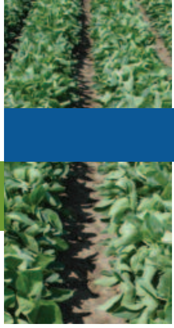

HEALTH-RELATED COSTS FROM FOODBORNE ILLNESS IN THE UNITED STATES

PRODUCE SAFETY PROJECT

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Foodborne illness is a serious public-health problem in the United States. In 1999, the Centers for Disease Control and Prevention (CDC) estimated that approximately 76 million new cases of food-related illness (resulting in 5,000 deaths and 325,000 hospitalizations) occur in the United States each year [1]. More recent data on sporadic illnesses and outbreaks suggests that this problem is not going away [2, 3].

At the same time, the aggregate economic cost of health losses associated with foodborne illnesses has not been sufficiently examined. The few studies that provide cost estimates are incomplete and/or based on limiting assumptions [4]. For example, most cost estimates include only a few, if any, of the long-term health outcomes associated with acute foodborne illnesses [5]. The derivation of an accurate cost-of-illness measure for foodborne illness is important as a guide to policymakers who seek to allocate scarce resources to programs designed to improve the health of Americans. The Government Accountability Office (GAO) reports that, in 1999, the same year of the CDC estimate, the federal government spent $1 billion on food safety efforts, while state governments spent another $300 million [6]. Without a good measure of the scope of the problem these funds are targeted towards, it is impossible to determine whether such expenditures—which are even more substantial a decade later—are reasonable.

In this study, I use the Scharff et al. (2009) enhanced food-safety, cost-of-illness model to provide a more complete estimate of the aggregate health costs from foodborne illness in the United States [7]. This approach is an improvement over past studies because it takes into account illnesses from all pathogens identified by Mead et. al. (1999); includes measures for health losses that are not included in many past studies; and presents uncertainty using confidence intervals and a sensitivity analysis. The methodology follows principles used by economists at the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA), the two primary food-safety agencies in the United States.

The primary objective of this study is to provide policymakers with measures of the economic burden of foodborne illnesses, both at the aggregate level and at the pathogen-specific level. The derivation of a measure for the aggregate health costs of foodborne illness is useful as a means of evaluating the importance of this problem relative to other pressing health problems. I do not include every cost associated with foodborne illness. Instead, I focus on costs of acute foodborne illnesses and a few long- term health-related costs. Costs to industry from reputation externalities and recalls are significant, but are not covered here. Nevertheless, my best estimate for the cost of foodborne illness in the U.S. is $152 billion a year. This suggests that foodborne illness continues to be a significant problem in the United States. Below, I present estimates of the cost of foodborne illness, both at the aggregate and pathogen- specific levels. I also examine how this cost of illness is distributed across the states. More detail about the methodology used can be found in Appendix B.

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The Cost of Foodborne Illness in the United States

The health-related cost of foodborne illness in the United States is the sum of medical costs (hospital services, physician services, and drugs) and quality-of-life losses (deaths, pain, suffering, and functional disability). This cost includes both costs to the person made ill (e.g.. pain and suffering losses) and costs to others in society (e.g. costs to insurance companies that pay medical expenses). Costs can be measured in a number of ways. Use of "willingness to pay" (WTP) to avoid illness, measurement of the monetary costs of illness to society, and hybrid approaches using both willingness-to-pay and monetary cost measures have all been used.

If the focus is on individual loss of well-being, a frequently-used economic measure is one that will accurately measure individuals' willingness to pay to avoid illness. Although these WTP studies do not elicit values not impacting the person whose value is measured, such as external medical costs covered by insurance, missing values can be added later if the analysis is focused on social costs. The most direct means of assessing WTP is through a stated-preference survey asking individuals to state the value of a small reduction of risk. These studies will only be accurate, however, if individuals answer survey questions in a fully informed and nonbiased manner. Using the stated-preference technique, Fox et al. (1995) estimated that the WTP to avoid a case of salmonellosis was between $68,000 and $191,800 [8]. More recently, Hammitt and Haninger (2007) found that the implicit WTP to avoid one mild case of foodborne illness (resulting in one day of illness that was not virulent enough to cause the person sickened to miss work) was $8,300 for adults and $24,900 for children [9]. The magnitude of these values, coupled with their lack of sensitivity to duration and severity, suggest that cognitive limitations in dealing with risk numbers might have led to an upward bias in elicited responses. Based on the Hammitt and Haninger survey and CDC data on the age distribution of illness severities, Roberts (2007) estimated that the annual cost of foodborne illness was $357 billion to $1.4 trillion [10].

Revealed preference (hedonic) studies are an alternative to stated-preference surveys. Using this method, economists look at actual behavior in the marketplace and infer a value for a given attribute (i.e. food safety) from product price differentials with varying levels of the particular attribute. This type of study will only yield accurate estimates if consumers have an intuitively accurate estimate of the risks associated with alternative products. This is unlikely to be the case in the food safety context. Despite the lack of a holistic hedonic measure, revealed- preference studies can play a role in estimating the cost of foodborne illness. Widely-cited estimates of the value of a statistical life and value of statistical life year have been calculated using this method [11]. These values can be used to attribute costs to both deaths and quality-of-life losses.

The cost-of-illness approach is an alternative means of estimating the economic burden of foodborne illness. Using this method, economists add up the directly measurable costs of illness, such as the cost of medical care and the cost of work loss. The problem with this approach is that it completely ignores the far more important losses from pain and suffering and lost utility from a reduced life expectancy. The social cost of a foodborne illness that kills an infant or elderly person will be limited to the medical costs incurred, which may be negligible. This clearly is an underestimate of society's value for these persons. The advantage of this method, however, is that the values used are easily understood by policymakers and, because it employs directly measurable costs, this method can be tailored to specific pathogens and populations of interest.

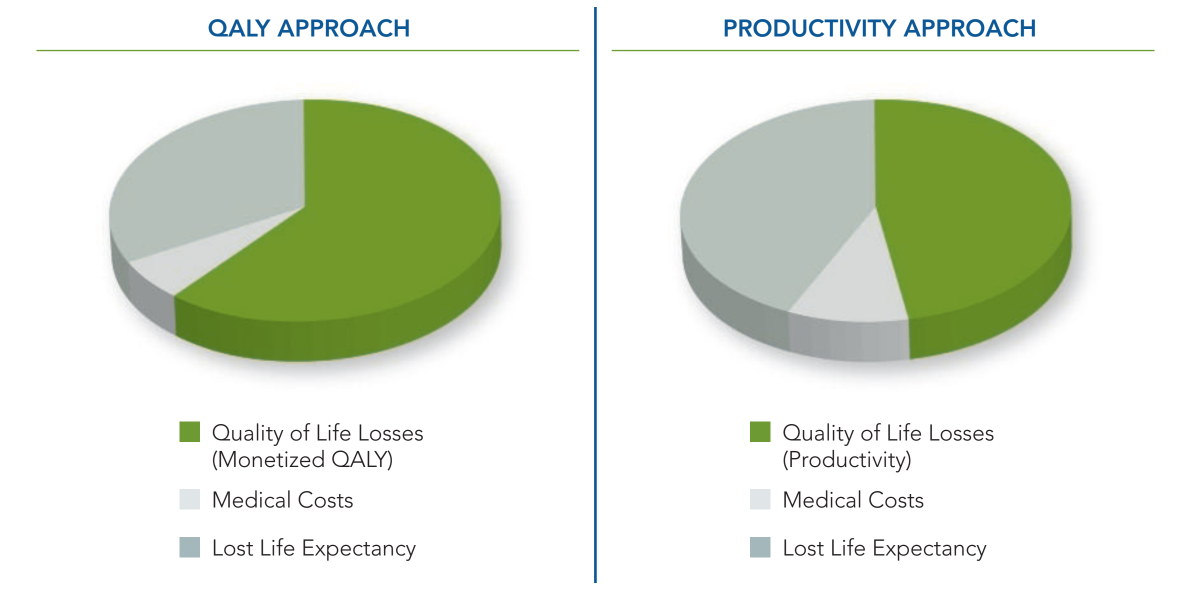
Recognizing the limitations of direct elicitation of WTP measures and needing measures flexible enough to be tailored to different pathogens, the primary food-safety agencies in the United States (FDA and USDA) use alternative, hybrid means for estimating the costs of foodborne illness. While both use similar methods for medical costs and mortality costs, the agencies have diverged on the means of assessing the economic impact of foodborne illness on other quality-of-life losses. USDA uses a conservative estimate for acute illnesses that includes productivity losses, but not pain and suffering losses or the impact of functional disability losses outside the workplace [12]. FDA uses a more inclusive measure that is based on revealed preference hedonic studies combined with quality-adjusted life year (QALY) loss estimates [7].[3]

In this study, I present estimates based on both methods, though I believe the FDA method yields estimates that more accurately reflect the full scope of costs.

The distribution of costs across cost categories is illustrated in Figure 1 for the QALY (FDA) and productivity (USDA) approaches. Although medical costs and lost life expectancy costs are the same in both cases, the effect of increasing the scope of quality-of-life losses under the QALY approach is evident. Quality-of-life losses make up a larger share of all costs when QALYs are used.

