Valuing Food Safety and Nutrition

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PART TWO: A Comparison of Valuation Methodologies

9. Valuation by the Cost of Illness Method: The Social Costs of *Escherichia coli* 0157:H7 Foodborne Disease

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Valuation by the Cost of Illness Method: The Social Costs of *Escherichia coli* O157:H7 Foodborne Disease

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> ". . . while we cannot definitely conclude that costs of illness measures produce a lower bound for willingness to pay, the lower bound conclusion seems plausible" (Berger et al. 1987: 977).

Microbial contamination of food is estimated to cause from 6.5 to 33 million human illnesses and 9,000 deaths annually in the United States (Bennett et al. 1987, Garthright et al. 1988). The cost of illness (COI) estimates for U.S. foodborne microbial illnesses range from $4 to $8 billion annually (Garthright et al. 1988, Todd 1989). These estimates of the damages society is paying for current levels of foodborne disease are useful in measuring the benefits of reducing foodborne disease. These benefits can be directly compared with the costs of regulatory programs to determine whether social welfare is maximized with current regulatory policies or whether the benefits exceed the costs of new regulatory policies. Thus, the estimates are an important piece of information for determining pathogen priorities for regulatory interventions.

Escherichia coli O157:H7 is the most recent microbial pathogen of concern—a four state outbreak associated with hamburger consumption commanded much of Secretary of Agriculture's, Mike Espy, time in the first two months of the Clinton Administration. *E. coli* O157:H7 causes a wide range of illness severities from mild cases of acute illness to death (Figure 9.1). Children under 5 are the population group most likely to be infected, although the elderly are also at somewhat greater risk than the average person (Griffin and Tauxe 1991). *E. coli* O157:H7 can also cause chronic kidney disease, hemolytic uremic syndrome (HUS), and is the leading cause of kidney failure in children. The medical costs and lost productivity associated with *E. coli*

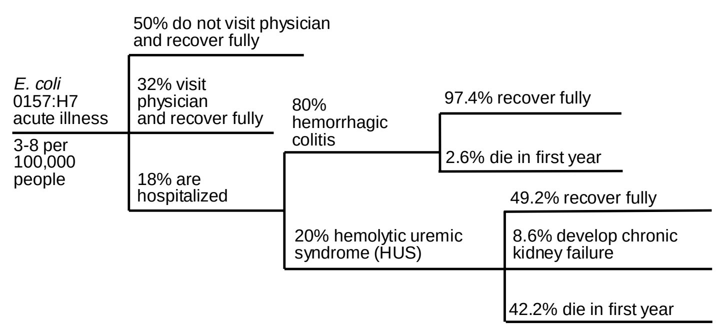

FIGURE 9.1 While 98 Percent Survive an *E. coli* O157:H7 Infection, It Can Cause Severe Outcomes

O157:H7 are estimated at $217-579 million annually using the conservative cost of illness method (COI).

This chapter begins with discussion of the COI methodology and its application. It concludes with a discussion of the major strengths and weaknesses of the COI and willingness to pay (WTP) methods for measuring the value of food safety and discusses how different groups might use COI or WTP estimates.

Cost of Illness Methodology

This chapter contributes to empirical knowledge about the social welfare function and the demand for food safety by using the COI method to estimate the current level of damages society is paying for cases of selected microbial foodborne diseases contracted in 1992, with special emphasis on *E. coli* O157:H7. Foodborne illness redirects societal resources away from preferred choices by increasing expenditures on medical services and by decreasing productivity. Excess medical procedures, physician services, hospital care, and drugs are purchased. Ill persons spend time at home or in the hospital that they would prefer to spend at work, in home production, or in school. Workers may also have reduced long-term productivity because of a foodborne pathogen causing chronic illness. The cost estimates presented here exclude the costs of pain and suffering and loss of leisure time since cost of illness theory has not arrived at reliable measures of these items. (See Table 9.1 for cost categories and the specific assumptions used for each cost category.)

Medical Costs

The cost of physician visits is estimated by dividing per capita annual national expenditures on physician services, $484 in 1990 updated using the physician services CPI to $545 (U.S. Statistical Abstract 1992: Table 138), by the average number of annual visits to physicians in 1989, 5.4 (U.S. Statistical Abstract 1992: Table 162), to arrive at $101 per visit. This number reflects the per visit cost of a physician visit for all reasons, not specifically for foodborne illness, and includes the portion paid by insurance. Those with mild illnesses who do not seek a physician's care may also attempt to self-medicate and incur some out-of-pocket costs; however, we do not have data on such expenses.

The average cost to community hospitals per patient (U.S. Statistical Abstract 1992: Table 170) is used to compute hospitalization costs: in 1990 the hospitalization cost was estimated at $687 per patient; updated to 1992 dollars (using the change in the hospital room CPI) this room rate is $817 per day. Fees for laboratory tests, supplies, medications, and physician visits while hospitalized are assumed to equal the costs of hospitalization (Roberts and Pinner 1990), or $817 per day in 1992, for a total cost of hospitalization estimate of $1,634 per day.

Acute illness procedures, such as hemodialysis and kidney transplant operations, are added onto hospital room and physician charges. Nationwide data bases are used, such as the published Medicare reimbursement rates and per capita expenditures on physicians' services from the Health Care Financing Administration (HCFA), the National Center for Health Statistics' National Hospital Discharge Survey (NHDS), the American Hospital Association's Hospital Statistics, or Blue Cross/Blue Shield charges.

The present value of medical costs for chronic conditions are estimated by determining the time spent receiving a medical service and applying an average cost per service to compute total costs. For example, dialysis costs for those ill with HUS were computed by using the average number of days on dialysis required for HUS patients (12 days) (Martin et al. 1990) and multiplying it by the daily rate of Medicare reimbursement for dialysis ($123) (Eggers 1993). Medicare billing records provide a major source of information on the medical costs of specific diseases. However, such information is specific to the Medicare population and may understate the treatment costs of diseases affecting a

TABLE 9.1 Assumptions Used to Estimate Annual Cost of Illness for Foodborne Disease, 1992

Cost Category and Severity	Costs During Acute Illness	Costs During Chronic Illness
Overview: Incremental costs due to foodborne disease.	Estimates of new cases annually are divided into severity level categories to estimate costs. Acute illness costs are not discounted, except for productivity losses for deaths occurring during the acute illness.	Some survivors develop chronic conditions. All lifetime costs are discounted at 3 percent per year to calculate the 1992 present value.
Medical Costs		
Mild cases (no physician visit)	No medical costs estimated. (Although some may self-medicate.)	Not relevant.
Moderate cases (visited physician)	Physician visit cost calculated by dividing the updated Health Care Financing Administration annual national expenditures on physician services by the National Center for Health Statistics annual physician visits. Laboratory expenses and medications are computed separately.	Not relevant.
Severe cases (hospitalized)	Hospital room cost is the American Hospital Association's average cost/day. An intensive care room is assumed to be double the cost of a regular room. Total fees for physician care, laboratory tests, and medications during hospitalization are assumed to be equal to hospital room costs. Operations/procedures, such as dialysis, are computed separately.	For known chronic conditions associated with the foodborne illness, chronic costs are computed the same as acute costs, except that they are computed for the remaining life of an individual and discounted back to 1992 using a 3 percent discount rate.

(*continues)*

TABLE 9.1 (*continued)*

Cost Category and Severity	Costs During Acute Illness	Costs During Chronic Illness
Productivity Losses	If ill person is a child under age 16, productivity loss is calculated for one parent/caretaker.	For children, the productivity loss is calculated for one parent/caretaker's time estimated for care of chronically ill child until age 16. After the age of 16, the ill individual's productivity loss is estimated.
Mild cases (no physician visit)	Productivity loss uses the BLS average weekly earnings for all nonagricultural workers (pre-tax, no fringe benefits) multiplied by 38 percent to account for fringe benefits, divided by 5 to get a daily rate, and multiplied by the estimated days lost from work.	The average weekly earnings are multiplied by 52 weeks, adjusted by the labor force participation rate for the age of the patient, and multiplied by the percentage of productive capacity lost. Or, an estimate of the proportion of productivity lost because of the disability is multiplied by Landefeld and Seskin's (1982) value of life according to the age of the patient to get the marginal lifetime productivity lost.
Moderate cases (visited physician)	Time away from work was estimated either by assuming the average duration of illness or by using estimates from survey data. The cost/day is estimated by adjusting BLS average weekly earnings as above.	
Severe cases (hospitalized)	Time away from work is assumed to be 3 times the days in the hospital, adjusted for weekends. The cost/day is estimated by adjusting BLS average weekly earnings as above.	

