

The background of the slide features a dark blue world map at the top. Below the map, a bright blue rectangular box contains the title text. At the bottom of the slide, there is a depiction of water with white-capped waves, and numerous bright blue rays of light emanate from the horizon, creating a sense of depth and optimism.

# **Value of Investing in Health Care**



# The Science of Making Better Decisions About Health: Cost-Effectiveness and Cost-Benefit Analysis

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## Abstract

Despite spending far more on medical care, Americans live shorter lives than the citizens of other high-income countries. The situation has been getting worse for at least three decades. This chapter describes the main scientific methods for guiding the allocation of resources to health: cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA), sketches their methodological progress over the last several decades, and presents examples of how medical practice in other high-income countries, where people live longer, follows the priorities indicated by cost-effectiveness analysis. CEA and CBA support democratic decisionmaking processes, which have themselves benefited from scientific inquiry; these are touched on at the end of the chapter.

## Introduction

Medical scientists are at work around the world producing new knowledge about health and disease and new technologies to combat disease and improve health. They have had many successes: from the epidemiological investigations around London's Broad Street pump that confirmed cholera's transmission by water, to the identification of the agents of infectious diseases themselves—bacteria and viruses—to the development of vaccines, antibiotics, and other interventions that have brought so many diseases under control.

Those discoveries are not the end of the story, nor are they the end of the need for good science. New knowledge and new technologies present human beings with choices. How those choices are made is as important to their ultimate effect on health as the knowledge and technologies themselves. Because of their importance, how those choices are made is equally in need of a scientific approach – an approach based on asking searching questions, seeking empirical evidence to address those questions, reasoning carefully about the evidence, and presenting the evidence and reasoning transparently so that others can understand, attempt to replicate, and agree or disagree with the conclusions.

Cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA) are two important components of the science of decisionmaking for health. Great strides have been made in both CEA and CBA in recent decades, not only in their scientific methods but also in their use for real-world decisions. I describe them in this chapter, sketch some of the methodological progress, and present examples to show how thinking about the cost-effectiveness of health interventions has contributed to

better health in high-income countries. CEA and CBA are not the only components of scientific decisionmaking, and I mention others, such as systematic reviews and meta-analysis. All these components support democratic decisionmaking processes, which have themselves benefited from scientific inquiry, and which I discuss briefly at the end of the chapter.

## The Decision Context: An International Perspective

The United States spends a much larger share of its national income on medical care than any other country, 18 cents of every dollar in 2011 (Table 1); that is 50 percent more than the next highest spender and almost double the amount spent by still other high-income countries. By rights then, the United States should have the best health in the world, including the longest life expectancy. Instead U.S. life expectancy at birth is 1 to 4 years shorter than in the other high-income countries in Table 1. The deficit continues across the lifespan, with U.S. life expectancy at age 65 also less than that in most of the other countries and no better than equal to the rest. A 2013 Institute of Medicine report shows that the situation has only gotten worse in recent years, as U.S. life expectancy has risen more slowly than that of other high-income countries.<sup>1</sup>

**Table 1. Health spending (as a percent of national income) and life expectancy at birth and at age 65, selected high-income countries**

	Health spending as a % of GDP, 2011	Life expectancy at birth, 2011	Life expectancy at 65, 2009	
			Men	Women
United States*	17.9	79	17	20
Netherlands	12.0	81	17	21
France	11.6	82	18	23
Canada*	11.2	81	18	21
Denmark	11.2	80	17	20
Germany	11.1	81	18	21
Switzerland	10.9	83	19	22
Greece	10.8	81	18	20
Austria	10.6	81	18	21
Belgium	10.6	80	18	21
Italy	9.5	82	18	22
Spain	9.4	82	18	22
Sweden	9.4	82	18	21
Japan**	9.3	83	19	24
United Kingdom*	9.3	81	18	21
Norway	9.1	81	18	21
Australia	9.0	82	19	22
Finland	8.9	80	17	22

Sources: Percent of gross domestic product (GDP) and life expectancy at birth from the World Bank, World Development Indicators 2013. Life expectancy at 65 from Health at a Glance 2011: OECD Indicators.<sup>2</sup>

Notes: \* These three countries are compared later in this chapter as to their policies about adult tetanus boosters and cervical cancer screening; note how they compare in terms of life expectancy. \*\*Japan has the longest life expectancy of any high-income country.



The differences do not arise from medical science. All these countries have access to the same scientific evidence and the same medical technologies as the United States. The same medical equipment, medications, and surgical procedures are available to all. The science base in medicine is so international that all countries, including the United States, routinely rely on randomized controlled trials and epidemiological studies conducted in the populations of other countries, not just their own. More than half of the clinical trials registered on [clinicaltrials.gov](http://clinicaltrials.gov) are located outside the United States. The Cochrane Collaboration, with branches around the world, bases its systematic reviews of what works in medicine on all the evidence, not just evidence for one country or a few countries.

The central thesis of this chapter is that differences in health across these countries arise in large part from differences in the way medical choices are made at the national level. Those choices involve how the national health sector is structured, the level of resources provided through public sources, and the framework created by national decisions for health plans, insurers, providers, and patients. Such decisions can involve more specific recommendations about the use of particular interventions, such as vaccines. They can be made by a variety of groups: governments; non-government groups such as medical professional societies, which develop guidelines for care; or organizations like the Institute of Medicine, which evaluate policies and propose changes.

To appreciate the difficulty of choosing well, consider the enormous range of possibilities facing decisionmakers. The medical sector alone offers many kinds of preventive care, acute care, chronic disease management, rehabilitative care, and palliative care. Public health programs may fall in the medical sector or cross sectors. An even wider range of activities outside of medicine are important for health and life expectancy: water and sewage systems; safe handling of food and related inspections of food imports, food manufacturing plants, and restaurants; building codes and construction methods; safety regulation and safe manufacture of consumer products; safe design and maintenance of roads, bridges, train tracks, airports; regulation of environmental pollutants; and many others.

