Costs of Food Safety Investments in the Meat and Poultry Slaughter Industries

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Abstract: To develop regulations efficiently, federal agencies need to know the costs of implementing various regulatory alternatives. As the regulatory agency responsible for the safety of meat and poultry products, the U.S. Dept. of Agriculture's Food Safety and Inspection Service is interested in the costs borne by meat and poultry establishments. This study estimated the costs of developing, validating, and reassessing hazard analysis and critical control points (HACCP), sanitary standard operating procedures (SSOP), and sampling plans; food safety training for new employees; antimicrobial equipment and solutions; sanitizing equipment; third-party audits; and microbial tests. Using results from an in-person expert consultation, web searches, and contacts with vendors, we estimated capital equipment, labor, materials, and other costs associated with these investments. Results are presented by establishment size (small and large) and species (beef, pork, chicken, and turkey), when applicable. For example, the cost of developing food safety plans, such as HACCP, SSOP, and sampling plans, can range from approximately $6000 to $87000, depending on the type of plan and establishment size. Food safety training costs from approximately $120 to $2500 per employee, depending on the course and type of employee. The costs of third-party audits range from approximately $13000 to $24000 per audit, and establishments are often subject to multiple audits per year. Knowing the cost of these investments will allow researchers and regulators to better assess the effects of food safety regulations and evaluate cost-effective alternatives.

Keywords: costs, food safety, investments, meat and poultry slaughter, regulation

Introduction

Both the U.S. Food and Drug Administration (FDA) and the U.S. Dept. of Agriculture's (USDA's) Food Safety and Inspection Service (FSIS) are responsible for ensuring the safety of food consumed in the United States, with FSIS having jurisdiction over meat, poultry, and egg products. To develop regulations efficiently, these federal agencies need to know the costs of implementing various regulatory alternatives, as specified in Executive Orders 12866 and 13563. The costs borne by industry to comply with a regulation are often due to food safety investments made by firms within the industry. In addition to regulatory compliance, Ollinger and others (2011) listed several other motivations for food firms to invest in food safety practices and technologies, such as the fear of lost sales in the event of a recall, to support an important brand, and to meet customer specifications. However, it is difficult to estimate the cost of these food safety investments, as they routinely change because of technological advancements, are often highly variable because of differences in firm size and process requirements, and are rarely published.

The objective of this study was to estimate the costs incurred by the meat and poultry industry to implement various food safety measures. Our focus is on costs of food safety measures that might be implemented in response to government regulations, but many establishments may also implement these in response to buyer requirements. We estimated establishment-level costs of implementing food safety interventions, assuming that each firm operates a single establishment (or plant). However, in some cases, firms with multiple establishments might experience economies of scale when implementing changes across establishments such that the cost per establishment is lower than it would be for a company with a single establishment. The food safety investments of interest for this study were developing, validating, and reassessing hazard analysis and critical control points (HACCP), sanitary standard operating procedures (SSOP), and sampling plans; food safety training for new employees; antimicrobial equipment and solutions; sanitizing equipment; and third-party audits. We also investigated the costs of microbial tests conducted at third-party laboratories.

Some of these investments are already mandated (for example, HACCP, SSOP, and sampling plans); thus, their costs were estimated by the agency when the final rules were published (FSIS 1996). However, these estimates need to be updated as the costs of food safety regulations are continually used and cited in regulatory analyses. Previously, FSIS would survey a small number of firms to inquire about their costs and use their own internal assumptions to project the costs to other establishments. Knowing the cost of food safety investments from a broader set of industry experts will allow regulators to better assess the effects of current regulations and provide more cost-effective alternatives in future rulemaking. These estimates are also useful for companies that are entering the industry.

Our study only assesses costs; the effectiveness of the interventions was not estimated. Many of the investments included in this study are not currently mandated (for example, specific antimicrobial equipment and solutions, sanitizing equipment, food safety training, audits). These are discretionary interventions or practices which may be used to comply with mandatory requirements.

Materials and Methods

To collect cost data on the selected food safety investments, we used a combination of primary and secondary sources. We collected primary data using an expert panel methodology and secondary data through various web searches. Using an accounting

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Table 1–Definitions and assumptions for selected food safety interventions.

Intervention	Definition	Assumptions
HACCP plans	A systematic, preventative approach to food safety from biological, chemical, and physical hazards. HACCP plans must be developed, validated, and reassessed.	Baseline is that establishment does not have a HACCP plan. Assume costs vary by establishment size, but not by species.
SSOP plans	Documented steps that must be followed to ensure adequate cleaning of product contact and non-product surfaces; considered one of the prerequisite programs of HACCP. SSOP plans must be developed, validated, and reassessed.	Baseline is that establishment does not have an SSOP plan. Assume costs vary by establishment size, but not by species.
Sampling plans	A detailed plan that describes what microbiological samples to take, when and how samples should be taken, and by whom. Sampling plans must be developed, validated, and reassessed.	Baseline is that establishment does not have a sampling plan. Assume costs vary by establishment size, but not by species.
Food safety training	Formal or informal training of management and production employees on the following topics: HACCP, SSOPs, humane handling, food defense, sampling, GMPs, sanitary dressing, and recall procedures.	Assume costs vary by establishment size, but not by species.
Antimicrobial equipment	Equipment designed to eliminate pathogens during the slaughter and processing of carcasses. Experts specified the most commonly used equipment.	Baseline is that establishment does not have any equipment installed. Equipment may vary by establishment size and species.
Antimicrobial solutions	Solutions with antimicrobial properties that are applied as sprays or dips to reduce contaminants on raw foods such as meat. Solutions considered include acidified sodium chlorite, bromine, chlorine dioxide, cetylpyridium chloride, organic acids, peracetic acid, trisodium phosphate, monochloramine, electrolyzed water, and hypochlorous acid.	Baseline is that establishment does not currently use antimicrobial solutions. Solutions may vary by establishment size and species.
Sanitizing equipment	Equipment designed to eliminate microorganisms from hands, boots, knives, and other small equipment used on the production floor. Equipment includes knife and other small equipment sanitizers, hand washing stations, boot washing stations, and floor foamers.	Baseline is that establishment does not have any equipment. Assume costs vary by establishment size, but not by species.
Third-party audits	Customer-driven inspections performed by non-government, independent organizations to confirm that an establishment is following recommended food safety procedures.	Assume costs vary by establishment size, but not by species. Include the costs of a consultant if needed. Costs are on a per-audit basis.

