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State Estimates for the Annual Cost of Foodborne Illness

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ABSTRACT

An understanding of the costs associated with foodborne illnesses is important to policy makers for prioritizing resources and assessing whether proposed interventions improve social welfare. At the national level, measured costs have been used by federal food safety regulatory agencies in regulatory impact analyses. However, when costs differ across states, use of national cost-of-illness values for state-based interventions will lead to biased estimates of intervention effectiveness. In this study, the costs of foodborne illness at the state level were estimated. Using a more conservative economic model, the average cost per case ranged from $888 (90% credible interval [CI], $537 to $1,419) in West Virginia to $1,766 (90% CI, $1,231 to $2,588) in the District of Columbia. A less conservative model generated average costs per case of $1,505 (90% CI, $557 to $2,836) in Kentucky to $2,591 (90% CI, $857 to $5,134) in Maryland. Aggregated across the states, the average national cost of foodborne illness was estimated as $55.5 billion (90% CI, $33.9 to $83.3 billion) using the conservative model and $93.2 billion (90% CI, $33.0 to $176.3 billion) using the enhanced model.

Despite major improvements to the system that ensures the integrity of our foods, foodborne illness continues to be a problem in the United States. The Centers for Disease Control and Prevention (CDC) found that there are approximately 48 million new cases of food-related illness each year, resulting in 128,000 hospitalizations and 3,000 deaths *(12, 13)*. The average case of foodborne illness has been conservatively estimated to cost $1,068, leading to an overall annual economic burden of $51.0 billion *(14)*. Cost-of-illness estimates have been useful for expressing the scope of the problem and evaluating the effectiveness of specific interventions *(7, 15)*. Although these interventions are implemented at both the national and state levels, cost-of-illness research to this point has largely focused on costs at the national level *(1, 4, 9, 14)*. However, when costs differ across states, use of national cost-of-illness values for state-based interventions will lead to biased estimates of intervention effectiveness.

Variation in cost-of-illness estimates across states. Cost-of-illness estimates are expected to differ across states for various reasons, including differences in the incidence of illness, differences in medical and productivity costs, and differences in welfare losses caused by death and lost quality of life. To the extent that existing data can be used to capture these differences, state-specific costs associated with foodborne illness can be estimated.

One source of variation in costs across states is incidence of illness: (i) the safety of local food supplies may differ, (ii) the proportion of the population vulnerable to foodborne illness (due to age or immunocompromised status) may differ, and (iii) people may consume more risky foods in some states than in others. Batz et al. *(2)* found that more than 97% of *Vibrio vulnificus* infection cases were linked to seafood. Thus, high seafood consumption increases the incidence of illness from *Vibrio* infection. Given that both Scharff *(14)* and Batz et al. *(1)* estimated that *Vibrio* is the most costly pathogen ($2.8 and $3.0 million, respectively), people who live in states with high levels of seafood consumption would be expected to face increased per capita costs due to foodborne illness associated with this pathogen.

Disparities in medical and productivity costs may also be a source of differences in state costs. Market conditions and regulatory regimes have an effect on cost of medical care for persons made ill by foodborne pathogens. Hay *(8)* found that hospital costs can vary significantly, e.g., costs in New Jersey were more than twice those in Maryland. Productivity losses from missed work due to illness depend on both the average cost of compensation and the likelihood that the ill person (or their caregiver) is employed. Thus, both cost of compensation and employment participation rates are important variables that affect costs.

Welfare losses due to death or lost quality of life also are potentially important sources of differences in state costs. These losses are typically assessed using a revealed preference measure for the value of statistical life (VSL), and VSL measures differ across geographic regions by income *(3)*. Given that average state household income ranges from under $37,000 in Mississippi to almost $72,000 in Maryland *(17)*, adjustments that incorporate these differences are likely to lead to sizable differences in costs associated with foodborne illness.

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Each of these factors suggests that the economic cost of foodborne illness is likely to differ across states. In this study, I compiled updated national estimates for the cost of foodborne illness as a baseline against which state cost estimates may be compared. I also estimated the cost of illness for each states. Here, I present summary statistics for these estimates. An on-line appendix provides detailed pathogen-specific estimates for each of the states.