How can decisionmakers select the best ways to improve health from this vast array of choices? That is the question addressed by the science of decisionmaking in health. It may not be coincidental that the countries that do better than the United States – longer life expectancies despite spending less of their national income on medical care – have been quicker to use those methods to help set priorities. Their better health does not derive from better scientific knowledge or better medical technologies, but from better choices.

Social scientists study how people make choices, how they can be misled or misconstrue choices, and how they can make choices that best serve their goals. Decision scientists have developed methods to help people make choices. The goal of these methods is to provide a formal process for evaluating decisions in order to help decisionmakers identify the best choices – the choices that serve their values and the values of those they represent – in situations where it is difficult for them to do so unaided.

CEA, which grew out of operations research and then began to blend with CBA, is a central decision-support method used in the medical sector. I describe it next, sketch its scientific evolution, and provide examples showing how it aligns with decisions about medical care in the United

States, Canada, and the United Kingdom. CEA is less useful for the wider range of choices that affect health, those that lie outside the medical sector. So I next discuss CBA, which comes from economics, and provide examples of its use.

This is perhaps a good place to explain why I say “aligns with.” CEA, which is relatively recent (CBA has a longer history), formalizes a way of thinking about social decisions that has probably always existed. The basic idea is simple: think about, even try to estimate, what a decision will cost and what its effects (benefits) will be. Then compare those with the costs and effects of competing possibilities to decide which is best. People have evaluated decisions in terms of costs and effects for eons, and some of the decisions I describe were made before CEA had developed into a formal method of evaluation.

It is important to remember that every high-income country, including the United States, provides medical services, and many other services crucial to good health, through systems that are largely financed by people other than those who receive the services or who make decisions about them. These decisions thus involve public goods, or what Nobelist Elinor Ostrom terms “social dilemmas”—terms that point to the fact that they affect groups, not just individuals—and are often made by public groups of one sort or another.<sup>3</sup> That being the case, I conclude the chapter by turning briefly to the processes of which CEA and CBA are a part – that is, the processes for making decisions about the social dilemmas of health in representative democracies. Because, as everyone agrees, CEA and CBA are aids to decisionmaking, not the entire decisionmaking process, and that process is as important to the quality and validity of decisions as are the CEAs and CBAs that inform it, perhaps more so. It is through that process that important social values, such as fairness and helping those worst off, are incorporated into decisions.

## Cost-Effectiveness Analysis: A Guide to Better Decisions

CEA begins with the objective of maximizing health subject to a budget constraint. In other words, if \$3 trillion is available for medical care for the U.S. population, CEA asks: What services should be purchased with that money to produce the best possible health for people living in the United States?

The next step is conceptually simple. Evaluate the choices – the alternatives facing decisionmakers – in the terms established by the objective (health) and the constraint (costs). Make sure to include whatever is already being done, the status quo, among the alternatives. Based on the scientific evidence, estimate how much each alternative contributes to health and how much it costs. Then rank the alternatives in terms of their contributions to health, starting with the one that contributes the least, and compare them.

Table 2 presents a particularly straightforward CEA of tetanus boosters for adults. The purpose of the analysis was to evaluate the U.S. Centers for Disease Control and Prevention’s recommendation that adults receive routine boosters at intervals of 10 years after the completion, at age 6, of a full schedule of childhood vaccinations. The analysis estimated the costs and years of life of three alternatives: no routine boosters after age 6; a single booster at age 65; and the recommended

boosters every 10 years. All three alternatives included boosters for deep wound injuries. (The authors of the analysis, Balestra and Littenberg,<sup>4</sup> identified a single booster at age 65 as worth considering based on evidence that the rate of tetanus in the United States, although low, rises sharply with age.) Projecting outcomes for a cohort of 3.6 million 6-year-olds over 80 years, the authors estimated that boosters at age 65 would prevent about 300 cases of tetanus, compared with no routine adult boosters. Boosters every 10 years were estimated to prevent an additional 500 cases. (Although tetanus toxoid is typically delivered in a combination vaccine that includes diphtheria and pertussis, the analysis considered only tetanus toxoid and assumed that it was delivered without the other two.)

**Table 2. Cost-effectiveness analysis of adult tetanus boosters**

	Undiscounted		Discounted at 5%/year			ICER, 2012
	Cost*	Life expectancy	Cost*	Life expectancy	ICER*	
No routine booster	\$0.832	68.315319	\$0.060	19.464526		
Booster at age 65	\$0.996	68.315417	\$0.074	19.464529	\$4,500	\$15,800
Booster every 10 yrs	\$4.135	68.315464	\$0.919	19.464532	\$281,700	\$986,100

Source: Adapted from Balestra DJ, Littenberg B. *J Gen Intern Med.* 1993;8:405-412.<sup>4</sup>

\*Note: Incremental cost-effectiveness ratio, 1986 dollars, rounded to the nearest hundred. All three alternatives include a booster in the event of a deep wound.

The alternatives are arranged in Table 2 in order of effectiveness, starting with no routine boosters, the least effective. If a more effective alternative costs less, the decision is easy. The less effective alternative can be eliminated from the choice set.

In this case, however, as commonly happens, greater effectiveness comes at higher cost, making the decision more difficult. So the next step is to compare alternatives two at a time, calculating a cost-effectiveness ratio to summarize the comparison. A cost-effectiveness ratio, often called an incremental cost-effectiveness ratio (ICER), is the difference in health between two alternatives, divided by the difference in their costs. For a single booster at age 65 compared with no routine boosters, the cost-effectiveness ratio is  $(\$0.074 - \$0.060) / (19.464529 - 19.464526)$ , which yields a cost-effectiveness ratio of \$4,500 for each year of life gained, in 1986 dollars. Scaled up to 2012 price levels, a single booster at age 65 would cost an additional \$15,800 for every year of life gained, compared with no routine boosters after age 6. This is very reasonable compared with many interventions routinely offered in high-income countries.