(*continues)*

TABLE 9.1 (*continued*)

Cost Category and Severity	Costs During Acute Illness	Costs During Chronic Illness
Death	The present value of a statistical life lost is computed as the average of male and female values given by Landefeld and Seskin (1982) for each age, updated to 1992 values using the change in average weekly earnings.	The value of a statistical life lost to chronic illness is Landefeld and Seskin's (1982) value for the age of the person in the year he/she dies, discounted back to 1992.
Other Costs: Travel, education, nursing home, lost leisure, pain, and suffering	Transportation costs to medical care and other costs are not estimated.	Not estimated.

non-Medicare population.[2] Information on procedure costs is frequently difficult to find and often requires estimates by experts, which may vary considerably.

Productivity Losses

Productivity losses because workers stayed home with foodborne illness are approximated by the Average Weekly Earnings for nonsupervisory production workers in private nonagricultural jobs published by the Bureau of Labor Statistics (BLS) in the U.S. Department of Labor, plus estimated fringe benefits. Pre-tax wages and fringe benefits are used because they approximate the worker's full marginal product. The number of hours spent visiting a physician or days spent at the hospital are added to days spent at home for recuperation from an illness to arrive at the amount of time to be valued. We assume that for every day spent in the hospital, twice as many days will be spent at home recuperating. Time spent by parents caring for children, as well as paid caretakers, is included in the productivity loss estimates. BLS reports that average weekly earnings in 1992 were $364.30 (U.S. BLS 1993).

Fringe benefits of 38 percent cover health plans, vacations, and retirement benefits (U.S. Statistical Abstract, Table 660) to bring the daily wage up to $100.55, or an hourly wage of $12.57. Assuming a labor force participation rate of 84 percent for a typical work force aged 25-44 years (U.S. Statistical Abstract, Table 609), the average daily loss of productivity is $100.55 x .84, or $84. By estimating the amount of time lost from regular activities and multiplying it by the rate of weekly earnings, a value for the time lost is derived. We assume that the value of an hour of time is the same for everyone, regardless of gender or race.

For those who die during either the acute illness or with chronic kidney failure (HUS), the present value of the reduced stream of earnings is calculated. Landefeld and Seskin's (1982) human capital/willingness to pay method is used and updated to 1992 prices. It generates the present value of expected lifetime after-tax income and housekeeping services at a 3 percent discount rate, includes an annual 1 percent increase in labor productivity, and has a risk aversion premium that increases the estimates by 60 percent. We averaged Landefeld and Seskin's estimates of these values across gender to get a single figure within each age group. The Landefeld and Seskin formula is:

(1) $$\text{Value of a statistical life} = \left[\sum_{t=0}^{T} Y_t / (1 + r)^t \right] \alpha$$

where T = remaining lifetime, t = a particular year, Y_t = after-tax income including labor and nonlabor income, r = household's opportunity cost of investing in risk-reducing activities, and α = risk aversion factor.

E. coli O157:H7 Disease Severity, Cases, and Costs

Escherichia coli O157:H7, one of many *E. coli* strains, causes diarrhea (often bloody), severe abdominal cramps, and sometimes fever and vomiting, along with potential neurological complications, kidney failure, or death. Some cases require hospitalization, but milder cases are more frequent (Figure 9.1). On average, the acute illness ends 6 to 8 days after onset (Griffin and Tauxe 1991). Hospitalized cases are most likely to have hemorrraghic colitis with bloody diarrhea and fully recover. More severe cases are hospitalized with HUS and about half the cases fully recover, slightly less than half die during the initial illness, and a few have chronic kidney failure for the remainder of their life. Half of the foodborne disease outbreaks have been associated with beef (often hamburger), but unpasteurized apple cider, unpasteurized milk, water, raw potatoes, turkey roll, and mayonnaise have also caused outbreaks (Griffin and Tauxe 1991). Some of these other foods may have been cross-contaminated by beef or cattle.

Centers for Disease Control and Prevention (CDC) researchers' 1991 survey of the literature found annual incidences of *E. coli* O157:H7 between 3 and 8 cases per 100,000 persons (Table 9.2) (Griffin and Tauxe 1991). With a U.S. population of 255.6 million in 1992, the number of cases would be between 7,668 and 20,448 annually. About 18 percent of all cases are hospitalized (1,381 to 3,681 cases), about 20 percent of the hospitalized cases develop HUS (276 to 736 cases), and about 1.9 percent of all cases die (146 to 389 people). The remaining 82 percent of nonhospitalized cases either see a physician (but are not hospitalized) or are ill but do not visit a physician. We assume that 50

TABLE 9.2 Annual Incidence of *Escherichia coli* 0157:H7 and Severity of Illness, U.S.

		Number of Cases	
Severity of Illness	Percent of Cases (%)	Low (#)	High (#)
No physician visit	50.00	3,834	10,224
Visited physician	32.00	2,454	6,543
Hospitalized			
Hemorrhagic colitis[a]			
Recovery	14.02	1,075	2,867
Acute illness death	0.38	29	78
Subtotal		1,104	2,945
HUS[b]			
Recovery	1.77	136	362
Chronic illness	0.31	24	63
Acute illness death[c]	1.52	116	311
Subtotal	100.00	276	736
Total U.S. incidence/year[d]	3-8/100,000	7,668	20,448

[a]Assumes no chronic conditions resulted from hemorrhagic colitis.
[b]Assumes both chronic and acute conditions resulted from HUS.
[c]During the chronic phase, using the low estimate of 24 chronic cases, 17 die, and using the high estimate of 63 chronic cases, 42 die before the average life expectancy of 77 years.
[d]U.S. residential population in 1992 = 255,600,000.

percent of the cases do not seek any medical attention (3,834 to 10,224 cases) and that the remainder, 32 percent of total cases, do visit a physician (2,454 to 6,543 cases). This is a higher rate of physician visits than for salmonellosis, but *E. coli* O157:H7's usually causes bloody diarrhea that is likely to scare people into seeing a physician.

To simplify the analysis, all cases are assumed to be four years of age at death or at the onset of the illness. This was the average age in the largest U.S. study of children with HUS where Martin et al. (1990) studied 117 children under age 18 with HUS in Minnesota. Griffin and Tauxe (1991) also cite several studies identifying age less than 5 years as a risk factor for *E. coli* O157:H7 disease. Of those 276-736 cases that contract HUS, about 8.5 percent (Martin et al. 1990), or 24 to 63 cases, are estimated to remain chronically ill. HUS patients are placed on hemodialysis during the acute phase of their illness. Since these cases occur in children, it is assumed that they will be transferred from hemodialysis to Continuous Cyclic Peritoneal Dialysis and then receive kidney transplants as soon as possible. Using the Health Care Financing Administration's data on the rates of kidney transplantation, survival after the operation, and survival on dialysis for pediatric patients, life tables for the 24 to 63 cases were estimated (Eggers, personal communication).

Acute Illness Medical Costs

For estimating costs, cases are divided into 5 disease severity categories: (1) mild cases with no physician visited, (2) cases who visited a physician, (3) cases hospitalized with hemorrhagic colitis, (4) cases hospitalized with HUS, and (5) cases that end in death.

No Physician Visited. Mild disease is assumed to include abdominal discomfort or diarrhea. These cases do not visit a physician and we assume they do not purchase over-the-counter medications. For those 3,834 to 10,224 persons with a mild illness who do not visit a physician, no medical costs are computed.

Physician Visit Only. These cases include cases of moderate diarrhea, usually bloody, lasting several days. We estimate these 2,454 to 6,543 persons visit a physician once or twice and have 1 or 2 laboratory tests. Not all cases are prescribed medications and these are not included in the estimated costs. As explained earlier (Table 9.1), a physician visit is estimated to cost $101 per visit and laboratory tests to cost $50 per test, or a total of $0.4 million to $2.0 million annually (Table 9.3).