MATERIALS AND METHODS

The basic method used to establish values for foodborne illness at the state level follows the approach I used previously *(14)*. Specifically, I replicated the Scallan et al. *(12, 13)* study to establish national estimates for the incidence of foodborne illness across pathogen categories. I then combined these values with cost-of-illness values as I described previously *(14)*. The result is a set of estimates for the cost of foodborne illness at the national level, similar to those I previously reported *(14)* but updated with more recent data. To convert national estimates to state estimates, I employed a wide array of adjustment factors to account for differences in both incidence and cost of illness across states.

Incorporation of uncertainty. Many of the variables employed in my models and in those of Scallan et al. *(12–14)* are estimated with a large degree of uncertainty. To incorporate this uncertainty into the model, I used Monte Carlo simulation modeling (100,000 iterations) in @Risk version 5.7 (Palisade Corp., Ithaca, NY). To replicate the Scallan et al. estimates for incidence of illness, I used the distributions and raw data contained in the technical appendices made available on the CDC website. I incorporated uncertainty associated with economic cost variables as described in the on-line appendix to my previous article *(14)*. Measures taken directly from my studies and those of Scallan et al. were assumed to covary across states. The results generated for cost per case (the most relevant measure for policy analysis, when combined with a measure for the policy's expected averted illnesses) are reported here with 90% credible intervals (CIs). CIs for other measures are available upon request.

Incidence of illness across states. I performed a full replication of the work of Scallan et al. *(12, 13)* to estimate baseline national incidence of illness rates for each of the 30 pathogens (plus a separate category of illnesses from unspecified origins) included in this study. I calculated state-specific incidence rates for illnesses from several pathogens (*Brucella, Cryptosporidium, Cyclospora cayetanensis, Giardia intestinalis, Listeria monocytogenes,* Shiga toxin–producing *Escherichia coli* [STEC], *Shigella,* and *Vibrio*) and diseases (salmonellosis and hepatitis A). The annual incidence of illness for pathogen *i* in state *s* (per 10,000 persons) is measured in equation 1.

$$\text{Incidence}_{is} = \frac{\left(\text{illnesses}_i \times \dfrac{\left(\sum_{y=1}^{T} \text{NNDSS}_{yis}\right)/T}{\sum_{s=1}^{50}\left[\left(\sum_{y=1}^{T} \text{NNDSS}_{yis}\right)/T\right]}\right)}{\text{Population}_{is} \div 1{,}000} \tag{1}$$

where NNDSS represents the data from the National Notifiable Disease Surveillance System *(6)* and *T* is time. For each pathogen in each state, up to 11 years of surveillance data (NNDSS_{yis}) were collected. The proportion of Scallan et al. illness estimates (illnesses_i) that are assigned to state *s* is determined by dividing the average number of illnesses in state *s* $\left(\sum_{y=1}^{T} \text{NNDSS}_{yis}\right)/T$ by the average number of illnesses in all states $\sum_{s=1}^{50}\left[\left(\sum_{y=1}^{T} \text{NNDSS}_{yis}\right)/T\right]$. The incidence rate is calculated by dividing the estimated number of illnesses (the numerator) by the population of the state (in thousands of residents). For pathogens that did not have sufficient state level surveillance data, I was not able to estimate state level incident rates. In these cases, the underlying incidence-of-illness rate for each pathogen is assumed to be fixed across states. In practice, for these pathogens the number of illnesses estimated by Scallan et al. (illnesses_i) is allocated across states proportional to each state's population.

Cost-of-illness models. Most federal agencies have used one of two cost-of-illness models to assess benefits from food safety interventions in regulatory impact analyses. Both models are limited to the health-related costs associated with foodborne illness, although other costs are associated with these illnesses, as described by the U.S. Department of Agriculture (USDA) Economic Research Service *(4)*. The first of these cost-of-illness models (the basic model) includes medical costs, lost productivity (for both ill workers and workers who must care for sick children), and lost utility (well-being) due to premature mortality. The second model (the enhanced model) adds lost utility due to pain and suffering associated with illness. A detailed description of how costs are derived was described previously *(14)*. Updates and adjustments to this model (to allow for the estimation of state-specific values) are described here.