Table 2–Qualifications of experts on the panel.

University and department affiliation	Degree	Meat slaughter	Meat processing	Poultry slaughter	Poultry processing	Small establishments	Large establishments
Texas Tech Univ. Dept. of Animal and Food Sciences	Ph.D., Animal Science	•	•			•	•
Penn State Univ. Dept. of Food Science	Ph.D., Food Technology / Microbiology	•	•	•	•	•	•
Texas A&M Univ. Dept. of Poultry Science	Ph.D., Food Science & Technology			•	•		
North Carolina State Univ. Dept. of Food, Bioprocessing, and Nutrition Sciences	Ph.D., Animal Science / Meat Science	•	•			•	•
Penn State Univ. Dept. of Animal Science	Ph.D., Meat Science	•	•	•	•	•	•
Purdue Univ. Dept. of Food Science and Agricultural & Biological Engineering	Ph.D., Food Process Engineering			•	•		
Purdue Univ. Dept. of Food Science	Ph.D., Food Science			•	•	•	•

approach, we estimated capital, labor, materials, and other costs associated with a range of interventions. Antle (1999) noted methodological shortcomings associated with the accounting approach to estimate the costs of regulation, including the inability of a small number of firms to represent industry average costs of production and the inability to differentiate costs between small and large establishments. However, we addressed these limitations by collecting data from industry experts that work with establishments of varying sizes, species, and geographic locations.

Before conducting the expert consultation, we conducted a search for published literature in scientific journals, trade publications, and extension publications to identify background information describing each intervention. To ensure consistency and understanding between the experts, we fully defined each

intervention and developed appropriate assumptions, as needed. These are summarized in Table 1. For example, we assumed that the establishment did not already have any plans or equipment, to determine the total cost of the intervention.

To conduct the expert consultation, we identified and recruited experts, developed meeting materials based on the data needs, and planned the logistics of the in-person meeting. We invited 19 potentially qualified experts, selected from well-known meat and poultry research and extension faculty recommendations from other experts, and internet searches. We asked each invited expert to rank their expertise levels on various aspects of the meat and poultry industries (such as production, slaughter, and processing) and list any potential conflicts of interest. We selected 7 qualified experts that are extension specialists, professors, and consultants with a mix of expertise in the beef, pork, and poultry industries, familiar with both small and large establishments. As shown in Table 2, these experts provided the range of expertise needed for the exercise. By limiting the panel to 7 experts, we were able to conduct the expert panel in person to ensure full engagement of the entire group. To prepare for the meeting, we created an agenda, background materials, PowerPoint presentation, and worksheets to record the results. The background materials consisted of a list of the interventions with their definitions and reference information, and the PowerPoint slides listed any assumptions about each intervention (for example, what species it applied to). These served as the basis for our discussion about each intervention.

We conducted the expert consultation in person in Research Triangle Park, North Carolina, in February 2015. We began the meeting with an overall discussion of the types of costs needed, then categorized establishment sizes, followed by a detailed discussion of each intervention. We displayed the cost estimates on a screen in the conference room as they were being constructed, and facilitated a discussion among the experts to reach consensus on each cost input. We used a consensus approach to ensure the experts engaged in discussion to reach a "best estimate" and avoid obtaining widely disparate estimates as can be the case when experts are providing individual estimates without discussing their underlying assumptions and process for estimation. We determined a margin of error estimate in which to calculate ranges of costs based upon the experts' level of certainty of cost estimates for each intervention.

In addition to collecting data through expert consultation, we also collected data through Internet searches and various contacts in academia and industry. Throughout the expert panel meeting, the experts referred us to various contacts at universities and animal nutrition and agricultural supply companies to obtain additional supporting information for developing cost estimates.

To collect cost data on microbiological tests, we obtained price lists from 5 laboratory websites:

- Barrow Agee Laboratories, LLC (www.balabs.com)
- Great Lakes Scientific, Inc. (www.glslab.com)
- Medallion Labs (www.medallionlabs.com)
- Merieux NutriSciences (www.merieuxnutrisciences.com)
- Midwest Laboratories, Inc. (www.midwestlabs.com)

These 5 laboratories vary in size and region. Employment levels at these laboratories range from 12 to 105 employees, and annual sales range from $2 to $22 million. Two of the laboratories are national and international in scope, one laboratory is regional, and the remaining 2 are single establishment, smaller companies. The prices of the various microbiological tests were compiled into an Excel spreadsheet, and the minimum, mean, and maximum prices were calculated for each test. During the expert panel meeting, the experts reviewed the price ranges as a validity check and provided information on the types of tests for which data were not available on laboratory price lists.