Hospitalized for Hemorrhagic Colitis. We estimate that eighty percent of hospitalizations for *E. coli* O157:H7 are for hemorrhagic colitis, typified by bloody diarrhea and severe abdominal cramps. The average length of hospitalization is 6.5 days with a range of 5 to 8 days (Steahr 1993). For the

TABLE 9.3 Medical Costs of Acute Illness from *Escherichia coli* 0157:H7 by Severity Category, 1992 Dollars, Typical Year

Severity Category	Base Rate	Frequency/ Case	Rate/ Case	Cases Low	Cases High	Total Costs Low	Total Costs High
	($)	(#)	($)	(#)	(#)	(million $)	
No physician visit	0	0	0	3,834	10,224	0	0
Visited physician							
Physician visits[a]	$101/visit	1-2	101-202	N/A	N/A	N/A	N/A
Laboratory tests	$50/case	1-2	50-100	N/A	N/A	N/A	N/A
Costs per case	N/A	N/A	151-302	2,454	6,543	0.4	2.0
Hospitalized[b]							
Hemorrhagic colitis							
Hospital room[c]	817/day	6.5	5,313	N/A	N/A	N/A	N/A
Physician fees, lab tests, etc.[d]	817/day	6.5	5,313	N/A	N/A	N/A	N/A
Costs per case	N/A	N/A	10,627	1,104	2,945	11.7	31.3
HUS[e]							
Hospital rooms[f]	1,090/day	15	16,349	276	736	4.5	12.0
Physician fees, lab tests, etc.[d]	1,090/day	15	16,349	276	736	4.5	12.0
Dialysis and medication[g]	123/day	12	1,478	130	346	0.2	0.5
Costs per case	N/A	N/A	34,176	N/A	N/A	9.2	24.5
Total						21.3	57.8

(continues)

TABLE 9.3 (*continued*)

[a]U.S. Statistical Abstract, 1990 per capita national expenditures on physicians services (Table 138), divided by per capita number of physician visits (Table 162), updated to 1992 using the CPI for physicians services.

[b]Includes those who survive and those who die during the acute illness.

[c]Costs of regular hospital room in 1990, updated to 1992 using the CPI for hospital rooms.

[d]Assumes physician fees, lab tests, etc. are comparable to the hospital room charge.

[e]Hospital costs include the medical costs of those who died, but exclude cost of neurological procedures and gastrointestinal procedures such as laparotomy that occurred in 7 percent of cases.

[f]Assumes regular hospital room 2/3 time, intensive care 1/3 time.

[g]Daily rate of medicare reimbursements for dialysis, updated to 1992 dollars using the CPI for medical care. Deaths are included in hospitalized cases.

estimated 1,104 to 2,945 cases with hemorrhagic colitis who fully recover, total costs are estimated from $11.7 to $31.3 million annually (Table 9.3).

Hospitalized for HUS. Twenty percent[3] of hospitalized *E. coli* O157:H7 cases are assumed to develop HUS, a severe disease characterized by kidney failure and neurological impairment. Half of the cases recover fully, many die, but a few develop chronic kidney failure, requiring lifelong dialysis or a kidney transplant. Neurological complications such as seizures, central nervous system deterioration, blindness, or partial paralysis may also result (Merck 1992). The study of 117 HUS cases in Minnesota found that the average hospital stay for HUS was 15 days, the average duration of dialysis in the hospital was 12 days, 8.5 percent of cases developed chronic kidney failure, and 15 percent developed neurological complications (Martin et al. 1990).

We estimated costs for kidney related disease, but did not estimate costs for the neurological complications or intestinal operations (laparotomies or colostomies) which often occur. Five of the 15 days in the hospital would be intensive-care days at double the normal hospital room charge and the physician fees, laboratory tests, and other charges during hospitalization would be the same as the hospital fee. We used Martin et al.'s (1990) finding that 47 percent of HUS cases required dialysis for an average of 12 days. The annual Medicare reimbursement rate for kidney dialysis for children ($44,958 updated to 1992 dollars) was used to determine a daily rate of $123/day (HCFA 1992). The acute illness medical costs for those hospitalized HUS cases is estimated to range from $9.2 million to $24.5 million annually (Table 9.3).

Deaths. We assume that deaths during acute illness occur among those hospitalized for hemorrhagic colitis (20 percent of deaths) or for HUS (80 percent of deaths).[4] The acute illness medical costs associated with these cases are included in the hospitalization categories.

Summary. Acute illness medical costs for the various disease severity categories are estimated to total between $21.3 and $57.8 million annually.

Chronic Illness Medical Costs for HUS Cases

Once chronic kidney failure occurs, the 4-year old patient either continues hemodialysis at the hospital on an outpatient basis, receives a transplant, or switches to peritoneal dialysis. During hemodialysis, the blood is removed from the patient, sent through a machine that balances its water and mineral content and removes toxic waste products, and then is returned to the patient. While the child has the option to continue hemodialysis at the hospital, most receive a kidney transplant or eventually switch to some form of peritoneal dialysis (performed within the abdominal cavity) since it can be carried on your person while going about normal activities. If there is no medical reason for choosing one form over another, the decision is left up to the parents. Some patients with skin infections or perforations in their peritoneum (i.e., from an operation or other medical condition) have no choice but to continue hemodialysis. Health Care Financing Administration (HCFA) statistics for pediatric end stage renal disease (ESRD) patients show that by the end of year one, 24 percent were undergoing hemodialysis in a facility, 29 percent were undergoing peritoneal dialysis at home, and 47 percent received a kidney transplant (HCFA 1992).

Since the costs of in-facility hemodialysis are reimbursed at the same rate as that of at-home peritoneal dialysis, the costs for pediatric dialysis patients reflect the same costs for both types of dialysis ($44,958 annually) (HCFA 1992). Assuming that the onset of illness occurs halfway through the initial year and that no chronic patients receive a transplant during the acute phase (Eggers personal communication), chronic patients require 6 months of dialysis (minus 12 days that were accounted for in the acute phase), for a total of $21,001/case, in the initial year.

Survival data on the Medicare ESRD program population were used to determine HUS dialysis and transplant patient survival (HCFA 1992). Data describing the percentage of renal disease patients receiving a transplant in the years following initial illness were used to determine those receiving transplants in a specific year. Costs of a kidney transplant were obtained from Medicare reimbursement data, updated to 1992 dollars ($104,625) (HCFA 1992). Survivability after a transplant depends on the type of kidney received, with higher survival rates for transplant recipients of a living related donor's kidney versus a kidney from a cadaver. Those surviving transplants require drug therapy for the remainder of their lives costing $4,000/year (Eggers 1993).

Summary. All lifetime medical costs were discounted at a rate of 3 percent and total $7.5 to $19.1 million dollars for 24 to 63 cases of chronic kidney failure caused by *E. coli* O157:H7 (Table 9.3).

Acute Illness Productivity Losses

No Physician Visit. An estimated 3,834 to 10,224 children have a mild illness and do not visit a physician. Griffin and Tauxe estimate that the average *E. coli* O157:H7 diarrheal illness lasts from 6 to 8 days and we assume that these mild cases experience perhaps 4 days of illness. We assume that a parent or caretaker stayed home to take care of the child and missed at least 2 days of work. The average age of the parent or caretaker was assumed to be between 25 to 44 years of age. Evaluated at the average private sector wage rate of $84 per day, this productivity loss totals $0.6 to $1.7 million annually (Table 9.4).

Physician Visit Only. For those 2,454 to 6,543 children with a moderate illness who visit a physician but are not hospitalized, we assume 4 work days would be missed by a parent or caretaker for this illness. Evaluated at the average private sector wage rate of $84 per day, the productivity loss totals between $0.8 and $2.2 million annually (Table 9.4).

Hemorrhagic Colitis Hospitalizations. We assumed that time spent at home recovering from the illness was twice as long as the hospitalization for a total of 19.5 days of illness (13 days at home, 6.5 in the hospital). A parent is assumed to be with the child in the hospital and stay home with the child until he or she is well. Adjusting for weekends, the average time lost from work would be 14 days evaluated at the average wage. For the estimated 1,104 to 2,945 cases of hemorrhagic colitis, total productivity losses range from $1.3 to $3.5 million (Table 9.4).

Hospitalized Cases Developing HUS. Productivity losses were estimated in a parallel fashion to those hospitalized for hemorrhagic colitis where recuperation at home is estimated to be twice the time spent in the hospital (30 days at home, 15 days in the hospital). Adjusting for weekends, lost workdays by the parents caring for the children are estimated at 32 days/case. The total acute illness productivity losses for cases developing HUS are estimated to range from $0.7 to $2.0 million (Table 9.4).

Deaths. Deaths are estimated to occur in 1.9 percent of all acute illnesses caused by *E. coli* O157:H7 (Griffin and Tauxe 1991), or 146 to 389 persons are estimated to die from this disease each year. The present value of each statistical death is valued at approximately $1.2 million in 1992 dollars, an average of the values given for male and female children 4 years old using Landefeld and Seskin's (1982) formula (see equation 1). The total productivity loss associated with deaths is estimated to range from $171.7 to $457.8 million annually (Table 9.4).

Summary. Acute illness productivity losses for the various disease severity categories are estimated to total between $175.1 and $467.2 million annually.

