

Estimated Cost to a Restaurant of a Foodborne Illness Outbreak

Sarah M. Bartsch, MPH¹, Lindsey Asti, MPH¹, Sindiso Nyathi, BA¹, Marie L. Spiker, MSPH, RD¹, and Bruce Y. Lee, MD, MBA¹

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Abstract

Objectives: Although outbreaks of restaurant-associated foodborne illness occur periodically and make the news, a restaurant may not be aware of the cost of an outbreak. We estimated this cost under varying circumstances.

Methods: We developed a computational simulation model; scenarios varied outbreak size (5 to 250 people affected), pathogen ($n = 15$), type of dining establishment (fast food, fast casual, casual dining, and fine dining), lost revenue (ie, meals lost per illness), cost of lawsuits and legal fees, fines, and insurance premium increases.

Results: We estimated that the cost of a single foodborne illness outbreak ranged from \$3968 to \$1.9 million for a fast-food restaurant, \$6330 to \$2.1 million for a fast-casual restaurant, \$8030 to \$2.2 million for a casual-dining restaurant, and \$8273 to \$2.6 million for a fine-dining restaurant, varying from a 5-person outbreak, with no lost revenue, lawsuits, legal fees, or fines, to a 250-person outbreak, with high lost revenue (100 meals lost per illness), and a high amount of lawsuits and legal fees (\$1 656 569) and fines (\$100 000). This cost amounts to 10% to 5790% of a restaurant's annual marketing costs and 0.3% to 101% of annual profits and revenue. The biggest cost drivers were lawsuits and legal fees, outbreak size, and lost revenue. Pathogen type affected the cost by a maximum of \$337 000, the difference between a *Bacillus cereus* outbreak (least costly) and a listeria outbreak (most costly).

Conclusions: The cost of a single foodborne illness outbreak to a restaurant can be substantial and outweigh the typical costs of prevention and control measures. Our study can help decision makers determine investment and motivate research for infection-control measures in restaurant settings.

Keywords

cost, economic burden, foodborne, outbreaks, restaurant

Restaurants in the United States comprise a multibillion-dollar industry (\$780 billion in 2016, composing 4% of the gross domestic product). The National Restaurant Association estimated that in 2016, 47% of every dollar spent on food was spent in a restaurant, and in 2015, the average American ate out approximately 5 times per week.^{1,2} From 1998 through 2013, restaurants played a role in 9788 (56%) of the 17445 foodborne illness outbreak events reported; this number translates to approximately 620 restaurant-associated outbreaks and 3000 to 11 500 illnesses annually.³ A total of 742 foodborne illness outbreaks with a single location of food preparation occurred in 2014, 485 (65%) of which were linked to restaurants.⁴ Although restaurant-associated foodborne illness outbreaks periodically appear in the news media,⁵ individual restaurants might not always be aware of how much they could cost. We posited that a better understanding of the economic burden of a foodborne illness outbreak (in the event that one occurs) could help restaurants

determine how much they could potentially invest in outbreak prevention and control; however, the economic value (eg, cost benefit, cost effectiveness) of these interventions would depend on the risk occurrence.

Previous economic studies have focused on reporting aggregate annual costs of foodborne illnesses to individuals or society.⁶⁻⁹ Many were limited to health-related costs of

¹ Public Health Computational and Operations Research, Global Obesity Prevention Center, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

Corresponding Author:

Bruce Y. Lee, MD, MBA, Johns Hopkins Bloomberg School of Public Health, Public Health Computational and Operations Research, Global Obesity Prevention Center, 615 N Wolfe St, Room W3501, Baltimore, MD 21205, USA.

Email: brucelee@jhu.edu

foodborne illnesses and varied in component costs.¹⁰ One restaurant-related study reported on the costs of an outbreak that occurred in the early 1970s,¹¹ and another reported only the legal expenses for an outbreak that occurred in 1978.¹² However, to our knowledge, no study has yet captured the full economic costs to a US restaurant. The objective of our study was to provide cost estimates of a foodborne illness outbreak to a US restaurant.

Methods

Using Microsoft Excel with a Crystal Ball add-in,¹³ we developed a computational Monte Carlo simulation model to represent a single outbreak of a particular pathogen originating from a single restaurant to determine the cost of a foodborne illness outbreak to a restaurant under varying circumstances. We estimated costs of the 15 foodborne pathogens that caused outbreaks in a restaurant during a 6-year period (2010-2015), as reported by the Centers for Disease Control and Prevention (CDC).¹⁴ Our first step was to define the number of people affected (ie, who developed symptoms) by the outbreak (ie, outbreak size) and the pathogen (*Bacillus cereus*, campylobacter, *Clostridium perfringens*, cyclospora, *Escherichia coli*, *Giardia*, hepatitis A, listeria, norovirus, salmonella, sapovirus, *Shigella sonnei*, *Staphylococcus aureus*, trichinella, or *Vibrio parahaemolyticus*). Each person affected then had a probability of being a restaurant employee, and each restaurant employee had probabilities of seeking ambulatory care (eg, outpatient setting or emergency department), being hospitalized, and dying. The probabilities of hospitalization and mortality varied by pathogen type, and each illness and hospitalization was associated with a pathogen-specific duration.

We assigned productivity losses caused by absenteeism by counting each day of work that symptomatic restaurant employees missed because of illness and hospitalization. We used daily wages as a proxy for productivity losses.¹⁵ We assumed all sick employees accrued losses for the duration of illness, except for hepatitis A, which has a long symptomatic duration; therefore, we applied the number of missed employment days reported in the scientific literature. Productivity losses for premature death resulted in the net present value of missed earnings for the duration of their remaining employment at the restaurant based on the annual wage and remaining years of employment at one place.^{15,16}

We considered outbreaks in 4 types of restaurants: fast food (quick service, specific menu, and offers minimal to no table service), fast casual (specific menu between fast food and casual dining and offers minimal table service), casual dining (broad menu and offers table service), and fine dining (dedicated meal courses and offers full table service). We assumed that each restaurant incurred reinspection fees as a result of the outbreak. Although inspection fees typically depend on the restaurant size and number of seats, we applied one flat fee regardless of size or type. We also included increases to a restaurant's insurance premium.