The comparison between boosters every 10 years and a single booster at age 65 is strikingly different. Boosters every 10 years cost an additional \$281,700 in 1986 dollars for each year of life gained – almost \$1 million in 2012 dollars.

That comparison, health for dollars, is the central contribution of CEA. CEA does not ask how much an intervention costs per person – in this case, not very much as Table 2 shows. Nor does it ask how much the vaccine costs per dose; the study used a price of 43 cents per dose (and assumed

no additional cost for administering it). Even today, a single dose costs a dollar or two. By these measures, it would hardly seem worthwhile to take the trouble to evaluate such an inexpensive intervention.

CEA asks: How much does it cost to contribute to the objective – good health? What is the cost in relation to what we really care about, health? Cost per dose, or cost per person, is not the point, and looking at those numbers can be misleading. It turns out that giving boosters every 10 years is a very expensive way to get better health.

That information by itself, however, is not enough to rule out boosters every 10 years. The next question is: What else is out there? What else can be done to improve health, and how does that compare with boosters every 10 years?

To illustrate that next step, Table 3 presents cost-effectiveness ratios for a larger set of choices. The first column shows the alternatives compared and the second column the cost-effectiveness ratio for that comparison from the original study. The third column adjusts the original ratios to 2012 dollars to permit comparisons across studies. The final column flips each cost-effectiveness ratio on its head to bring attention back to the goal, better health: it shows the number of additional healthy years that can be produced by that intervention, compared with its alternative, for an expenditure of \$1 million.

The final column shows that there are many possibilities for improving health that make better use of health resources. Aspirin for men at high risk of heart disease is cost saving, an easy choice.<sup>5</sup> Smoking cessation programs are next most productive, bringing 161 years for each \$1 million; the number reflects the cost-effectiveness ratios of a mixture of programs with different approaches, weighted by enrollment.<sup>6</sup> Aspirin for lower-risk men,<sup>5</sup> total knee arthroplasty for people at low risk of perioperative complications,<sup>7</sup> and tetanus boosters at 65<sup>4</sup> are also productive choices.

Clearly tetanus boosters every 10 years would not be at the top of the list, but neither would they automatically be rejected. The guideline for using CEA is to select the most productive choices first – the ones that contribute the most to health – and keep selecting as long as the resources hold out. If sufficient resources are available to provide all the interventions, all would be provided. If the resources are used up by interventions that provide more health, boosters every 10 years would not be provided — or should not be provided. The title of the table includes the economic term “opportunity cost.” The opportunity cost of a choice is the benefit lost because of that choice. Good decisions bring the most benefit – whatever was not chosen would have brought less. Table 3, last column, illustrates the concept. If the choice is tetanus boosters every 10 years, and smoking cessation programs are not chosen, each year gained from tetanus boosters has an opportunity cost of 161 years, the years lost because smoking cessation programs were not provided.

This may be a good point at which to make clear that CEA is designed to set priorities, given that health is the objective. It does not set the budget. That comes from elsewhere. To be more explicit, CEA is not a tool for controlling costs. It is a tool for making the best possible use of



Table 3. Opportunity costs: healthy years for \$1 million, selected interventions

	Cost per healthy year (original year \$)	Cost per healthy year (2012 \$)	Healthy years per \$1 million (2012 \$)
Tetanus boosters			
Booster at age 65	4,527 (1986)	15,845	63
Booster every 10 years	281,748 (1986)	986,118	1
Total knee arthroplasty (TKA) for advanced knee osteoarthritis			
TKA, low risk of perioperative complications	9,700 (2006)	11,971	84
TKA, medium risk of complications	18,700 (2006)	23,077	43
TKA, high risk of complications	28,100 (2006)	34,678	29
Aspirin to prevent heart disease			
men 45, 10-year risk 2.5%	9,800 (2003)	13,686	73
men 45, 10-year risk 5.0% or higher	cost-saving	cost-saving	cost-saving
Mammography for breast cancer			
women 50-79, screened every 2 years	25,021 (2002)	36,349	28
Screening for diabetes			
age 55/high blood pressure vs no screening	34,375 (1997)	60,794	16
all adults 55 vs adults w high blood pressure	360,966 (1997)	638,384	2
Screening once for HIV			
HIV prevalence = 1.0%	30,800 (2004)	41,209	24
HIV prevalence = 0.1%	60,700 (2004)	81,214	12
Diet/exercise to prevent diabetes			
adults at high risk of diabetes	143,000 (2000)	227,495	4
adults with diabetes	35,400 (2000)	56,317	18
Smoking cessation			
15 programs weighted by % enrolled	3,294 (1995)	6,198	161

Sources: Tetanus boosters, Balestra and Littenberg, 1993<sup>4</sup> and Table 2; TKA, Losina, Walensky, Kessler, et al, 2009<sup>7</sup>; aspirin, Pignone, Earnshaw, Tice, et al, 2006<sup>5</sup>; mammography, Mandelblatt, Saha, Teutsch, et al, 2003;<sup>8</sup> diabetes screening, Hoerger, Harris, Hicks, et al, 2004;<sup>9</sup> HIV screening, Paltiel, Walensky, Schackman, et al, 2006;<sup>10</sup> diet/exercise, Eddy, Schlessinger, Kahn, 2005;<sup>11</sup> and smoking cessation, Cromwell J, Bartosch WJ, Fiore MC, et al, 1997.<sup>6</sup>

whatever health resources are available. By itself CEA will not reduce U.S. medical spending, nor even reduce its growth rate. It can help the United States allocate medical spending more effectively to improve health and move closer to the life expectancies achieved by other high-income countries, but it will not control costs.

