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Public Disclosure of Tests for Salmonella: The Effects on Food Safety Performance in Chicken Slaughter Establishments

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Abstract

This report examines how disclosing the identities of chicken slaughter establishments with poor or mediocre performance on Food Safety and Inspection Service (FSIS) tests for *Salmonella* affects subsequent test outcomes. Empirical results show that public disclosure of the identities of such establishments is strongly correlated with a substantial drop in *Salmonella* levels over 2006-10. The reduction in *Salmonella* levels demonstrated that the FSIS *Salmonella* standard on carcasses of young chickens could be lowered. FSIS then reduced its *Salmonella* standard on young chicken carcasses by more than 50 percent in 2011.

Keywords: Food safety, *Salmonella*, chicken, FSIS, regulation, slaughter

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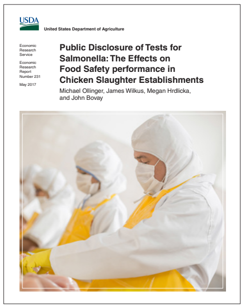

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What Is the Issue?

The assured safety of chicken and other food products is of vital concern for Americans, especially the elderly, children, people with suppressed immune systems, and others vulnerable to foodborne illness. To provide this assurance, the Food Safety and Inspection Service (FSIS) or its U.S. Department of Agriculture antecedents have been regulating food safety in meat since before 1900. Amid mounting food safety concerns, FSIS promulgated the Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP) rule in 1996. For chicken-related salmonellosis illnesses, these provisions had a substantial short-term impact, reducing annual instances in the United States by 190,000 from 1996 to 2000, but with little further effect (Williams and Ebel, 2000).

Notwithstanding the large effect of the PR/HACCP rule, Painter et al. (2013) estimated that from 1998 to 2008, 650,000 people became ill each year from poultry contaminated with *Salmonella* and other bacteria. Food safety experts have long recognized that many consumers contract a foodborne illness because they cannot directly observe the food safety of the products they buy. Some sophisticated institutional buyers undertook their own *Salmonella* or other testing programs to measure food safety, but many other buyers that did not test their produce had no direct knowledge of the safety of the products they purchased. This began to change in 2003 when FSIS announced its intention to update regulations and raised the possibility of making results for *Salmonella* testing for individual establishments publicly available.

Information about *Salmonella* levels of the products sold by their suppliers would give institutional buyers information that would enable them to take food safety into account in their purchasing decisions. FSIS had promulgated a standard for the number of samples in a test that could be positive for non-typhoidal *Salmonella* (hereafter referred to as *Salmonella*) for livestock and poultry carcasses and ground meat and poultry under the PR/HACCP rule. FSIS began testing at establishments in 1996 and publishing industry-level data on the results of such tests, but without identifying the performance of individual establishments.

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

Over the 8 years following 2003, FSIS (1) in 2006 adopted an easy-to-understand metric for rating an establishment's performance on *Salmonella* tests and informed the industry that regulatory changes were forthcoming; (2) from 2008 to 2010 disclosed the identities of establishments with mediocre or poor performance on *Salmonella* tests on the agency's website; and (3) in 2011 established a new *Salmonella* standard for chicken carcasses that was less than half the 2005 level.

This ERS report examines the impact of the regulatory changes in the levels of *Salmonella* on young chicken carcasses from FSIS tests. ERS researchers reasoned that if food safety is important to institutional buyers and performance on *Salmonella* testing is a measure of food safety, then chicken slaughter establishments would have an incentive to improve performance if test results were made public. The availability of more information to the public, starting in 2006, should lead to a reduction in *Salmonella* levels.

What Did the Study Find?

We define poor performance as failing to stay within the FSIS standard's percentage of samples allowed to test positive for *Salmonella*. Good performance equals a *Salmonella* share of less than half the FSIS standard; mediocre performance means the establishment meets the FSIS standard but does not outperform it. The ERS analysis showed that:

- Chicken slaughter establishments identified as having poor or mediocre performance on *Salmonella* tests in 1 year were almost certain to improve their performance the following year. The odds of an establishment with mediocre performance showing improvement were about 7 to 1. For those with poor performance, the odds were much higher at 49 to 1.

- The adoption of an easily interpreted numerical rating of performance on *Salmonella* tests, with subsequent disclosure of test results to the public, was followed by a sharp drop in *Salmonella* levels on young chicken carcasses. ERS results show that the percentage of samples testing positive for *Salmonella* declined by about 30 percent over 2006-08.