Because a restaurant's insurance premium depends on the restaurant's size and location, we varied insurance increases and applied them to the annual insurance premium for general liability insurance.¹⁷ We assumed that other parts of the insurance policy (eg, property insurance) would not be affected.

We assumed that each restaurant would incur costs to retrain staff members. This retraining included the training program cost and 8 hours of productivity losses for each staff member. Employee wages varied by type of employee, and the number of employees varied by restaurant type. We assumed that each outbreak was associated with a loss in restaurant revenue because of decreased meal sales. Because this loss of revenue can be difficult to determine and highly variable, we used the number of meals as a proxy. For each person affected (ie, total number of illnesses in the outbreak), we assumed that a specified number of decreased meals were sold (ie, meals lost). We determined total lost meal sales to the restaurant by estimating the number of meals lost per illness multiplied by the outbreak size and by the average cost per meal by restaurant type. Thus, a restaurant's lost revenue depended on the restaurant type and outbreak size.

We conducted scenarios that varied the cost of lawsuits, legal fees, and fines paid by a restaurant, because they varied widely and data were limited. The amount of lawsuits and legal fees came from the amount compensated for consumer plaintiffs in the 26 foodborne illness lawsuits decided by jury verdicts reported from 2010 through 2014. These cases were identified through 2 jury verdict and settlement databases and included foodborne illness cases that were legally resolved through the court system.¹⁸ Given that the variability of these awards, which ranged from \$9856 to \$1 428 971 in 2012 dollars, and the likelihood that a restaurant will incur these costs is unknown, we conducted extensive sensitivity analyses on this parameter (described hereinafter). Similarly, the amount and likelihood of incurring fines is variable and not well described; thus, we based estimates for this cost range on past fines reported in news articles.^{19,20}

Data Inputs

Model inputs (Table 1) used pathogen-specific data when these data were available and came from nationally representative data sources (eg, wages from the US Bureau of Labor Statistics,¹⁵ duration of hospitalization from the Healthcare Cost and Utilization Project).^{45,46} We derived pathogen-specific probabilities for hospitalization and mortality by using CDC data on the number of illnesses, hospitalizations, and deaths from foodborne illness outbreaks occurring in a restaurant.¹⁴ By limiting the CDC data to outbreaks occurring only in restaurants, we excluded more vulnerable or specialized populations (eg, nursing home residents), which may have more severe outcomes that require the use of additional health care resources; outbreak investigations typically generate these data and endeavor to capture data on all health care use. Restaurant type-specific

Table 1. Computational simulation model input parameters, values, and sources used to estimate the cost of a foodborne illness outbreak to a single US restaurant

Parameter	Value	Data Source
Hourly wages for food preparation and serving occupations, median (10%-90% range), \$	9.81 (8.57-18.18) ^a	Bureau of Labor Statistics ¹⁵
Hourly wages for fast-food workers, median (10%-90% range), \$	9.66 (8.48-12.54) ^a	Bureau of Labor Statistics ¹⁵
Cost per fast-food restaurant meal, mean, \$ ^b	5.44 ^a	Lutz ²¹
Cost per fast-casual restaurant meal, mean, \$ ^b	11.15 ^a	Lutz ²¹
Cost per casual-dining restaurant meal, mean, \$ ^b	15.48 ^a	The NPD Group ²²
Cost per fine-dining restaurant meal, mean, \$ ^b	32.13 ^a	The NPD Group ²²
Reinspection fees, point estimate, \$	129.78 ^a	Los Angeles County Department of Public Health ²³
Cost of training program, mean (SE), \$	162.22 (6.65) ^{a,c}	Columbus Public Health ²⁴ ; SafeServ Training ^{25,26}
Probability of ill person seeking ambulatory care, mean (SE), %	18.4 (3.3) ^{a,c}	Hall et al ²⁷ ; Scallan et al ²⁸ ; Scallan et al ²⁹
Probability of hospitalization for person ill with <i>Bacillus cereus</i> , %	CDC point estimate (range ^d): 1.1 (1.0-1.2)	CDC ¹⁴
Probability of hospitalization for person ill with campylobacter, %	Scallan et al point estimate: 0.4 CDC point estimate (range ^d): 9.0 (8.1-9.9)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with <i>Clostridium perfringens</i> , %	Scallan et al point estimate: 17.1 CDC point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with cyclospora, %	Scallan et al point estimate: 0.6 CDC point estimate (range ^d): 5.0 (4.5-9.9)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with <i>Escherichia coli</i> , %	Scallan et al point estimate: 6.5 CDC point estimate (range ^d): 25.0 (22.5-27.9)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with <i>Giardia</i> , %	Scallan et al point estimate: 29.5 ^f CDC point estimate (range ^d): 20.0 (18.0-22.0)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with hepatitis A, %	Scallan et al point estimate: 8.8 CDC point estimate (range ^d): 34.2 (27.8-37.6)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with listeria, %	Scallan et al point estimate: 31.5 CDC point estimate (range ^d): 81.5 (73.3-89.6)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with norovirus, %	Scallan et al point estimate: 94.0 CDC point estimate (range ^d): 1.1 (1.0-1.2)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with salmonella, %	Scallan et al point estimate: 0.03 CDC point estimate (range ^d): 11.6 (10.5-12.8)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with sapovirus, %	Scallan et al point estimate: 27.2 CDC point estimate (range ^d): 1.2 (1.1-1.3)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with <i>Shigella sonnei</i> , %	Scallan et al point estimate: 0.4 CDC point estimate (range ^d): 11.7 (10.5-12.9)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with <i>Staphylococcus aureus</i> , %	Scallan et al point estimate: 20.2 CDC point estimate (range ^d): 1.7 (1.5-1.8)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with trichinella, % ^g	Scallan et al point estimate: 6.4 CDC point estimate (range ^d): 23.1 (20.8-25.4)	Scallan et al ³⁰ CDC ¹⁴
Probability of hospitalization for person ill with <i>Vibrio parahaemolyticus</i> , %	Scallan et al point estimate: 24.3 CDC point estimate (range ^d): 7.5 (6.7-8.2)	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with campylobacter, %	Scallan et al point estimate: 22.5 CDC point estimate: 0 ^e Scallan et al point estimate: 0.1	Scallan et al ³⁰ CDC ¹⁴ Scallan et al ³⁰