## The Scientific Evolution of CEA

The purpose of CEA is comparison – comparison of alternative health interventions in order to identify those that make the most productive use of resources. To serve that purpose, CEAs must be comparable. And, as Table 3 suggests, they need to be comparable across a wide range of very different interventions aimed at very different health conditions. When they are not comparable, they can lead to poorer choices, not better ones. Much of the methodological development over the 40-50 years since CEA was first applied in health has gone to making CEAs comparable. I will briefly describe two central developments: the Quality-Adjusted Life-Year (QALY) and the Reference Case.

The QALY was developed because a comprehensive measure of health is needed that allows comparisons of interventions that deal with different diseases. Cases of disease, used in some early CEAs, could not serve the purpose; the implications for health of a case of diabetes are very different from those of a case of influenza. Lives saved was an improvement but did not take into account that some measures save many more years of life than others. Years of life, used in the tetanus booster study, improved on lives saved by giving more credit to interventions that saved many years but did not give credit for improvements in the quality of life – less pain, better function – that are important contributions of some interventions.

And so the QALY was created.<sup>12</sup> QALYs are years of life with each year weighted by the state of health, or quality, of that year. Quality is measured on a 0-1 scale – 0 for death, 1 for perfect health. Weights are elicited from a representative sample of people using various methods: standard gamble, time tradeoff, paired comparisons, or rating scales. Early QALY systems were the Quality of Well-Being (QWB) scale, the Health Utilities Index, and the EuroQoL (now the EQ-5D and EQ-5D-5L).<sup>a</sup> Health utility measurement, as it is often called, continues to be an active field of research.

QALYs address a crucial issue, but CEAs need to be comparable in other ways as well: health states included in QALYs, resources counted and their valuation, discount rate, methods for exploring uncertainty, how results are reported, and much more. I was fortunate enough to co-chair, with Milton Weinstein, one of the early efforts to address the issue of the broader comparability of CEAs. The U.S. Public Health Service convened the first Panel on Cost-Effectiveness in Health and Medicine in 1993 and asked the panel to assess the state of the field and provide recommendations for the conduct of CEAs “in order to improve their quality and encourage their comparability.”<sup>12</sup> Michael McGinnis, Assistant Surgeon General (retired), explained: “The overarching goal for this work has been to move the field forward so that over the next decade, State and Federal decisionmakers will have access to robust information with respect to the true cost per health effect gained for the continuum of health-related interventions – be they preventive, palliative, curative, or rehabilitative.”<sup>12</sup> Thus, at the outset, the panel’s charge directed it to take a broad view and consider how CEA could inform decisions across the entire range of health interventions.

<sup>a</sup> See the appendix to Gold, Siegel, Russell, et al, chapter 4, for a description of these systems.<sup>12</sup>

To meet that charge the panel's recommendations defined a "reference case" analysis.<sup>12-15</sup> In the words of the panel "To promote comparability of CEAs ..., the panel proposes that studies include ... a reference case. The reference case is defined by a standard set of methods and assumptions. It includes a set of standard results: the reference case results. While an investigator might also present results based on different methods and assumptions to serve the other purposes of the analysis, the reference case serves as a point of comparison across studies. It should be included whenever the CEA is intended to contribute to decisions about the broad allocation of health care resources."<sup>13</sup> The Second Panel on Cost-Effectiveness in Health and Medicine<sup>b</sup> was convened in 2012 to review and update the reference case; that panel's report is due in 2016.

In the last 20-25 years, CEA has become an integral part of decisionmaking in many health agencies around the world, and the reference case has been a powerful organizing principle and a popular name for the resulting standards. Those agencies, like Australia's Pharmaceutical Benefits Advisory Committee (PBAC), the Canadian Agency for Drugs and Technologies in Health (CADTH), and the United Kingdom's National Institute for Health and Care Excellence (NICE), each have their own guidelines for economic evaluations, which are designed to promote comparability across the studies that inform their recommendations.<sup>16-18</sup> In addition, the World Health Organization (WHO) has guidelines for CEA,<sup>19</sup> and the Gates Foundation has developed its own reference case.<sup>c</sup>

Since the first panel published its recommendations, many strands of research have contributed to the improvement of CEA. They include better methods for systematic review and meta-analysis of the health and medical literature, which have contributed to better estimates of the parameters needed for CEAs. Contributions from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses),<sup>d</sup> the Cochrane Collaboration,<sup>e</sup> and the Agency for Healthcare Research and Quality (AHRQ)<sup>f</sup> have been particularly important, as well as reports like the Institute of Medicine's Finding What Works in Health Care: Standards for Systematic Reviews.<sup>g</sup> Advances in simulation modeling, another methodology fundamental to CEA, and standards for modeling, have also been important; I would mention NIH's CISNET modeling network<sup>h</sup> and the recommendations of the 2012 ISPOR-SMDM (International Society for Pharmacoeconomics-Society for Medical Decision Making) Modeling Good Research Practices Task Force.<sup>20</sup>

## How CEA Results Align with National Choices

I will now turn to examples that illustrate the differences in medical choices between the United States and two other English-speaking countries, Canada and the United Kingdom. Both Canada

<sup>b</sup> See <http://2ndcep.hsrb.ucsd.edu/> for more information.

<sup>c</sup> Bill and Melinda Gates Foundation Methods for Economic Evaluation Project (MEEP), prepared by NICE International; final report submitted to the Foundation in January 2014.

<sup>d</sup> For more information on PRISMA, go to <http://www.prisma-statement.org/>.

<sup>e</sup> For more information on the Cochrane Collaboration, go to <http://www.cochrane.org/Cochrane-reviews>.

<sup>f</sup> See <http://effectivehealthcare.gov/> to access information about products produced by AHRQ's Effective Health Care Program.

<sup>g</sup> Available at <http://www.iom.edu/Reports/2011/Finding-What-Works-in-Health-Care-Standards-for-systematic-Reviews.aspx>.