Table 3–Wage rates for animal slaughtering and processing industry, 2014, excluding benefits.

Labor category	Dollars per hour (median)
Food scientists and technologists	$27.08
Production occupations	$12.16
Management occupations	$42.15
Animal handlers (slaughterers and meat packers)	$12.29

Calculating cost estimates

The total costs of investments for a meat or poultry establishment to respond to regulatory requirements may encompass capital equipment, labor, materials, utilities, repairs and maintenance, annual amortization costs, and other costs. Capital equipment costs include new equipment and installation costs and are estimated in dollars. Labor costs include wages for managers, food scientists, production employees, and animal handlers and are associated with each of the interventions. These costs are estimated in hours per year by type of employee and then multiplied by median hourly wages from the Bureau of Labor Statistics (BLS). Materials costs include ingredients, packaging, and cleaning supplies. These costs are estimated in dollars per year for each food safety intervention. Utilities costs include increased water use, liquid and solid waste disposal or sewer costs, and energy for operating establishment equipment or interventions during various stages of the process (estimated in dollars per year). Utilities costs were estimated at $3 per 1000 gallons of water used, to heat or chill the water being used in the process. Water and sewer costs were estimated at $0.0037 per gallon. Annual repairs and maintenance costs are estimated at 10% of capital equipment costs. Annual amortization costs for capital equipment are calculated based on years of life or useful life of equipment and an interest rate of 7%. Equipment under $1 million was amortized over 4 y, and equipment over $1 million was amortized over 10 y. Other costs include the cost of hiring consultants and travel to establishments for consultants. We assumed that consultants charge $250 per h and their travel costs are $1000 per trip, which is the sum of airfare ($500), lodging ($200), meals ($200), and rental car ($100).

To calculate labor costs, estimates of wage rates for the Animal Slaughtering & Processing industry (NAICS code 311600) were obtained from the BLS website, shown in Table 3. We used the following labor categories in our analysis: Food scientists and technologists, production occupations, management occupations, and animal handlers at slaughterers and meat packers. These wage rates do not account for benefits, which the BLS estimates at 35% of wages for manufacturing industries (BLS 2015). However, when an analyst uses the cost spreadsheet developed under this study, a benefits rate can be applied to the wage rates as needed.

We estimated costs for 2 establishment sizes—small and large—whose sizes were determined based on slaughter volume per shift by species as determined by the experts. Although the FSIS Public Health Inspection System (PHIS) provides slaughter volume and establishment size data, our analysis did not use the HACCP size categories from the original 1996 Pathogen Reduction;

Table 4–Typical operating characteristics and slaughter volumes, by size and species, for meat and poultry establishments.

	Beef		Pork		Chicken		Turkey	
Operating characteristic	Small (<500 head per shift)	Large (500+ head per shift)	Small (<8000 head per shift)	Large (8000+ head per shift)	Small (<60000 birds per shift)	Large (+60000 birds per shift)	Small (<12000 birds per shift)	Large (12000+ birds per shift)
Hours per shift	8	8	8	8	8	8	8	8
Shifts per d	1	2	1	2	1	2	1	2
Days per wk	4	5.5	4.5	5.5	4	5.5	4	5
Hours per wk	32	88	36	88	32	88	32	80
Weeks per y	50	50	50	50	50	50	50	50
Hours per y	1600	4400	1800	4400	1600	4400	1600	4000
Shifts per y	200	550	225	550	200	550	200	500
Days per y	200	275	225	275	200	275	200	250
Average number of head per shift[a]	182	1439	2271	9567	59312	115398	6650	20891
Number of head per year[b]	36400	791450	510975	5261850	11862400	63468900	1330000	10445500

Note: Assumptions shown are an annual average and do not reflect seasonality of production, primarily for turkeys.
[a]Calculated by averaging the 2014 annual slaughter volumes for each size grouping and species, and dividing by the number of shifts operated per year.
[b]Calculated by multiplying the average number of head per shift by the number of shifts per year.

hazard analysis and critical control point (HACCP) Systems rule[i]—we only distinguished between small and large establishments as these are more reflective of differences in costs incurred for food safety. The experts estimated the breakpoint slaughter volume between small and large establishments that would be most characteristic in terms of practices and equipment used (shown in Table 4). To estimate costs for small and large establishments, we then estimated operating hours per year, operating shifts per year, and average annual slaughter volumes for each size and species combination, as described below. For example, with beef, a small establishment would slaughter less than 500 head per shift, whereas a large establishment would slaughter 500 or more head per shift. We converted the per-shift breakpoint volumes into annual breakpoint volumes by multiplying the per-shift breakpoint volumes by the average number of shifts per day, days per week, and weeks per year (also estimated by the experts, as described below). Finally, we used the annual breakpoint values for each species to assign the establishments in FSIS's PHIS database to size categories, and then calculated the average 2014 annual slaughter volume for each size grouping and species.