Foodborne illnesses are caused by a variety of pathogens. Each pathogen manifests itself in a unique way. For some, illnesses are likely to be mild with no lasting effects. For others, the corresponding illness is characterized by a high hospitalization and death rate. Also, many have a probability of some long-term health problems [5]. For this reason it is important to estimate costs

Figure 1



[3] The monetized QALY provides an adjusted WTP measure for lost quality of life. Included in this measure are productivity losses (at home and at the workplace) and pain and suffering losses.

separately for each pathogen. The pathogen-specific costs for the major cost categories are illustrated in Table 1. Pathogen differences are clear when shown in this light. Typhoid fever (caused by *Salmonella typhi*) is characterized by relatively high medical costs. Alternatively, those made ill by *Giardia lamblia* have higher quality-of-life losses and those infected with *Vibrio vulnificus* have a large chance of dying from their illness.

Table 1

COST OF FOODBORNE ILLNESS IN THE UNITED STATES[a]

	Hospital Services	Physician Services	Drugs	Deaths	Quality of Life[b]	Total Cost Per Case
Bacterial						
Bacillus cereus	4	21	3	0	198	226
Botulism, foodborne	157,703	1885	37	542,012	24,726	726,362
Brucella spp.	3,692	107	5	60,689	6,206	70,698
Campylobacter spp.	137	33	5	616	8,110	8,901
Clostridium perfringens	2	21	3	221	263	510
E. coli O157:H7	921	54	4	12,460	1,399	14,838
E. coli, Non-O157 STEC	6	21	3	0	1,309	1,339
E. coli, Other	5	21	3	0	1,339	1,368
Listeria monocytogenes	78,127	1541	43	1,573,209	42,222	1,695,143
Salmonella, Typhi	21,641	816	35	35,767	4,251	62,509
Salmonella, nontyphoidal	278	35	5	3,239	5,590	9,146
Shigella spp.	214	34	5	1,227	5,611	7,092
Staphylococcus	103	25	3	85	601	818
Streptococcus, foodborne	93	24	3	0	2,167	2,288
Vibrio cholerae, toxigenic	3,485	228	16	0	1,699	5,428
Vibrio vulnificus	34,950	595	42	3,009,896	243	3,045,726
Vibrio, other	152	27	3	19,947	1,681	21,810
Yersinia enterocolitica	293	35	5	181	6,713	7,227
Parasitic						
Cryptosporidium parvum	126	25	3	1,834	2,436	4,424
Cyclospora cayetanensis	19	21	3	0	1,489	1,531
Giardia lamblia	44	22	3	39	3,567	3,675
Toxoplasma gondii	1,280	49	3	26,197	1,899	29,429
Trichinella spiralis	3,224	87	5	0	8,548	11,864
Viral						
Norwalk-like viruses	42	22	3	106	413	586
Rotavirus	96	27	3	0	1,028	1,155
Astrovirus	41	22	3	0	1,202	1,268
Hepatitis A	495	36	3	7,540	3,119	11,193
Unknown agents						
	76	23	3	429	898	1,430
Expected Cost Per Case of Foodborne Illness in the United States						**1,851**

[a] Costs in this and other tables in this report are as of September 2009.
[b] Using a monetized QALY based on EQ-5D survey instrument.

Table 2 demonstrates the total cost of illness for each pathogen in the United States. Although the majority of costs accrue to unknown agents, infection by other well- known pathogens such as *Campylobacter*, *Listeria* and *Salmonella* have large measurable costs. The total cost of foodborne illness to the United States is almost $152 billion a year. Monte Carlo simulations were used to account for uncertainty in estimates. Confidence intervals based on those simulations are also presented.

Table 2

TOTAL COST OF FOODBORNE ILLNESS IN THE UNITED STATES

	Cases	Cost Per Case[a] ($)	Total Cost to U.S. Residents ($ Millions)	Confidence Interval	
				5%	95%
Bacterial					
Bacillus cereus	29,439	226	**7**	<1	16
Botulism, foodborne	62	726,362	**45**	17	74
Brucella spp.	818	70,698	**58**	14	101
Campylobacter spp.	2,112,302	8,901	**18,803**	4,388	36,695
Clostridium perfringens	267,403	510	**136**	33	239
E. coli O157:H7	66,905	14,838	**993**	296	1,689
E. coli, Non-O157 STEC	5,368	1,339	**7**	2	13
E. coli, Other	4,422	1,368	**6**	1	11
Listeria monocytogenes	5,205	1,695,143	**8,823**	2,277	15,365
Salmonella, Typhi	536	62,509	**34**	16	51
Salmonella, nontyphoidal	1,597,411	9,146	**14,609**	3,185	29,091
Shigella spp.	96,686	7,092	**686**	124	1,519
Staphylococcus	199,121	818	**163**	54	271
Streptococcus, foodborne	54,789	2,288	**125**	31	220
Vibrio cholerae, toxigenic	52	5,428	**<1**	<1	<1
Vibrio vulnificus	51	3,045,726	**154**	33	275
Vibrio, other	5,511	21,810	**120**	25	215
Yersinia enterocolitica	93,321	7,227	**674**	150	1,369
Parasitic					
Cryptosporidium parvum	46,978	4,424	**208**	44	421
Cyclospora cayetanensis	32,322	1,531	**49**	11	88
Giardia lamblia	175,033	3,675	**643**	96	1,423
Toxoplasma gondii	121,048	29,429	**3,562**	855	6,273
Trichinella spiralis	56	11,864	**1**	<1	1
Viral					
Norwalk-like viruses	9,899,026	586	**5,802**	1,691	9,885
Rotavirus	41,963	1,155	**48**	14	86
Astrovirus	41,963	1,268	**53**	9	119
Hepatitis A	906	11,193	**10**	2	18
Unknown agents					
	67,012,102	1,430	**95,806**	25,242	166,564
All Illnesses	81,910,799	1,851	**151,626**	38,987	264,825

[a] Using a monetized QALY based on EQ-5D survey instrument.

Table 3 provides a summary of costs using both the QALY and productivity loss approaches. In addition to mean costs, which increase from $102.7 billion to $151.6 billion when the more inclusive QALY measure is used, I also include 90% confidence intervals to account for uncertainty. Notably, while the mean QALY measure is higher, there is also more uncertainty associated with it. On the one hand, the productivity measure does not include a measure of lost utility from pain and suffering, but, on the other, the data used to derive the estimates (employment and compensation cost data from the Bureau of Labor Statistics) are more certain.

Table 3

HEALTH-RELATED COSTS FROM FOODBORNE ILLNESS IN THE UNITED STATES

Measure of Lost Utility	Mean Cost ($ millions)	CI		Cost Per Illness ($)	CI	
		5%	95%		5%	95%
Monetized QALY	151,626	38,987	264,825	1,851	478	3,227
Productivity Proxy	102,708	64,083	141,382	1,261	788	1,733

The Cost of Foodborne Illness Across States

In addition to understanding the burden of foodborne illness for the nation as a whole, it is also often useful to understand the impact of these illnesses on individual states. Differences in wages, costs of medical care, and exposure to pathogens all affect the cost of illness for a particular state. Table 4 provides estimates of the economic cost of foodborne illness for the states using the QALY approach. Total costs range from $245 million in Wyoming to $18.6 billion in California. As expected, larger states have higher total costs. The cost per case of foodborne illness is presented in the last column of Table 4. Here, real differences in state costs are more evident. Lower medical costs and a less harmful mix of pathogens lead to a cost per case of only $1,731 in Kentucky. Alternatively, greater exposure to higher cost pathogens leads to costs of $2,008 per case in Hawaii. The ability to differentiate costs for the states is limited in the QALY model, however. Differences in valuation of lost quality of life are likely to exist, but have not been incorporated into the model at this point. Inclusion of such values would almost certainly lead to even more differentiation of costs across the states.

By contrast, state differences in costs are more evident when the productivity model is used. Figure 2 illustrates the cost per case of foodborne illness for medical costs, productivity losses, and total costs. Omitting the District of Columbia (which experiences extremely high productivity losses because of the large number of commuters from Virginia and Maryland), the total cost per case of foodborne illness is between $1,064 in Kentucky and $1,506 in Connecticut. The maps in Figure 2 reveal other interesting facts. Medical costs are lowest in the Great Plains states, while productivity costs are lower in the South. Alternatively, both medical costs and productivity losses are relatively high in California and the Northeast.