<sup>h</sup> See <http://cisnet.cancer.gov/about/>.

and the United Kingdom spend much less of their national income on medical care, yet have longer life expectancies at birth and at age 65 than the United States (Table 1). Both countries consider cost-effectiveness in setting medical policies, at the provincial level in Canada and the national level in the United Kingdom, and have increasingly formalized the use of CEA in recent years. The United Kingdom created NICE in 1999 to recommend services to be provided by the National Health Service (NHS). NICE includes an economic evaluation – a CEA – in every appraisal and has become a world leader in cost-effectiveness methods.<sup>i</sup> CEA also plays a role in decisions made by Canada's provincial health plans; more detail will be provided in the section on process, which includes the process in Ontario, home to almost 40 percent of Canadians.

### **Tetanus Boosters**

Consider the recommendations for tetanus boosters in the United States, Canada, and the United Kingdom. The CEA presented earlier showed that a single booster at age 65 is good value, but that providing routine boosters every 10 years is an expensive way to produce better health.

All three countries recommend a series of doses of tetanus toxoid before the age of 6 – five doses in the United Kingdom and six in the United States and Canada – followed by a booster just before or during adolescence.<sup>j</sup> For adults, both the United States and Canada recommend boosters every 10 years. The United Kingdom does not recommend routine adult boosters. The NHS site says: “After the full course of five injections, you should have life-long immunity against tetanus. However, if you or your child has a deep wound, it’s best to get medical advice.”<sup>21</sup> The NHS also recommends that anyone traveling to a country with “limited medical facilities” get a booster first if their last one was more than 10 years ago.

The national recommendations are in line with national spending. The United Kingdom, which spends only 9.3 percent of its national income on medical care, recommends the most limited use of tetanus boosters, not even including one at age 65. Canada, at 11.2 percent, and the United States, at 17.9 percent, recommend routine adult boosters every 10 years.

The tetanus vaccine has been available for 90 years, and these recommendations were probably not influenced by an actual CEA in any country. The CEA mindset, however – how does this intervention contribute to better health – would be easy to apply informally. A few back-of-the-envelope estimates of the number of cases prevented and the cost of repeated boosters would point to the same conclusion. A formal analysis is not always necessary. Long before NICE, the United Kingdom led in applying the CEA mindset to decisions about the National Health Service.<sup>22</sup>

### **Cervical Cancer Screening**

In 1981, Eddy published a CEA that evaluated the cost-effectiveness of screening for cervical cancer at different frequencies.<sup>23</sup> In my 1994 book,<sup>24</sup> I devote an entire chapter to cervical cancer

<sup>i</sup> In support of my earlier point that CEA is not a cost-control mechanism, NICE was created at the same time that the Blair administration, as a matter of policy, increased spending on the NHS to bring health spending's share of national income up to the average for Europe.

<sup>j</sup> Tetanus recommendations, see: United Kingdom: NHS, <http://www.nhs.uk/conditions/vaccinations/pages/vaccination-schedule-age-checklist.aspx>; Canada: <http://www.phac-aspc.gc.ca/im/ptimprog-progimpt/table-1-eng.php> and <http://www.phac-aspc.gc.ca/im/vpd-mev/tetanus-eng.php>; United States: <http://www.cdc.gov/vaccines/vpd-vac/tetanus/fs-parents.html>.

screening and discuss the American Cancer Society's first attempt, in 1980, to reduce the frequency of cervical cancer screening based on Eddy's results. Similar results from a 1990 article are shown in Table 4, updated to 2012 dollars.<sup>25</sup>

**Table 4. Opportunity costs: Cervical cancer screening by screening interval**

Screening intervals compared	Cost per year of life gained (2012 \$)	Life-years per \$1 million
Every 3 years vs. no screening	\$48,618	20.57
Every 2 years vs. every 3	\$1,534,582	0.65
Annually vs. every 2 years	\$3,890,556	0.26

Source: Adapted from Eddy DM, 1990.<sup>25</sup>

No one questions that screening for cervical cancer is effective, but the CEA showed that its cost-effectiveness depends strikingly on screening frequency. In most cases cervical cancer is a slow-moving disease; few new cases are discovered with annual screening, and the cost in health of not catching them immediately is small, while the cost in resources of screening so often is large. As screening grows more frequent, the cost of an additional year of life rises sharply. As Table 4 shows, screening every year instead of every 2 years costs, in 2012 dollars, almost \$4 million for each year of life gained.

In response to Eddy's 1981 study,<sup>23</sup> which was available even earlier, the American Cancer Society (ACS) changed its recommendation for annual screening and recommended screening every 3 years. The reaction, subsequently repeated in response to other recommendations to limit screening, persuaded ACS to go back to its original recommendation despite the CEA results. In 2002, ACS tried again, recommending at least 3 years between screenings for women with negative tests.<sup>k</sup> Yet U.S. physicians continue to conduct more frequent screening.<sup>26,27</sup>

The United Kingdom and Canada, along with other high-income countries that achieve longer life expectancies while spending less than the United States on medical care, have long recommended cervical cancer screening at 3-5 year intervals. The NHS introduced screening in the 1980s: "Women aged between 25 and 49 are invited for testing every 3 years, and women aged between 50 and 64 are invited every 5 years."<sup>28</sup> The Canadian recommendations are to begin routine screening at age 25, screen women 25-69 every 3 years, and stop screening women 70 and older who have had three negative screens in the preceding 10 years.<sup>29</sup> These recommendations are based as much on the benefit/risk considerations as on cost-effectiveness. For example, the Canadian Preventive Services Task Force notes: "...the recommended 3-year interval balances the small incremental potential for benefit from shorter intervals against the greater potential for harm from increased testing and procedures with more frequent screening. Most countries outside North America use 3- or 5-year intervals." A 2004 Commonwealth Fund survey of five countries—which shows that the United

<sup>k</sup> See [http://www.cancersocietyofamerica.org/cervical\\_cancer.html](http://www.cancersocietyofamerica.org/cervical_cancer.html) for current American Cancer Society guidance on cervical cancer screening.