Through a consensus process, the experts developed assumptions for typical operating characteristics (for example, hours per shift, shifts per d, and days per wk) by establishment size and species (Table 4). The assumptions reflect annual averages, although for some species, particularly turkeys, establishments may vary their operating hours and production volumes by season. The number of hours per shift and shifts per day are the same across species, although the days per wk vary by species, resulting in different hours per wk by species. We calculated the number of hours per y by multiplying the number of hours per shift by the number of shifts per d, the number of days per wk, and the number of weeks per y. For example, with a large beef, pork, or chicken establishment, multiplying 8 h per day times 2 shifts per day times 5.5 d per wk times 50 wk per y results in 4400 h per y. We calculated the number of shifts per year by multiplying the number of shifts per day by the number of days per wk and the number of weeks per y, and the number of days per y by multiplying the number of days per wk by the number of weeks per y. For example, with a large beef, pork, or chicken establishment, 2 shifts per day times 5.5 d per wk times 50 wk per y results in 550 shifts per y. We used the estimated operating hours when calculating establishment-level costs that are based on number of operating hours and the estimated slaughter volumes when estimating establishment-level costs that are based on throughput.

Based on input from the experts and their level of certainty in the estimates, we applied a margin of error for each intervention

Table 5–Costs of developing, validating, and reassessing HACCP, SSOP, and sampling plans, by establishment size ($ per plan).[a]

Cost activity	Small establishments	Large establishments
HACCP plans		
Initial costs		
Develop plan internally	$13540	–
Develop plan with consultant	$17770	$43080
Validate plan	$10832	$8666
Annual costs		
Reassess plan	$365	$730
SSOP plans		
Initial costs		
Develop plan internally	$13540	–
Develop plan with consultant	$10270	$43080
Validate plan	$10832	$8666
Annual costs		
Reassess plan	$365	$730
Sampling plans		
Initial costs		
Develop plan with consultant	$6542	$87240
Validate plan	$32496	$46997
Annual costs		
Reassess plan	$243	$486

Note: blank cells indicate that a large establishment would not develop a plan internally without the use of a consultant. Estimated costs do not vary by species.
HACCP, hazard analysis and critical control points; SSOP, sanitary standard operating procedures.
[a]The margin of error is 50%.

[i]Large establishments have 500 or more employees; small establishments have between 10 and 499 employees; and very small establishments have fewer than 10 employees or annual sales of less than $2.5 million.

Table 6–Estimated training costs for new employees (per employee).[a]

Course	Employee type	Labor hours	Course fee	Travel costs	Total cost
HACCP	Management	24	$500	$1000	$2512
	QA	24	$500	$1000	$2150
	Production	4	$500	0	$549
SSOP	Management	12	$500	$1000	$2006
	QA	12	$500	$1000	$1825
	Production	10	$500	$0	$622
Humane handling	Production	8	$312	$0	$410
Food defense	Management	8	$150	$1000	$1801
	QA	8	$150	$1000	$1367
	Production	8	$150	$0	$247
Sampling	QA	24	$1000	$0	$1650
GMPs	Management	8	$250	$0	$587
	QA	8	$250	$0	$467
	Production	8	$250	$0	$347
Sanitary dressing	Production	10	$0	$0	$122
Recall procedures	Management	4	$250	$1000	$1419
	QA	4	$250	$1000	$1358

Notes: Travel costs are zero in cases where establishments would not typically send employees for external training but would instead conduct the training at the establishment location. Estimated training costs are the same across species. We used the wage rate for the Food Scientists and Technologists labor category for the QA employee type.
GMP, good manufacturing practice; HACCP, HACCP, hazard analysis and critical control points; QA, quality assurance; SSOP, sanitary standard operating procedures.
[a]The margin of error is 50%.

Table 7–Estimated annual costs of antimicrobial equipment used in meat slaughter and processing establishments, by size (per establishment).[a]

Equipment	Beef	Pork
Small establishments		
Spray cabinet	$38025	$78635
Hand sprayer for carcasses	$19575	$48557
Handheld hot water sprayer for carcasses	$27037	
Hand sprayer for subprimals or trim	$19559	
Large establishments		
Steam vacuum	$431914	
Steam pasteurization cabinet	$269673	
Spray cabinet	$575584	$1771242
Automated spray on subprimals/trimmings	$31102	$43909
Hotbox/chilling	$1677456	
Sprayers in coolers	$44975	
Blast chill		$1860313

Note: blank cells indicate the equipment is not used by an establishment that slaughters that species.
[a]The margin of error is 50% for small establishments and 20% for large establishments.

Table 8–Estimated annual costs of antimicrobial equipment used in poultry slaughter and processing establishments, by size (per establishment).[a]

Equipment	Chickens	Turkeys
Small establishments		
Chiller (water)	$63941	$51135
Dip tank	$28946	$22543
Large establishments		
Inside-outside bird washer	$134371	$154498
Pre-chill drench (CPC) or spray cabinet (PAA)	$151294	$80037
Chiller (water)	$745146	$462551
Post-chill dip tank/finishing chiller	$86769	$57537
Post-chill spray bars	$66136	$36904

CPC, cetylpyridium chloride; PAA, peracetic acid.
[a]The margin of error is 50% for small establishments and 20% for large establishments.

that ranged from 10% to 50%, depending on the investment. For example, if the experts were fairly certain of an estimate, we applied a 10% margin of error, but if they were somewhat uncertain of an estimates, we applied a 50% margin of error. The margin of error also allows the user to see how costs may differ across different size plants within the same plant size category. Applying a margin of error allowed us to estimate a low and high estimate for each investment. In this paper, we present the midpoint estimates for all costs, but the range of costs is available in Viator and others (2015b). All calculations were done in a cost-estimating tool developed in Microsoft Excel.