(continued)

Table 1. (continued)

Parameter	Value	Data Source
Probability of mortality for person ill with <i>Clostridium perfringens</i> , %	CDC point estimate: 0 ^e	CDC ¹⁴
Probability of mortality for person ill with <i>Escherichia coli</i> , %	Scallan et al point estimate: 0.1 CDC point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with <i>Giardia</i> , %	Scallan et al point estimate: 0.4 ^f CDC point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with hepatitis A, %	Scallan et al point estimate: 0.1 CDC point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with listeria, %	Scallan et al point estimate: 2.4 CDC point estimate: 25.93	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with norovirus, %	Scallan et al point estimate: 15.9 CDC point estimate: 0.02	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with salmonella, %	Scallan et al point estimate: 0.1 CDC point estimate: 0.04	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with sapovirus, %	Scallan et al point estimate: 0.5 CDC point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with <i>Shigella sonnei</i> , %	Scallan et al point estimate: 0.1 CDC point estimate: 0.14	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with <i>Staphylococcus aureus</i> , %	Scallan et al point estimate: 0.1 CDC et al point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with trichinella, % ^g	Scallan et al point estimate: 0.1 CDC et al point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Probability of mortality for person ill with <i>Vibrio parahaemolyticus</i> , %	Scallan et al point estimate: 0.2 CDC point estimate: 0 ^e	Scallan et al ³⁰ CDC ¹⁴
Duration of illness for any pathogen, range, d	Scallan et al point estimate: 0.9 (3-7)	Scallan et al ³⁰ Assumption ^h
Duration of illness for <i>Bacillus cereus</i> , mean, d	1	HHS ³¹
Duration of illness for campylobacter, range, d	(5-7)	Fitzgerald ³²
Duration of illness for <i>Clostridium perfringens</i> , mean, d	1	HHS ³¹
Duration of illness for cyclospora, range, d	(7-14)	Cama and Mathison ³³
Duration of illness for <i>Escherichia coli</i> , range, d	(5-7)	CDC ³⁴
Duration of illness for <i>Giardia</i> ⁱ , range, d	(7-28) ^c	Daly et al ³⁵ ; Gardner and Hill ³⁶ ; CDC ³⁷
Duration of illness for listeria, range, d	(1-3)	Ooi and Lorber ³⁸
Duration of illness for norovirus, range, d	(1-3)	Glass et al ³⁹ ; Patel et al ⁴⁰
Duration of illness for salmonella, range, d	(3-7)	Dekker and Frank ⁴¹
Duration of illness for sapovirus, range, d	(1-3) ^c	Glass et al ³⁹ ; Patel et al ⁴⁰
Duration of illness for <i>Shigella sonnei</i> , range, d	(5-7)	Dekker and Frank ⁴¹
Duration of illness for <i>Staphylococcus aureus</i> , range, d	(2-4)	HHS ³¹
Duration of illness for trichinella, median (range), d	23.5 (14.0-35.0)	Hall et al ⁴²
Duration of illness for <i>Vibrio parahaemolyticus</i> , median (range), d	5 (2-8) ^c	HHS ³¹ ; McLaughlin et al ⁴³
Duration of missed workdays due to hepatitis A, mean (interquartile range), d ^l	15.5 (7.0-18.0)	Berge et al ⁴⁴
Duration of hospitalization for a food poisoning illness, mean (SE), d	2.15 (0.08)	HCUP ⁴⁵
Duration of hospitalization for a campylobacter illness, mean (SE), d	3.60 (0.10)	HCUP ⁴⁵
Duration of hospitalization for an <i>Escherichia coli</i> illness, mean (SE), d	3.94 (0.43)	HCUP ⁴⁵
Duration of hospitalization for a <i>Giardia</i> illness, mean (SE), d	3.80 (0.28)	HCUP ⁴⁵
Duration of hospitalization for a hepatitis A illness, mean (SE), d	3.87 (0.29)	HCUP ⁴⁵
Duration of hospitalization for a listeria illness, mean (SE), d	11.20 (1.13)	HCUP ⁴⁵
Duration of hospitalization for a norovirus illness, mean (SE), d	2.65 (0.02)	HCUP ⁴⁵
Duration of hospitalization for a salmonella illness, mean (SE), d	4.37 (0.16)	HCUP ⁴⁵
Duration of hospitalization for a <i>Shigella sonnei</i> illness, mean (SE), d	3.29 (0.29)	HCUP ⁴⁵
Duration of hospitalization for a <i>Staphylococcus aureus</i> illness, mean (SE), d	2.50 (0.27)	HCUP ⁴⁶
Duration of training program, point estimate, d	1 ^c	Columbus Public Health ²⁴ ; SafeServ Training ^{25,26}

(continued)

Table 1. (continued)

Parameter	Value	Data Source
Duration of employment at 1 place, median, y	4.2	Bureau of Labor Statistics ¹⁶
Employees at a fast-food restaurant, mean, n	15.5	Statista ⁴⁷
Employees at a fast-casual restaurant, mean, n	25	National Restaurant Association, Deloitte ⁴⁸
Employees at a casual-dining restaurant, mean, n	32	National Restaurant Association, Deloitte ⁴⁸
Employees at a fine-dining restaurant, mean, n	33	National Restaurant Association, Deloitte ⁴⁸

Abbreviations: CDC, Centers for Disease Control and Prevention; HCUP, Healthcare Utilization Project; HHS, US Department of Health and Human Services.

^aIn 2017 US dollars.

^bFast-food restaurant: quick service, specific menu, and offers minimal to no table service. Fast-casual restaurant: specific menu between fast food and casual dining and offers minimal table service. Casual-dining restaurant: broad menu and offers table service. Fine-dining restaurant: dedicated meal courses and offers full table service.

^cModeled values are pooled across sources cited.

^dRange is $\pm 10\%$ of point estimate.

^eNo hospitalizations or deaths due to this pathogen were reported in the CDC data during the 6-year period.

^fAverage of Shiga toxin-producing *Escherichia coli* (STEC) O157 and STEC non-O157 values reported by Scallan et al.

^gSupplemented with data on outbreaks occurring at a camp and private residence; only 1 restaurant-associated outbreak in the 6-year period with 2 illnesses.