Table 4

ANNUAL HEALTH-RELATED COSTS OF FOODBORNE ILLNESS FOR EACH STATE[a]

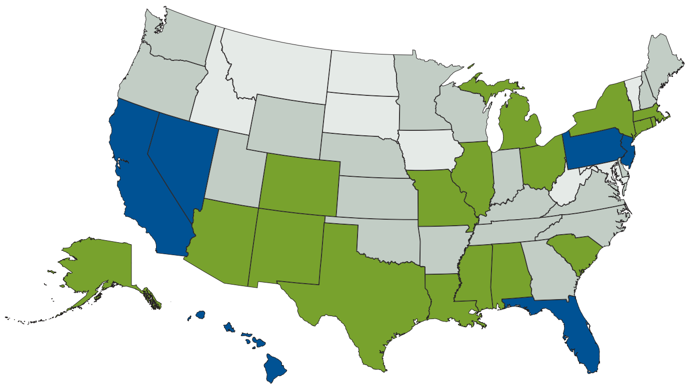
	Medical Costs ($ millions)	Quality of Life Losses ($ millions)	Lost Life Expectancy ($ millions)	Total Cost ($ millions)	Cost per Case ($)
Alabama	139	1,462	720	2,321	1,834
Alaska	23	206	107	336	1,829
Arizona	203	1,821	919	2,943	1,829
Arkansas	78	952	454	1,484	1,899
California	1,484	11,129	6,000	18,613	1,877
Colorado	151	1,449	737	2,336	1,814
Connecticut	118	1,098	677	1,893	1,949
District of Columbia	22	183	109	314	1,935
Delaware	24	264	129	418	1,805
Florida	727	5,996	3,075	9,799	1,984
Georgia	272	2,946	1,503	4,721	1,876
Hawaii	54	417	239	710	2,008
Idaho	32	438	212	682	1,747
Illinois	458	3,995	2,035	6,487	1,836
Indiana	168	1,915	985	3,069	1,778
Iowa	72	942	478	1,491	1,805
Kansas	80	857	407	1,343	1,764
Kentucky	111	1,274	605	1,990	1,731
Louisiana	150	1,454	710	2,314	1,859
Maine	37	407	239	683	1,877
Maryland	126	1,755	1,004	2,884	1,871
Massachusetts	210	2,100	1,164	3,474	1,921
Michigan	320	3,069	1,569	4,958	1,776
Minnesota	142	1,610	795	2,546	1,789
Mississippi	93	1,011	482	1,586	1,932
Missouri	201	1,819	889	2,909	1,812
Montana	20	294	142	457	1,762
Nebraska	47	545	289	881	1,812
Nevada	89	707	358	1,154	1,793
New Hampshire	38	404	239	681	1,892
New Jersey	389	2,676	1,530	4,595	1,918
New Mexico	58	603	301	963	1,820
New York	657	6,113	3,605	10,375	1,930
North Carolina	234	2,793	1,460	4,487	1,866
North Dakota	14	195	103	312	1,769
Ohio	374	3,551	1,918	5,843	1,837
Oklahoma	102	1,124	541	1,767	1,796
Oregon	96	1,121	600	1,817	1,813
Pennsylvania	463	3,908	2,345	6,716	1,949
Rhode Island	34	336	201	571	1,917
South Carolina	143	1,421	738	2,302	1,937
South Dakota	18	257	130	405	1,850
Tennessee	170	1,859	936	2,965	1,798
Texas	756	7,107	3,455	11,317	1,805
Utah	65	757	363	1,185	1,742
Vermont	15	197	108	321	1,850
Virginia	221	2,380	1,235	3,835	1,840
Washington	166	1,909	994	3,069	1,781
West Virginia	44	552	311	907	1,816
Wisconsin	157	1,792	943	2,892	1,864
Wyoming	14	159	72	245	1,738

[a] Using a monetized QALY based on EQ-5D survey instrument.

Figure 2

STATE DIFFERENCES IN THE COST PER CASE OF FOODBORNE ILLNESS

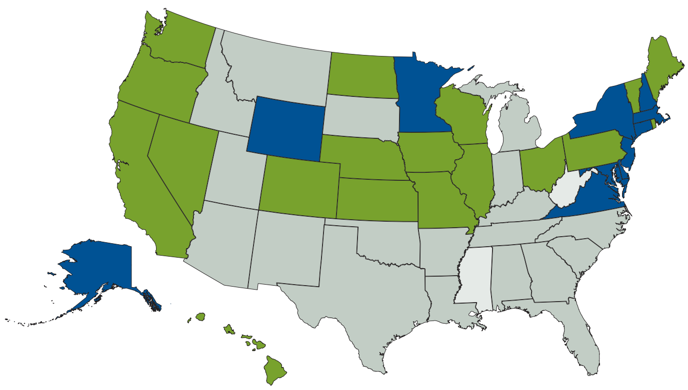
(known pathogens using the productivity proxy)



Medical Costs

Typical medical costs from a case of foodborne illness range from $78 in Montana to $162 in New Jersey. A sizable share of the difference in values is due to geographic disparities in physician and hospital charges. Differences in the mix of pathogens causing illness account for the remainder of the disparity in medical costs across the states (due to differences in illness severity).

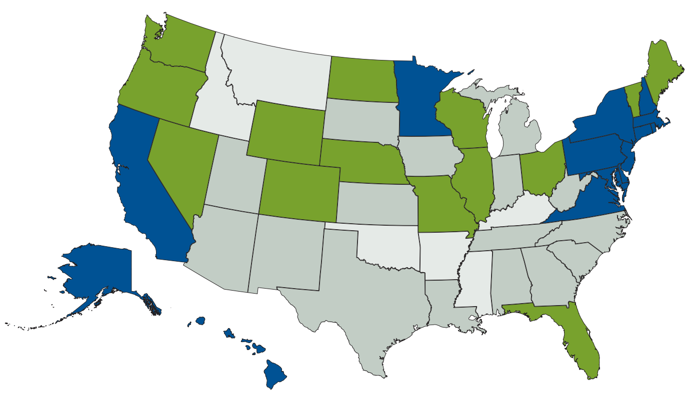
Cost per Case: $70 to $90 | $90 to $110 | $110 to $130 | $130+



Productivity Losses

The average productivity loss from a case of foodborne illness is between $377 (Mississippi) and $924 (Delaware). Differences in wages, benefits, and employment account for some of the disparity. The selection of pathogens causing illness also has an effect. States with high employment of other states' residents have higher productivity losses.

Cost per Case: $300 to $400 | $400 to $500 | $500 to $600 | $600+



Total Cost per Case

The total cost of foodborne illness is the sum of medical costs, productivity losses, and utility losses from premature mortality. Residents of states in the northeast experience the highest costs from foodborne illness ($1,506 in Connecticut), while residents in the central portion of the country experience a lower cost of illness ($1,064 in Kentucky).

Cost per Case: $1,000 to $1,100 | $1,100 to $1,200 | $1,200 to $1,300 | $1,300+

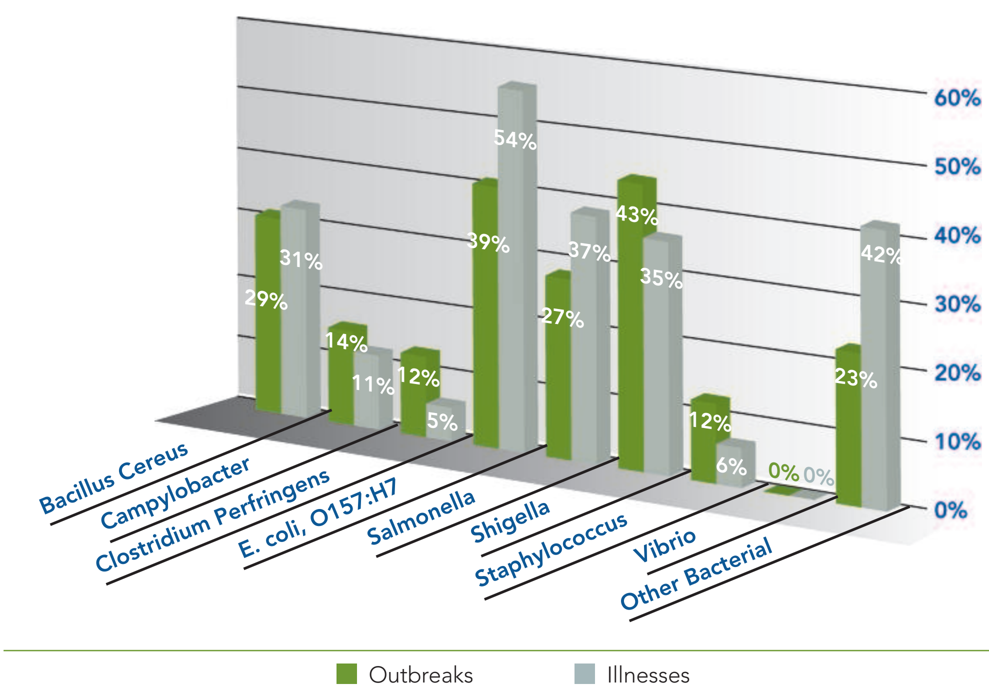
Produce-Related Costs

Given the fact that produce has been linked to the largest number of outbreaks involving FDA-regulated foods, it is useful to estimate the cost of illness linked to these commodities. The measured differences in costs across the states are due to both (1) variation of state medical and productivity costs and (2) state-level differences in the incidence of illness from each pathogen. Given the close association of certain pathogens with identified product categories (e.g. fresh spinach and *E. coli* O157:H7), it stands to reason that costs will also vary across product categories. In this section I evaluate produce-related costs by isolating the proportion of illnesses attributable to contaminated produce for each pathogen.