The basic (B) model for the estimation of cost of illness is described by equation 2, and the enhanced (E) model is described by equation 3:

$$\begin{aligned}\text{BCost}_{is} = {} & \text{Hospital}_{is} + \text{Physician}_{is} + \text{Pharma}_{is} \\ & + \text{Prod}_{is} + \text{CProd}_{is} + \text{VSL}_{is} + \text{Sequel}_{is}\end{aligned} \tag{2}$$

$$\begin{aligned}\text{ECost}_{is} = {} & \text{Hospital}_{is} + \text{Physician}_{is} + \text{Pharma}_{is} \\ & + \text{CProd}_{is} + \text{QALY}_{is} + \text{VSL}_{is} + \text{Sequel}_{is}\end{aligned} \tag{3}$$

Costs associated with pathogen *i* in state *s* are a linear additive function of each of the state- and pathogen-specific cost components. Although ECost_{is} is a more complete model of economic cost because it includes a measure for pain and suffering, current methods used to monetize loss of quality-adjusted life years (QALYs) are controversial *(10)*. Nevertheless, I report ECost_{is} estimates with BCost_{is} estimates because (i) pain and suffering is a legitimate economic cost and (ii) this method continues to be used by the U.S. Food and Drug Administration *(21)* in recent regulatory analyses of food safety rules. The enhanced model does not include productivity losses for workers made ill because this value is assumed to be captured by the QALY loss estimate.

Foodborne illness may lead to substantial medical costs that differ by pathogen and state (e.g., Hospital_{is}, Physician_{is}, and Pharma_{is}). Measured hospitalization costs (Hospital_{is}) are pathogen specific *(5)* and are based on the cost for hospital services. These estimates are updated to include hospital costs reported by the Healthcare Cost and Utilization Project through 2012 *(18)* and are denominated in 2013 dollars using the hospital services consumer price index *(20)*. I used Hay's *(8)* study on differences in state level hospitalization costs as a basis for assessing differences in costs across states. Physician costs (Physician_{is}) include costs for physician services (outpatient and inpatient) and costs for tests ordered by physicians. I used the 2014 edition of *Medical Fees in the United States* from the Practice Management Information Corporation *(11)* for up-to-date estimates of physician fees and for deriving state-specific fees based on geographic adjustment factors. Pharmaceutical costs (Pharma_{is}) were updated to 2013 dollars using the prescription drug consumer price index *(20)*.

Productivity losses can also accrue as a result of foodborne illness. Costs are incurred because ill workers must take sick leave or because parents must take time away from work to care for their sick children. Although individuals may also take time away from work to act as caregivers for others, I was not able to assess how often this occurs, and as a result, these costs are not included. Measured productivity losses are critically dependent on accurate contemporary measures of compensation costs and labor force participation. I made three adjustments to productivity loss estimates in my original model *(14)* by (i) revising the average hourly cost of compensation to reflect December 2013 Bureau of Labor Statistics (BLS) *(19)* estimates, (ii) updating the measure for labor force participation using the 2013 BLS data and U.S. Census data *(16),* and (iii) using state-level estimates for cost of compensation and labor force participation to assess state-specific costs associated with foodborne illness *(19).* Expected lost work days associated with specific illnesses are unchanged from those I sued previously *(14)* and are assumed to be invariant across states.

The economic costs associated with lost consumer welfare ($QALY_{is}$ and VSL_{is}) are also important and will vary across time and states. I used the Bellavance et al. *(3)* estimate for VSL income elasticity and the 2013 U.S. Census data on income *(17)* to account for changes in income between 2010 and 2013 and to derive state-specific measures for VSL. Although I do not have estimates for QALY losses that differ across states, monetized QALY losses are expected to vary because they are based on VSL values. Thus, the adjustments for VSL figures also have an effect on state and national estimates for monetized QALY losses.