^hRange covers most of the pathogen-specific durations modeled.

ⁱDuration can last up to 6 weeks; however, 1-3 weeks was used to be conservative (excluding more severe illnesses) and capture duration with prompt treatment.

^jValues are missed workdays for those seeking outpatient care.

inputs, such as cost per meal and number of employees, came from survey and industry data and from the National Restaurant Association.^{21,22,45,47,48} A 3% discount rate adjusted all past and future costs to 2017 US dollars (Table 1).

Simulations and Sensitivity Analyses

Each Monte Carlo simulation consisted of 1000 trials that varied each parameter throughout its distribution (Table 1). For each pathogen and restaurant type, we used multiway sensitivity analyses to systematically vary the outbreak size (5-250 people affected) following reported outbreaks¹⁴; the proportion of affected people who were employees (5%-90%); the number of meals lost per illness (0-100); lawsuits and legal fees (none [\$0], minimum [\$11 426], median [\$85 690], and maximum [\$1 656 569]); fines (\$0-\$100 000); and annual insurance rate increase (5%-75%)^{49,50} that was applied to the annual insurance premium, which ranged from \$545 to \$6280.¹⁷ This insurance increase was similar to past increases in health insurance and restaurant premiums. We also examined the impact of varying these key parameters on costs by restaurant type. Additional sensitivity analyses varied the pathogen-specific probabilities of hospitalization and mortality to those reported by Scallan et al.³⁰ We report results as median and 95% credibility intervals (CrIs).

Results

The estimated cost of a foodborne illness outbreak varied by outbreak conditions (Table 2). The cost of an outbreak for a fine-dining restaurant was higher than for a fast-food

restaurant under the same conditions even when there was no loss in revenue (ie, 0 meals lost per illness; \$8273 vs \$3968). The cost per person was not constant across outbreaks of various sizes, because other costs (eg, reinspection fees and fines, which are relatively fixed) did not scale linearly with the outbreak size. For example, at a fine-dining restaurant, a 5-person outbreak cost \$1655 per person, whereas a 250-person outbreak cost \$52 per person, assuming the same conditions. The cost of an outbreak also varied by pathogen. The most expensive outbreaks were caused by listeria (\$4768-\$2 915 601), because it accrued the highest productivity losses resulting from its high probability of hospitalization and mortality. The least expensive outbreaks were caused by *Bacillus cereus* (\$3891-\$2 578 714), because it accrued the lowest productivity losses resulting from its short duration, low probability of hospitalization, and no association with mortality. Comparing the 2 most common causes of foodborne illness outbreaks, norovirus and salmonella, a single salmonella outbreak cost \$63-\$21 198 more than a norovirus outbreak under the same conditions because it accrues higher direct costs as a result of being associated with a higher probability of hospitalization (Table 3).

Changes in the total cost of an outbreak when varying the values of different parameters are shown in a tornado diagram (Figure 1). The diagram is shaped like the funnel cloud of a tornado: the parameter with the greatest impact is at the top, and the width of the bar represents the range of the resulting outbreak costs when that parameter increases or decreases. The cost of lawsuits and legal fees and the number of ill people in the outbreak were the biggest drivers of the outbreak cost. Lawsuits and legal fees had the largest impact on the overall

Table 2. Median (95% CrI) cost (in 2017 US dollars) of restaurant-associated foodborne illness outbreaks from the restaurant perspective under various circumstances: results from a computational simulation model^a

Scenario ^b	Cost of a Restaurant-Associated Foodborne Illness Outbreak, \$ Median (95% CrI) Outbreak Size (No. of Ill People)					
	5	15	50	100	150	250
Fast-food restaurant^c						
High impact	1 768 429 (1 768 013-1 768 918)	1 774 967 (1 774 130-1 776 031)	1 797 928 (1 795 347-1 800 871)	1 830 204 (1 825 806-1 836 260)	1 863 510 (1 856 064-1 872 465)	1 928 608 (1 916 558-1 943 164)
Moderate impact	142 453 (142 184-142 791)	145 543 (145 129-145 997)	156 280 (155 399-157 409)	171 816 (170 078-173 873)	187 128 (184 710-190 193)	218 246 (214 050-222 998)
Low impact	35 402 (35 141-35 674)	35 592 (35 275-35 927)	36 225 (35 665-36 839)	37 103 (36 227-38 192)	38 145 (36 740-39 767)	39 887 (37 792-42 335)
Very low impact	3968 (3727-4288)	4149 (3865-4510)	4777 (4250-5393)	5666 (4773-6759)	6671 (5294-8181)	8550 (6403-11 045)
Fast-casual restaurant^c						
High impact	1 773 644 (1 773 046-1 774 633)	1 786 000 (1 784 897-1 787 641)	1 829 056 (1 826 059-1 833 094)	1 890 279 (1 884 967-1 897 925)	1 952 502 (1 943 987-1 962 725)	2 075 028 (2 061 550-2 094 752)
Moderate impact	146 248 (145 772-147 018)	152 214 (151 601-153 137)	173 027 (171 848-174 692)	202 886 (200 850-205 923)	232 542 (229 789-236 909)	292 467 (287 589-298 590)
Low impact	37 750 (37 304-38 510)	37 940 (37 440-38 792)	38 597 (37 865-39 678)	39 592 (38 479-41 261)	40 571 (38 976-42 844)	42 470 (40 017-45 966)
Very low impact	6330 (5863-7063)	6504 (6011-7320)	7183 (6418-8347)	8113 (6995-9949)	9121 (7551-11 451)	11 085 (8658-14 586)
Casual-dining restaurant^c						
High impact	1 777 509 (1 776 788-1 778 672)	1 794 177 (1 793 019-1 795 968)	1 852 385 (1 849 317-1 856 544)	1 935 316 (1 929 854-1 942 998)	2 019 049 (2 010 524-2 029 388)	2 184 918 (2 171 310-2 204 785)
Moderate impact	149 029 (148 435-150 005)	157 154 (156 433-158 276)	185 551 (184 247-187 362)	226 190 (224 097-229 414)	266 679 (263 870-271 210)	348 234 (343 252-354 555)
Low impact	39 448 (38 889-40 413)	39 642 (39 017-40 736)	40 294 (39 470-41 563)	41 279 (40 090-43 108)	42 263 (40 582-44 718)	44 181 (41 651-47 808)
Very low impact	8030 (7441-8973)	8201 (7587-9207)	8878 (8014-10 223)	9826 (8591-11 787)	10 817 (9195-13 346)	12 765 (10 321-16 456)
Fine-dining restaurant^c						
High impact	1 786 082 (1 785 342-1 787 274)	1 819 409 (1 818 237-1 821 228)	1 935 917 (1 932 832-1 940 101)	2 102 132 (2 096 664-2 109 853)	2 269 163 (2 260 622-2 279 512)	2 601 605 (2 587 980-2 621 481)
Moderate impact	153 438 (152 827-154 443)	169 889 (169 152-171 045)	227 438 (226 121-229 263)	309 710 (307 612-312 962)	391 859 (389 034-396 407)	556 693 (551 703-563 045)
Low impact	39 690 (39 114-40 686)	39 884 (39 245-41 015)	40 537 (39 700-41 833)	41 522 (40 324-43 370)	42 514 (40 814-44 975)	44 424 (41 884-48 064)
Very low impact	8273 (7666-9246)	8443 (7810-9478)	9120 (8242-10 491)	10 069 (8819-12 049)	11 061 (9423-13 609)	13 001 (10 556-16 711)