Figure 3 illustrates the number of bacterial outbreaks and illnesses attributable to produce, based on 2003-2007 data from the CDC's Foodborne Disease Outbreak Surveillance System [2]. Outbreaks in which no food was implicated were dropped from the analysis. An outbreak was considered to be associated with produce if at least one of the vehicles of contamination was a fresh, canned, or processed produce item. While most of the outbreaks have been linked to "fresh produce" (items like leafy greens and tomatoes that are eaten raw), the available outbreak data does not distinguish between fresh, canned, and processed items. Illnesses associated with each outbreak were divided evenly between the vehicles implicated in the outbreak. The number of illnesses attributable to produce products was estimated separately for nine specific pathogens and four pathogen categories.

Figure 3

% OF OUTBREAKS AND ILLNESSES ATTRIBUTABLE TO PRODUCE
(bacterial pathogens)

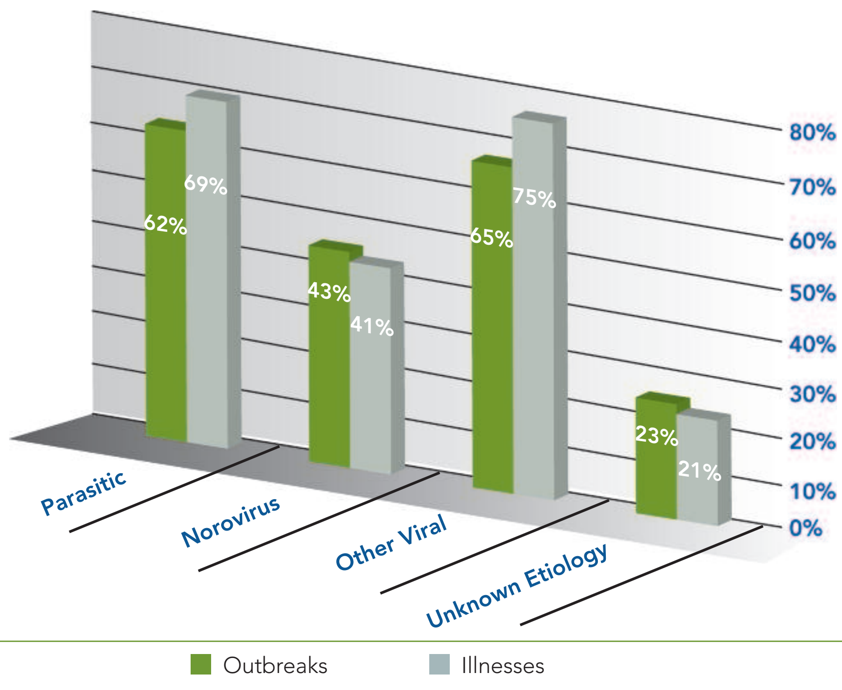


The incidence of illness from a pathogen that has contaminated a produce item varied widely across the bacterial pathogens examined. Understandably, no *Vibrio* outbreaks were associated with produce (*Vibrio* is generally found in shellfish). At the other extreme, 39% of *E. coli* outbreaks and 54% of *E. coli* illnesses were attributable to produce.

Outbreaks and illnesses attributable to non-bacterial etiologies are shown in Figure 4. Produce is a common vehicle for Norovirus, the agent most commonly found in foodborne illness outbreaks, and other viruses. Surprisingly, so are parasitic pathogens (though the small number of identified parasite outbreaks suggests that these numbers are less robust). Outbreaks in which a pathogen was not identified, but a food vehicle was, are relatively unlikely to be attributable to produce.

Figure 4

% OF OUTBREAKS AND ILLNESSES ATTRIBUTABLE TO PRODUCE
(non-bacterial etiologies)



The burden of foodborne illness attributable to produce is exhibited in Table 5. Produce (fresh, canned, and processed) accounts for roughly one quarter of all foodborne illnesses. Illnesses vary across the states due to both population variations and differences in incidence of illness. The cost per case is somewhat higher for produce-attributable illnesses ($1,961 vs. $1,851 for all products) than for illnesses caused by pathogens delivered through other vehicles. This difference is due to the relatively higher proportion of illnesses attributable to produce for high- cost etiologies (i.e. *E. coli*), opposed to low- cost etiologies (i.e. those with an unknown etiology).

Table 5

COSTS FROM PRODUCE RELATED FOODBORNE ILLNESS

State	Illnesses	Total Cost ($ millions)	Cost Per Case ($)
United States	**19,677,547**	**38,593**	**1,961**
Alabama	303,801	580	1,908
Alaska	44,219	85	1,913
Arizona	384,868	745	1,936
Arkansas	189,032	402	2,125
California	2,372,499	4,678	1,972
Colorado	309,605	585	1,890
Connecticut	234,194	497	2,121
District of Columbia	39,296	82	2,082
Delaware	55,536	104	1,869
Florida	1,201,633	2,551	2,123
Georgia	607,588	1,204	1,982
Hawaii	85,144	186	2,184
Idaho	94,242	171	1,812
Illinois	847,771	1,620	1,910
Indiana	413,126	760	1,840
Iowa	199,503	380	1,903
Kansas	182,832	330	1,806
Kentucky	275,213	483	1,756
Louisiana	298,568	578	1,935
Maine	87,586	177	2,020
Maryland	369,024	737	1,998
Massachusetts	437,321	903	2,065
Michigan	667,476	1,220	1,827
Minnesota	345,183	646	1,872
Mississippi	198,383	405	2,043
Missouri	386,039	724	1,876
Montana	62,528	114	1,828
Nebraska	116,952	224	1,912
Nevada	153,589	282	1,838
New Hampshire	86,194	176	2,036
New Jersey	572,976	1,167	2,037
New Mexico	126,914	240	1,889
New York	1,296,528	2,706	2,087
North Carolina	578,894	1,142	1,973
North Dakota	42,367	78	1,847
Ohio	762,576	1,472	1,930
Oklahoma	235,815	436	1,851
Oregon	241,280	463	1,917
Pennsylvania	828,152	1,747	2,109
Rhode Island	71,611	148	2,072
South Carolina	286,587	592	2,064
South Dakota	53,239	105	1,978
Tennessee	394,631	734	1,859
Texas	1,502,414	2,788	1,856
Utah	163,794	293	1,790
Vermont	42,267	84	1,992
Virginia	500,395	965	1,929
Washington	412,800	765	1,854
West Virginia	119,035	227	1,909
Wisconsin	377,174	753	1,997
Wyoming	33,818	60	1,766

Discussion: Why the Cost of Foodborne Illness Matters

To some, the use of economic values to characterize pain, suffering, and death is a disturbing exercise that is ethically suspect. It has been argued that food safety is a right that should not have a price tag attached to it and that the justification of spending should be based on consumer willingness to pay for safety with little regard for the relative cost-effectiveness of controls. In this section, I address each of these concerns and conclude with this economist's view of how the values presented in this report can be used in a policy context.

The Ethics of Valuing Life/Pain and Suffering

In this report, the value of a statistical life (VSL) provides the basis for evaluating the economic cost of both death and pain and suffering. The economic concept of the VSL is often misunderstood. Economists do not try to make the argument that an individual's life has an intrinsic value that we can measure. Instead, what we try to do in economics is figure out how much people are willing to pay to eliminate a risk of mortality (*not* mortality itself). Implicitly, we make these tradeoffs all the time. For example, do we want to pay $1000 more for a car with a certain safety feature? Few of us buy every safety feature available. Why? We forego certain safety features because we'd rather spend the money on something else, such as taking a vacation. More generally, we make choices between risk and utility all the time. We choose to drive to a party (a very dangerous prospect) because we think the fun from the party is worth the risk of operating a motor vehicle. For policy purposes, we try to capture society's preferences for risk using the recognition that people make choices involving risk. A simple example: If the average person requires a $700 increase in salary to accept a 1/10,000 chance of being killed on the job in any given year, the equation is: $700 = 1/10,000*Death. This implies that Death = $7 million. So, in essence, the value of statistical life is the average citizen's value for reducing a risk to life, not the intrinsic value of life.

It is obvious that there are limitations to this approach; for example, if the people who are the basis for these values have few job options, they may be willing to take a small salary increase to accept a high risk of being killed on their job, whereas people who have more job options might insist on much more money to accept that risk. Similarly, parents may be willing to pay much more to avoid a risk of death for their child than they would be to pay to reduce their own risks. From a policy perspective, however, despite these and other recognized problems with this approach, by using values- based consumer preferences, the policymaker presumably more closely aligns policy decisions with the preferences of the citizens she represents. It is of course recognized that an approach to deriving a value of statistical life that is less dependent on labor market conditions, could result in higher VSL estimates. Nevertheless, currently available alternatives are subject to greater biases than those found in VSL estimates.