Results and Discussion

Each investment has associated capital equipment, labor, materials, utilities, and other costs. The costs for written plans are presented on a per-plan basis, food safety training on a per-employee basis, antimicrobial solution costs on a per-head basis, audits on a per-audit basis, and microbial tests on a per-test basis; antimicrobial and sanitizing equipment costs are presented on a per-establishment basis. The findings are presented by establishment size in cases where the experts believe the costs vary by size.

HACCP plans

HACCP is a system used to prevent food safety hazards through the identification of hazards, establishment of controls for the identified hazards, monitoring of controls, and periodic verification that the system works. All meat and poultry establishments in the United States are required to have a written HACCP plan for each product produced (FSIS 1996). The initial costs of developing and validating a HACCP plan and the annual costs of reassessing the plan were estimated and are summarized in Table 5. These costs include labor hours for writing the plan, but do not include the costs of microbial testing or capital equipment that may aid in meeting critical control points or regulatory performance standards. Small establishments will either (a) develop the entire plan internally using company employees or (b) hire a consultant to assist in plan development. The experts estimated they will use 500 labor hours to develop it on their own, thus the total cost of developing a HACCP plan internally is $13540. Under the 2nd option of hiring a consultant, the experts estimated 250 labor hours, a consultant's fee ($10000), and travel costs ($1000), bringing the total cost of developing a HACCP plan with a consultant to $17770. A large establishment would use an assumed 1000 labor hours and hire a consultant (at a cost of $15000 plus $1000 in travel expenses), resulting in a total cost of $43080. The cost to develop a 2nd plan (for a 2nd product) would be 75% of the cost

Table 9–Estimated costs of antimicrobial solutions, low and high cost methods (per head).[a]

	Small establishments		Large establishments	
Species	**Low-cost method**	**High-cost method**	**Low-cost method**	**High-cost method**
Beef				
Solution	Hypochlorous acid	Organic acids	Organic acids	Peracetic acid
Cost	$0.050	$1.750	$0.175	$0.265
Pork				
Solution	Hypochlorous acid	Organic acids	Organic acids	Peracetic acid
Cost	$0.050	$1.750	$0.150	$0.200
Chickens				
Solution	Hypochlorous acid	Peracetic acid	Hypochlorous acid	Peracetic acid
Cost	$0.001	$0.900	$0.001	$0.900
Turkeys				
Solution	Hypochlorous acid	Peracetic acid	Hypochlorous acid	Peracetic acid
Cost	$0.001	$0.900	$0.001	$0.900

[a]The margin of error is 10%.

to develop the 1st plan; the cost to develop a 3rd plan would be 50% of the cost to develop the 1st plan, and so on. In consultation with the experts, we assumed that costs of HACCP plans do not vary by the species that the plant slaughters.

To validate a HACCP plan, the establishment must demonstrate that their HACCP system adequately controls potential food safety hazards. Validation involves documentation of scientific support that the HACCP system theoretically works and in-plant demonstration that it can be executed within the establishment. Establishments are required to validate each HACCP plan within 90 d of operating within a new or modified HACCP system (USDA 2013). The experts estimated that a small establishment would use 400 labor h to validate a plan for a total cost of $10832, and a large establishment would use 320 h for a total cost of $8666. It is assumed that a large establishment would have employees with more specialized knowledge and would thus be able to validate a plan more efficiently than a small establishment.

Establishments are required to reassess their HACCP plans at least once annually or more frequently if there has been a significant change in their process. Reassessment involves reassessing the hazard analysis to ensure that all hazards are considered. This also involves reviewing records (that is, through test results and monitoring) to ensure food safety goals are being met by the HACCP system (USDA 2013). We assume a small establishment will spend 30 h reassessing its HACCP plan, for a total cost of $365, and a large establishment will spend 60 h per reassessment for a total cost of $730. Large establishments typically reassess their plans 2 to 3 times per year, whereas small establishments typically reassess their plans once per year (as required by federal regulation).

SSOP plans

SSOP plans are the documented sanitation procedures in food production plants, required by FSIS as a prerequisite program of HACCP (FSIS 1996). SSOPs are generally documented steps that must be followed to ensure adequate cleaning of product contact and nonproduct surfaces. Using the same assumptions as for developing HACCP plans, the cost of developing, validating, and reassessing SSOP plans was estimated (Table 5). For small and large establishments that use their own labor to develop a SSOP plan, the total cost is the same amount needed for a HACCP plan ($13540 for small establishments and $43080 for large establishments). Generally, if a consultant develops a HACCP plan, he or she will also develop the SSOP plan, resulting in efficiencies. Therefore, if a small establishment uses a consultant, the total cost is $10270, which is lower than the cost to develop a HACCP plan because of decreased consultant costs. The costs to validate and reassess the SSOP plan are the same as the HACCP plan for small and large establishments.

