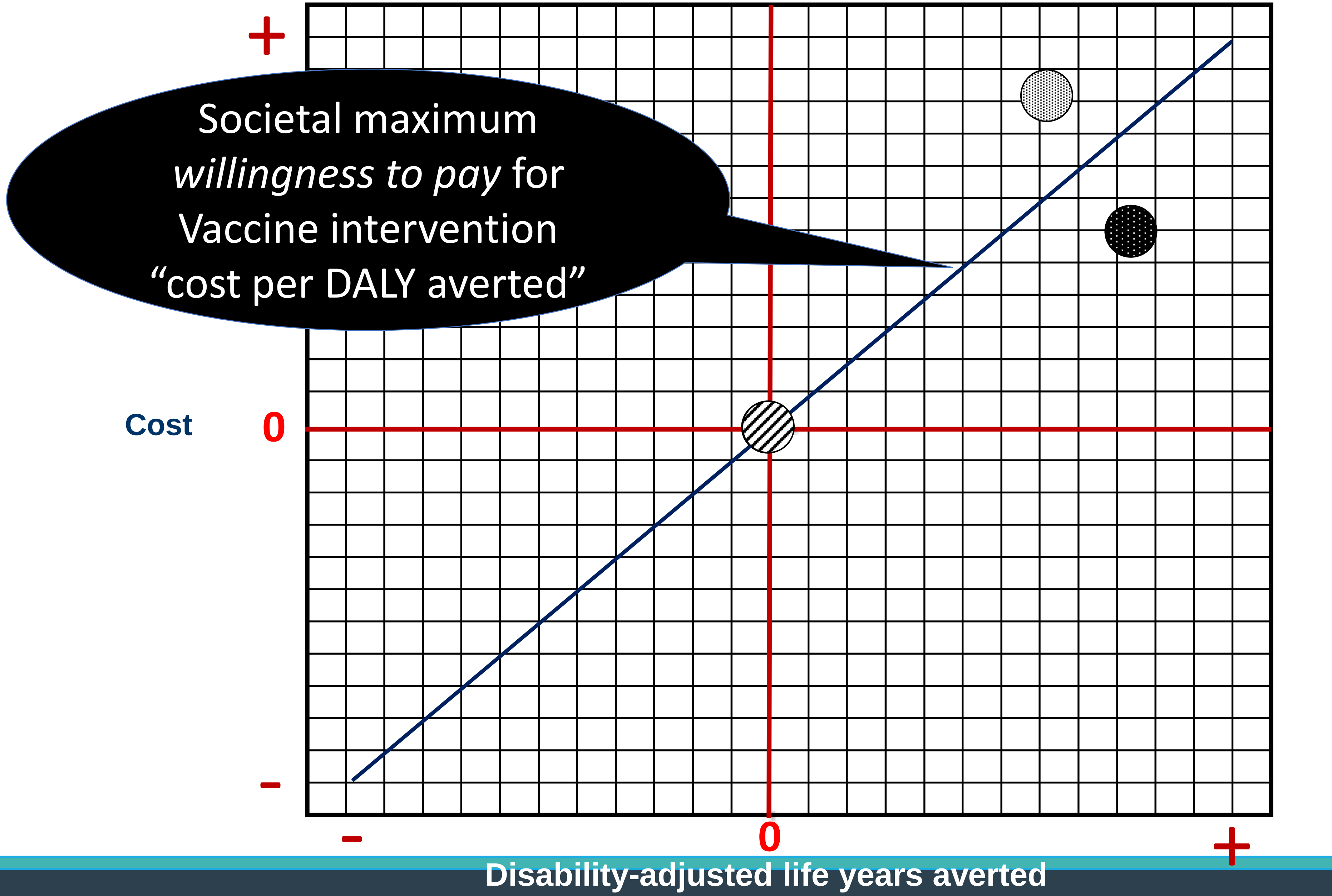
C: Moderate

D: Weak

E: Compelling evidence for rejection

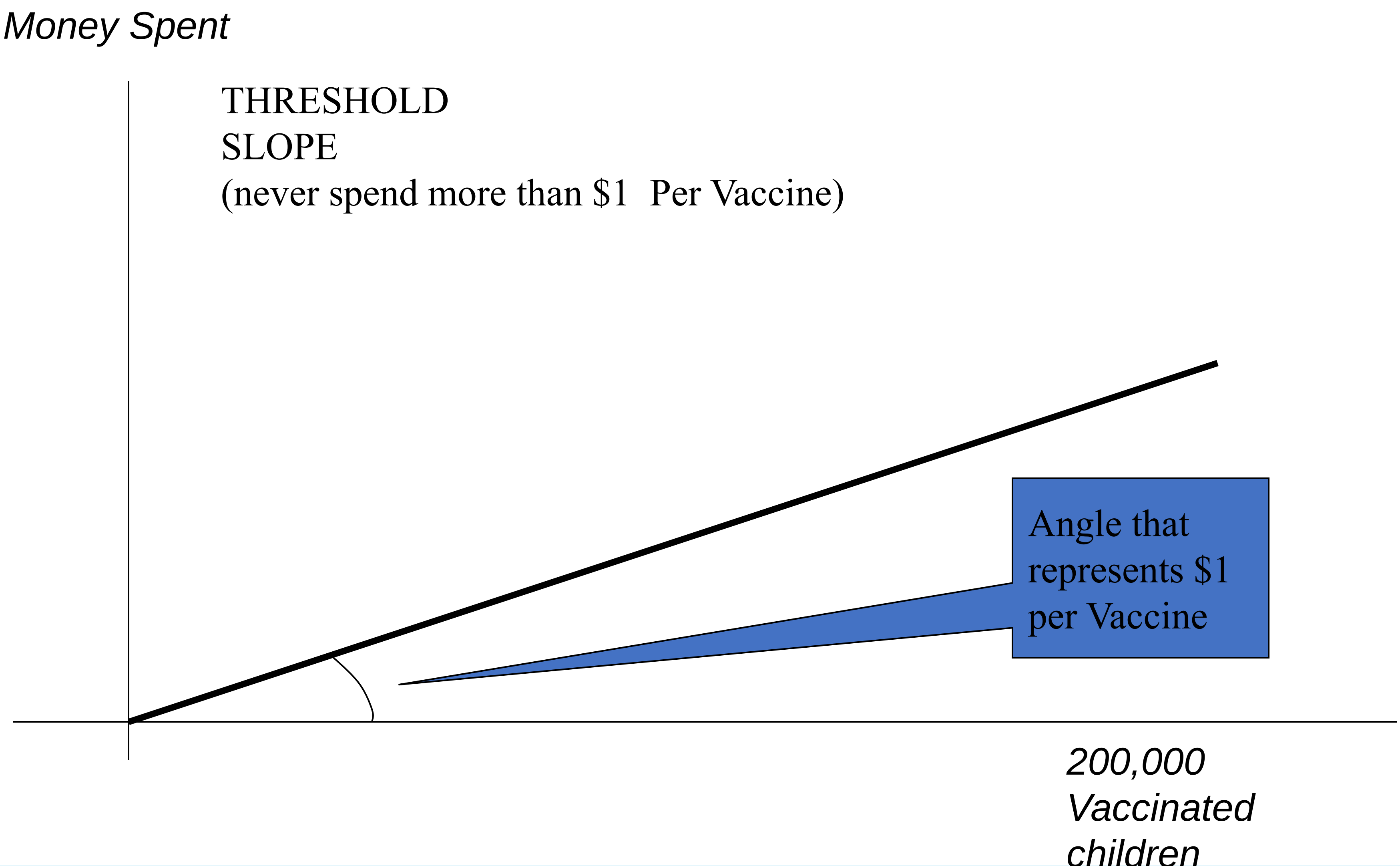
Laupacis, Andreas, et al. "How attractive does a new technology have to be to warrant adoption and utilization? Tentative guidelines for using clinical and economic evaluations." CMAJ: Canadian Medical Association Journal 146.4 (1992): 473.

When is an intervention "cost-effective"?