Food Safety is a Right

Another argument against using economic values to inform food safety policy is that every individual has the right to be free from foodborne pathogens. Thus, if food safety is a right, economic evaluation is unnecessary and the goal should be to eliminate foodborne illness at all cost. In support of this argument, one could point to, the Federal Food Drug and Cosmetic Act of 1938 (FD&C Act), which states: "A food shall be deemed to be adulterated… [i]f it bears or contains any poisonous or deleterious substance which may render it injurious to health." Sec. 402. [21 USC §342]. Contamination of a product with harmful pathogens can lead to that product being deemed adulterated. So then, if safe food is a right, why do we still have foodborne illness? The answer is that: (1) the presence of pathogens in food is a complicated problem involving numerous, not fully understood vectors of contamination; (2) society has limited resources with which to solve the problems it faces; and (3) it has limited information on the extent, causes, and adequacy of methods available to prevent foodborne disease. Economic analysis can help us set priorities regarding which foodborne illness problems to tackle first—even as we continue to strive to achieve the ultimate goal of eliminating these illnesses.

Given that we have to make choices and set priorities, the use of economic analyses designed to reflect consumer preferences is a reasonable way to make those choices. It is recognized, however, that there are likely certain benefits of reducing foodborne illness that have not been fully characterized and monetized—for example, there likely are long-term medical impacts of infection by some pathogens that have not been characterized, and that if fully understood, would result in significantly higher estimated costs. Such costs, while not presently known or monetized, should not be dismissed, and precautionary steps may be warranted to avoid them in appropriate cases.

Conclusion

In this report, I have demonstrated that, using what I conclude is the best currently-available measure, the mean economic cost of foodborne illness is approximately $152 billion (95% CI $39-$265 billion), of which almost $39 billion can be attributed to produce. These values certainly have importance in terms of placing the problem of food safety and, specifically, the problem of produce safety in the proper perspective. This is a large problem that deserves the attention of policymakers.

This does not mean, however, that any program that costs a fraction of this value is justified by the overall magnitude of the problem. From an economic perspective, a program is worth its cost if the last dollar invested yields more than a dollar in benefits to society. We must be cautious, of course, not to overstate the precision of these cost estimates; they can be an important and valuable—but imperfect—tool available to help make decisions and set priorities on food safety. In mid-19th century London, John Snow, operating on incomplete information, removed the handle of a well in order to bring an end to a cholera epidemic. Similarly, in dealing with foodborne illness, policy makers facing imperfect information and on-going foodborne disease may well rationally decide, to take a similarly dramatic step to reduce pathogen levels in the nation's food supply. By providing more comprehensive cost-per-case values for all pathogens and specifically for produce-related illnesses, however, this report can contribute to assessments about whether current food safety proposals make sense, or what priority should be placed upon those proposals. The cost of foodborne illness is significantly greater in this report than in some past studies, but only because this study included costs of all pathogens and a more comprehensive measure of economic cost. It is my hope that the improvements made here will lead to better decision-making, both at the legislative and regulatory level.

APPENDIX A: State Rankings

As demonstrated above, the burden of foodborne illness falls unevenly across the states. The following tables provide state rankings for the number of illnesses and costs associated with these illnesses. Tables are provided for both all illnesses and those illnesses attributable to a produce vehicle.

Table A1

NUMBER OF FOODBORNE ILLNESSES

Rank	State	Illnesses
	The United States	**81,910,799**
1.	California	9,914,868
2.	Texas	6,271,730
3.	New York	5,375,122
4.	Florida	4,939,310
5.	Illinois	3,533,862
6.	Pennsylvania	3,446,085
7.	Ohio	3,181,257
8.	Michigan	2,792,153
9.	Georgia	2,516,209
10.	North Carolina	2,404,537
11.	New Jersey	2,395,361
12.	Virginia	2,084,734
13.	Massachusetts	1,808,576
14.	Indiana	1,726,560
15.	Washington	1,722,587
16.	Tennessee	1,649,454
17.	Arizona	1,609,026
18.	Missouri	1,605,538
19.	Wisconsin	1,551,417
20.	Maryland	1,541,601
21.	Minnesota	1,423,779
22.	Colorado	1,288,188
23.	Alabama	1,265,600
24.	Louisiana	1,244,347
25.	South Carolina	1,188,745
26.	Kentucky	1,149,810
27.	Oregon	1,002,404
28.	Oklahoma	983,958
29.	Connecticut	971,254
30.	Iowa	826,178
31.	Mississippi	820,890
32.	Arkansas	781,266
33.	Kansas	761,514
34.	Utah	680,497
35.	Nevada	643,769
36.	New Mexico	529,048
37.	West Virginia	499,373
38.	Nebraska	486,299
39.	Idaho	390,457
40.	Maine	363,856
41.	New Hampshire	359,750
42.	Hawaii	353,274
43.	Rhode Island	297,778
44.	Montana	259,305
45.	Delaware	231,396
46.	South Dakota	218,910
47.	Alaska	183,880
48.	North Dakota	176,566
49.	Vermont	173,536
50.	District of Columbia	162,317
51.	Wyoming	140,718

Notes:

1. For illnesses from pathogens not reported to CDC, the numbers above only reflect population trends, not trends in the incidence of foodborne illness.
2. For illnesses from pathogens reported to CDC, the number of illnesses for each pathogen is the product of the CDC report and the Mead et al. (1999) underreporting multiplier .
3. The total number of illnesses reported here differs from the number reported by Mead et al. (1999). Adjustments were made based on changes in incidence of illness or, where such data does was not available, based on changes in state populations. See Appendix B for more detail.

Table A2

NUMBER OF PRODUCE-RELATED FOODBORNE ILLNESSES

Rank	State	Illnesses
	The United States	**19,677,547**
1.	California	2,372,499
2.	Texas	1,502,414
3.	New York	1,296,528
4.	Florida	1,201,633
5.	Illinois	847,771
6.	Pennsylvania	828,152
7.	Ohio	762,576
8.	Michigan	667,476
9.	Georgia	607,588
10.	North Carolina	578,894
11.	New Jersey	572,976
12.	Virginia	500,395
13.	Massachusetts	437,321
14.	Indiana	413,126
15.	Washington	412,800
16.	Tennessee	394,631
17.	Missouri	386,039
18.	Arizona	384,868
19.	Wisconsin	377,174
20.	Maryland	369,024
21.	Minnesota	345,183
22.	Colorado	309,605
23.	Alabama	303,801
24.	Louisiana	298,568
25.	South Carolina	286,587
26.	Kentucky	275,213
27.	Oregon	241,280
28.	Oklahoma	235,815
29.	Connecticut	234,194
30.	Iowa	199,503
31.	Mississippi	198,383
32.	Arkansas	189,032
33.	Kansas	182,832
34.	Utah	163,794
35.	Nevada	153,589
36.	New Mexico	126,914
37.	West Virginia	119,035
38.	Nebraska	116,952
39.	Idaho	94,242
40.	Maine	87,586
41.	New Hampshire	86,194
42.	Hawaii	85,144
43.	Rhode Island	71,611
44.	Montana	62,528
45.	Delaware	55,536
46.	South Dakota	53,239
47.	Alaska	44,219
48.	North Dakota	42,367
49.	Vermont	42,267
50.	District of Columbia	39,296
51.	Wyoming	33,818

Notes:

1. Produce is defined broadly to include fresh, canned and processed produce items.
2. The number of produce-related foodborne illnesses is estimated as the product of the total number of foodborne illnesses and the proportion of illnesses in outbreaks that are associated with a produce vehicle of transmission.

Table A3

TOTAL COST OF FOODBORNE ILLNESS

Rank	State	Total Cost ($ millions)
	The United States	**152,369**
1.	California	18,613
2.	Texas	11,317
3.	New York	10,375
4.	Florida	9,799
5.	Pennsylvania	6,716
6.	Illinois	6,487
7.	Ohio	5,843
8.	Michigan	4,958
9.	Georgia	4,721
10.	New Jersey	4,595
11.	North Carolina	4,487
12.	Virginia	3,835
13.	Massachusetts	3,474
14.	Indiana	3,069
15.	Washington	3,069
16.	Tennessee	2,965
17.	Arizona	2,943
18.	Missouri	2,909
19.	Wisconsin	2,892
20.	Maryland	2,884
21.	Minnesota	2,546
22.	Colorado	2,336
23.	Alabama	2,321
24.	Louisiana	2,314
25.	South Carolina	2,302
26.	Kentucky	1,990
27.	Connecticut	1,893
28.	Oregon	1,817
29.	Oklahoma	1,767
30.	Mississippi	1,586
31.	Iowa	1,491
32.	Arkansas	1,484
33.	Kansas	1,343
34.	Utah	1,185
35.	Nevada	1,154
36.	New Mexico	963
37.	West Virginia	907
38.	Nebraska	881
39.	Hawaii	710
40.	Maine	683
41.	Idaho	682
42.	New Hampshire	681
43.	Rhode Island	571
44.	Montana	457
45.	Delaware	418
46.	South Dakota	405
47.	Alaska	336
48.	Vermont	321
49.	District of Columbia	314
50.	North Dakota	312
51.	Wyoming	245

Note:

The total cost of foodborne illness is the sum of medical costs, quality of life losses (including lost productivity), and lost life expectancy. Quality of life and lost life expectancy losses are estimated using revealed preference values for risk avoidance.