Sampling plans

Sampling plans detail the number and size of samples to be taken, the product or location from where they should be taken and how they should be taken, microbiological tests to be conducted, and the maximum allowable positive test results for acceptance or rejection (van Schothorst and others 2009). Sampling plans should be based on sound statistical concepts to achieve a high degree of confidence in the acceptability of the food product being produced; the type of food product, its intended use, and its microbiological history are also important factors to consider when developing a sampling plan (National Research Council 1985). Because of the complexity of sampling plans, we assumed that all establishments will hire a consultant to develop their microbiological sampling plans. The experts estimated that a small establishment will spend $6542 to develop a sampling plan (including 20 labor h, $5000 on consultant fees, and $1000 on travel fees for the consultant), $32496 to validate the plan (which includes 1200 labor hours), and $243 annually to reassess the plan, as shownn in Table 5. A large establishment is estimated to spend 3000 labor hours, $5000 on consultant fees, and $1000 on travel fees for a total of $87240 to develop a sampling plan. The cost of validating the sampling plan will be $46997, which includes 960 labor h, $20000 in consultant fees, and $1000 in travel fees for the consultant. In consultation with the experts, we assumed that the costs of sampling plans do not vary by the species that the plant slaughters.

Food safety training for new employees

The implementation of a written food safety plan requires personnel that are trained to follow it. Moreover, Wilcock and others (2011) found that training employees on the program and their expectations was key to having an effective HACCP program. Training is also recommended in other areas, such as personal hygiene (Nel and others 2004; DeBoeck and others 2016) and quality control (Topliceanu 2015).Meat and poultry slaughter establishments may opt to send employees to an external formal food safety training, or they may conduct formal or informal training on-site. External food safety training is provided by university and extension personnel, consulting firms, and professional industry associations. Per-employee costs of training were estimated

for new management staff, quality assurance staff, and production employees in the following areas of food safety: HACCP, SSOP, humane handling, food defense, sampling, good manufacturing practices (GMPs), sanitary dressing, and recall procedures (Table 6). The experts estimated the number of hours typically spent on each type of training and an average course fee. We assumed that management and quality assurance staff attend external third-party trainings, whereas production employees attend trainings onsite, conducted by establishment employees who have received external training. The course fees shown for production employees are the equivalent of establishment personnel labor hours spent preparing and delivering the trainings. Travel costs are incurred by management employees and quality assurance staff who travel to trainings. In consultation with the experts, we assumed that training costs do not vary by the species that the plant slaughters.

Labor hours included in the experts' cost estimates represent the amount of time that establishments should spend on training, not the amount of time that establishments actually spend. The experts believe that establishments spend approximately one-third of the actual time on training that is recommended.

Antimicrobial equipment

Establishments have an incentive to use antimicrobial equipment technologies to meet more stringent pathogen control standards, although FSIS does not mandate the use of specific equipment. The antimicrobial equipment used by an establishment will vary based on the establishment size and species slaughtered. For example, beef and pork establishments may use spray cabinets or hand sprayers for carcasses, whereas poultry establishments may use water chillers and dip tanks to apply antimicrobials. The total annual costs for these pieces of equipment in meat and poultry establishments are shown in Tables 7 and 8, respectively. The total annual costs are the sum of annualized purchase and installation costs of capital equipment, labor costs, water and energy costs, and repair and maintenance costs. Initial capital equipment costs, labor hours required per shift, and water usage were estimated by the expert panelists.

A small beef establishment is estimated to spend between $19559 and $38025 on antimicrobial equipment, depending on whether they use hand sprayers or a spray cabinet. The investment for large establishments is much higher, at $1.6 million if a hotbox chilling unit is installed. For a small chicken establishment, the investments range from $28946 to $63941. Large chicken establishments are estimated to spend more on equipment, ranging from $66136 for post-chill spray bars to $745146 for a water chiller.

Antimicrobial solutions

Antimicrobial solutions are used in conjunction with the antimicrobial equipment described above. The experts estimated the low and high cost solutions for each species and establishment size, shown in Table 9. Hypochlorous acid is the lowest cost solution for all small establishments, regardless of species, and peracetic acid is the highest cost solution for all poultry establishments, regardless of size. Overall, the solution costs are similar across species on a per-gallon basis but vary based on the volume of the solution needed per head or bird. Furthermore, large establishments receive volume discounts on solutions; thus, their per-head costs are lower than small establishments.

Sanitizing equipment

Sanitizing equipment at a slaughter establishment includes knife and other equipment sanitizers, boot washing stations, hand washing stations, and floor foamers (also called entryway foamers). Using assumptions from the expert panel on the cost of sanitizing equipment and typical number of equipment stations per establishment, estimates were developed for installing and operating sanitizing equipment for small and large establishments by species (Table 10). Capital equipment costs were amortized over 5 y, the expected life of the equipment. To calculate labor costs, the experts estimated that production employees spend 0.25 h per shift monitoring the dosage of chemicals in the equipment (not labor time spent in sanitizing hands, boots, or knives). Materials for this intervention include quaternary ammonia for boot washing stations and soap, sanitizers, paper towels, and gloves

Table 10–Estimated sanitizing equipment costs by establishment size and species (per establishment).[a]