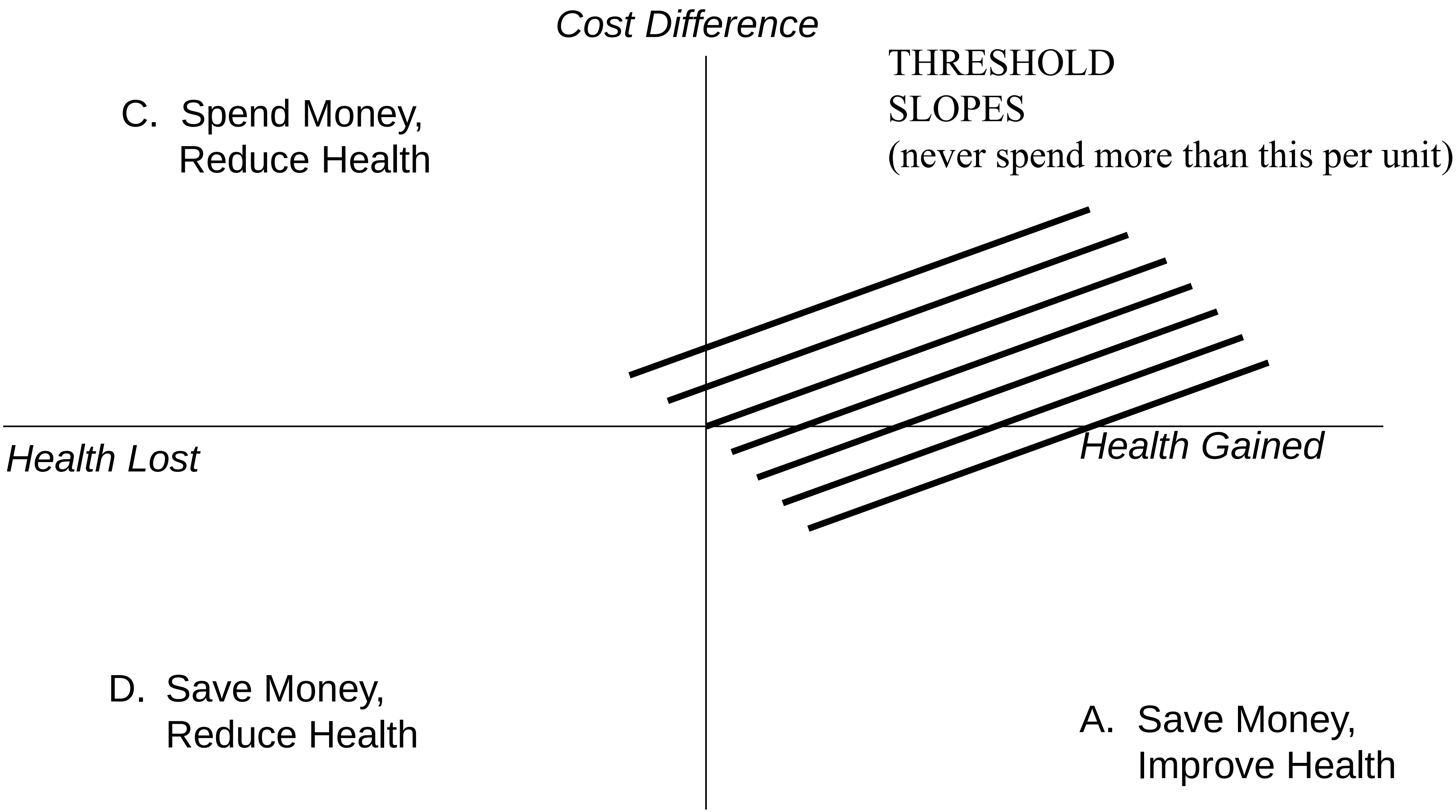


WILLINGNESS-TO-PAY THRESHOLD

Spending On Vaccines: The Sorrow Of Consumption Quotas

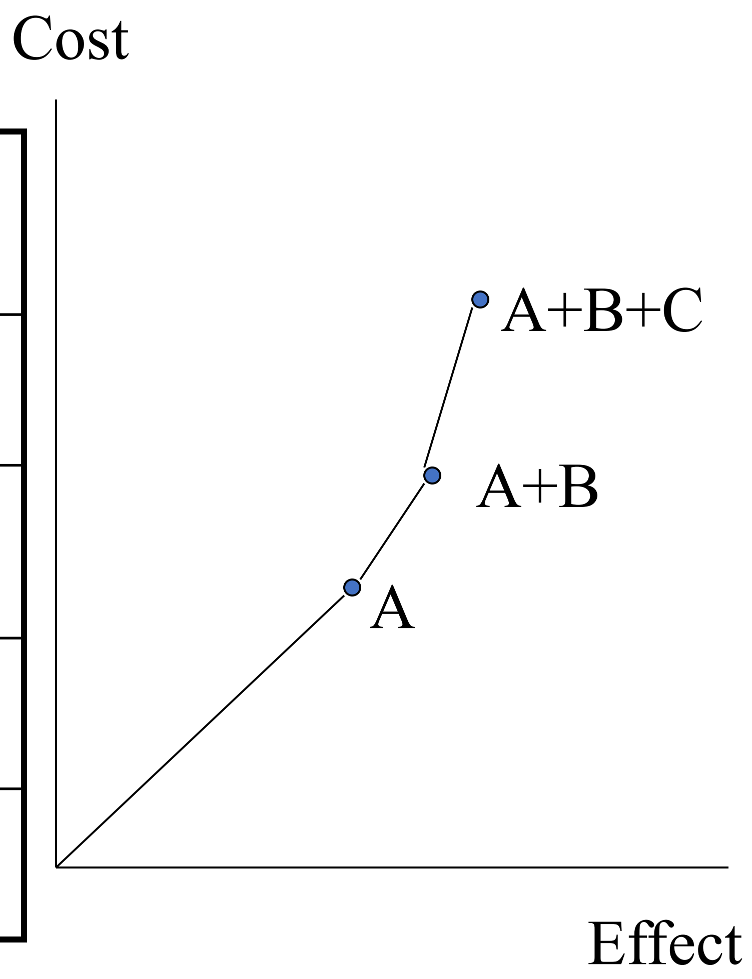


Price Thresholds are Efficient