The final category of costs is costs associated with chronic sequelae of disease, including Guillian-Barré syndrome (*Campylobacter* infection), hemolytic uremic syndrome (STEC infection), listeriosis during pregnancy, and reactive arthritis (*Campylobacter, Salmonella, Shigella,* and *Yersinia* infections). The costs associated with each of these outcomes were updated to 2013 dollars using the medical care consumer price index *(20).* State costs are assumed to differ because of differences in incidence of illness, although the cost per case estimates for sequelae are invariant across states.

RESULTS

The updated cost-of-illness model generates new estimates for the economic costs associated with foodborne illness at both the state and national levels. These estimates are presented for both the basic and enhanced models. In addition to cost per case estimates, which (when combined with illness reduction expectations) are most useful for intervention effectiveness studies, I also report cost per resident and total cost estimates, which give policy makers the ability to understand the relative burden and scope of foodborne illness problems in their jurisdictions.

State differences in cost of foodborne illness. Differences in underlying costs and the incidence of illness for pathogens with higher (and lower costs) both affect the expected economic costs associated with foodborne illness. Summary aggregate measures for cost of illness at the state level are reported in Table 1. Using the more conservative basic cost-of-illness model, the cost per case of foodborne illness ranged from $888 in West Virginia to $1,766 in nearby District of Columbia. The difference between the two costs ($877) is significant (90% CI, 684 to 1,175) and is driven by distribution of illnesses and important cost determinants (especially income differences between these states). An analysis of the next highest and lowest cost states (Maryland and Mississippi) reveals a similar result.

Cost per resident and total cost burden estimates are also presented in Table 1. Although these values are less important as measures of intervention effectiveness, they are useful for policy makers who want to evaluate how their states are performing relative to other states and to correctly prioritize foodborne illness as a problem within their states. Cost per resident tracks cost per case estimates in terms of relative burden, whereas total cost is largely determined by state population (California has the highest aggregate burden, as expected).

Cost estimates using the enhanced model are reported in Table 2. As expected, estimated costs are higher in this model because of the inclusion of pain and suffering costs. Relative costs are similar to those for the basic model, although there are some differences. For example, using this method, Maryland is the highest cost state, with an average cost per case of $2,591 (90% CI, $857 to $5,134), and Kentucky is the lowest cost state, with an average cost per case of $1,505 (90% CI, $557 to $2,836).

Ultimately, the most important measure for intervention effectiveness at the state level is likely to be a pathogen-specific measure for cost per case. Tables A1 through A51 in the on-line appendix (http://hdl.handle.net/1811/65080) report pathogen-specific costs for each of the 50 U.S. states plus the District of Columbia. Estimates are reported for both the basic and enhanced models. For all states, illnesses from *V. vulnificus* infection have the highest cost per case, and illnesses from *Bacillus cereus* infection have the lowest cost per case, although estimated costs differ (e.g., for *B. cereus* infections, cost per case ranges from $132 in Mississippi to $294 in the District of Columbia).

Some differences in cost per resident (a potentially useful measure for prioritization of efforts) were found among states. For example, in Connecticut the cost per resident from *Listeria* infection ($18.05) was higher than that from *Salmonella* infection ($15.55), whereas in Arkansas the cost from *Listeria* infection ($2.86) was lower than that from *Salmonella* infection ($22.51). The 10 states with the highest and lowest costs per resident are identified for four pathogens in Table 3. The patterns that emerged were expected. For example, for *Vibrio* infection each of the states with the highest cost per resident is a coastal state and the lowest cost states are generally inland, reflecting lower consumption of potentially contaminated seafood. Similarly, costs associated with STEC O157:H7 infection are highest in high beef consumption states, and costs associated with *Salmonella* infection are higher in warmer southern states where contamination with high levels of these bacteria at picnics is a potential risk factor.