- The decline of young chicken samples testing positive for *Salmonella* of about 60 percent over 2006-10 enabled FSIS to reduce the standard for the number of samples testing positive for *Salmonella* by about half.

- The Internet appears to be an effective communication tool through which market forces, set in motion by better information about the food safety performance of slaughter establishments, can discipline establishments that perform poorly on *Salmonella* tests. The result is a level of food safety determined more by market demand and less by direct regulation.

How Was the Study Conducted?

The key data required to conduct this analysis were *Salmonella* test results from FSIS. The agency also provided administrative data and Dun & Bradstreet information on the characteristics of slaughter establishments for 2000-14.

Because many factors could be responsible for differences in performance on *Salmonella* tests, ERS researchers used an econometric model that captured three regulatory periods and accounted for establishment size and other variables related to plant operations. They chose a fixed-effects model to allow for establishment-specific characteristics, such as initial food safety technology, that do not change over time. However, the model did not account for the effects of standards imposed on chicken slaughter establishments by their customers and changes in meat and poultry food-safety recall policies.

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Introduction

Salmonellosis is the second most common cause of foodborne illness in the United States, resulting in an estimated 1,000,000 illnesses, 19,000 hospitalizations, and 380 deaths each year (Scallan et al., 2011). Painter et al. (2013) estimated that 650,000 people got sick annually from poultry contaminated with *Salmonella* and other bacteria over 1998–2008.

USDA's Food Safety and Inspection Service (FSIS), the Federal agency that oversees the food safety of poultry, has been concerned about foodborne illnesses caused by *Salmonella* for many years. In 1996, FSIS promulgated the Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP) rule. This regulation had a substantial short-term impact--Williams and Ebel (2012) found that PR/HACCP reduced chicken-related salmonellosis illnesses by 190,000 over 1996-2000 but had little effect afterward.

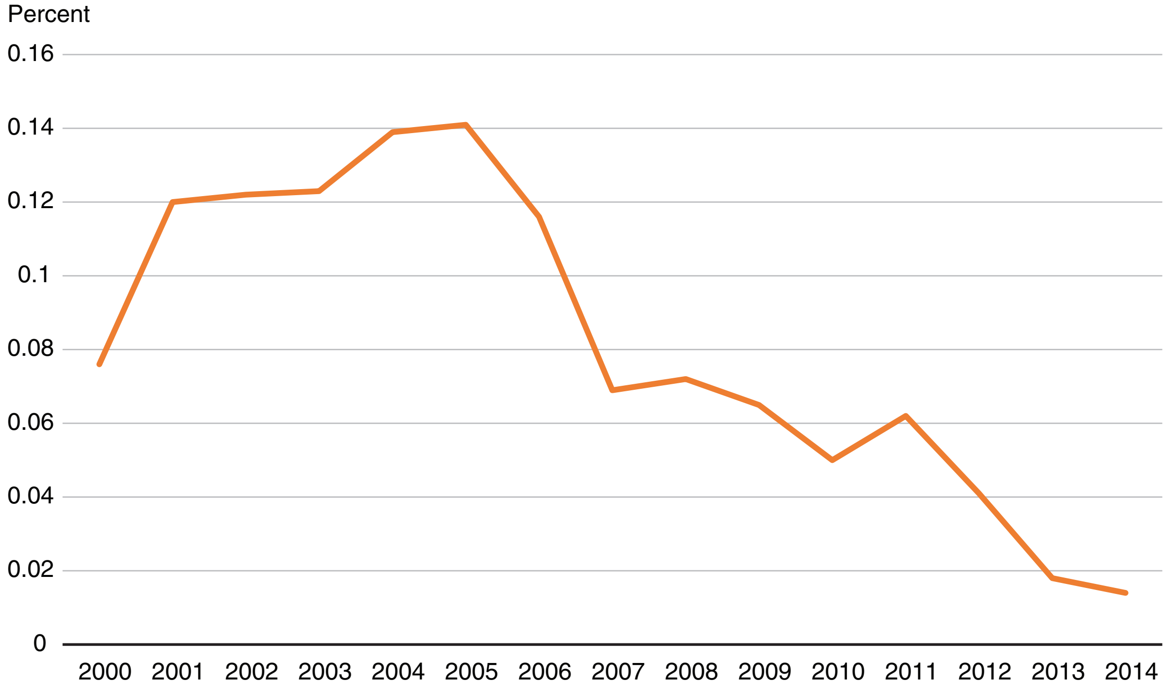
One provision of PR/HACCP requires slaughter establishments for young chickens to meet a *Salmonella* sampling standard based on *Salmonella* levels present when PR/HACCP was promulgated. FSIS verifies through routine sampling that establishments meet this standard. Starbird (2005) argued that food safety sampling provides the necessary information for guiding purchasing decisions–all else equal, consumers would prefer to buy from an establishment with better food safety performance. However, FSIS used its *Salmonella* sampling data for its own monitoring program and published only industry-level *Salmonella* test results, e.g., data from all establishments that slaughter young chickens. These industry-level data assured FSIS that meat and poultry generally met the FSIS *Salmonella* standard, but industry-level data do not distinguish excellent from adequate food safety performance and thus do not enable institutional buyers to purchase products based on the best food safety information.