TABLE 9.4 Productivity Loss During Acute Illness from *Escherichia coli* 0157:H7 by Severity Category, 1992 Dollars, New Cases in Typical Year

Severity Category	Base Rate	Work Days Missed	Rate/ Case	Cases		Total Costs	
				Low	High	Low	High
	($)	(#)	($)	(#)	(#)	(million $)	
No physician visit[a]	84	2	169	3,834	10,224	0.6	1.7
Visited physician[a]	84	4	338	2,454	6,543	0.8	2.2
Hospitalized[b]							
Hemorrhagic colitis	84	14	1,176	1,104	2,945	1.3	3.5
HUS	84	32	2,715	276	736	0.7	2.0
Death during acute illness[c]	1,178,280	all	1,178,280	146	389	171.7	457.8
Total						175.1	467.2

[a]Average duration of illness 6-8 days; (Griffin and Tauxe 1991) assume miss work half that time—2 days for mild cases with no physician visit and 4 days for moderate cases with physician visit. Average weekly earnings for all private, nonagricultural jobs divided by 5 days and adjusted to 1992 prices.

[b]Assumes work missed for 3 times the number of days hospitalized adjusted for weekends by multiplying by 5/7.

[c]Landefeld and Seskin's (1982) adjusted willingness to pay/human capital estimate for 4 year olds, updated to 1992 prices using the change in average weekly earnings (U.S. BLS).

Chronic Illness Productivity Losses for HUS Cases

The annual productivity loss due to chronic HUS illness is the sum of the value of those who died prematurely and the survivors' lost productivity while seeking medical treatment (until the age of 16, the parents or caretakers' time is valued for transporting the child to the medical treatment).

Chronic HUS Illness Deaths. The average lifespan in the United States today is 77 years. However, medicare data indicate that for the 24 to 63 cases with chronic kidney failure, 17 to 42 will die prematurely of complications during dialysis or a kidney transplant operation (in fact, 7 to 16 of these children will die before the age of 16) (HCFA 1992). The present value of a statistical life is estimated using the Landefeld and Seskin (1982) formula in equation 1. The present value of the productivity loss for the 17 to 42 premature deaths for chronic HUS is estimated at $11.1 to $30.3 million (Table 9.5).

Productivity Loss for HUS Survivors. A caretaker or parent is assumed to spend 18 hours out of a 40 hour workweek with their child's hemodialysis treatment as a hospital outpatient, or a loss of 45 percent of work time during the initial year of illness.[5] In the second year, all children who did not yet receive a transplant are assumed to have switched to peritoneal dialysis, resulting in a 1 percent decline in productivity until the child is age 16 (conversation with Mary O'Shay, nurse in the pediatric ESRD unit in a hospital in Buffalo, New York).[6] Assuming the parent was in the 25 to 29 year old age group when the child was born (the modal age group for first birth—U.S. Statistical Abstract 1992: Table 82), an average age of 31 is assumed when the child is age 4. The value of annual productivity lost is computed as the 45 percent (first year) and 1 percent (subsequent years) productivity loss times BLS's average weekly earnings times 52 for a 31 year old in year 1 (for a 32 year old in year 2, and so on) multiplied by BLS's labor force participation rate by age group until year 12 when the child is 16, and further multiplied by 138 percent to add in fringe benefits. This reduced stream of earnings is converted into present values.

At age 16 and after, productivity losses are computed by adjusting the patient's annual earnings by age. Transplant recipients 16 to 40 years of age have a 23 percent productivity loss from what they would have earned without any illness, 40-64 year olds a 39 percent loss, and 65 plus a 13 percent loss (Garner 1984). Dialysis patients 16 to 40 encounter a 37 percent loss, 40-64 have a 46 percent loss, and 65 plus a 5 percent loss. At and after time period 12, when the patients are age 16 and over, 88 percent of all survivors have received transplants, while 12 percent remain on dialysis. The disability loss per year is computed as the appropriate percentage productivity loss times the average weekly earnings times 52 multiplied by the labor force participation rate by age group. Over an average lifespan of 77 years, productivity lost, discounted at 3 percent annually, ranges from $1.7 to $4.3 million (Table 9.5).

Summary. The total productivity loss due to chronic illness deaths and lost productive output ranges from $12.8 to $34.6 million annually.

TABLE 9.5 Summary of Costs for Disease Caused by *Escherichia coli* 0157:H7, 1992

Cost Category	Estimated Cost: Low	Estimated Cost: High
	(million $)	
Medical Costs		
Acute illness medical costs[a]		
Mild case/no physician visit	0.0	0.0
Moderate case/physician visit	0.4	2.0
Hospitalized with hemorrhagic colitis	11.7	31.3
Hospitalized with HUS	9.2	24.5
Subtotal	21.3	57.8
Chronic illness medical costs		
Chronic HUS cases (present value)	7.5	19.1
Total medical costs	28.8	76.9
Productivity Losses		
Acute illness productivity losses		
Mild case/no physician visit	0.6	1.7
Moderate case/visited physician	0.8	2.2
Hospitalized with hemorrhagic colitis	1.3	3.5
Hospitalized with HUS	0.7	2.0
Deaths (present value)	171.7	457.8
Subtotal	175.1	467.2
Chronic illness productivity losses		
Chronic HUS survivors-present value	1.7	4.3
Chronic HUS subsequent deaths-present value	11.1	30.3
Subtotal	12.8	34.6
Total productivity losses	187.9	501.8
TOTAL COSTS	217	579

[a] Medical costs for deaths during the acute illness are included in the hospitalization categories.

Discussion and Policy Implications

Annual costs for *E. coli* O157:H7 disease are estimated to total $217 to $579 million a year, using the COI method (Table 9.5). Medical costs are only 13 percent of total estimated costs—10 percent during the acute illness and 3 percent for chronic kidney failure (HUS). Productivity losses account for 87 percent of estimated costs—79 percent for persons who die during the acute phase of the illness, 2 percent for persons who survive the acute illness, 5 percent for persons who die during the chronic illness, and 1 percent for survivors with reduced productivity because of chronic kidney failure (HUS).

This analysis excludes the following costs and consequently underestimates the social damages:

- Some HUS cases have more than one transplant operation but only one was included in the costs. A few HUS cases have multiple complications, including intestinal surgery such as colostomy, cardiac involvement, respiratory complications, neurological damage, pancreatic destruction, or blindness. One mother wrote that her surviving child's medical bills during his intensive care were $300,000 (Heersink 1994).
- Pain and suffering during acute and chronic illness as well as the loss of a child.
- Lost leisure time for the patient and her or his family.
- Impact on the demand for food products (e.g., hamburgers), lost business for firms, and lawsuits.
- The cost of self-protective behaviors undertaken by industry and consumers.
- Resources spent by federal, state, and local governments investigating outbreaks.

Including these cost components would increase the cost estimates. In July 1994 the American Gasteroentological Association held a consensus conference on *E. coli* O157:H7 and some of these omitted medical outcomes may be clarified and case estimates for disease severity may be altered.

Productivity losses for deaths dominated the cost estimates. However, if the discount rate is raised from 3 percent to OMB's preferred 7 percent (circular 94A) the value of a statistical life estimates would drop considerably since those most likely to become ill are 4 year olds who are far from their peak earning years.[7] Offsetting this, however, are considerations that protecting children from foodborne risks may be more highly valued by society than protecting adults (National Academy of Sciences 1993).

Fisher et al.'s (1989) survey of the literature on premium wages for high risk jobs concluded that the studies were reasonably consistent. They concluded that the willingness to accept lower pay to reduce job risk indicated a value of a statistical life ranged from $1.6 million to $8.5 million (1986 dollars). These values are based on a generic value of life for the working population. Updated to 1992 dollars using the change in BLS's Average Weekly Earnings, the range becomes $1.9 million to $10.2 million for each statistical life. Substituting these estimates for the previous estimates of *E. coli* deaths slightly increases the low estimate from $217 million to $322 million annually, but dramatically increases the high estimate from $579 million to over $4 billion annually.

Data Implications. *E. coli* O157:H7 was unknown as a human pathogen 20 years ago. We can expect that advances in rapid testing such as creating tests for more pathogens, increasing test rapidity, and decreasing testing costs, as well as advances in the science of epidemiology, will lead to discovery of other foodborne pathogens. One wonders how often foodborne disease outbreaks go unnoticed. Only 91,678 cases of foodborne disease were discovered by CDC in the years 1983-1987 (Bean et al. 1990), although other CDC researchers (Bennett et al. 1987) estimate that 6.5 million foodborne disease cases occur annually; or, only 0.28 percent of estimated cases were reported in this 5-year period.

The January 1993 *E. coli* outbreak in the Northwest demonstrates the difficulty of identifying the incidence of foodborne disease and the need for new data collection systems. Persons eating at 95 different restaurants became ill and there were 500 culture confirmed cases and 4 deaths in four states. The Centers for Disease Control and Prevention reported: "Despite the magnitude of this outbreak, the problem may not have been recognized in three states if the epidemiological link had not been established in Washington" state (MMWR 1993).