Updated national estimates. My 2012 study *(14)* included estimated costs based on 2010 data. Since that time, the national economy has improved, prices and incomes have risen, and more people are working. As a result of these factors, updated estimates based on 2013 data are higher than previous estimates. Table 4 lists national

TABLE 1. *Cost of illness for all U.S. states, basic model, 2013*

State	Cost (US$) Per case Mean	Per case 90% CI	Per resident	Total cost (US$ million)
Alabama	969	(609–1,517)	147	712
Alaska	1,292	(828–2,002)	193	142
Arizona	1,039	(663–1,608)	157	1,037
Arkansas	918	(575–1,443)	141	418
California	1,279	(818–1,986)	192	7,355
Colorado	1,266	(808–1,965)	190	1,003
Connecticut	1,462	(891–2,345)	220	793
Delaware	1,161	(748–1,787)	176	163
DC	1,766	(1,231–2,588)	266	172
Florida	1,109	(696–1,741)	171	3,341
Georgia	1,092	(686–1,713)	167	1,666
Hawaii	1,325	(779–2,152)	203	285
Idaho	999	(618–1,576)	152	245
Illinois	1,169	(756–1,802)	176	2,266
Indiana	983	(627–1,524)	147	968
Iowa	1,154	(718–1,818)	176	545
Kansas	1,089	(693–1,691)	164	476
Kentucky	906	(589–1,386)	136	598
Louisiana	960	(618–1,483)	147	679
Maine	1,116	(707–1,742)	168	223
Maryland	1,476	(876–2,389)	223	1,321
Massachusetts	1,472	(922–2,323)	223	1,494
Michigan	1,057	(669–1,647)	158	1,563
Minnesota	1,316	(833–2,053)	200	1,082
Mississippi	889	(554–1,408)	138	413
Missouri	1,095	(699–1,698)	166	1,004
Montana	977	(629–1,503)	147	150
Nebraska	1,165	(733–1,821)	177	331
Nevada	1,014	(660–1,553)	151	421
New Hampshire	1,403	(845–2,258)	211	280
New Jersey	1,446	(885–2,311)	217	1,934
New Mexico	976	(618–1,519)	148	308
New York	1,233	(819–1,873)	186	3,652
North Carolina	990	(641–1,523)	150	1,477
North Dakota	1,186	(752–1,846)	178	129
Ohio	1,039	(681–1,584)	156	1,807
Oklahoma	1,028	(640–1,618)	156	601
Oregon	1,129	(709–1,766)	170	668
Pennsylvania	1,190	(747–1,872)	179	2,289
Rhode Island	1,269	(794–2,001)	191	201
South Carolina	1,006	(621–1,596)	154	734
South Dakota	1,083	(669–1,712)	167	141
Tennessee	954	(611–1,473)	144	933
Texas	1,118	(709–1,741)	169	4,469
Utah	1,131	(695–1,794)	171	495
Vermont	1,252	(795–1,949)	190	119
Virginia	1,345	(828–2,132)	203	1,674
Washington	1,318	(811–2,087)	198	1,381
West Virginia	888	(537–1,419)	133	246
Wisconsin	1,177	(739–1,844)	180	1,032
Wyoming	1,208	(752–1,903)	182	106
United States	1,149	(730–1,787)	174	54,902

costs for both economic models. Using the more conservative basic model, the average cost per case of foodborne illness in the United States is now $1,149, and total costs are now $54.9 billion (compared with $1,068 and $51.0 billion, respectively, in 2010). Similarly, for the enhanced cost model, the cost per case is now $1,925, and the total cost is now $92.0 billion (compared with $1,626 and $77.7 billion, respectively, in 2010).