Buyers and consumers have had strong negative reactions to meat and poultry suppliers with poor food safety performance and would likely punish establishments with poor performance on FSIS *Salmonella* sampling if they became aware of the results. Piggott and Marsh (2004) and Marsh, Schroeder, and Mintert (2004) showed that recalls and other negative food safety events adversely affect meat and poultry demand. Thomsen et al. (2006) found that meat recalls led to declines in sales of branded frankfurter products by more than 20 percent. Jin and Leslie (2003) found that consumers abandoned restaurants with poor hygiene records.

If information about the food safety performance of individual establishments is not publicly available, establishments have an incentive to invest in food safety only up to the point necessary to meet the requirements mandated under the PR/HACCP rule. This may explain the relatively weak food

Figure 1

Share of young chicken samples testing positive for *Salmonella* spp over 2000-14



Source: U.S. Department of Agriculture, Economic Research Service estimates using *Salmonella* test data from USDA, Food Safety and Inspection Service.

safety performance in the early 2000s (fig. 1).[1] A high incidence of salmonellosis and little change in food safety performance prompted policymakers at FSIS to call for regulatory change (Federal Register, 2003). Afterward, FSIS embarked on a series of regulatory changes (table 1) that revealed greater information about individual establishment performance on *Salmonella* and coincided with a sharp drop in *Salmonella* levels (fig. 1).

This report empirically examines how disclosing the identities of young-chicken slaughter establishments with poor or mediocre *Salmonella* tests affected their performance on later *Salmonella* tests. Figure 1 and table 1 show that the timing of improvements on tests for *Salmonella* coincides with changes in FSIS policies. However, characteristics such as being part of a firm that owns other establishments--as well as the establishment's size, food safety technologies, and performance of FSIS verification tasks, (i.e., for sanitation), along with buyer standards--have been shown by Ollinger and Moore (2008) and Muth et al. (2007) to affect performance on tests for *Salmonella* and may also account for the changes.

The report contributes to the existing literature in two ways. First, it highlights a novel regulatory approach in which public disclosure of results of *Salmonella* tests may have motivated improved performance on future tests. Second, it illustrates the importance of better information to reducing moral hazard in food safety. Holmström (1982, p. 324) asserts that "Moral hazard refers to the problem of inducing agents to supply proper amounts of productive inputs when their actions cannot be observed and contracted for directly." He argues (p. 339) that "relative performance evaluation (establishment-level *Salmonella* test results) can be helpful in reducing moral hazard costs."

[1]The PR/HACCP rule was fully implemented by January of 2000.

Table 1
Important regulatory changes affecting the chicken-slaughter industry over 1996-2012