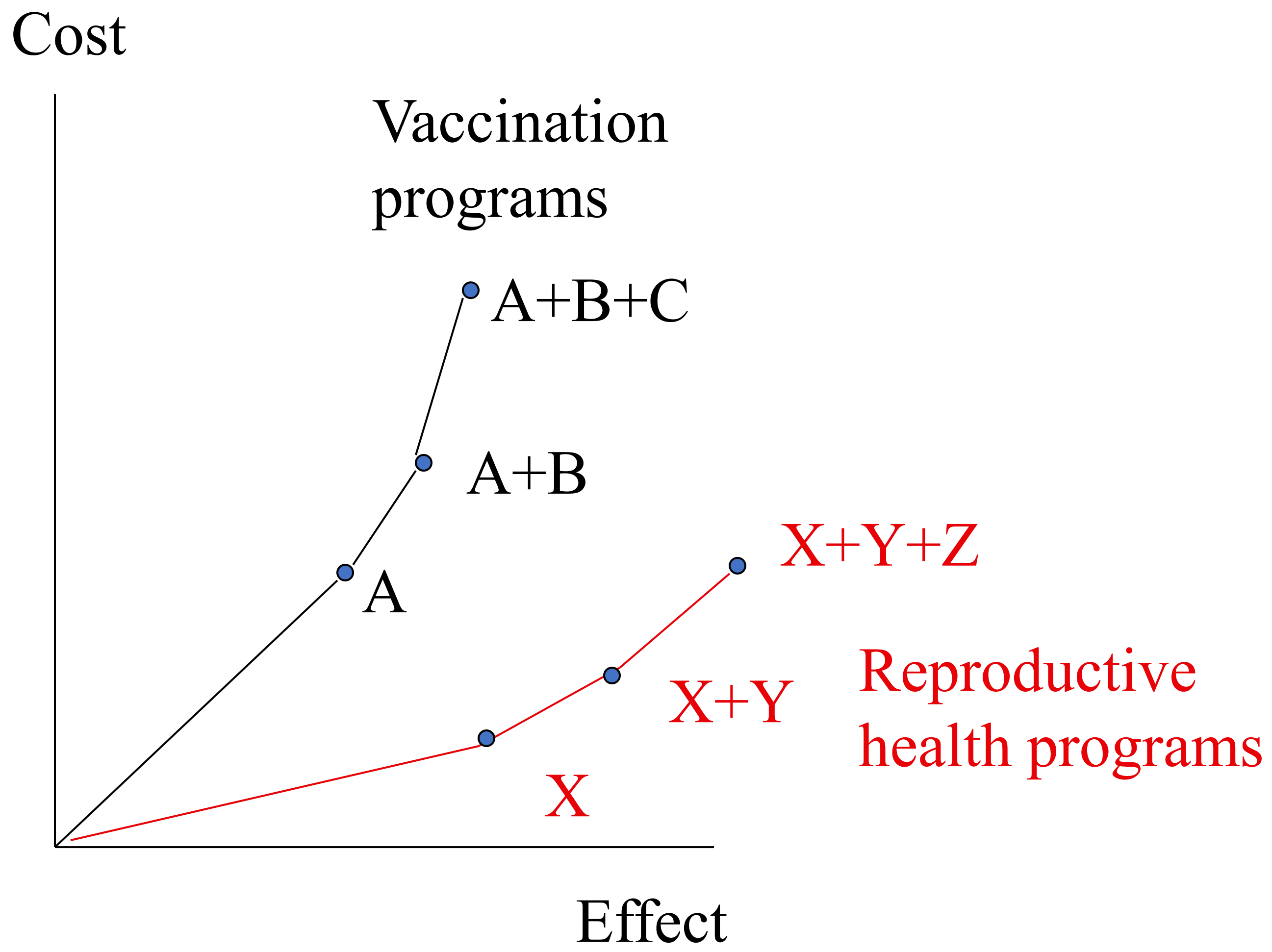
Health Programs in Region B

	Cost In $100	Effect	C/E	ΔC	ΔE	ΔC/ΔE (ICER)
Ø	$0	0	0	NA	NA	NA
A	$100	100	1	100	100	$1 per YLL saved
A+B	$150	140	1.1	50	40	$1.25 per YLL
A+B+C	$200	165	1.2	50	25	$2 per YLL