TABLE 2. *Cost of illness for all U.S. states, enhanced model, 2013*

State	Cost (US$)			
	Per case			
	Mean	90% CI	Per resident	Total (US$ million)
Alabama	1,706	(604–3,283)	259	1,253
Alaska	2,171	(782–4,188)	324	238
Arizona	1,765	(642–3,366)	266	1,762
Arkansas	1,650	(576–3,196)	254	752
California	2,096	(772–4,010)	314	12,053
Colorado	2,064	(752–3,952)	311	1,636
Connecticut	2,381	(838–4,627)	359	1,291
DC	2,530	(1,020–4,738)	381	246
Delaware	1,897	(695–3,617)	287	266
Florida	1,963	(694–3,814)	302	5,915
Georgia	1,921	(672–3,730)	293	2,928
Hawaii	2,289	(784–4,476)	351	492
Idaho	1,689	(595–3,230)	257	414
Illinois	1,929	(709–3,685)	290	3,739
Indiana	1,638	(594–3,112)	245	1,611
Iowa	1,972	(689–3,811)	301	931
Kansas	1,841	(661–3,526)	278	805
Kentucky	1,505	(557–2,836)	226	994
Louisiana	1,643	(599–3,131)	251	1,161
Maine	1,795	(655–3,411)	270	359
Maryland	2,591	(857–5,134)	391	2,320
Massachusetts	2,441	(863–4,756)	370	2,477
Michigan	1,753	(635–3,341)	262	2,593
Minnesota	2,210	(783–4,272)	335	1,817
Mississippi	1,648	(571–3,212)	256	766
Missouri	1,866	(674–3,571)	283	1,710
Montana	1,625	(588–3,084)	245	249
Nebraska	1,940	(693–3,720)	295	552
Nevada	1,657	(624–3,120)	247	689
New Hampshire	2,408	(820–4,723)	363	480
New Jersey	2,443	(861–4,754)	367	3,267
New Mexico	1,667	(600–3,179)	253	527
New York	1,880	(727–3,531)	283	5,569
North Carolina	1,642	(601–3,121)	249	2,449
North Dakota	1,954	(698–3,752)	294	213
Ohio	1,666	(628–3,132)	250	2,898
Oklahoma	1,843	(638–3,575)	280	1,077
Oregon	1,857	(666–3,549)	280	1,099
Pennsylvania	1,960	(710–3,759)	295	3,771
Rhode Island	2,076	(742–3,998)	312	328
South Carolina	1,815	(630–3,534)	277	1,324
South Dakota	1,920	(659–3,728)	297	251
Tennessee	1,607	(585–3,050)	242	1,572
Texas	1,943	(689–3,755)	294	7,769
Utah	1,976	(680–3,836)	298	865
Vermont	2,042	(733–3,919)	310	194
Virginia	2,320	(799–4,539)	350	2,889
Washington	2,188	(766–4,237)	329	2,293
West Virginia	1,533	(531–2,940)	229	425
Wisconsin	1,992	(706–3,840)	304	1,746
Wyoming	2,058	(721–3,984)	311	181
United States	1,925	(692–3,696)	291	92,001

Table 4 also lists estimates based on an aggregation of state costs. Theoretically, these costs should be the same. However, because of simplifying modeling assumptions at the national level, these costs may be different from costs calculated at the national level when high-cost illnesses are not randomly distributed across states. A small significant difference in costs was found, suggesting that state costs are not randomly distributed and that the state-based measure

TABLE 3. *Cost of illness per resident for selected pathogens, 2013*

	STEC O157:H7		*Listeria monocytogenes*		*Salmonella*, nontyphoidal		*Vibrio vulnificus*	
Ranking	State	Cost per resident (US$)	State	Cost per resident (US$)	State	Cost per resident (US$)	State	Cost per resident (US$)
Highest cost	Idaho	8.91	Connecticut	18.05	Mississippi	26.33	Hawaii	8.03
	Iowa	7.56	New Jersey	14.94	Florida	25.88	Maryland	3.02
	South Dakota	7.26	Massachusetts	13.29	Hawaii	23.43	Connecticut	2.76
	Nebraska	6.98	Hawaii	12.74	South Carolina	22.63	Washington	2.73
	Minnesota	6.85	Rhode Island	12.53	Arkansas	22.51	Florida	1.98
	Wisconsin	5.44	Pennsylvania	12.19	Massachusetts	21.73	Delaware	1.98
	Utah	5.38	New Hampshire	12.07	Georgia	20.02	DC	1.81
	North Dakota	4.89	New York	11.87	Louisiana	19.64	Virginia	1.77
	Wyoming	4.85	Maryland	11.83	Maryland	19.23	Louisiana	1.72
	Vermont	4.81	DC	10.42	South Dakota	17.35	New Jersey	1.34
Lowest cost	Texas	1.35	Iowa	3.70	Maine	10.32	New York	0.27
	Alabama	1.31	Nevada	3.69	Ohio	10.30	Michigan	0.24
	DC	1.18	Alaska	3.61	Oregon	10.27	Missouri	0.22
	West Virginia	1.16	South Dakota	3.42	North Dakota	9.67	Ohio	0.22
	Georgia	1.12	Kentucky	3.05	Kentucky	9.44	Indiana	0.20
	Florida	0.92	Utah	2.92	Indiana	9.19	New Mexico	0.19
	Alaska	0.85	Arkansas	2.86	Idaho	9.17	Oklahoma	0.19
	Mississippi	0.57	Montana	2.40	Michigan	8.96	Kentucky	0.13
	South Carolina	0.57	Idaho	2.32	West Virginia	8.71	Wyoming	0.11
	Louisiana	0.48	Mississippi	2.32	Nevada	7.62	Utah	0.09
U.S. avg		2.20		6.97		15.17		0.92