^aThe cost of each outbreak from the restaurant perspective depends on several parameters (eg, fines, lawsuits and legal fees, and number of employees). These scenarios attempt to capture a range of costs across sensitivity analysis estimates included in the model. The restaurant perspective included: productivity losses for ill restaurant employees, inspection fees, fines, lawsuits and legal fees, lost revenue (measured by decreased meals sold per illness), staff retraining, and insurance premium increases.

^bThe scenarios are as follows: Very low impact: 5% of those affected were restaurant employees; restaurants lose 0 meals per illness (ie, \$0) or lawsuits and legal fees (\$0), have an annual insurance premium of \$545, and incur a 5% insurance increase. Low impact: 5% of those affected were restaurant employees; restaurants lose 0 meals per illness, incur fines of \$20 000 and lawsuits and legal fees of \$11 426, have an annual insurance premium of \$545, and incur a 5% insurance increase. Moderate impact: 10% of those affected were restaurant employees; restaurants lose 50 meals per illness, incur fines of \$50 000 and lawsuits and legal fees of \$85 690, have an annual insurance premium of \$3423, and incur a 40% insurance increase. High impact: 30% of those affected were restaurant employees; restaurants lose 100 meals per illness, incur fines of \$100 000 and lawsuits and legal fees of \$1 656 569, have an annual insurance premium of \$6280, and incur a 75% insurance increase.

^cFast-food restaurant: quick service, specific menu, and offers minimal to no table service. Fast-casual restaurant: specific menu between fast food and casual dining, and offers minimal table service. Casual-dining restaurant: broad menu and offers table service. Fine-dining restaurant: dedicated meal courses and offers full table service.

Table 3. Cost (in 2017 US dollars) of restaurant-associated foodborne illness outbreaks of 4 pathogens^a from the restaurant perspective: results from a computational simulation model

Scenario ^b	Bacillus cereus			Listeria			Norovirus			Salmonella		
	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	
Fast-food restaurant, \$ ^c												
Using probabilities of hospitalization and mortality derived from CDC data ¹⁴												
Very low impact	3891 (3659-4171)	4847 (4528-5240)	4748 (4457-5153)	3911 (3658-4198)	58902 (52636-68928)	3911 (3658-4198)	3974 (3704-4266)	5775 (4590-7312)	3974 (3704-4266)	3974 (3704-4266)	8661 (6548-11057)	
High impact	1767959 (1767726-1768235)	1907045 (1906269-1908241)	1773163 (1772409-1774286)	1768077 (1767777-1768444)	2233539 (2195028-2288966)	1768077 (1767777-1768444)	1768412 (1768044-1768882)	1912716 (1906496-1920732)	1768412 (1768044-1768882)	1768412 (1768044-1768882)	1928871 (1917910-1943252)	
Using probabilities of hospitalization and mortality from Scallan et al ³⁰												
Very low impact	3891 (3659-4171)	4838 (4520-5230)	4790 (4494-5203)	3911 (3658-4198)	42625 (37853-49936)	3911 (3658-4198)	3974 (3704-4266)	5767 (4571-7317)	3974 (3704-4266)	3974 (3704-4266)	9262 (7375-11381)	
High impact	1767959 (1767726-1768235)	1906992 (1906212-1908175)	1773416 (1772639-1774603)	1768077 (1767777-1768444)	2135340 (2106471-2174664)	1768077 (1767777-1768444)	1768412 (1768044-1768882)	1912672 (1906388-1920760)	1768412 (1768044-1768882)	1768412 (1768044-1768882)	1932538 (1922857-1945112)	
Fast-casual restaurant, \$ ^c												
Using probabilities of hospitalization and mortality derived from CDC data ¹⁴												
Very low impact	6247 (5803-6979)	7275 (6714-8273)	7116 (6599-8137)	6243 (5797-7068)	63452 (55151-83168)	6243 (5797-7068)	6329 (5853-7048)	8233 (6771-10327)	6329 (5853-7048)	6329 (5853-7048)	11229 (8829-14861)	
High impact	1773176 (1772698-1773939)	2052200 (2051133-2054706)	1778527 (1777403-1781228)	1773305 (1772766-1774056)	2389051 (2342314-2515871)	1773305 (1772766-1774056)	1773634 (1773073-1774634)	2058188 (2051329-2068384)	1773634 (1773073-1774634)	1773634 (1773073-1774634)	2075561 (2062946-2094336)	
Using probabilities of hospitalization and mortality from Scallan et al ³⁰												
Very low impact	6247 (5803-6979)	7266 (6705-8262)	7162 (6636-8192)	6243 (5797-7068)	46473 (40438-60644)	6243 (5797-7068)	6329 (5853-7048)	8224 (6753-10327)	6329 (5853-7048)	6329 (5853-7048)	11852 (9665-15292)	
High impact	1773176 (1772698-1773939)	2052143 (2051087-2054643)	1778802 (1777632-1781599)	1773305 (1772766-1774056)	2287360 (2252192-2377711)	1773305 (1772766-1774056)	1773634 (1773073-1774634)	2058144 (2051224-2068417)	1773634 (1773073-1774634)	1773634 (1773073-1774634)	2079346 (2067901-2096940)	
Casual-dining restaurant, \$ ^c												
Using probabilities of hospitalization and mortality derived from CDC data ¹⁴												
Very low impact	7947 (7378-8881)	8986 (8294-10192)	8814 (8176-10055)	7935 (7367-8988)	65187 (56789-85037)	7935 (7367-8988)	8027 (7430-8941)	9932 (8365-12180)	8027 (7430-8941)	8027 (7430-8941)	12942 (10451-16731)	
High impact	1777041 (1776432-1778007)	2162035 (2160854-2164716)	1782395 (1781133-1785303)	1777168 (1776507-1778139)	2498921 (2452085-2625975)	1777168 (1776507-1778139)	1777492 (1776796-1778702)	2168054 (2161097-2178358)	1777492 (1776796-1778702)	1777492 (1776796-1778702)	2185424 (2172680-2204351)	
Using probabilities of hospitalization and mortality from Scallan et al ³⁰												
Very low impact	7947 (7378-8881)	8975 (8285-10181)	8856 (8214-10101)	7935 (7367-8988)	48177 (42075-62536)	7935 (7367-8988)	8027 (7430-8941)	9924 (8348-12185)	8027 (7430-8941)	8027 (7430-8941)	13547 (11299-17131)	
High impact	1777041 (1776432-1778007)	2161982 (2160804-2164646)	1782656 (1781372-1785657)	1777168 (1776507-1778139)	2397204 (2361936-2487861)	1777168 (1776507-1778139)	1777492 (1776796-1778702)	2168008 (2160994-2178388)	1777492 (1776796-1778702)	1777492 (1776796-1778702)	2189203 (2177690-2206926)	