Spending to improve estimates of foodborne illnesses and deaths appears to be cost-effective, considering COI estimates presented here and the inspection budgets for the regulatory agencies. Current inspection program costs are $1 billion annually (U.S. GAO 1991), less than the estimated foodborne disease costs from microbial pathogens. While it may cost $8 to $24 million/year to build an adequate foodborne disease surveillance data base to identify new pathogens and estimate annual foodborne disease incidence rates, this is less than 5 percent of current inspection budgets. Roberts and Smallwood (1991) have identified several types of data collection that would improve estimates of human foodborne illnesses.

Some new data collection efforts are underway: USDA's Food Safety and Inspection Service is starting to collect baseline data on the pathogens in slaughter animals; USDA's Animal and Plant Health Inspection Service is expanding its animal surveys to include human pathogens; CDC has initiated a pilot multi-center diarrheal diseases surveillance study; and Thomas Steahr, University of Connecticut, has started analysis of the National Hospital Discharge Survey by International Classification of Disease codes related to foodborne pathogens (see Chapter 17 in this book). What is needed now is integration and analysis of data from these various data bases to paint a more complete picture of the magnitude and severity of human foodborne illness.

Priority Setting. Medical costs and productivity losses have been estimated for selected foodborne bacterial and parasitic pathogens (Table 9.6). *E. coli* O157:H7 is the fourth most costly at $200-600 million annually. The most costly pathogen is a parasite, *Toxoplasma gondii*, that infects fetuses during pregnancy if the mother is exposed. These costs are estimated at $2.6 billion

TABLE 9.6 Medical Costs and Productivity Losses Estimated for Selected Foodborne Pathogens, 1992

Foodborne Pathogen[a]	Estimated Cases (#)	Foodborne Deaths (#)	Estimated Total Costs (million $)
Bacteria:			
Salmonella	1,920,000	960-1,920	1,188-1,588
Campylobacter jejuni or *coli*	2,100,000	120-360	907-1,016
Escherichia coli O157:H7	7,668-20,448	146-389	217-579
Listeria monocytogenes	1,526-1,581[b]	378-433	209-233
Parasites:			
Toxoplasma gondii	2,090	42	2,628[c]
Trichinella spiralis	131	0	0.8
Taenia saginata	894	0	0.2
Taenia solium	210	0	0.1[d]
TOTAL			5,000-6,000

Source: Roberts 1993.

[a]Analysis assumes 100 percent of human illnesses are foodborne for *Campylobacter*, *Escherichia coli*, *Trichinella*, and the *Taenias* and assumes 96 percent of *Salmonella* cases, 85 percent of *Listeria* cases, and 50 percent of *Toxoplasma* cases are foodborne.

[b]These case estimates may be high.

[c]Productivity losses are high for survivors who develop mental retardation or blindness as a result of toxoplasmosis. These costs exclude toxoplasmic encephalitis infections in 2,250 to 10,200 AIDS patients annually, which are a significant cause of premature death (50 percent of cases may also have a foodborne origin).

[d]Estimates do not include costs for cystericercosis which may have an indirect foodborne transmission.

annually. *Salmonella* is next with costs of $1.2-1.6 billion annually, followed by *Campylobacter* with costs of around $1 billion annually. This list of pathogens, however, is incomplete (Bennett et al. 1987).

Better identification of the pathogens that are the most costly would pinpoint which should be targeted for benefit/cost analyses for control on the farm, during processing, or during marketing. Better identification of who is at high-risk of foodborne disease would enable regulatory programs to be tailored to these high-risk groups. Better identification of high-risk foods would also inform consumers, who can be expected to alter their food handling and food consumption practices to maximize their utility.

Theoretical Considerations of Valuation

Economists cannot assess the value of microbial food safety directly by observing prices in the marketplace since pathogens are too small to be seen without a microscope. Food purchasers are not able to determine whether foods are contaminated with pathogens before purchase, estimate the likelihood of illness from handling raw foods or ingesting those pathogens, or estimate the likely distribution of possible foodborne disease severities. This lack of information means purchasers at every point in the food production and marketing chain buy an uncertain and unknown amount of foodborne disease risk along with the other product characteristics. As a result of imperfect information, consumer choice is hampered; too little safety is produced in the marketplace (Viscusi 1989); and the optimum mix of industry-provided food safety, consumer self-protection, and government protection is unknown and uncertain.

Instead of directly assessing willingness to pay by observing behavior in the marketplace, economists have developed methods to measure "willingness to pay": (1) contingent valuation where people are asked what they would be willing to pay for safety (contingent upon the scenario presented), (2) experimental laboratory simulation of a food safety market, (3) hedonic method attempting to separate food safety from other product characteristics, and (4) conjoint analysis used by marketing firms to evaluate potential attributes of new products. Two variations on the willingness to pay technique look at willingness to spend more time doing something (e.g., preparing food or searching for a food) to avoid foodborne illness and willingness to buy a product at all—a time honored way of avoiding "unsafe" foods is to not purchase them.

The COI method assesses the damages imposed upon society by the current level of foodborne illness and is one measure of the value of food safety, namely society's resources currently expended on medical costs, productivity losses, and other costs of foodborne illness. Whether society would prefer to pay more or less than these damages in exchange for reducing foodborne disease risks is uncertain, although two types of evidence suggest that the COI is less than WTP for reducing foodborne disease risks. First, delegation of food inspection to local, then state and federal authorities began early showing demand for collective action to reduce foodborne disease (U.S. federal meat inspection began in 1890/1891 for exported pork bellies and 1906 for domestically consumed meat). Concern about the 1993 deaths and illnesses from *E. coli* O157:H7 associated with hamburgers has been high enough that the parents of the ill children have formed a lobbying group, S.T.O.P. (Safe Tables Our Priority), to increase the level of food safety. The second line of inquiry is theoretical and several authors suggest that the COI method is a lower bound of WTP estimates (Quiggin 1992, Harrington and Portney 1987). These models examine both the individual's self-protection actions and the demand for collective action to reduce risks. Some preliminary WTP estimates for safer food will be discussed later in this chapter.

Comprehensive models of society's optimal level of food safety are being developed (see Eom's model in Chapter 2). Environmental economists have contributed much of the theoretical and empirical work on modeling and estimating the value of risk reduction (Mitchell and Carson 1989, Cropper and Oates 1992). When complete, a comprehensive theory that evaluates social preferences for food safety will encompass:

(1) Preferences for collective action as well as preferences for self protection by industry and consumers, including the cost of choices avoided (for consumers the costs of reducing consumption of tasty, high-risk foods and for firms the costs of not entering high-risk food producing/processing/retailing operations). Consumer demand models valuing product characteristics (Deaton and Muellbauer 1980) have not yet been applied to microbial food safety. Household production models where goods and health are jointly produced (Choi and Jensen 1991, Cropper and Oates 1992, Harrington and Portney 1987) sometimes focus on just morbidity or just mortality, but Berger et al. (1987), Shogren and Crocker (1991), and Quiggin (1992) include both in their models.

(2) Determination of the optimal level of food safety and the demand for governmental intervention to administer and enforce the "socially optimum" level of food safety (which implies knowledge about the costs of alternative methods of preventing foodborne disease by governmental intervention at any stage along the food chain from the farm to the table).

(3) The high costs of all participants in the marketplace and regulatory arena to keep informed of the latest scientific developments (e.g., epidemiology and rapid laboratory tests for microbes) linking new diseases with food, identifying individuals at high-risk for foodborne disease, identifying high-risk food consumption practices, and

identifying high-risk food production, marketing, handling, and preparation practices.

(4) The benefits to society of reduced human illness costs (reduction in medical and productivity losses) at the current level of food safety for microbial contaminants.

(5) The willingness of high-risk and risk-averse individuals to pay for safer food as well as risk neutral consumers. (High-risk consumers include young children, the elderly, AIDS patients, diabetics, cancer patients, those with organ transplants, and persons with liver or kidney problems, high-iron levels in their blood, low stomach acidity, or genetic predisposition). Persons preferring high-risk food consumption practices, such as rare hamburgers or lightly cooked eggs, may also be willing to pay a premium for safer products (Williams and Brown 1991).

(6) Altruism and the willingness of society to pay for the safety of others. Magat and Viscusi found that altruism is "of sufficient consequence to emerge from the regulatory analysis footnotes and become an integral part of such policy analyses" (1992: 84) and concluded that there is no fixed relationship between private valuations and altruism.