TABLE 4. *Alternative estimates of the economic cost of foodborne illness, 2013*

Model	Cost per case ($)		Cost per resident ($)		Total cost ($ million)	
	Mean	90% CI	Mean	90% CI	Mean	90% CI
National						
Basic	1,149	733–1,780	174	106–260	54,902	33,498–82,260
Enhanced	1,925	694–3,700	291	103–552	92,001	32,518–174,063
State based						
Basic	1,162	738–1,803	176	107–263	55,544	33,874–83,252
Enhanced	1,951	705–3,747	295	105–560	93,206	32,997–176,285

for national cost of illness is a better measure of costs. As a result, the new best estimate for the national cost of illness is conservatively $55.5 billion (or $93.2 billion using the more controversial enhanced model).

DISCUSSION

The basic finding of this study is that costs associated with foodborne illness differ significantly across U.S. states. Consequently, policy makers at the state level would be better served by using state-based estimates of costs than by using national estimates. Differences in labor market variables, medical costs, and incidence of illness all play a role in these cost differences.

Limitations. Although the best available science was used to estimate the cost of foodborne illness across states, limitations to this approach exist. First, the costs reported here are not a complete accounting of all costs associated with foodborne illnesses. As Buzby and Roberts *(4)* reported, the costs associated with these types of illnesses also include unmeasured costs to family members, costs to industry from identified outbreaks, and costs to the public health community from monitoring, tracking, and responding to reported illnesses and outbreaks. Future research aimed at defining these costs would be beneficial.

Another limitation of this analysis is that the state-level incidence rates used in this analysis are limited in both scope and quality. The scope of state-level incidence rates is limited to pathogens that are reported as part of the NNDSS *(6)*. Illnesses caused by other important pathogens, such as *Campylobacter, Toxoplasma gondii,* and norovirus, and the broad group of illnesses caused by unknown agents are assumed to have a uniform incidence rate equal to that of the nation at large. To the extent that true incidence rates for these pathogens differ across states, overall differences in state illness costs are suppressed. The quality of the state-specific incidence rates is also limited. Because values from a passive surveillance system are used to adjust incidence rates, these rates are sensitive to the effectiveness of the surveillance system. As a result, I may have overestimated the incidence of illness in some states and underestimated the incidence in others. Inaccurate state-specific incidence rates would affect burden-of-illness (scope) measures (cost per resident and total state costs) but not cost per case measures. The generation (and inclusion into this study) of more data on incidence of illness across states would improve the accuracy of included estimates.

Use of cost-of-illness estimates. Cost-of-illness measures are used in various ways. Overall scope measures are often used to bring attention to a problem or to prioritize efforts toward finding solutions to problems. These are valid uses. However, aggregate measures of this sort cannot be used to justify a specific intervention, such as a law, a regulation, or a private initiative. Instead, the effectiveness of food safety interventions should be assessed by comparing the cost of the intervention with the number of illnesses averted times the expected cost per case of that illness (benefits). If benefits exceed costs, the intervention is a success and should be implemented or continued. This general approach is used by the federal government, although evaluations at the state level have also been completed *(15, 21)*. I have compiled an on-line appendix to accompany this article that provides state-based cost-per-case estimates for various pathogens to provide state policy makers with a reference that can be used to evaluate interventions implemented at a local level.

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