Table A4

TOTAL COST OF FOODBORNE ILLNESS BY FOOD SOURCE OF CONTAMINATION

		Cost ($ millions)	
Rank	State	Produce	Other
	The United States	**38,593**	**113,775**
1.	California	4,678	13,935
2.	Texas	2,788	8,530
3.	New York	2,706	7,669
4.	Florida	2,551	7,249
5.	Pennsylvania	1,747	4,970
6.	Illinois	1,620	4,867
7.	Ohio	1,472	4,371
8.	Michigan	1,220	3,738
9.	Georgia	1,204	3,517
10.	New Jersey	1,167	3,428
11.	North Carolina	1,142	3,344
12.	Virginia	965	2,870
13.	Massachusetts	903	2,571
14.	Washington	765	2,303
15.	Indiana	760	2,309
16.	Wisconsin	753	2,138
17.	Arizona	745	2,197
18.	Maryland	737	2,147
19.	Tennessee	734	2,232
20.	Missouri	724	2,185
21.	Minnesota	646	1,900
22.	South Carolina	592	1,711
23.	Colorado	585	1,751
24.	Alabama	580	1,742
25.	Louisiana	578	1,736
26.	Connecticut	497	1,396
27.	Kentucky	483	1,507
28.	Oregon	463	1,355
29.	Oklahoma	436	1,331
30.	Mississippi	405	1,180
31.	Arkansas	402	1,082
32.	Iowa	380	1,112
33.	Kansas	330	1,013
34.	Utah	293	892
35.	Nevada	282	872
36.	New Mexico	240	723
37.	West Virginia	227	680
38.	Nebraska	224	657
39.	Hawaii	186	524
40.	Maine	177	506
41.	New Hampshire	176	505
42.	Idaho	171	511
43.	Rhode Island	148	422
44.	Montana	114	342
45.	South Dakota	105	300
46.	Delaware	104	314
47.	Alaska	85	252
48.	Vermont	84	237
49.	District of Columbia	82	232
50.	North Dakota	78	234
51.	Wyoming	60	185

Table A5

TOTAL COST PER CASE OF FOODBORNE ILLNESS

Rank	State	Cost per Case ($)	Rank	State	Cost per Case ($)
	The United States	**1,851**			
1.	Hawaii	2,008	27.	Alaska	1,829
2.	Florida	1,984	28.	Arizona	1,829
3.	Connecticut	1,949	29.	New Mexico	1,820
4.	Pennsylvania	1,949	30.	West Virginia	1,816
5.	South Carolina	1,937	31.	Colorado	1,814
6.	District of Columbia	1,935	32.	Oregon	1,813
7.	Mississippi	1,932	33.	Missouri	1,812
8.	New York	1,930	34.	Nebraska	1,812
9.	Massachusetts	1,921	35.	Delaware	1,805
10.	New Jersey	1,918	36.	Iowa	1,805
11.	Rhode Island	1,917	37.	Texas	1,805
12.	Arkansas	1,899	38.	Tennessee	1,798
13.	New Hampshire	1,892	39.	Oklahoma	1,796
14.	California	1,877	40.	Nevada	1,793
15.	Maine	1,877	41.	Minnesota	1,789
16.	Georgia	1,876	42.	Washington	1,781
17.	Maryland	1,871	43.	Indiana	1,778
18.	North Carolina	1,866	44.	Michigan	1,776
19.	Wisconsin	1,864	45.	North Dakota	1,769
20.	Louisiana	1,859	46.	Kansas	1,764
21.	Vermont	1,850	47.	Montana	1,762
22.	South Dakota	1,850	48.	Idaho	1,747
23.	Virginia	1,840	49.	Utah	1,742
24.	Ohio	1,837	50.	Wyoming	1,738
25.	Illinois	1,836	51.	Kentucky	1,731
26.	Alabama	1,834			

Note:

The total cost per case is the sum of the cost per case of medical costs, quality of life losses (including lost productivity), and lost life expectancy. Quality of life and lost life expectancy losses are estimated using revealed preference values for risk avoidance.

Table A6

TOTAL COST PER CASE BY FOOD SOURCE OF CONTAMINATION

Rank	State	Cost per Case ($)	
		Produce	Other
	The United States	**1,961**	**1,816**
1.	Hawaii	2,184	1,953
2.	Arkansas	2,125	1,827
3.	Florida	2,123	1,939
4.	Connecticut	2,121	1,895
5.	Pennsylvania	2,109	1,898
6.	New York	2,087	1,880
7.	District of Columbia	2,082	1,888
8.	Rhode Island	2,072	1,867
9.	Massachusetts	2,065	1,875
10.	South Carolina	2,064	1,896
11.	Mississippi	2,043	1,896
12.	New Jersey	2,037	1,881
13.	New Hampshire	2,036	1,847
14.	Maine	2,020	1,832
15.	Maryland	1,998	1,831
16.	Wisconsin	1,997	1,821
17.	Vermont	1,992	1,805
18.	Georgia	1,982	1,843
19.	South Dakota	1,978	1,808
20.	North Carolina	1,973	1,832
21.	California	1,972	1,848
22.	Arizona	1,936	1,795
23.	Louisiana	1,935	1,836
24.	Ohio	1,930	1,807
25.	Virginia	1,929	1,812
26.	Oregon	1,917	1,780
27.	Alaska	1,913	1,803
28.	Nebraska	1,912	1,780
29.	Illinois	1,910	1,812
30.	West Virginia	1,909	1,787
31.	Alabama	1,908	1,811
32.	Iowa	1,903	1,774
33.	Colorado	1,890	1,790
34.	New Mexico	1,889	1,798
35.	Missouri	1,876	1,792
36.	Minnesota	1,872	1,762
37.	Delaware	1,869	1,785
38.	Tennessee	1,859	1,778
39.	Texas	1,856	1,788
40.	Washington	1,854	1,758
41.	Oklahoma	1,851	1,779
42.	North Dakota	1,847	1,745
43.	Indiana	1,840	1,758
44.	Nevada	1,838	1,779
45.	Montana	1,828	1,741
46.	Michigan	1,827	1,759
47.	Idaho	1,812	1,726
48.	Kansas	1,806	1,751
49.	Utah	1,790	1,727
50.	Wyoming	1,766	1,729
51.	Kentucky	1,756	1,723

Note:

The total cost per case is the sum of the cost per case of medical costs, quality of life losses (including lost productivity), and lost life expectancy. Quality of life and lost life expectancy losses are estimated using revealed preference values for risk avoidance.

Table A7

MEDICAL COSTS PER CASE OF FOODBORNE ILLNESS

Rank	State	Cost per Case ($)
	The United States	**112**
1.	New Jersey	162
2.	Hawaii	152
3.	California	150
4.	Florida	147
5.	Nevada	139
6.	District of Columbia	138
7.	Pennsylvania	134
8.	Illinois	130
9.	Arizona	126
10.	Missouri	125
11.	Alaska	123
12.	New York	122
13.	Connecticut	122
14.	Texas	120
15.	Louisiana	120
16.	South Carolina	120
17.	Ohio	118
18.	Colorado	117
19.	Massachusetts	116
20.	Michigan	114
21.	Mississippi	113
22.	Rhode Island	113
23.	New Mexico	111
24.	Alabama	110
25.	Georgia	108
26.	Virginia	106
27.	Delaware	106
28.	New Hampshire	105
29.	Kansas	104
30.	Oklahoma	104
31.	Tennessee	103
32.	Wisconsin	101
33.	Maine	101
34.	Arkansas	100
35.	Minnesota	100
36.	Indiana	97
37.	Nebraska	97
38.	North Carolina	97
39.	Kentucky	97
40.	Oregon	96
41.	Washington	96
42.	Wyoming	96
43.	Utah	96
44.	Vermont	89
45.	West Virginia	87
46.	Iowa	87
47.	South Dakota	84
48.	Maryland	82
49.	Idaho	81
50.	North Dakota	81
51.	Montana	78

Note:

Medical cost losses are based on state-specific costs for hospitalization, drugs, and physician visits.

Table A8

MEDICAL COST PER CASE BY FOOD SOURCE OF CONTAMINATION

		Cost per Case ($)	
Rank	State	Produce	Other
	The United States	**128**	**107**
1.	New Jersey	175	159
2.	Hawaii	166	147
3.	California	160	147
4.	Florida	156	144
5.	District of Columbia	148	135
6.	Pennsylvania	146	131
7.	Nevada	146	137
8.	Illinois	136	127
9.	Arizona	135	123
10.	New York	132	119
11.	Connecticut	132	118
12.	Missouri	131	123
13.	Alaska	129	121
14.	South Carolina	128	118
15.	Louisiana	126	118
16.	Texas	126	119
17.	Ohio	125	115
18.	Massachusetts	124	113
19.	Colorado	124	115
20.	Rhode Island	122	110
21.	Michigan	120	113
22.	Mississippi	120	111
23.	New Mexico	116	109
24.	Alabama	116	108
25.	New Hampshire	114	103
26.	Georgia	114	106
27.	Virginia	112	104
28.	Delaware	111	104
29.	Arkansas	110	96
30.	Maine	109	99
31.	Oklahoma	109	103
32.	Wisconsin	109	99
33.	Kansas	109	103
34.	Tennessee	109	102
35.	Minnesota	105	98
36.	Nebraska	104	95
37.	Oregon	103	94
38.	North Carolina	103	95
39.	Indiana	102	96
40.	Washington	102	94
41.	Kentucky	100	96
42.	Utah	100	95
43.	Wyoming	99	95
44.	Vermont	95	87
45.	Iowa	93	85
46.	West Virginia	92	86
47.	South Dakota	90	83
48.	Maryland	87	80
49.	North Dakota	86	80
50.	Idaho	86	80
51.	Montana	82	77

Note:

Medical cost losses are based on state-specific costs for hospitalization, drugs, and physician visits.