These theoretical considerations need to be formally specified in a model in order to provide a structure for asking and interpreting WTP questions. *Until the theory is fully developed, we believe that the COI is the superior method for evaluating societal preferences for food safety. The COI, or damage function, approach does reflect current resources society expends for the actual risks and the opportunity cost of these resources, their market price, is measured by the COI methodology.*

Advantages and Disadvantages of COI and WTP Methods

The COI method is a simple, concrete, and understood method of valuing food safety. The technique is relatively well accepted by Congress, as revealed by the Congressional request for Rice et al. (1989) to estimate the *Cost of Injury in the United States* using this method. COI estimation was codified by Rice in the 1970s and was extended by Landefeld and Seskin. Economists have been using the COI technique or its close relative, damage assessment, to estimate society's resources consumed by treating ill people and by taking self-protective actions in an attempt to reduce the probability of illness (Harrington et al. 1991). COI calculations aid in the understanding of the economic impact of foodborne disease, enable targeting of pathogen reduction efforts towards the most expensive diseases, and permit comparisons with the costs of control efforts to determine the most cost beneficial interventions (Table 9.7). Benefit-cost

TABLE 9.7 Strengths and Weaknesses of Different Valuation Methods

Method	Strengths	Weaknesses
COI	COI is simple, concrete, and understood: measures society's resources currently spent on foodborne illness	May not be close association between COI and society's or individuals' willingness to pay to avert illness
	Permits aggregation of the full distribution of illness and death outcomes using $	Depends on incidence and severity data for foodborne illness which are spotty for acute illnesses and almost nonexistent for chronic complications
	Based on market-observed costs of medical services and wages	Difficulty measuring productivity losses for: nonwage earners, undervalued workers, lives lost
	Facilitates comparison of costs across pathogens for prioritization of pathogen intervention efforts	Lower bound since may omit costs of lost leisure, pain and suffering, self-protection actions
	COI useful in Benefits/Cost Analysis evaluating government programs or regulations	
WTP	More consistent with consumer demand theory than COI	Measures what individuals say rather than what they do
	Easy to examine a subsector of the population	Limited studies; results not yet validated by other researchers
	Allows comparison of consumer preferences for different food technologies or reduced risk from specific foodborne pathogens	Potential for sample and question bias: results in questionable generalizability
	Permits gathering of consumer preferences for alternative risk reduction strategies: decreases in consumption, increases in self protection actions, WTP premium for consumption of safer food	Aggregation problem: results of WTP on a population basis may be strange
		May be complicated to value pathogens found on several meat or poultry products or several pathogens found on one product

analysis has been well-documented in the literature and has been widely used by government agencies, contributing to its familiarity among noneconomists as well as economists.

Secretary of Agriculture Mike Espy announced plans to overhaul the current inspection system and replace it with one that is based on scientific data on foodborne disease risks. Estimation of the current levels of social costs, by whatever method, will help describe and quantify the current social costs of foodborne disease and the demand for food safety. Prior to allocating increased governmental resources towards foodborne disease reduction, however, we need to evaluate whether individuals prefer to control these hazards themselves or prefer stricter regulations to reduce levels of *E. coli* O157:H7 and other microbial pathogens in the food chain. No one has determined the socially optimum mix of public and private strategies to reduce foodborne disease.

The disadvantage of the COI method is its dependence on incidence and severity data for foodborne illness, which are spotty for acute illnesses and almost nonexistent for chronic complications. While the data for microbial illness may be better than that for chemically induced illness, the lack of data leaves holes in our knowledge about the extent and the consequences of microbial foodborne disease. Incidence data could be improved by training of laboratory technicians and physicians to improve pathogen identification coupled with mandatory state reporting requirements for the major foodborne diseases. Another disadvantage of COI is that there may be no association between food protection costs and the value that society places on averting the illness. In other words, while foodborne illness may ultimately cost society billions of dollars, society may not be willing to spend the public money (in the form of increased taxes today or reallocation of current government resources) to reduce or eliminate it. Society may prefer that individuals (and not the government or industry) practice self-protective behaviors; if someone chooses to eat high-risk foods or practice sloppy kitchen sanitation, then that individual should pay the price (i.e., gets the illness she or he deserves). However, this preference for self-protection assumes that the individual can completely protect her or himself from microbial hazards, an unwarranted assumption since thorough cooking does not eliminate heat stable toxins produced by such pathogens as *Staphylococcus aureus* and *Bacillus cereus*. Moreover, this individualistic approach also ignores the fact that both government and industry currently spend large resources on food safety efforts which may or may not be effective or efficient.

Harrington and Portney (1987) warn that the COI measure is only a lower bound of the true social cost of illness because the opportunity costs of self-protective behaviors are ignored. For microbial foodborne contaminants, these opportunity costs may be a part of daily life whether someone eats at home or in a restaurant. Opportunity costs include the perceived welfare loss from tradeoffs in consumption of high risk foods such as oysters on the half shell, sushi, homemade ice cream, and rare hamburgers for lower risk foods. The costs also include the time spent in food protection activities, such as keeping the kitchen sanitary and refrigerating food immediately after purchase and after cooking, that could have been spent in an alternative activity. In equilibrium, households will equate all their activities at the margin so that the value of their marginal time spent in self-protective activities will be equated with their marginal after-tax wage rate. Thus, using the wage rate as a proxy for the value of time spent in self-protective activities is defensible. Another method of valuing opportunity costs associated with food safety activities is to equate the marginal value of food safety with the marginal after-tax wage rate plus the marginal value of leisure time lost during the illness, plus the marginal value of pain and suffering.

In contrast, the WTP method's greatest strength is that it directly values what an individual is willing to pay to avoid a foodborne illness (Table 9.7). It includes all the benefits of improved food safety, such as reduction of pain and suffering and loss of leisure time, that are usually excluded from COI estimates. Also, the WTP concept is derived from demand theory and is the most appropriate measure of the value of risk reduction. In a contingent valuation survey, researchers can ask questions about tradeoffs with other risk reduction options, such as decreasing consumption of a high-risk food or increasing self-protection actions such as grinding one's own hamburger, and evaluate these choices alongside the willingness to pay for a "safer" food.

WTP estimates for food safety, however, are new and results have not been replicated. Mitchell and Carson (1989), Solow and Arrow (NOAA 1993), and other chapters in this book have catalogued an impressive array of problems designing and interpreting WTP studies. Among the concerns are sample and question bias, incomparability across studies, use of different measurements (cents per pound versus cents per meal), and the measurement of what people say rather than what they actually do. Another difficulty arises when trying to value the cost of avoiding a death due to foodborne illness—what type of survey question best asks the question? Also, when trying to describe the whole distribution of illness and death outcomes from microbial foodborne illness, detailed information is needed which is similar to that needed for COI estimation. Over time as WTP methods become standardized, as the variation in answers becomes better understood, and as results are replicated, WTP will become more accepted by policy makers.

Uses of Food Safety Valuations

The correct method for valuing food with reduced levels of microbial contamination may depend on who will use the information and for what purpose. The government, private individuals, and industry will find each method useful, but perhaps to different extents (Table 9.8).

TABLE 9.8 Uses for Food Safety Valuation Methods

User	COI Method	WTP Method
Government	COI estimates of society's resources used on foodborne disease, plus estimates of the preventable portion, enable comparisons with the costs of intervention strategies to determine the most cost beneficial pathogen control strategies.	WTP higher prices or tax dollars for safer foods versus willingness to undertake self-protection activities provides guidance in formulating regulations which could improve safety or increase prices.
Industry	COI estimates of the affected population group in a foodborne outbreak help to determine legal liability sums in class action suits, or the amount of damage caused by industry.	WTP estimates for specific subsectors of the U.S. population (e.g., immunosuppressed individuals) help define the viability of niche markets for pathogen-reduced foods.
Individual	COI information aids decision making about acceptable foodborne disease risks.	WTP method permits individuals to make their preferences known for alternative risk reduction strategies: decreases in consumption, increases in self-protection actions, WTP premium for safer food.

Government

Government is interested in the societal benefits and costs of the current foodborne disease regulatory program as well as benefits and costs of alternative programs. Regulation is defined in the broadest possible sense and includes contamination prevention at the production, processing, and marketing levels; product liability rules; food storage and preparation codes; guidelines for food safety information on consumer packages of food; government certification of food safety label claims; government inspection; and food safety education programs. For example, FSIS has designed food handling instructions for raw meat and poultry that are intended to raise consumer awareness of microbial contamination and increase self-protection actions (*Federal Register*, August 2, 1993). Included in the costs are the costs of implementing and enforcing any program.