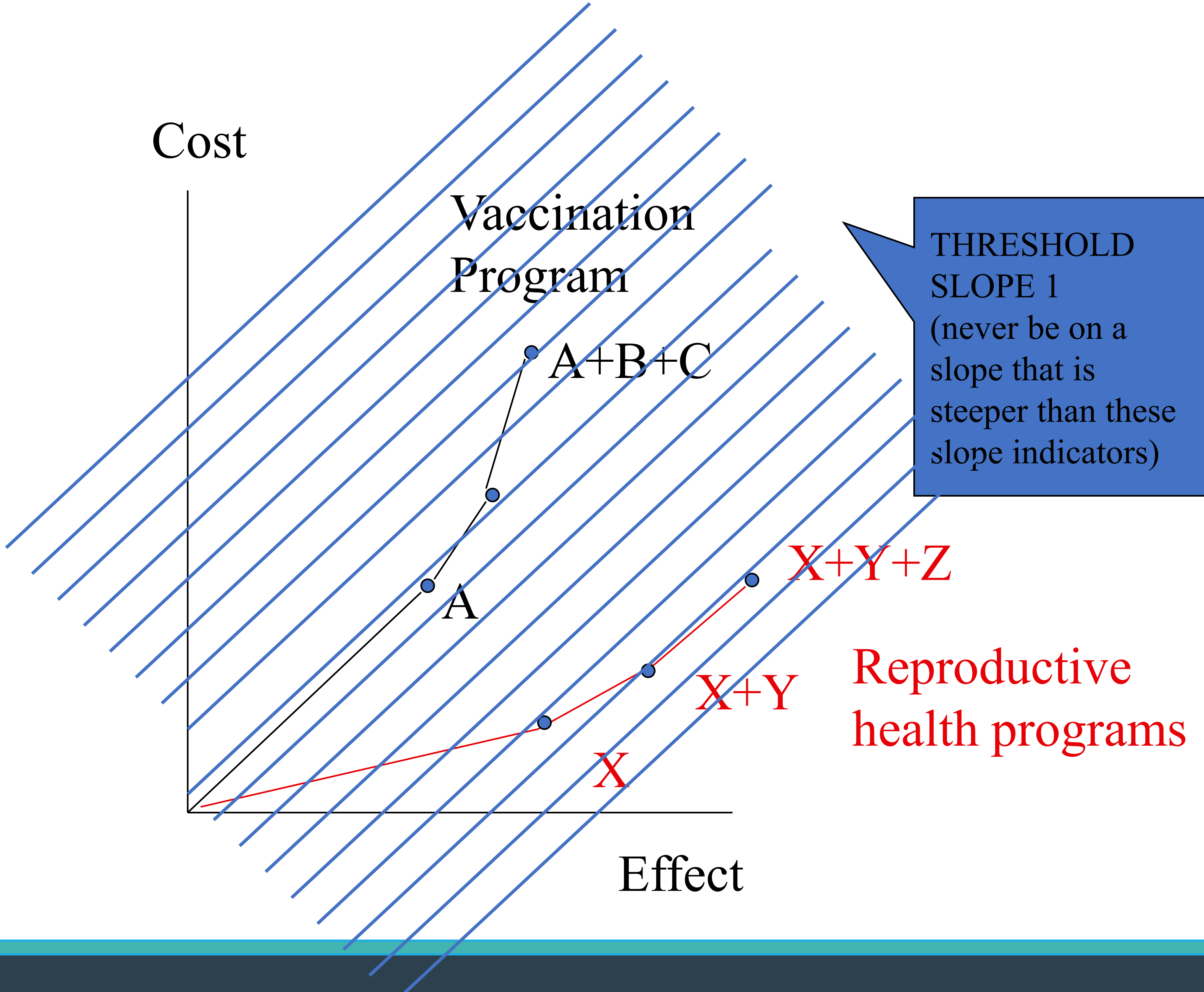


YLL is “year of life lost”