Table A9

COST PER CAPITA OF FOODBORNE ILLNESS

State	Population	Cost ($ million)	Cost per Capita ($)
The United States	**301,621,157**	**152369**	**505**
Alabama	4,627,851	2,321	502
Alaska	683,478	336	492
Arizona	6,338,755	2,943	464
Arkansas	2,834,797	1,484	523
California	36,553,215	18,613	509
Colorado	4,861,515	2,336	481
Connecticut	3,502,309	1,893	541
D.C.	588,292	314	534
Delaware	864,764	418	483
Florida	18,251,243	9,799	537
Georgia	9,544,750	4,721	495
Hawaii	1,283,388	710	553
Idaho	1,499,402	682	455
Ilinois	12,852,548	6,487	505
Indiana	6,345,289	3,069	484
Iowa	2,988,046	1,491	499
Kansas	2,775,997	1,343	484
Kentucky	4,241,474	1,990	469
Louisiana	4,293,204	2,314	539
Maine	1,317,207	683	518
Maryland	5,618,344	2,884	513
Massachusetts	6,449,755	3,474	539
Michigan	10,071,822	4,958	492
Minnesota	5,197,621	2,546	490
Mississippi	2,918,785	1,586	543
Missouri	5,878,415	2,909	495
Montana	957,861	457	477
Nebraska	1,774,571	881	496
Nevada	2,565,382	1,154	450
New Hampshire	1,315,828	681	517
New Jersey	8,685,920	4,595	529
New Mexico	1,969,915	963	489
New York	19,297,729	10,375	538
North Carolina	9,061,032	4,487	495
North Dakota	639,715	312	488
Ohio	11,466,917	5,843	510
Oklahoma	3,617,316	1,767	489
Oregon	3,747,455	1,817	485
Pennsylvania	12,432,792	6,716	540
Rhode Island	1,057,832	571	540
South Carolina	4,407,709	2,302	522
South Dakota	796,214	405	509
Tennessee	6,156,719	2,965	482
Texas	23,904,380	11,317	473
Utah	2,645,330	1,185	448
Vermont	621,254	321	517
Virginia	7,712,091	3,835	497
Washington	6,468,424	3,069	474
West Virginia	1,812,035	907	501
Wisconsin	5,601,640	2,892	516
Wyoming	522,830	245	468

APPENDIX B: Methodology Used to Estimate Costs

Total Health-Related Cost from Foodborne Illness

The health-related cost of foodborne illness for the United States is calculated in a bottom-up manner. First, for each state (s), the total cost of an illness caused by a particular pathogen (p) is estimated to be the product of the number of cases attributed to that pathogen in that state ($Cases_{ps}$) and the cost per illness from that pathogen in that state ($Cost_{ps}$). Next, for a given state, the cost of illness is summed across all 28 pathogen categories examined (including the category of unknown pathogens). Finally, the cost is summed across the 50 states and the District of Columbia to estimate a total cost of foodborne illness for the United States. Mathematically, this is calculated as follows:

$$\text{Health Related Cost} = \sum_{s=1}^{51} \sum_{p=1}^{28} Cases_{ps} \times Cost_{ps}$$

Cases

The number of cases of pathogen p in a given state is estimated in two ways, depending on availability of data.

A number of foodborne pathogens are classified as notifiable diseases. Where the CDC has collected data on the pathogen through its National Notifiable Diseases Surveillance System (NNDSS) [13], I use the CDC number (CDC_{ps}) modified by an underreporting factor (UR_p) and adjusted to reflect the fact that not all illnesses from specified pathogens are due to infection through a foodborne vector ($\%Foodborne_p$) [1]. Illnesses are required to be reported to the CDC if they are caused by *Brucella*, *E. coli*, *Listeria*, *Salmonella*, *Shigella*, *Cryptosporidium*, *Cyclospora*, *Giardia*, and Hepatitis A. The number of illnesses from these pathogens are calculated as:

$$Cases_{ps} = CDC_{ps} \times UR_p \times \%Foodborne_p$$

The number of illnesses caused by other pathogens is the product of the number of illnesses estimated by Mead et. al. (1999) ($Mead_i$), adjusted to account for the proportion of the U.S. population in the state in question (State_Adj) and updated to account for the increase in the U.S. population since 1997 (Pop_Adj) [1, 14].

$$Cases_{ps} = Mead_p \times State\_Adj_s \times Pop\_Adj$$

The total number of cases of foodborne illness estimated to have occurred in 2009 is 81.9 million. More current CDC estimates of the number of cases of foodborne illness in the United States are expected to be released shortly. When this occurs, the numbers in this analysis will have to be updated to reflect the most up-to-date estimates.

Cost

Estimation of the cost of foodborne illness is more involved. $Cost_{ps}$ is estimated to be the sum of medical costs (doctor visits, lab costs, drugs, and hospitalization) and losses to quality of life (lost life expectancy, lost utility from pain and suffering, and lost productivity from missing work due to illness) [7].

$$Cost_{ps} = Medical_{ps} + Lost\_Quality_{ps}$$

Sequelae

Adding to the complexity of the model is the fact that many pathogens result in both acute diarrheal illnesses and sequelae that manifest themselves as chronic or acute conditions distinct from the original diarrheal illness. Where identified, the cost of these sequelae are estimated and categorized based on type of cost and are included in the cost per case figures for the pathogens they are associated with. Costs are estimated for sequelae from *Campylobacter* (Guillain-Barré syndrome, reactive arthritis (RA)), *E. coli* (hemolytic uremic syndrome with or without end-stage renal disease), *Listeria* (harm to newborns from infected mothers), *Salmonella* (RA), *Shigella* (RA), and *Yersinia* (RA). Costs from Guillain-Barré syndrome are a function of the probability of having the sequelae, hospital costs, physician costs, and disability losses updated to reflect current medical costs [15-18]. Costs from hemolytic uremic syndrome (HUS) are based on the Frenzen et. al. (2005) economic cost study of HUS and include medical costs, the cost of premature mortality and productivity losses [18, 19]. Costs of sequelae from infection with *Listeria* are drawn from the Buzby et al. (1996) study (updated to reflect current costs) and includes the cost of disabilities in newborns and the productivity losses for their parents [12, 18]. Both Guillain-Barré and *Listeria* costs are underestimates of the true costs because they do not include pain and suffering costs. Finally, reactive arthritis costs are estimated to be the sum of medical costs and monetized QALY losses (productivity losses in the USDA model) [17]. QALY losses are based on duration of illness and proportion of days in which symptoms are present [17, 20]. The costs assessed may be a lower bound estimate because duration is capped at six months due to a paucity of research on the long-term effects of reactive arthritis.

As Table C1 demonstrates, costs resulting from sequelae constitute a significant portion of costs associated with a number of pathogens and represent a nontrivial portion of the overall cost of foodborne illness.

Table C1

COST OF CHRONIC SEQUELAE[a]

Pathogen Sequelae	Cost Per Case ($)	% of Total Cost for Pathogen	Total Social Cost ($ million)
Campylobacter			
Guillain-Barré	2,165	24.3	4,573
Reactive Arthritis[b]	3,742	42.0	7,904
E. coli			
Hemolytic Uremic Syndrome	6,224	41.9	627
Listeria	41,440	2.4	111
Harm to Newborns			
Salmonella			5,403
Reactive Arthritis[b]	3,742	40.9	
Shigella			361
Reactive Arthritis[b]	3,742	52.8	
Yersinia			349
Reactive Arthritis[b]	3,742	51.8	
Total Cost (all pathogens)		**12.7**	**19,328**

[a] Estimates based on estimates using QALY losses.
[b] Reactive arthritis values are very conservative. They do not include arthritis symptoms that persist more than 25 weeks past the resolution of the acute foodborne illness because reliable data on these chronic conditions are lacking.

Medical Costs

Medical Costs for physician services, pharmaceuticals and hospital costs are calculated separately.

$$\text{Medical}_{ps} = \text{Physician}_{ps} + \text{Pharma}_{p} + \text{Hospital}_{ps}$$

Physician services include the cost of both outpatient and inpatient costs for physician services, as well as the cost of lab work to analyze stool samples (when such samples are collected from) [7, 21-23]. Physician costs are modified for each state by a cost of practice index (developed by Medicare to allow doctors in different areas to charge rates based on local market conditions) [22]. Between 12.7% and 92.2% of persons afflicted with an illness see a physician, depending on the pathogen implicated in the illness [1, 7, 21].