The COI method is useful to identify the burden of the current level of microbial foodborne disease. After identifying the most costly microbial contaminants, pathogen-specific control options can be identified from the farm to the table, benefit/cost analyses of the options performed, informed choices made among the control options, and adjustments made in regulations and regulatory budgets to reduce foodborne disease risks. Individuals benefit from efficient allocation of tax dollars.

The WTP method gives a more comprehensive estimate of the value to society of reducing foodborne disease risks. WTP estimates are, theoretically, a more accurate reflection of value than COI. To the extent WTP measures are higher than COI, the COI may be undervaluing social preferences.

Private Individuals

Private individuals are interested in the probability that they will contract a disease, and possibly die, from exposure to microbial contaminants in food. Since the disease outcomes depend on the type of pathogen, individual genetics, immune system functioning, medical history, type of contaminated food, and the amount of microbes ingested (dose), individuals need to know their susceptibility to various microbial pathogens. Different pathogens, unfortunately, are associated with different risk factors and there is no easy answer to achieve risk quantification for individuals. Individuals can take some generic self-protection actions, such as eating animal protein products that have been well-cooked, practicing good kitchen sanitation, following refrigeration guidelines, and wearing gloves when handling raw animal protein products. To make taste and risk tradeoffs for microbial pathogens, individuals need to know both the risks and the effectiveness of various self-protection actions in reducing risks. As taxpayers, private individuals are concerned with the level of their taxes spent on food safety and how their taxes, and the level of food safety, change under different regulatory strategies.

Industry

Industry is concerned about the probability that their customers survive to see another day and make another purchase (Choi and Jensen 1991) and about the probability that illnesses can be traced to the firm, since the firm could suffer damages from loss of reputation or lawsuits from ill customers and/or stockholders. In the Jack-in-the-Box *E. coli* outbreak of 1993, ill customers and parents of children who died filed suits for medical costs and pain and suffering losses. In April 1993, stockholders of Foodmaker, Inc. also filed suit claiming a loss of $50 million from court costs and sales lost due to adverse publicity. Industry is also interested in reducing food spoilage and increasing the shelf-life of food, actions which may also reduce microbial pathogens. At the turn of the century many dairies and grocers included the word "Sanitary" in their names (Caswell and Roberts 1994). Firms no longer advertise that their products are safe. However, safety may again become an important product attribute since USDA's Food Safety and Inspection Service (FSIS) is permitting irradiated chicken to be labeled "irradiated to control foodborne pathogens."

Specific groups of individuals and industry would probably benefit more from WTP approaches, which are more able to predict and estimate "the market" for a particular food safety advance and to target special consumer groups. WTP could be used to identify and evaluate consumer preferences for different risk reduction strategies (such as cooking instructions, warning labels for high-risk consumers, or identification of lower-risk production techniques). The knowledge of these preferences would facilitate government's role in providing safer food and industry's desire to find new markets.

Conclusion

The decision to utilize the COI method to estimate the costs to society of *E. coli* O157:H7 was generated by USDA's involvement in a food safety regulation on pre-cooked meat patties (*Federal Register*, August 2, 1993). COI was considered more reliable, more accepted, and a conservative underestimate of the social costs of foodborne disease. Losses on a societal basis were needed, rather than costs to individual consumers who vary in their specific susceptibility to microbial foodborne disease.

The analysis demonstrates that foodborne illness deaths (*E. coli* O157:H7) are major contributors to cost estimates and that chronic disease springing from the acute illness phase are also important contributors to costs (*Toxoplasma gondii*). The costs of selected foodborne diseases at $5-6 billion annually is several times greater than the cost of current foodborne inspection programs costing around $1 billion annually (U.S. GAO 1991) and many times greater than the estimated $8-24 million cost of creating an improved foodborne disease data base, suggesting that social welfare would be increased by creating a data base and using it to reduce foodborne disease risks. Such a data base could more accurately identify pathogens, associated foods, and the distribution of human health consequences. Investing in more information about foodborne disease risks and control options appears to be very cost-effective.

Cost estimates for microbial foodborne disease can be expected to change as epidemiologists refine their case and death estimates, new data bases are explored or created, and cost estimation methods become standardized. Future research will also clarify the impact of microbial contaminants in food on the health of various subpopulations for whom WTP measures will more clearly reflect the potential market for specific, safer foods or food uses.

Notes

1. The views expressed in this chapter are not official policy of USDA. The authors are indebted to several health professionals for information on the clinical course and cost of treating *E. coli* O157:H7 disease: Paul Eggers, Health Care Financing Administration, for much of the data on the treatment and costs of end stage renal disease; Patricia Griffin, Centers for Disease Control and Prevention, for access to the literature and judgment calls about medical care assumptions used in the analysis; and Mary O'Shay, pediatric nurse, Buffalo, New York and Kim O'Connor, social worker, Children's Hospital, Washington, D.C. The authors wish to thank several economists for their insightful comments: Fay Dworkin, U.S. Consumer Product Safety Commission; Fred Kuchler and C.-T. Jordan Lin, Economic Research Service; and Julie Caswell, University of Massachusetts.

2. This method allows future changes in technology (i.e., fewer days required for dialysis) or cost revisions to be incorporated easily into an updated analysis. Another advantage of this method is it facilitates standardization of cost estimates across pathogens when similar cost per service estimates are used. The disadvantage is that the average number of days or the average service cost may not be specific enough to the particular disease. For instance, those on dialysis for HUS may differ from those on dialysis for another disease such as diabetes; HUS patients may require more frequent dialysis and thus cost more than an average dialysis patient. Allowances can be made for these additional factors; however such specific information is often lacking.

3. HUS cases are estimated by Griffin and Tauxe (1991) to be 3.6 percent of total cases and that 18 percent of cases are hospitalized; thus, 3.6/18 = 20 percent are HUS cases.

4. Patricia Griffin, personal communication July 1993, estimates that 5 percent of deaths occur in nonhospitalized cases, however, so our assumptions here will overestimate hospitalization costs by 5 percent.

5. Productivity losses for a parent or caretaker of a sick child (less than 16 years of age) are based on the time necessary to obtain treatment. Since over 80 percent of the chronically ill children receive transplants by the fourth year after acute illness, these productivity losses mostly involve taking the child to the hospital for hemodialysis or caring for children on peritoneal dialysis until the transplant operation. Hemodialysis involves 4-hour treatments 3 times per week at a hospital. Allowing a half hour before and after each treatment for scheduling variability, 15 hours/week are required for hemodialysis. In addition, there is travel time to and from the hospital (estimated at 1 hour for each trip) and time missed from school (3 half days per week). Most facilities have Monday through Saturday hours, so conceivably treatments can be scheduled after school or on Saturdays to avoid missing school. (However, the 4-hour duration of treatments and the limited number of dialysis machines limits the possibility of after-school time). Some facilities do not have flexible scheduling. Others offer tutoring to compensate for time missed from school. Moreover, since children must go to hospital

facilities and not to free-standing facilities as adults can, travel time may be increased to get to a limited number of facilities. Assuming 1 hour per trip and no loss of school time, the minimum amount of time required for children on hemodialysis is 18 hours/week. Since children are encouraged to switch to peritoneal dialysis and then transplantation as soon as possible, all of the patients' parents/caretakers require this time commitment for the half year of dialysis in the acute phase and 24 percent require this time commitment by the end of year 1, with the remainder assumed to be on peritoneal dialysis by end of year 2. For a hemodialysis patient's parents/caretakers, 18 hours out of a 40 hour productive week results in a 45 percent productivity loss.

6. Among the two major types of peritoneal dialysis, Continuous Ambulatory Peritoneal Dialysis (CAPD) or Continuous Cyclic Peritoneal Dialysis (CCPD), CCPD is preferred for younger patients and CAPD for older patients. CCPD requires a machine which fills and drains solution into the child's peritoneum while she/he sleeps (10-12 hours/night every night). This requires the help of a parent/caretaker to connect the catheter to the child at night and disconnect it in the morning. While parents and the child can sleep during the treatment, the child must be monitored (blood pressure, weight, check for infections) during the day. Most, if not all, parents can relegate these responsibilities, possibly to a school nurse, so that they can still work full time. In rare instances, the parent may decide to pull the child from school and oversee her/his care. This may happen in 1-2 percent of cases. We assume a 1 percent productivity loss for a parent/caretaker of a child on CCPD peritoneal dialysis until age 16.