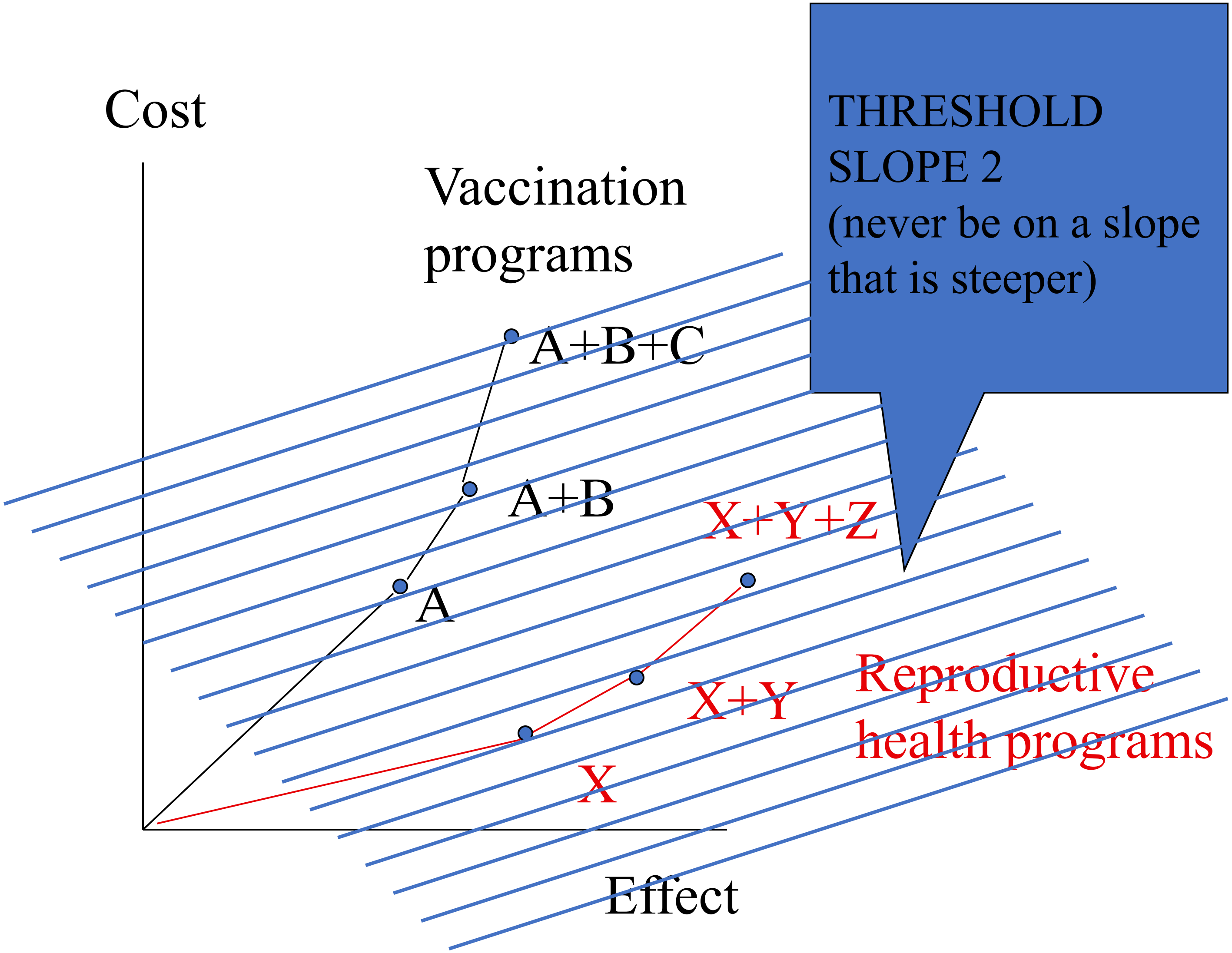
Choose your Strategy



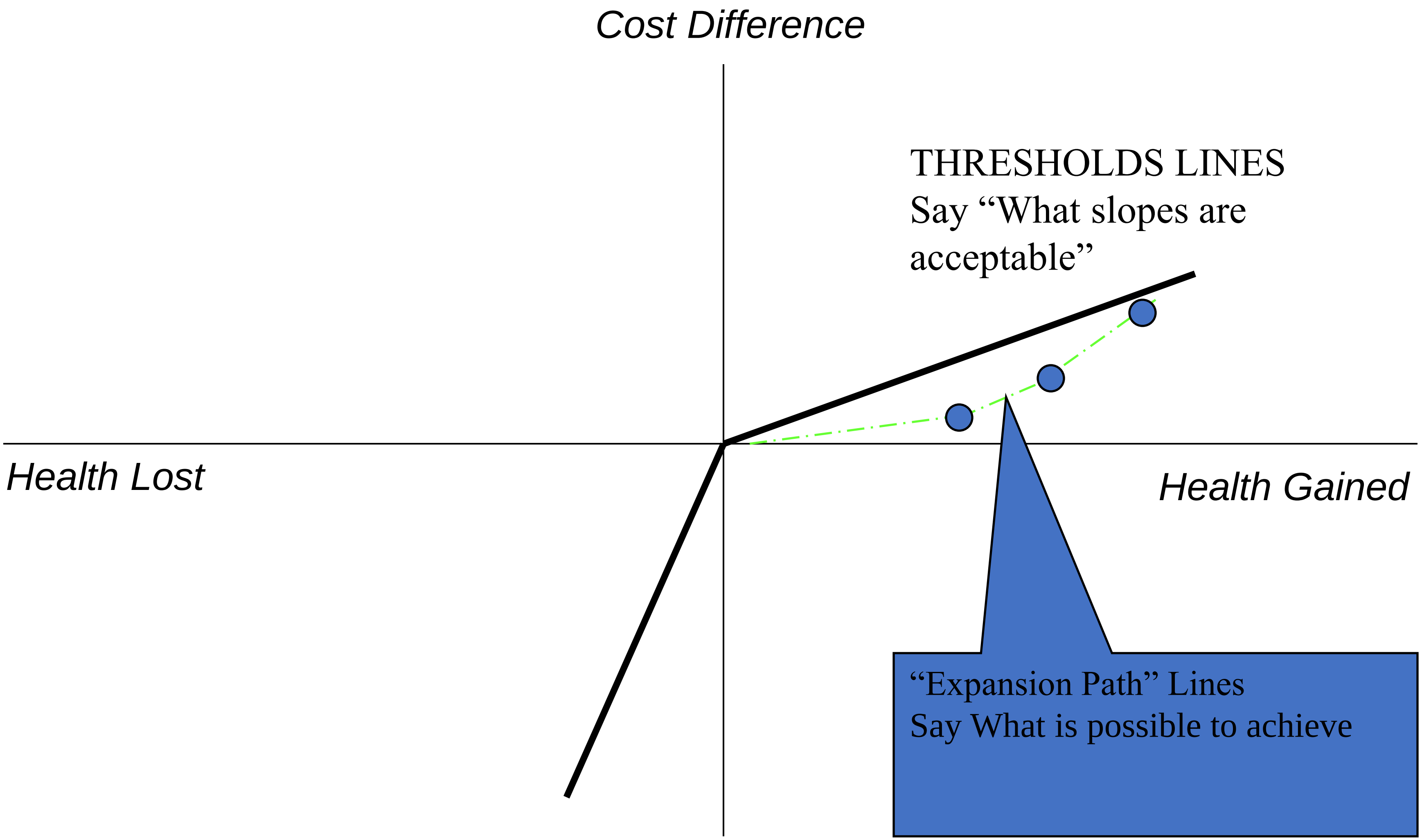
High Willingness To Pay



Low Willingness To Pay



Two Kinds of Lines



Willingness-to-Pay Thresholds

- The ceiling ICER beyond which interventions are not considered to be cost-effective.
- Reflects the maximum value decision makers attach to health benefits
- More simply, represents the budget constraint faced by decision-makers.
- Three general approaches for identifying thresholds:
  - Based on % per capita GDP (most common)
  - Based on % per capita national incomes
  - Based on benchmark interventions
  - Based on league tables.

Marseille, Elliot, et al. "Thresholds for the cost–effectiveness of interventions: alternative approaches." Bulletin of the World Health Organization 93.2 (2015): 118-124.

Willingness-to-Pay Threshold

- Under WHO-CHOICE recommendations:
  - if the ICER (valued in DALYs averted) is between the GDP per capita and 3 times the GDP per capita => cost-effective
  - if the ICER (valued in DALYs averted) is less than the GDP per capita => very cost-effective
- Common U.S. WTP thresholds:
  - $50,000/QALY to $150,000 per QALY