States screens more frequently than Canada, the United Kingdom, Australia, or New Zealand for both cervical and breast cancer—underscores the point.<sup>30</sup> All those countries spend less than the United States to achieve longer life expectancies.

## Cost-Benefit Analysis: Looking for Health Beyond Medical Care

For choices in the medical sector, a comprehensive measure of health like the QALY is sufficient to measure everything, or almost everything, of value that is gained from an alternative. Choices that fall outside the medical sector may involve substantial benefits of other kinds, in addition to better health. Good decisions require that everything of value be considered in making a choice. But how to aggregate the different benefits? Some form of aggregation, of summarizing benefits (and costs), makes it easier to compare alternatives and to give appropriate weight to each benefit. When benefits are not summarized decisionmakers, who are overwhelmed with information, may focus on one or two and lose sight of the rest.

CBA allows the aggregation of health and non-health benefits because it values benefits, as well as costs, in money terms. In the United States, the Office of Management and Budget requires that a CBA be performed for all ‘economically significant’ regulations proposed by Federal agencies.<sup>31</sup>

Under this requirement, many of the U.S. Environmental Protection Agency’s (EPA) regulations, which involve substantial health benefits, are subject to CBA.<sup>32</sup> In 2011, for example, EPA published a CBA of the 1990 Clean Air Act amendments, which compared their costs and benefits to those of the legislation in force when they were enacted, the 1970 Clean Air Act and 1977 amendments.<sup>33</sup> The analysis valued a variety of benefits: reductions in mortality and illness; improvements in visibility at recreational sites and in residential areas; benefits to commercial timber, agricultural crops, and recreational fishing; and reduced materials damage. The report noted that other potential, and even known, benefits had been identified but left unvalued “... many beneficial outcomes involving human health or environmental improvement could not be expressed in terms of economic values because the scientific and economic studies to support such valuations remain inadequate or unavailable.”<sup>33</sup>

Costs (public and private) and benefits were projected to rise over the three decades covered by the analysis, 1992-2020, with benefits consistently much greater than costs: by 2020, benefits were projected to reach almost \$2 trillion, compared with \$65 billion in costs.<sup>33</sup> Mortality benefits made up 90 percent of the monetized benefits. For those uncomfortable with valuing lives and health in money terms, the report included a rough cost-effectiveness ratio: the projected cost per life saved in 2020 was \$280,000. If each premature death avoided means 5 more years of life, on average, that works out to \$56,000 per year of life, or 18 years of life for \$1 million. The calculation ignores, of course, non-health benefits.

Table 5 details the projected health benefits, in natural units, for the two pollutants for which epidemiological evidence is strong and supports projections, fine particles and ozone. For other pollutants, such as carbon monoxide, estimates of the health benefits were not possible, e.g., because their effects could not be distinguished from those of co-occurring pollutants.

**Table 5. Health effects of the 1990 Clean Air Act Amendments, numbers of cases, 2010 and 2020**

Health Effect Reductions (PM2.5 & Ozone Only)	Pollutant(s)	Year 2010	Year 2020
PM2.5 Adult Mortality	PM	160,000	230,000
PM2.5 Infant Mortality	PM	230	280
Ozone Mortality	Ozone	4,300	7,100
Chronic Bronchitis	PM	54,000	75,000
Acute Bronchitis	PM	130,000	180,000
Acute Myocardial Infarction	PM	130,000	200,000
Asthma Exacerbation	PM	1,700,000	2,400,000
Hospital Admissions	PM, Ozone	86,000	135,000
Emergency Room Visits	PM, Ozone	86,000	120,000
Restricted Activity Days	PM, Ozone	84,000,000	110,000,000
School Loss Days	Ozone	3,200,000	5,400,000
Lost Work Days	PM	13,000,000	17,000,000

Source: U.S. Environmental Protection Agency 2011.<sup>33</sup> Exhibit 8. Differences in key health effects outcomes associated with fine particles (PM2.5) and ozone between the *With-CAAA* and *Without-CAAA* scenarios for the 2010 and 2020 study target years (in number of cases avoided, rounded to 2 significant digits).

Note: The table shows the reductions in risk of various air pollution-related health effects achieved by the 1990 Clean Air Act Amendment programs, with each risk change expressed as the equivalent number of incidences avoided across the exposed population.

This CBA confirmed that a choice that had already been made was, and continued to be, beneficial: the benefits exceed the costs by a wide margin. It is more difficult to find evidence to show how CBA contributes earlier in the process, when choices are being considered but have not yet been made, because not all of the process is open to public view. As proponents of CEA and CBA often point out, the framework itself, and the experience of working with that framework, can shape the alternatives considered and the final choice in significant ways, leading participants to uncover new technological options, evidence for new health and non-health effects, better ways to value those effects, and new ideas for institutional arrangements to address a problem, in addition to testing their views of the costs and benefits of each option against careful estimates.<sup>34,35</sup>

Nichols' history<sup>36</sup> of an early CBA of regulations to reduce lead in gasoline shows how CBA can work prospectively to help identify promising alternatives and make decisions. Lead levels in gasoline had been substantially reduced by the early 1980s, in part because other environmental regulations required cars to be outfitted with catalytic converters, which fared better with unleaded gasoline. EPA was under no outside pressure to do more. But evidence suggested substantial benefit from reducing lead in gasoline still further. When a preliminary analysis supported the idea, the

agency proceeded with a full CBA and a regulatory proposal. The new regulation, to reduce lead in gasoline from 1.1 grams per leaded gallon to 0.1 grams, went into effect in 1985.<sup>37</sup>

In Nichols' words the CBA "played a key role in shaping the rule."<sup>36</sup> The CBA showed, for example, that reducing lead to 0.1 grams per leaded gallon would yield substantial benefits at reasonable cost but that a complete ban might cause problems for heavy agricultural machinery; so EPA considered, but did not propose, a ban. (Congress included a ban in the 1990 Clean Air Act Amendments).<sup>38</sup> Although sensitivity analyses indicated that only under very unlikely circumstances might refineries fail to meet the schedule for reducing lead, analysts designed a lead banking program to make the transition still easier: refineries that reduced lead ahead of schedule could save the difference to use later or to sell to other refineries. As a third example, after the analysis began, EPA staff learned of new evidence that linked lead in gasoline to hypertension in adults.