Equipment	Small establishments	Large establishments
Beef		
Knife sanitizer		
Number of stations	2	15
Total annual cost	$1496	$11252
Boot washing station		
Number of stations	1	2
Total annual cost	$997	$14347
Hand washing station		
Number of stations	2	5
Total annual cost	$1496	$7813
Floor foamers		
Number of stations	3	10
Total annual cost	$7865	$83784
Pork		
Knife sanitizer		
Number of stations	2	15
Total annual cost	$1597	$11252
Boot washing station		
Number of stations	1	2
Total annual cost	$1098	$14347
Hand washing station		
Number of stations	2	5
Total annual cost	$1597	$7813
Floor foamers		
Number of stations	3	10
Total annual cost	$8616	$83784
Chicken		
Knife sanitizer		
Number of stations	2	15
Total annual cost	$1496	$11252
Boot washing station		
Number of stations	1	2
Total annual cost	$997	$14347
Hand washing station		
Number of stations	2	5
Total annual cost	$1496	$7813
Floor foamers		
Number of stations	3	10
Total annual cost	$7,865	$83,784
Turkey		
Knife sanitizer		
Number of stations	2	15
Total annual cost	$1496	$10698
Boot washing station		
Number of stations	1	2
Total annual cost	$997	$13793
Hand washing station		
Number of stations	2	5
Total annual cost	$1496	$7259
Floor foamers		
Number of stations	3	10
Total annual cost	$7865	$76730

[a]The margin of error is 50% for the number of units needed and 25% for the dollar estimates.

Table 11–Estimated third-party audit costs, by establishment size (per audit).[a]

	Small establishments	Large establishments
Without use of consultant		
Labor costs	$6019	$8093
Auditor fee	$6500	$15000
Travel costs	$1000	$1000
Total costs	$13519	$24093
With use of a consultant		
Labor costs	$1686	
Consultant costs	$8000	
Auditor fee	$6500	
Travel costs	$2000	
Total costs	$18186	

Note: Costs of an audit with use of a consultant were not estimated for large establishments because the experts believe that large establishments would not typically use a consultant to conduct audits.
[a]The margin of error is 25%.

Table 12–Estimated microbiological test costs (per test).

Type of test	Mean cost
Aerobic plate count (screen)	$18
Campylobacter (confirm)	$74
Campylobacter (screen)	$43
Clostridium perfringens (confirm)	$50[a]
Clostridium perfringens (screen)	$29
Coliforms (screen)–Petrifilm	$18
Coliforms (screen)–MPN	$25
Enterobacteriaceae (screen)	$23
Generic *E. coli* (screen)–Petrifilm	$18
Generic *E. coli* (screen)–MPN	$25
Listeria Monocytogenes (confirm)	$36
Listeria Monocytogenes (screen)	$32
Non-O157 STEC (confirm)[b]	$266
Non-O157 STEC (screen)	$33
STEC O157:H7 (confirm)	$213
STEC O157:H7 (screen)	$32
Salmonella (confirm)	$40
Salmonella (screen)	$25
Shigella	$50
Staphylococcus aureus (confirm)	$30[a]
Staphylococcus aureus (screen)	$21
Staphylococcus Enterotoxin	$101
Total plate count (screen)	$16
Residue–antibiotics	$20
Residue–pesticides	$358

MPN, most probable number.
[a]Only a single estimate was available across the five testing laboratories.
[b]This test is for all 6 non-O157 STEC.

for hand washing stations. The costs were estimated by the experts at $1 per d for small establishments and $5 per shift for large establishments for knife sanitizers and hand and boot sanitizing stations. The material used in floor foamers was estimated at $9 per gallon, based on information from a manufacturer. Assuming that small establishments use 3 gallons per day and large establishments use 30 gallons per day, the daily cost is $27 for small establishments and $270 for large establishments. Capital equipment and labor costs are the same across species, but materials costs vary when the number of shifts are applied to calculate the annual estimates. If an establishment were to purchase all of the sanitizing equipment listed in Table 7, the total annual costs would range from $11854 for a small beef, chicken, or turkey establishment to $117197 for a large beef, pork, or chicken establishment.

Third-party audits

Third-party audits provide credible verification that an establishment is following its written plans, such as HACCP plans, SSOP plans, humane handling plans, food defense plans, and others. Third-party audits are increasingly being used as a method to improve the safety of food, both in perception and in reality (Peterson 2011). They are often customer driven by distributors, retailers, and foodservice, but can also be used as a marketing tool (Ollinger and others 2011). Primary certification in the meat and poultry industry, such as the global food safety initiative (GFSI), the Intl. organization for standardization (ISO), and safe quality foods (SQF), provide standards-based third-party audits. ISO and SQF are benchmarked by GFSI; therefore, the experts calculated the cost of a GFSI audit. Costs for an audit are the same across species and are presented in Table 11.

Audits are generally conducted twice per year, although the costs presented here are on a per-audit basis. Small establishments may hire a consultant to help prepare for an audit, whereas a large establishment would usually not. If an establishment does not use a consultant, the Food Safety Manager at the establishment will work with a technician; if using a consultant, the Food Safety Manager would work directly with the consultant and would not need a technician. The total cost of a third-party audit is the sum of labor costs, the auditor fee, travel costs for the auditor, and the consultant fee (if applicable). Labor time spent on an audit requires retrieving records, meeting with the auditor to answer questions, and providing the auditor a tour of the establishment. Between 6 and 10 employees at a large establishment will likely spend approximately 3 d on an audit. Time spent preparing for the audit is not included; according to the experts, establishments prepare continuously for audits throughout the year. The auditor fee is estimated at $2500 per d, regardless of establishment size. An auditor spends approximately 2.5 d at a small establishment and 6 d at a large establishment. Thus, the total costs of a third-party audit without a consultant are $13519 for a small establishment and $24093 for a large establishment. The cost for a small establishment increases to $18186 if the establishment uses a consultant.