  - Some Economists argue patients are willing to pay 1x-3x of annual income
  - Could the increase in WTP be related to Pharmaceutical Pricing indices?
- U.K. Method

Cost per QALY	Accepted	Restricted	Rejected
< £20,000	14	3	1
£20,000 - £30,000	0	4	0
> £30,000	1	4	3

Source: Towse and Pritchard, 2002

ICER CALCULATION, INCREMENTAL RATIOS AND DOMINANCE

Incremental cost-effectiveness ratio (ICER)

Incremental Thinking

- Compare one alternative with another
  - Start by comparing the least expensive to the 2nd most expensive, to the 2nd most expensive, to the 3rd most expensive, etc.
- Focus on
  - Difference in costs: $Cost_O - Cost_N$
  - Difference in effects: $Effect_O - Effect_N$
  - where O is Old intervention and N is New intervention

	Effectiveness Decreases	Effectiveness Increases
Cost Increases	Never Do	Cost-effective
Cost Decreases	Cost-effective	Always Do

Incremental cost-effectiveness ratio (ICER)

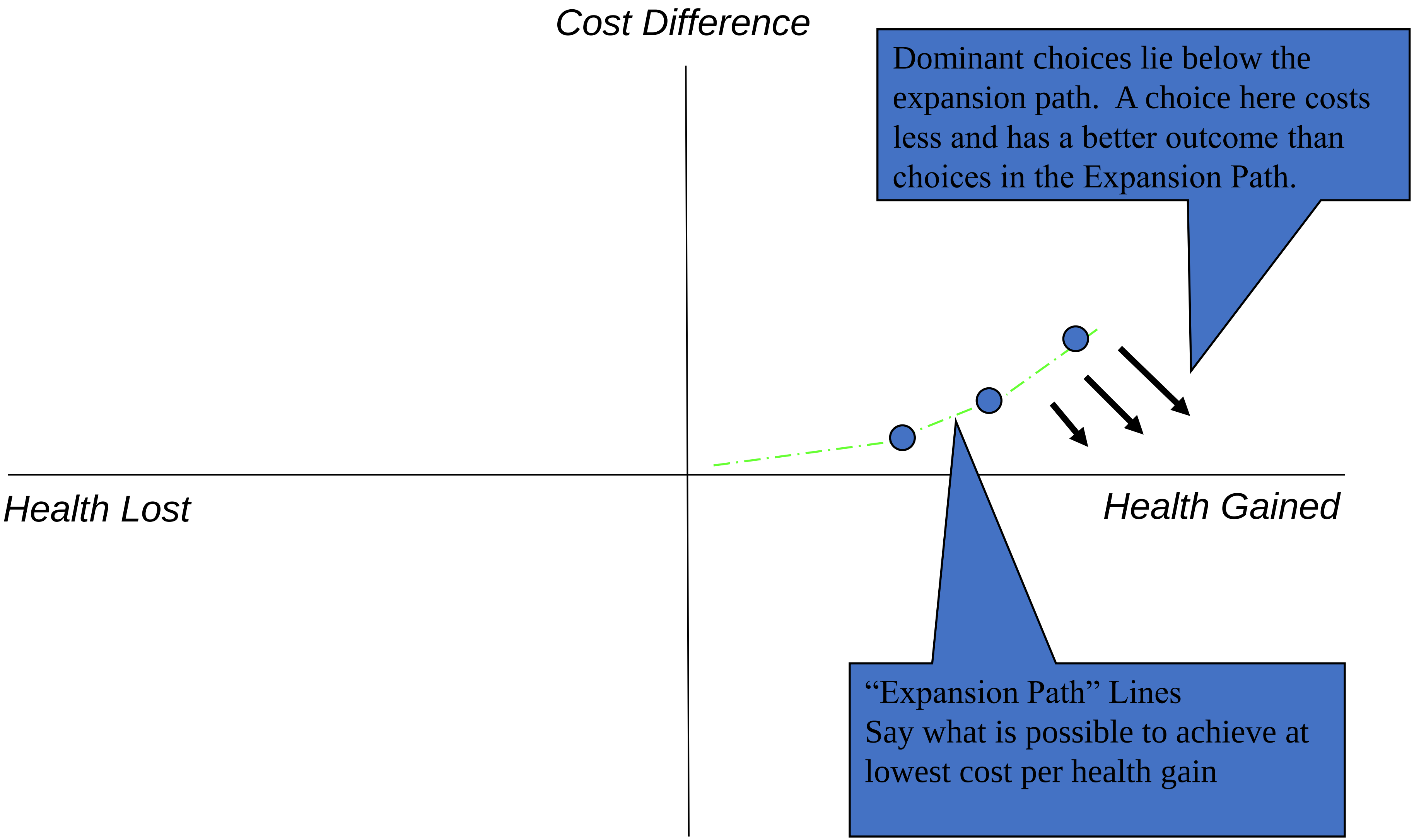
- Defined as the ratio between the incremental cost and the incremental effect between two interventions

$$\frac{Cost_O - Cost_N}{Effect_O - Effect_N} = \frac{\Delta\, Cost}{\Delta\, Effect} = ICER$$