The final CBA considered four very different kinds of benefit: (1) health benefits to children because less lead in gasoline would reduce the number who suffered physical and cognitive problems from elevated blood lead levels; (2) less damage to catalytic converters and thus better control of conventional pollutants; (3) lower expenditures on car maintenance due to less mis-fueling (use of leaded gas in cars designed for unleaded); and (4) fewer deaths and less morbidity related to hypertension.

Valuing benefits in money terms allowed these different benefits to be aggregated and showed their importance relative to each other. The first three categories of benefit – children's health, conventional pollutants, and car maintenance – were projected to be \$1,657 million in 1988, well above the projected additional refining costs of \$532 million (both 1983 dollars). The benefits from reducing hypertension were far larger: an additional \$5.4 billion, bringing total benefits to about \$7 billion.<sup>36</sup> The agency's legal counsel advised, however, that the hypertension benefits could not be used to support the legal case for regulation because the scientific evidence for the lead-hypertension link had not yet been peer reviewed. So the results were presented two ways – with and without the benefits from reducing hypertension. The hypertension benefits served to make the conclusion more robust: benefits exceeded costs.

It may be worth spending a little space to discuss the science behind the valuation of benefits in CBA. The social sciences, as I mentioned earlier, study how people make decisions and the circumstances under which they make the best decisions, those that bring them what they want. Different social sciences have chosen different natural laboratories for this study. Economists' natural laboratory is the market. The theory with which they approach real-world markets is the theory of the competitive market. In competitive markets, well-informed buyers and sellers, none of them large enough to manipulate the market, exchange money for goods; the buyers receive all the benefit of the good, the sellers incur the full costs of producing the good.

When these conditions hold, and only when they hold, market prices represent, at one and the same time, how much people are willing to pay for one more unit of the good and how much it costs to produce one more unit of the good. Buyers' willingness to pay reflects a tradeoff – to obtain this good the buyer had to forego other goods. The buyer had to value it more highly than other goods. It is the tradeoff between this good and other goods that is the fundamental measure of value, with

money as the common medium for measuring tradeoffs; the money price of a good represents the amount of other goods given up. The willingness to give them up signals that the buyer values this good more than the other goods. On the supply side, the cost of producing the good reflects the value of the goods that could not be produced, the opportunity cost of producing this good instead of others. In short, the competitive market system is a system for working through values and allocating resources to their mostly highly valued uses.

In the real world, of course, many markets fall well short of the requirements for competitive markets – certainly most of the markets that make up the medical sector do. So they don't produce the kinds of outcomes that accurately reflect people's valuations of goods and services. The purpose of CBA – the reason it was developed – is to evaluate the pros and cons of choices that arise in poorly functioning markets, or that occur outside of markets altogether, and in tallying those pros and cons, to approximate the results that would come naturally from competitive markets: measures of benefits for each alternative that correctly represent the willingness to pay of those affected, their true valuation; and measures of cost for each alternative that correctly represent the costs of production, their true opportunity costs.

Fifty years ago, economists valued lives and health for purposes of CBA at the present value of future earnings.<sup>39</sup> Several economists, including Drèze, Schelling, and Mishan argued that this was wrong.<sup>44</sup> They reasoned that life-saving should be valued at what the people affected would be willing to pay, the same principle that operates in the competitive market, and not by their discounted future earnings. By the 1980s, the concept “that social decisions should, so far as possible, reflect the interests, preferences and attitudes to risk of those who are likely to be affected by the decisions” was accepted as a better way to think about valuing life-saving.<sup>40</sup>

Since then, the basic principle in CBA has been that benefits should be valued as the people involved value them. Dollar valuations, like QALY weights, come from the people who will experience the benefits or from people like them. The methods used in the two CBAs I have described follow that principle: benefits are valued based on evidence from markets or, if the good is not sold in markets, from related markets, evidence that reveals people's tradeoffs, their valuations. Lives saved, for example, are valued based on the tradeoffs revealed in labor markets, between wages and risk of death or injury on the job.<sup>32</sup> The analysis of lead in gasoline was an early case of the use of this “value of a statistical life.”

The willingness-to-pay principle in CBA has been criticized for its link to people's incomes – people with more money can be “willing” to pay more than people with less money. In actual CBAs, this problem is at least somewhat attenuated by using average willingness to pay. CBA has also been criticized for ignoring the distributional consequences of decisions based on CBA, just as QALYs have been criticized for treating all QALYs as equal. Such criticisms are reasons why the process to which CEA and CBA contribute is important.

## The Process that Includes CEA/CBA

Everyone agrees that CEA and CBA are aids to decisionmaking, not machines that produce decisions all by themselves without human intervention. A CEA or CBA is one element in a larger

decisionmaking process. That process is often spelled out in legislation, agency guidelines, or the opening decisions of committees, and it involves many of the elements we associate with good science and representative democracy.

The process itself is as important as the CEA or CBA. This section sketches some features of the process, or processes, to which CEA and CBA contribute. This is not my area of expertise, so it is not a comprehensive summary; a few examples are provided that point to the importance of process and to some common elements that, in many cases, we simply take for granted will be present.