Microbiological tests

All meat and poultry slaughter establishments are required to conduct microbiological tests on their products to ensure that they are maintaining process control and meeting federal regulations, policies, and performance standards. These tests also provide establishments with data to improve their processes and focus pathogen-control efforts where needed. FSIS currently conducts testing for chemical residues and 4 major pathogens of concern: *Salmonella*, *Campylobacter*, *E. coli* O157:H7, and *Listeria monocytogenes* (USDA/FSIS 2011). Many establishments conduct additional testing beyond what is required by federal regulations (Viator and others 2015a). Mean costs were calculated for 31 different microbiological tests, including confirmation, and screening test costs, as displayed in Table 12. The mean costs ranged from $18 to $358 per test, depending on the type of test. As discussed in the Materials and Methods section, pricing information was obtained from 5 testing laboratories that were used as the basis for the estimates. Most test costs did not vary more than $10 between laboratories, providing evidence that the estimates are generally reliable. The largest variations were for *Staphylococcus Enterotoxin* and Residues–Pesticides, but these estimates were based on fewer than 5 responses and are thus less reliable than other estimates. The mean costs presented in Table 12 do not vary by establishment size; however, larger establishments may receive volume discounts from laboratories.

In addition to the per-test costs of conducting microbiological testing, establishments also incur labor costs for selecting and preparing samples and shipping the samples to the testing laboratory. For example, Muth and others (2015) cite a labor time of 1 h for plant personnel and $75.35 for overnight shipping for each sample. Thus, these costs are typically much greater than the price paid to the third-party laboratory.

Establishments that conduct microbiological tests in onsite laboratories may realize cost savings compared with using offsite, third-party laboratories. The experts agreed that more testing occurs in-house than through third-party laboratories and estimated that onsite tests are approximately 50% less costly than third-party laboratories. In addition, establishments do not incur the costs of shipping samples to a third-party laboratory. However, the cost savings of using an onsite laboratory may be offset by a larger number of tests conducted, as establishments with in-house laboratories typically conduct more tests as part of their routine operations than those without in-house laboratories. The experts generally believed there is no establishment-size cutoff for in-house testing; however, they believe most establishments producing ready-to-eat meat product use both in-house and third-party laboratories. Establishments that are part of large corporations may send their samples to corporate laboratories, thus incurring shipping costs.

Overall, larger establishments rely on high production volumes to minimize costs of production and thus are more likely to use automated equipment to control pathogens. Small establishments can control pathogens by using more labor-intensive processes and cleaning methods (Ollinger and others 2004). This is evident in our analysis of antimicrobial equipment, where the costs are estimated for larger, more sophisticated equipment for large establishments, and hand-held, manual equipment for small establishments. However, for the remaining investments in this study (that is, HACCP plans, SSOP plans, food safety training, third-party audits), both small and large establishments conduct these activities but at different levels.

Conclusions

Meat and poultry slaughter establishments incur substantial costs associated with food safety investments that are focused on improving the safety of meat and poultry products sold in the U.S. The estimated costs presented in this paper can be used to develop a better understanding of the costs of current food safety practices and to estimate the costs of potential future food safety regulations. Future research could estimate the adoption rates of these technologies and practices among meat and poultry establishments. Using estimated adoption rates, the cost estimates presented in this paper could be summed to determine the total costs of a set of food safety investments assuming the remaining establishments adopt those investments. Future research could also develop cost estimates for other types of operations such as meat and poultry processing.

One of the key lessons learned during the process of conducting this study was to make the best use of the limited time available for the experts to work together in estimating the costs of food safety investments. Although we provided relevant background materials to the experts prior to conducting the panel, we were flexible in incorporating new resources as identified by the experts throughout the process. We conducted the expert panel in-person to focus their attention on the exercise but found it was also useful to allow for breaks so that the experts could reach out to other known experts and vendors to provide additional information for the discussion. We also found that developing the cost estimates at a detailed level provided a greater depth of understanding of the underlying assumptions, which increased the validity of the resulting total cost estimates for each intervention. Finally, rather than trying to estimate a low, medium, and high estimate for each cost, which would have been a tedious and lengthy process, the experts were able to provide a general estimate of the level of certainty in their estimates.

The results of this study are subject to several limitations. We focused on a selected set of food safety investments, but meat and poultry establishments may use other important types of interventions to ensure the safety of their products. Furthermore, for feasibility of the study, we based the estimates on commonly used approaches including assuming establishments will hire a consultant to develop a sampling plan and that management and QA staff will receive external food safety training whereas all other employees will receive internal training. Because we strived to find a diverse group of experts, not all of the experts were familiar with every intervention or investment made by meat and poultry slaughter and processing establishments and therefore some estimates were based on information from fewer experts. In addition, some cost categories were not captured in our analysis such as taxes and insurance premiums, which vary by region, and salvage value of capital equipment, which is difficult to determine on a general basis. Finally, the wage estimates are national averages and could vary by region and establishment size.

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Authors' Contributions

As the study manager, Viator coordinated the expert panel, analyzed the cost data, and drafted the manuscript. Muth provided oversight for the study, moderated the expert panel, and contributed to preparing the manuscript. Brophy researched prior studies and collected secondary data. Noyes advised on the study methodology and presentation and interpretation of findings.

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