Net Monetary Benefit

$$NMB = (WTP * \Delta Effect) - \Delta Cost$$

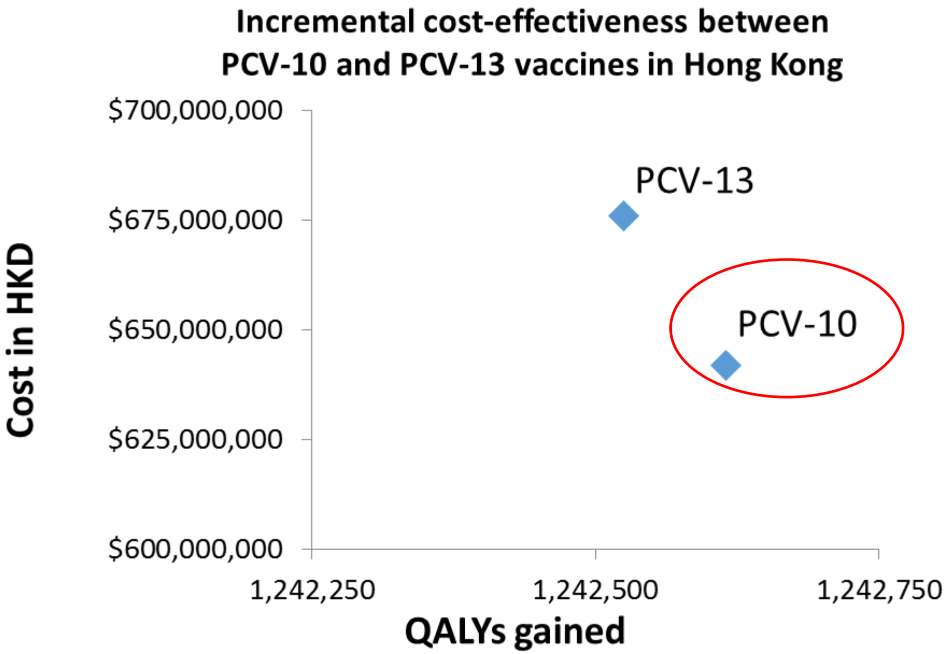
Strong Dominance



Strong Dominance Example

Cost-effectiveness of infant vaccination with the 10-valent pneumococcal (PCV-10) vaccine vs. the current 13-valent (PCV-13), in Hong Kong in 2011

- PCV-10 exhibits dominance because it has a lower cost and higher health gains (e.g. QALYs gained) compared to PCV-13



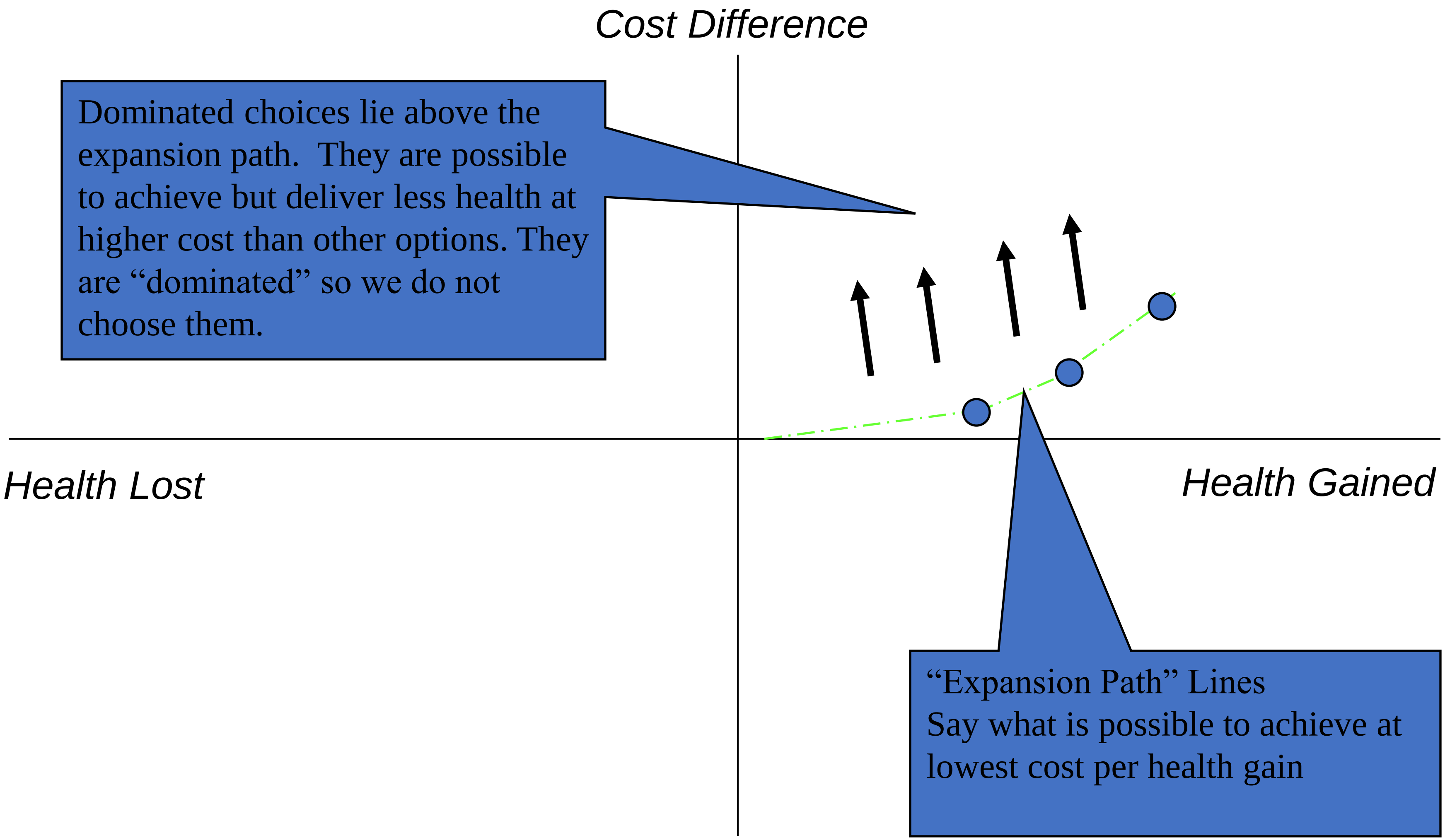
Lee, Kenneth KC, et al. "The health economic impact of universal infant vaccination with the 10-valent pneumococcal nontypeable Haemophilus influenzae protein D conjugate vaccine as compared with 13-valent pneumococcal conjugate vaccine in Hong Kong." Value in Health Regional Issues 2.1 (2013): 64-74.