Nichols' account of the lead in gasoline regulations contains numerous references to the process: the posting of a preliminary regulatory proposal and CBA, with a public comment period; the changes in the analysis and in the regulatory proposal as those involved learned more, sometimes from the public comments; the advice from legal counsel.<sup>36</sup> Similarly, EPA's 2011 summary report on the 1990 Clean Air Act amendments makes frequent references to process.<sup>33</sup> An example from the acknowledgements: "the full integrated report and this summary report were reviewed by the EPA Science Advisory Board's Advisory Council on Clean Air Compliance Analysis ... and its three technical subcommittees." The three technical subcommittees specialized in air quality modeling, health effects, and ecological effects.

In Canada, the Ontario Health Technology Advisory Committee,<sup>1</sup> created in 2003 to advise the Ontario Ministry of Health and Long Term Care about nondrug technologies, has developed a multi-criteria decision framework to guide its deliberations. An article describing the framework states: "Designing a process that weighs scientific evidence appropriately, takes cost and values into consideration, and makes decisions fairly is not straightforward."<sup>41</sup> Only technologies approved by Health Canada, whose duties include safety and efficacy regulation of drugs and health products, are considered. Once the technology comes to Health Quality Ontario, the committee considers four categories of criteria in making its recommendation: (1) overall clinical benefit, (2) consistency with societal and ethical values, (3) value for money, and (4) feasibility of adoption into the health system. CEA, item number 3 in the list, enters through only one of the four categories.

In the United Kingdom, NICE is known for giving CEA a central role in making recommendations to the National Health Service. Yet the overview of the decisionmaking process, the 93-page Guide to the Methods of Technology Appraisal 2013,<sup>18</sup> spends at least as much time on the process of which CEA is a part as on guidelines for the CEA itself. Section 4 (seven pages), "Involvement and Participation," deals with the processes for ensuring that all points of view are represented, including patients, clinicians and manufacturers. Section 6 (10 pages), "The Appraisal of the Evidence and Structured Decision-making," discusses how an appraisal committee should be composed, what evidence it should consider, how it should seek and incorporate public comment, the social and ethical values it is bound to take into account, the need for transparency in its deliberations, for clarity in explaining the reasons for its recommendations, and other conditions. NICE explicitly states that "life-extending treatment at the end of life" may be evaluated differently from the general guidelines for cost-effectiveness, using a weighting of QALYs different from that for other technologies, so the process spells out the general approach and exceptions to that approach.

<sup>1</sup> Now Health Quality Ontario. Go to <http://www.hqontario.ca/> for more information.



Any scientific, empirically based method for evaluating choices requires projections of what will happen as a result of the choice. This is the contribution of CEAs and CBAs. Part of a good process is setting standards for those CEAs/CBAs—i.e., they are used to compare, so they must be comparable. I have mentioned some of the standards in the course of this chapter. Here, I want to point out that standards have been developed by every group that uses these decisionmaking tools. EPA, for example, explains that its Guidelines for Preparing Economic Analyses<sup>42</sup> provide “(3) ... an overarching framework for economic analyses throughout the Agency and across EPA Program Offices; and (4) ensure that important subjects such as uncertainty, timing, and valuation of costs and benefits, are treated consistently in all economic analyses at EPA.” Standards for the analyses that inform decisions are part of defining the decisionmaking process.

The processes aided by CEA/CBA involve what Ostrom calls “social dilemmas.”<sup>3</sup> These are situations in which people need to act collectively to solve problems. Ostrom points out that behavioral experiments show that people act cooperatively much more often than would be predicted by theories based on pursuing individual self-interest. Further, “field research also shows that individuals systematically engage in collective action to provide local public goods or manage common-pool resources without an external authority to offer inducements or impose sanctions.” Whether we are hardwired to cooperate, or have learned to do so, there are many situations in which cooperation leads to better outcomes for everybody, and human beings have the good sense to try to cooperate in those situations. Many of those decisions affect our health.

Ostrom<sup>3</sup> reports two experimental findings that begin to explain how people arrive at cooperative solutions. First, talking face-to-face is important: “simple, cheap talk allows individuals an opportunity to make conditional promises to one another and potentially to build trust that others will reciprocate.” Notice, in this regard, the omnipresence of committees – committees that meet in person – in the decisionmaking processes I have described. Second, people set up structures and rules that encourage cooperation and discourage refusal to cooperate, or, as Ostrom puts it, they “solve second-order social dilemmas that change the structure of the first-order dilemma.” ... “Most robust and long-lasting common-pool regimes involve clear mechanisms for monitoring rule conformance and graduated sanctions for enforcing compliance.” In this regard, notice the effort that goes into developing a process – who is represented on a committee, what evidence the committee is to consider, how the committee’s work is to be reviewed – as well as structures and regulations designed to enforce a decision once it is adopted, which I have not covered in this chapter.

This is a story of people developing new techniques and new institutions to guide choices in social dilemma situations in medical care and public health. Social scientists who work with CEA and CBA are contributing to that process. They might also fruitfully devote some of their scientific attention to the rest of the process. They could ask, “What is this process that is aided by CEA/CBA? How well does it work? How could it be structured to work better?” Some social scientists have been approaching the issue from the other side – the process rather than the CEA/CBA – and conversations among those working on the two sides might be useful. Ostrom<sup>3</sup> has said: “... individuals temporarily caught in a social-dilemma structure are likely to invest resources to innovate and change the structure itself in order to improve joint outcomes.” CEA and CBA are part of changing the structure to improve the outcomes of decisions about health. What more can we do, as social scientists, to help?

## Implications for Practice

Although the United States spends far more of its national income on medical care than any other high-income country, U.S. citizens live shorter lives. If this situation is to change, U.S. decisionmakers in health and medicine need to make more use of the decision practices and supports used by other high-income countries, particularly CEA and CBA, to help direct resources to more productive ways to improve health.

## Implications for Research

To support better health in the United States, more research needs to focus on providing decisionmakers with the information that will help them identify the uses of medical spending that contribute the most to better health. Government agencies and medical professional societies should expand their efforts to consult with decisionmakers on a research agenda, conduct the necessary studies, and publicize the results.

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