(continued)

Table 3. (continued)

Scenario ^b	Bacillus cereus			Listeria			Norovirus			Salmonella		
	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	250-Person Outbreak Median (95% CrI)	5-Person Outbreak Median (95% CrI)	
Fine-dining restaurant, \$ ^c												
Using probabilities of hospitalization and mortality derived from CDC data ¹⁴												
Very low impact	8190 (7603-9153)	9228 (8519-10466)	9057 (8400-10330)	65425 (57026-85305)	8177 (7591-9262)	10177 (8593-12466)	8270 (7654-9211)	13178 (10688-16996)				
High impact	1785613 (1784985-1786608)	2578714 (2577517-2581419)	1790968 (1789687-1793902)	2915601 (2868753-3042694)	1785739 (1785059-1786737)	2584733 (2577770-2595065)	1786062 (1785344-1787303)	2602111 (2589357-2621056)				
Using probabilities of hospitalization and mortality from Scallan et al. ³⁰												
Very low impact	8190 (7603-9153)	9218 (8510-10455)	9099 (8439-10376)	48421 (42309-62798)	8177 (7591-9262)	10169 (8576-12451)	8270 (7654-9211)	13799 (11529-17386)				
High impact	1785613 (1784985-1786608)	2578660 (2577466-2581348)	1791233 (1789925-1794257)	2813883 (2778607-2904577)	1785739 (1785059-1786737)	2584688 (2577666-2595094)	1786062 (1785344-1787303)	2605886 (2594355-2623628)				

Abbreviation: CrI, credibility interval.

^aOnly 4 of 15 pathogens reported: *Bacillus cereus* was the lowest-costing outbreak and *listeria* was the highest-costing outbreak. Norovirus and salmonella are the 2 most common causes of foodborne illness outbreaks.
^bVery low impact: 5% of those affected were restaurant employees; restaurants lose 0 meals per illness, do not incur fines (ie, \$0) or lawsuits and legal fees (\$0), have an annual insurance premium of \$545, and incur a 5% insurance increase. High impact: 30% of those affected were restaurant employees; restaurants lose 100 meals per illness, incur fines of \$100,000 and lawsuits and legal fees of \$165,569, have an annual insurance premium of \$6280, and incur a 75% insurance increase.

^cFast-food restaurant: quick service, specific menu, and offers minimal to no table service. Fast-casual restaurant: specific menu between fast food and casual dining and offers minimal table service. Casual-dining restaurant: broad menu and offers table service. Fine-dining restaurant: dedicated meal courses and offers full table service.