Pharmaceutical costs are not state-specific, but are differentiated based on whether the person with an illness saw a physician or was hospitalized [7, 18, 24, 25].

Hospital costs are determined based on the average charges reported by hospitals for admissions with relevant ICD-9 condition codes (as reported in AHRQ's Healthcare Cost & Utilization Project database) [26]. These costs do not include physician services in hospitals. Hospitalization rates are taken from Mead et al. (1999)[1]. Costs are modified to account for state differences in hospitalization costs [27].

Lost Quality of Life

Different methods of estimating quality of life losses due to injury and illness have been developed. Two methods representing the approaches of the U.S. Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA) are presented for comparison. The USDA approach is more conservative and, by their own admission, does not account for pain and suffering losses attributable to illnesses [12].

Both the USDA and the FDA employ a measure to account for losses due to reduced life expectancy. The value of statistical life (VSL) measure used by both is based on hedonic wage studies that suggest workers must be paid a premium to engage in work associated with a higher risk of death. A meta-analysis of a number of such studies in 2003 yielded an average VSL of $6.7 million [11]. Updated to account for inflation, the value in 2009 is $7.9 million [18]. This value is applied to deaths resulting from foodborne illness. State differences in VSL measures are not available at this point.

The USDA Approach

To account for other quality of life losses, the USDA measures productivity losses based on the number of days of work lost due to illness and the forgone compensation resulting from such absences. This study improves on the USDA approach by adjusting for state differences in employment cost and employment rates [7, 28]. Additionally, when children are ill, caregivers who work are also assumed to have productivity losses. Approximately 58% of families will have one parent take off work to be a caregiver when their child is ill [29]. The inclusion of productivity losses due to illnesses affecting children leads to an increase in the productivity loss estimate by almost 50%.

The USDA-inspired formula for lost quality of life is:

$$\text{Lost\_Quality}_{ps} = \text{VSL}_{p} + \text{Prod\_Loss}_{ps}$$

The FDA Approach

The FDA approach employs a more inclusive quality of life loss measure. FDA starts with quality adjusted life year (QALY) measures that are widely used in cost –effectiveness research. For example, using state-of-the-art EQ-5D measures for QALY losses suggests that an individual with a case of foodborne illness that does not require hospitalization will experience utility losses of 47.3% over the period that person is ill [7]. This measure accounts for pain, suffering, and functional disability. The discounted value of a day lost (VSLD) can easily be derived from VSL numbers and is estimated to be $956 [11, 18]. This means that a mild illness that lasts for one day will result in $452 in utility losses. Productivity losses are not included in this approach since functional disability is already accounted for.

In sum, the FDA approach can be illustrated as:

$$\text{Lost\_Quality}_{ps} = \text{VSL}_p + \text{QUALD}_p \times \text{VSLD}$$

As the above equation suggests, the QALY approach does not allow for state differences in lost quality of life.

Produce-Related Costs from Foodborne Illness

The burden of foodborne illness for produce is also presented above. If the percent of pathogen p and state s pathogens attributable to produce is $\text{Prod\%}_{ps}$, the total number of foodborne illnesses associated with produce is:

$$\text{Produce Illnesses} = \sum_{s=1}^{51} \sum_{p=1}^{28} \text{Cases}_{ps} \times \text{Prod\%}_p$$

$\text{Prod\%}_p$ is based on 2003-2007 data from the CDC's Foodborne Disease Outbreak Surveillance System [2]. First, outbreaks with no associated food product are dropped. Next, outbreaks with a produce product (fresh, canned, or processed) are identified and illnesses are divided evenly between each of the listed food vehicles. The number of illnesses attributable to produce products was estimated separately for nine specific pathogens and four pathogen categories. For each category, this number is divided by the total number of illnesses attributable to outbreaks in that category, yielding $\text{Prod\%}_p$. Too few outbreaks were identified to reliably estimate state-specific values for the proportion of illnesses attributable to produce.

The total cost of produce-related illnesses is simply the product of the number of produce illnesses and the cost per case, summed across states and pathogens.

$$\text{Produce Related Cost} = \sum_{s=1}^{51} \sum_{p=1}^{28} \text{Cases}_{ps} \times \text{Prod\%}_p \times \text{Cost}_{ps}$$

Although I assume that pathogen-specific costs associated with each case of foodborne illness do not vary by food type, the average cost per case of foodborne illness will be affected by any change in the distribution of illnesses across pathogen type.

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References

1. Mead, P.S., et al., *Food-Related Illness and Death in the United States.* Emerging Infectious Diseases, 1999. 5(5): p. 607-625.
2. Centers for Disease Control and Prevention. *Outbreak Surveillance Data.* 2009 [cited May 5, 2009]; Available from: http://www.cdc.gov/foodborneoutbreaks/outbreak_data.htm.
3. Centers for Disease Control and Prevention. *FoodNet Reports.* 2009 [cited May 5, 2009]; Available from: http://www.cdc.gov/FoodNet/reports.htm.
4. Buzby, J.C. and T. Roberts, *The Economics of Enteric Infections: Human Foodborne Disease Costs.* Gastroenterology, 2009. 136: p. 1851-1862.
5. Roberts, T., et al., *The Long-Term Health Outcomes of Selected Foodborne Pathogens.* 2009, Center for Foodborne Illness Research and Prevention. p. 28.
6. General Accounting Office, *Food Safety: Overview of Federal and State Expenditures.* 2001.
7. Scharff, R.L., J. McDowell, and L. Medeiros, *The Economic Cost of Foodborne Illness in Ohio.* Journal of Food Protection, 2009. 72(1): p. 128-136.
8. Fox, J.A., et al., *Experimental auctions to measure willingness to pay for food safety, in Valuing Food Safety and Nutrition*, J.A. Caswell, Editor. 1995, Westview Press: Boulder.
9. Hammitt, J.K. and K. Haninger, *Willingness to Pay for Food Safety: Sensitivity to Duration and Severity of Illness.* American Journal of Agricultural Economics, 2007. 89(5): p. 1170-1175.
10. Roberts, T., *WTP Estimates of the Societal Costs of U.S. Food-Borne Illness.* American Journal of Agricultural Economics, 2007. 89(5): p. 1183-1188.
11. Viscusi, W.K. and J.E. Aldy, *The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World.* Journal of Risk and Uncertainty, 2004. 27(1): p. 5-76.
12. Buzby, J.C., et al., *Bacterial Foodborne Disease: Medical Costs and Productivity Losses*, U. S. Department of Agriculture, Editor. 1996, Economic Research Service. p. 100.
13. Centers for Disease Control and Prevention, *National Notifiable Diseases Surveillance System.* 2009.
14. Census Bureau, *Statistical Abstract of the United States: 2009* 2009.
15. Allos, B.M. and M.J. Blaser, *Campylobacter jejuni and the expanding spectrum of related infections.* Clinical Infectious Diseases, 1995. 20: p. 1092-1099.
16. Frenzen, P., *Economic cost of Guillain-Barré syndrome in the United States.* Neurology, 2008. 71(1): p. 21-27.
17. Havelaar, A.H., *Health Burden in the Netherlands due to infection with thermophilic Campylobacter spp.* Epidemiology and Infection, 2000. 125(3): p. 505-522.
18. Bureau of Labor Statistics, *Consumer Price Index - All Urban Consumers.* 2009.
19. Frenzen, P.D., A. Drake, and F.J. Angulo, *Economic Cost of Illness Due to Escherichia coli O 157 Infections in the United States.* Journal of Food Protection, 2005. 68(12): p. 2623-2630.
20. Townes, J.M., et al., *Reactive arthritis following culture-confirmed infections with bacterial enteric pathogens in Minnesota and Oregon: a population-based study*. Annals of the Rheumatic Diseases, 2008. 67(12): p. 1689-1696.
21. Hawkins, M., et al., *The Burden of Diarrheal Illness in FoodNet, 2000-2001,* in Conference on Emerging Infectious Diseases. 2002: Atlanta, GA.
22. Practice Management Information Corporation, *Medical Fees in the United States.* 2009, Los Angeles: PMIC.
23. American Medical Association, *Outpatient Services CPT.* 2007, Chicago, IL: American Medical Association.
24. Cohen, M.L., et al., *An Assessment of Patient-Related Economic Costs in an Outbreak of Salmonellosis.* New England Journal of Medicine, 1978. 299(9): p. 459-460.
25. Frenzen, P., *Foodborne Illness Cost Calculator: STEC O157.* 2007, Economic Research Service.
26. Agency for Healthcare Research and Quality, *Healthcare Cost and Utilization Project.* 2009.
27. Hay, J., *Hospital Cost Drivers: An Evaluation of State-Level Data.* 2002, University of Southern California: Los Angeles. p. 41.
28. Bureau of Labor Statistics, *Employer Costs for Employee Compensation.* 2009.
29. Department of Health and Human Services. *Family, Work and Child Care.* 2002 [cited 2009; Available from: http://aspe.hhs.gov/hsp/connections-charts04/ch3.htm