Strong Dominance

- It is important to also put results in tables
  - Lining up alternatives in order by costs helps to make it obvious that the higher cost alternatives are associated with lower effectiveness

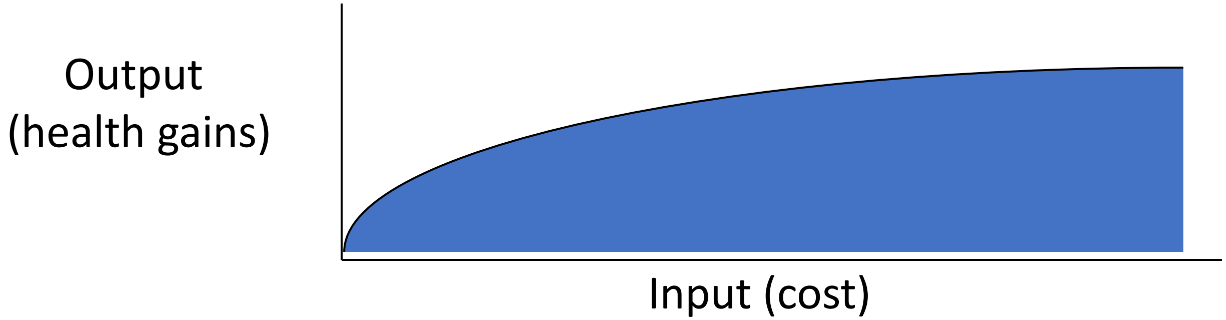
Alternative	Cost	QALYs
PCV-10	$641,860,544	1,242,615
PCV-13	$675,994,429	1,242,525

Dominated Choices



Eliminating Dominated Alternatives Graphically

- Non-dominated alternatives get increasingly flatter as we move from less expensive to more expensive undominated alternatives
- Graph should resemble a “production function”
  - First unit of input produces more output than next unit of input and this trend continues
  - Creates a graph looking like the one below



BI and ROI Calculation

Budget Impact (Simplified)

- Assume the difference in cost of an ACE represents the gain or expense for implementing a vaccine per-patient.
- In order to support investment in vaccines, these gains or expenses multiplied by the entire at-risk population (i.e. the population that you intend to vaccinate) represent the total cost for society to implement.
- The budget impact is not the total cost, but the cost per person who pays into the health system (e.g. taxes)

Cost Difference *dCost* × **Vaccine Prevalence** *N* = **Total Cost of the Program** *dCost x N* ÷ **Total Paying Population** *P* = **Budget Impact** $\frac{dCost \times N}{P}$

Question

There are 227 million children in India who would benefit from Hib vaccine. There are 1.3 billion people living in the country, of which half are taxpayers. As a health economist you have calculated the cost-effectiveness of the Hib vaccine from the societal perspective.

The government of India, would like you to assess the total cost for the country to implement this vaccination program which will be financed from the taxes collected. What is the budget impact per person per year?

Answer

- Cost difference = -$3.63
- No. of children vaccinated = 22 million
- **Total program cost** = $3.63 x 22 million
  = $80 million

- Total population of India = 1.3 billion
- **Total paying population** = 0.5 x 1.3 billion = 650 million

- **Budget Impact** = Total program cost / paying population
  = $80 million / 650 million
  = $0.12 per person per year

Return on Investment (ROI)

ROI (%) = (Net Profit / Investment) x 100

Net Profit = Total Program Savings - Total Program Cost

- A linear function, not adjusted for anything else
- Important to define the amount of time over which an investment is being measured
- Expressed as a *percent* of total investment returned or lost at the end of the time horizon
- Can also be considered as the time to achieve 100% ROI (full return)
    - = Time Period considered / ROI

Question

Assume that the program cost calculated above represents an up-front for all children between Years 0 and 1. Investing in the Hib vaccine will save $180 million in healthcare treatment costs over the next 10 years.

1. What is the return on investment (ROI) for introducing Hib vaccine?
2. How long will it take to receive a full return on the investment?

Answer

- Total program cost = $80 million
- Total program savings = $180 million
- Total time period = 10 years

- **Net profit** = $180 million - $80 million
  = $100 million

- **ROI** = (Net Profit / Investment) x 100 = $\frac{\$100\text{ million}}{\$\ 80\text{ million}}$ x 100 = 125%

for every 1$ invested, you get $1.25 back

- **Time to receive 100% ROI** = $\frac{10\text{ years}}{125\%}$ = 8 years