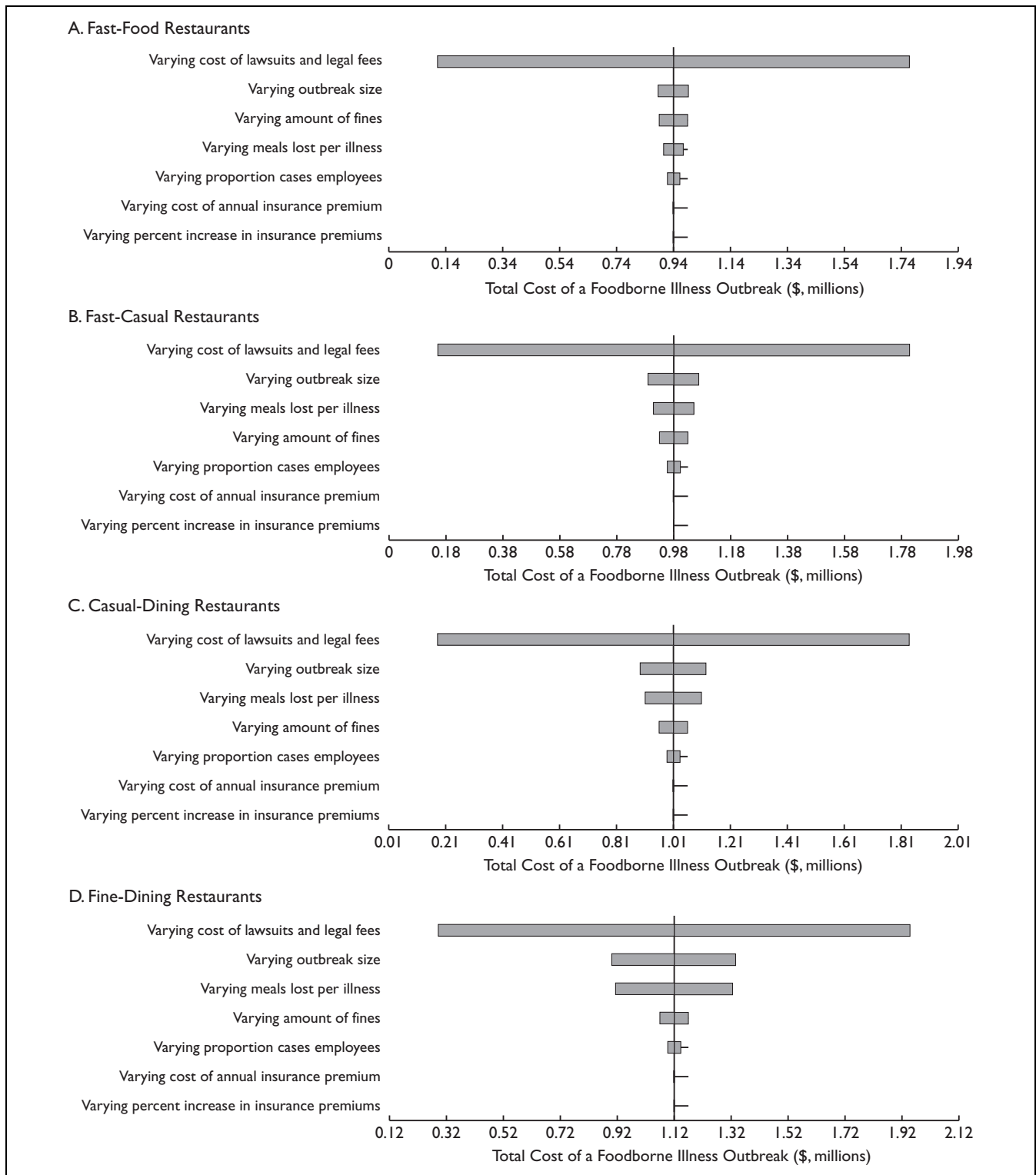


Figure. Impact of key parameters on the cost of restaurant-associated foodborne illness outbreaks from the restaurant perspective for (a) fast-food, (b) fast-casual, (c) casual-dining, and (d) fine-dining restaurants. The x-axis shows the total cost of an outbreak; the vertical line indicates the cost for which all variables on the y-axis are held at their midpoint values. The width of the bar shows the range of impact each parameter had when varied from its minimum value to its maximum value. Outbreak size (number of ill people) varied from 5 to 250; proportion of cases that are restaurant employees varied from 0% to 90%; meals lost per illness varied from 1 to 100; lawsuits and legal fees varied from \$0 to \$1 656 569; fines varied from \$0 to \$100 000; annual insurance premium varied from \$545 to \$6280; and increase in insurance premium varied from 5% to 75%. Fast-food restaurant: quick service, specific menu, and offers minimal to no table service. Fast-casual restaurant: specific menu between fast food and casual dining and offers minimal table service. Casual-dining restaurant: broad menu and offers table service. Fine-dining restaurant: dedicated meal courses and offers full table service.

cost of a foodborne illness outbreak, regardless of restaurant type. For example, the median cost of an outbreak at a fast-casual restaurant was \$979 793 (95% CrI, \$969 073-\$994 842); attributing the highest lawsuits and legal fees (ie, \$1 656 569) resulted in the outbreak costing a total of \$1.81 million (95% CrI, \$1.80 million-\$1.82 million). Additionally, lawsuits and legal fees had an additive effect on the total outbreak cost. For example, to a fast-food restaurant, a 5-person foodborne illness outbreak with no lawsuits and legal fees cost an estimated \$3868; with \$500 in lawsuits and legal fees, it cost \$4480; and with \$100 000 in lawsuits and legal fees, it cost \$103 987 (all other variables being equal).

Cost of an Outbreak in a Fast-Food Restaurant

The total cost of a foodborne illness outbreak to a fast-food restaurant varied by pathogen; however, the total cost of an outbreak did not vary by more than 16% (ie, \leq \$326 494) across all pathogens, outbreak sizes, and probabilities of hospitalization and mortality. The maximum difference was between a single outbreak of *Bacillus cereus* (\$2.2 million) and a single outbreak of listeria (\$2.5 million) under the high-impact scenario (Table 3). Fines had the third-largest impact of all key parameters explored via sensitivity analysis on total outbreak costs (Figure 1a); however, this parameter only increased or decreased the total cost by approximately \$50 000. The marginal increase in cost for an additional person affected varied by the number of meals lost per illness, ranging from \$68 (10 meals lost per illness) to \$330 (50 meals lost per illness). For every 10 additional meals lost per illness, the total cost increased by a marginal \$262 to \$285 for a 5-person outbreak and \$13 348 to \$13 839 for a 250-person outbreak.

Cost of an Outbreak in a Fast-Casual Restaurant

Although the total cost of a foodborne illness outbreak to a single fast-casual restaurant varied by pathogen, the total cost did not vary by more than 15% (\leq \$336 852) across all pathogens, outbreak sizes, and probabilities of hospitalization and mortality (Table 3). Following lawsuits and legal fees and outbreak size, the number of meals lost per illness had the next largest impact on total outbreak costs (Figure 1b), increasing or decreasing total costs by \$70 000. Total outbreak costs increased by a marginal \$83 to \$642 per additional illness (assuming 10-50 meals lost per illness) and varied by meals lost per illness. For every 10 additional meals lost per illness, total costs increased by a marginal \$539 (5-person outbreak) to \$27 914 (250-person outbreak).

Cost of an Outbreak in a Casual-Dining Restaurant

Although the total cost of a single outbreak varied by pathogen, it did not vary by more than 14% (ie, \leq \$336 886) across all pathogens, outbreak sizes, and probabilities of hospitalization and mortality (Table 3). Increasing outbreak size by 1

illness (holding all else constant) increased the total costs by a marginal \$132 to \$845, varying with the number of meals lost per illness (10-50 meals). For every 10 additional meals lost per illness, total costs increased by a marginal \$750 to \$814 for a 5-person outbreak and a marginal \$38 595 to \$38 794 for a 250-person outbreak. Fines, the proportion of affected people who were employees, annual insurance premiums, and increases in insurance had relatively little impact on total costs (increasing or decreasing cost by \$50 000) (Figure 1c).