CAPD does not require a machine and, as such, provides greater freedom. Instead, the solution required for dialysis is emptied into a bag attached to the catheter leading to the peritoneum. The solution is left in the abdomen for 4 hours and then emptied into a bag. This draining process is done 5 times per day for children (4 times/day for adults) and takes 30 to 40 minutes each time (totaling about 3 hours/day or 21 hours/week). Generally, a child needs help by a parent/caretaker (possibly by the school nurse) with this process until she/he is mature enough to do it by her/himself. Although the age of maturity depends on the child, estimates are that between ages 11 and 16 the child can perform the exchange by her/himself. We assume that by age 16 children will have switched from CCPD to CAPD peritoneal dialysis and that there will be no productivity loss for a parent/caretaker since the child will be performing the procedure by her/himself. While the child must also be monitored (blood pressure, etc.) with CAPD, we assume parents will be able to work full-time with this form of dialysis.

7. Since the value of a statistical life, which is based on the potential stream of income to be earned over a remaining lifetime, is much higher for a 4-year old than for a 50-year old, the current analysis which assumes an average age of 4-years for individuals having *E. coli* O157:H7 disease may bias the COI estimate upward. However, evidence from several studies supports the view that children are most seriously affected. Data from the 1993 outbreak in Washington state, where physicians and lab technicians are trained to identify the *E. coli* O157:H7 pathogen, found a median age of 7.5 for 477 cases. Epidemiologic data suggest that the age distribution of the disease may be somewhat bimodal, with children (whose immune systems are immature) more likely to contract the disease and survive the acute phase to develop chronic sequelae such as HUS and with some immunocompromised elderly also at risk and more likely to die in the acute phase.

References

Bean, Nancy H., Patricia M. Griffin, Joy S. Goulding, and Cecile B. Ivey. 1990. Foodborne Disease Outbreaks, 5-Year Summary, 1983-1987. *MMWR: Morbidity and Mortality Weekly Report* 39(SS-1):15-57.

Bennett, John V., M.D., Scott D. Holmberg, M.D., Martha F. Rogers, M.D., and Steven L. Solomon, M.D. 1987. Infectious and Parasitic Diseases. In *Closing the Gap: The Burden of Unnecessary Illness,* ed. Robert W. Amler and H. Bruce Dull, 102-114. New York, NY: Oxford University Press.

Berger, Mark C., Glenn C. Blomquist, Don Kenkel, and George S. Tolley. 1987. Valuing Changes in Health Risks: A Comparison of Alternative Measures. *Southern Economic Journal* 73:967-984.

Caswell, Julie A. and Tanya Roberts. 1994. Vertical Quality Control Systems: A Potential Marketing Advantage for Cooperatives. In *Competitive Strategy Analysis for Agricultural Marketing Cooperatives*, ed. Ronald W. Cotterill. Boulder, CO: Westview Press.

Choi, E. Kwan and Helen H. Jensen. 1991. Modeling the Effect of Risk on Food Demand and the Implications for Regulation. In *Economics of Food Safety*, ed. Julie A. Caswell, 29-44. New York, NY: Elsevier Science Publishing Company, Inc.

Cropper, Maureen L. and Wallace E. Oates. 1992. Environmental Economics: A Survey. *Journal of Economic Literature* 30(2):675-740.

Deaton, Angus and John Muellbauer. 1980. *Economics and Consumer Behavior*. Cambridge, U.K.: Cambridge University Press.

Eggers, Paul. 1993. *Medicare End Stage Renal Disease Program Expenditures per Person by Treatment Group, 1992*. Health Care Finance Administration, Office of Research and Demonstration, Tables 48 and 49.

Fisher, A., L. G. Chestnut, and D. M. Violette. 1989. The Value of Reducing Risks of Death: A Note on New Evidence. *Journal of Policy Analysis and Management* 8(1):88-100.

Garner, Thesia I. 1984. Economic Analysis of End-Stage Renal Disease Treatments. University of Maryland, Ph.D. Dissertation, Department of Textiles and Consumer Economics, 96. Ann Arbor, MI: University Microfilms International.

Garthright, W. E., D. L. Archer, and J. E. Kvenberg. 1988. Estimates of Incidence and Cost of Intestinal Infectious Diseases in the United States. *Public Health Report* 103(2):107-116.

Griffin, Patricia and Robert Tauxe. 1991. The Epidemiology of Infections Caused by *Escherichia coli O157:H7*. Other Enterohemorrhagic *E. coli*, and the Associated Hemolytic Uremic Syndrome. *Epidemiologic Reviews* 13:60-98.

Harrington, W. and P. Portney. 1987. Valuing the Benefits of Health and Safety Regulation. *Journal of Urban Economics* 22:101-112.

Harrington, W., A. J. Krupnick, and W. O. Spofford, Jr. 1991. *Economics and Episodic Disease: The Benefits of Preventing a Giardiasis Outbreak*. Washington, D.C.: Resources for the Future.

Health Care and Financing Administration (HCFA). 1992. *Health Care Financing*

Research Report End Stage Renal Disease, 1990. Publication No. 03328, Tables 35-37, 48-49. Department of Health and Human Services.

Heersink, Mary. 1994. Letter to Tanya Roberts, ERS, April 18.

Landefeld, J. S. and E. P. Seskin. 1982. The Economic Value of Life: Linking Theory to Practice. *American Journal of Public Health* 72(6):555-566.

Magat, Wesley A. and Kip W. Viscusi. 1992. *Informational Approaches to Regulation*. Cambridge, MA: The MIT Press.

Martin, D. L., K. L MacDonald, K. E. White, J. T. Soler, and M. T. Osterholm. 1990. The Epidemiology and Clinical Aspects of the Hemolytic Uremic Syndrome in Minnesota. *New England Journal of Medicine* 323(17):1161-1167.

Merck. 1992. *The Merck Manual*, Volume 1, *General Medicine*, Volume 2, *Specialties*, 16th ed. Rahway, NJ: Merck and Company, Inc.

Mitchell, R. C. and R. T. Carson. 1989. *Using Surveys to Value Public Goods*. Washington, D.C.: The Johns Hopkins University Press.

MMWR. 1993. Update: Multistate Outbreak of *Escherichia coli* 0157:H7 Infections from Hamburgers-Western United States, 1982-1993. *Morbidity and Mortality Weekly Report* 42(14):258-260.

National Academy of Sciences, National Research Council. 1993. *Pesticides in the Diets of Infants and Children*. Washington D.C.: National Academy Press.

National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. 1993. Natural Resource Damage Assessments Under the Oil Pollution Act of 1990. *Federal Register* 58(10-January 15):4601-4614.

Quiggin, John. 1992. Risk, Self-Protection, and Ex Ante Economic Value—Some Positive Results. *Journal of Environmental Economics and Management* 23:40-53.

Rice, D. P., E. J. MacKenzie, and Associates. 1989. *Cost of Injury in the United States: A Report to Congress.* San Francisco, CA: Institute for Health and Aging, University of California and Injury Prevention Center, The Johns Hopkins University.

Roberts, Tanya. 1993. Cost of Foodborne Illness and Prevention Interventions. In *Proceedings of the 1993 Public Health Conference on Records and Statistics Toward the Year 2000*, 514-518.

Roberts, T. and R. Pinner. 1990. Economic Impact of Disease Caused by *Listeria monocytogenes*. In *Foodborne Listeriosis,* ed. A. J. Miller, J. L. Smith, and G.A. Somkuti, 137-149. Amsterdam, The Netherlands: Elsevier Science Publishing Company, Inc.

Roberts, T. and D. Smallwood. 1991. Data Needs to Address Economic Issues in Food Safety. *American Journal of Agricultural Economics* 73:934-942.

Shogren, J. F. and Thomas D. Crocker. 1991. Risk, Self-Protection, and Ex Ante Economic Value. *Journal of Environmental Economics and Management* 20:1-15.

Steahr, Thomas E. 1993. Department of Agricultural and Resource Economics, University of Connecticut, preliminary tabulations of the National Hospital Discharge Survey.

Todd, E. C. D. 1989. Preliminary Estimates of Costs of Foodborne Disease in the United States. *Journal of Food Protection* 52:595-601.

U.S. Bureau of the Census. 1992. *Statistical Abstract of the United States, 1992* (112th edition). Washington, D.C.: U.S. GPO.

U.S. Bureau of Labor Statistics (BLS). 1993. *Employment and Earnings*, monthly. Washington, D.C.: U.S. GPO.

U.S. General Accounting Office (GAO). 1991. *Federal Food Safety and Quality Programs*. Washington, D.C.: United States Government Printing Office.

Viscusi, W. Kip. 1989. Toward a Diminished Role for Tort Liability: Social Insurance, Government Regulation, and Contemporary Risks to Health and Safety. *Yale Journal on Regulation* 6(1):65-107.

Williams, Richard A., Jr. and Robert N. Brown. 1991. Health and Safety Regulation of Small, High-Risk Subpopulations. NE-165 Working Paper #21. Storrs, CT: University of Connecticut.