Cost of an Outbreak in a Fine-Dining Restaurant

Across all pathogens, outbreak sizes, and probabilities of hospitalization and mortality, the total cost of a foodborne illness outbreak to a fine-dining restaurant did not vary by more than 12% (ie, \leq \$336 888), which was the maximum difference between a single outbreak of *Bacillus cereus* and a single outbreak of listeria under the same conditions (Table 3). For each additional ill person, total costs to a fine-dining restaurant increased by a marginal \$303 to \$419 (with 10 meals lost per illness) and \$1605 to \$1681 (with 50 meals lost per illness), all else being equal. In addition, total costs increased by a marginal \$1583 to \$1647 for every 10 additional meals lost per illness for a 5-person outbreak and a marginal \$80 212 to \$80 430 for every 10 additional meals lost per illness for a 250-person outbreak.

Discussion

Our study aimed to fill a gap in the literature on the cost of foodborne illness outbreaks. Restaurants can use our results to help determine the potential economic burden of a single foodborne illness outbreak under various circumstances and what factors have the largest impact on these costs (ie, lawsuits and legal fees and outbreak size). By demonstrating how much a single outbreak might cost under varying circumstances, our study can help decision makers (eg, restaurant owners) determine how much they should consider investing in improving their infection-control measures. It may also motivate further research to identify effective strategies for preventing foodborne illness outbreaks in restaurant settings, because the potential cost savings of preventing an illness are not inconsequential. However, the potential economic value (eg, cost benefit and cost effectiveness) of such infection-control measures would depend on and increase with the likelihood that a restaurant has an outbreak.

To help benchmark this cost, a single foodborne illness outbreak might cost a fast-food restaurant 0.1 to 57.9 times the amount that the restaurant spent on marketing (approximately \$33 000) in 1 year.^{51,52} This cost shifts to 0.1 to 16.5 times (approximately \$132 661 spent on marketing^{53,54}) for a casual-dining restaurant. To add perspective, a single outbreak could account for the annual wages of 2 to 127 restaurant staff members or could consume a substantial proportion of a single fast-food restaurant location's annual profit. For

example, a single 15-person foodborne illness outbreak could constitute 0.2% to 68.3% of a single fast-food restaurant's average annual profit (\$2.6 million⁵⁵), 0.3% to 72.3% of a fast-casual restaurant location's average annual revenue (\$2.47 million⁵⁶), and 0.5% to 101.1% of the \$1.8 million average annual revenue of 1 franchise location among the top 100 independent restaurants in 2015.⁵⁷

Foodborne illness outbreaks may be avoided in some cases by infection prevention and control measures in restaurants, many of which may cost less than an outbreak itself. For example, giving a sick employee time off may cost \$78 to \$3451 depending on the length of the employee's illness (1-42 days) and the person's wages (assuming 8 hours of productivity losses per day), with most illnesses lasting less than 1 week. The examination associated with staff training can cost \$162 plus 1 day of productivity losses that it consumes.²⁴⁻²⁶ A food-handler training program focusing on basic food safety, cross-contamination, time and temperature, and cleaning and sanitation costs \$15 for an online course and assessment.⁵⁸ Surveillance testing of high-risk foods to identify potential contamination before reaching a restaurant costs \$18 to \$266 per test for in-house laboratories in the meat and poultry production industry.⁵⁹ The cost and availability of these options may vary by location and other circumstances. Although these costs may be lower than the costs of an outbreak, their economic value would depend on the risk of an outbreak occurring.

Although analyses at both the national level⁶⁰ and state level⁶¹ have not found associations between routine health inspection scores and incidence of foodborne illness outbreaks, evidence shows that various contributing factors are associated with foodborne illness outbreaks at restaurants. Many factors and conditions in restaurants are known to contribute to foodborne illness outbreaks, such as unsanitary conditions, ill employees not given paid sick leave, suboptimal safe and proper food-handling practices, or inadequate cleaning practices.⁶² Some associations between these factors and foodborne illness may be difficult to measure, because some behaviors (eg, employees working while ill) may not be well monitored or recorded. Nonetheless, outbreaks may be prevented through food safety precautions. For example, restaurants that have not had foodborne illness outbreaks were more likely than restaurants that have had an outbreak to have a certified kitchen manager, which was associated with less barehand contact with food.⁶³ These food-safety precautions and prevention and control measures aimed at reducing contributing factors and violations can be less costly than an outbreak itself.

The cost of an outbreak to a restaurant could exceed our estimates. Smaller establishments could lose even more customers after an outbreak because they do not have the marketing and damage-control mechanisms to recoup their image. Repeated outbreaks could have an additive effect on lost customers and even lead to closures of locations for periods of time. For example, in 2015, Chipotle Mexican Grill had several foodborne illness outbreaks (norovirus,

E coli, and salmonella) beginning in July and continuing through November that resulted in numerous closures in several states, leading to considerable media coverage.⁵ As a result, sales dropped 14.6% in the fourth quarter of 2015 alone compared with the same quarter the previous year.⁶⁴ An even more drastic example is the closure and bankruptcy of Chi-Chi's restaurants in the United States after an outbreak of hepatitis A in 2003.

Limitations

This study was limited in that all models are simplifications of real life and, as such, cannot include every possible event or outcome.⁶⁵ We did not include some circumstances that may further increase costs, such as employees suffering severe illnesses and outcomes, which would result in larger productivity losses. We did not include any subsequent costs that restaurants may incur after an outbreak. For example, restaurants may need to invest in special campaigns (eg, advertisements and sales promotions) to regain consumer confidence, and staff turnover may result in training new hires.

Conclusions

Our study shows that a single foodborne illness outbreak can incur substantial costs, enough to compose a large portion of a restaurant's annual profits. Many of these costs outweigh the costs of various infection prevention and control measures that are available to restaurants. To our knowledge, our study is the first to quantify these costs to a restaurant. Restaurant decision makers can consider these results when planning investments in appropriate policies and interventions to prevent foodborne illness outbreaks.

Declaration of Conflicting Interests

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