Regulation	Date	Policy changes
PR/HACCP[1]	07-25-1996	FSIS mandates first performance standards (tolerances). Slaughter establishments for young chickens permitted 12 carcasses out of 51 to test positive for *Salmonella*. All slaughter establishments had to test for generic *E. coli*, and all establishments had to have and maintain a PR/HACCP plan. There are other requirements. Phased in by 2000.
Fed Reg. Notice[2]	04-16-2003	FSIS announced its intent to update regulations and asked for public comments to inform the policy. FSIS indicated a future possibility of publicizing individual performance results on tests for *Salmonella* in chicken carcasses.
Fed Reg. Notice[3]	02-27-2006	FSIS announced a plan to publish aggregate industry performance records quarterly and provide establishments with individual sample results as soon as they are available. FSIS phased out the A-B-C-D system and replaced it with a Category 1, 2, or 3 ranking system that identifies establishment performance on *Salmonella* tests.
	05-30-2006	Policy implementation date for the change.
Fed Reg. Notice[4]	01-28-2008	FSIS announced that it will publish the names of establishments with mediocre or poor performance on tests for *Salmonella* (Categories 2 & 3) online monthly.
	03-28-2008	The first document including the name of underperformers was published for month of March. FSIS also began using the 2T categorization. This is a category of high-performing Category 2 establishments. They had 6 or fewer positive samples on their last *Salmonella* sample set and 7 to 12 positive samples on the prior sample set. Category 2 establishments met only the 7 to 12 positive sample level of performance on both sets.
Fed Reg. Notice[5]	05-14-2010	Establishments were required to have no more than 5 out of 51 chicken carcasses test positive for *Salmonella*. FSIS no longer published the names of establishments with mediocre performance (Category 2).
	07-01-2011	Policy implementation date for the change.

FSIS = USDA, Food Safety and Inspection Service.
[1]Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP Systems, 61 Fed. Reg. 38,806 (July 25, 1996), https://www.gpo.gov/fdsys/pkg/FR-1996-07-25/pdf/96-17837.pdf (last visited Dec. 8, 2016).
[2]Announcement of and Request for Comment on FSIS' Tentative Determinations on the Availability of *Salmonella* Test Results, 68 Fed. Reg. 18,593 (April 16, 2003). https://www.gpo.gov/fdsys/pkg/FR-2003-04-16/pdf/03-8971.pdf (last visited Dec. 8, 2016).
[3]Salmonella Verification Sample Result Reporting: Agency Policy and Use in Public Health Protection, 71 Fed. Reg.9,772 (Feb. 27, 2006). https://www.gpo.gov/fdsys/pkg/FR-2006-02-27/pdf/06-1783.pdf (last visited Dec. 8, 2016).
[4]*Salmonella* Verification Sampling Program: Response to Comments and New Agency Policies. 73 Fed. Reg. 4,767 (Jan. 28, 2008), https://www.gpo.gov/fdsys/pkg/FR-2008-01-28/pdf/E8-1432.pdf (last visited Dec. 8, 2016).
[5]New Performance Standards for *Salmonella* and *Campylobacter* in Young Chicken and Turkey Slaughter Establishments; New Compliance Guides, 75 Fed. Reg. 27,288 (May 14, 2010), https://www.gpo.gov/fdsys/pkg/FR-2010-05-14/pdf/2010-11545.pdf (last visited Dec. 8, 2016).

FSIS Regulation

FSIS standards form a foundation upon which meat and poultry establishments can build their food safety programs. A brief discussion of current meat and poultry food safety regulations follows.

FSIS and its antecedent USDA agencies have regulated the food safety of meat since 1890, when the pork industry asked for inspection of hog bellies to certify that they were trichinella-free for export. In 1906, Congress mandated the antemortem and postmortem inspection of cattle, sheep, swine, and goats used for human food--their carcasses, parts, and further-processed products (34 Stat. 674).

Congress greatly expanded USDA's regulatory authority with the passage of the Wholesome Meat Act of 1967 (81 Stat. 584) and the Wholesome Poultry Products Act of 1968 (82 Stat. 791). These laws, among other things, prohibited the shipment in interstate commerce of adulterated or misbranded meat or poultry products, the terms "adulterated" and "misbranded" being defined very nearly as they are in the Food, Drug, and Cosmetic Act (52 Stat. 1040, 1046-1048). On the basis of this expanded authority, and in response to the recommendations of various advisory bodies, FSIS promulgated regulations to ensure that meat and poultry food was processed under sanitary conditions and that the control of foodborne microbial pathogens was maintained. Not least among these regulations were those implemented under the July 25, 1996, final rule "Pathogen Reduction; Hazard Analysis and Critical Control Point (HACCP) Systems" (61 Fed. Reg. 38,806).

Testing Young Chickens for *Salmonella*

Under the PR/HACCP rule, ground meat and poultry and all livestock and poultry carcasses had to meet FSIS performance standards (tolerances) for *Salmonella* when tested. It required that chicken slaughter establishments have no more than 12 samples in a set of 51 samples of carcasses testing positive for *Salmonella*.[2] Under this system, an establishment's first set and each set that followed a set that met the FSIS *Salmonella* standard was referred to as an "A" set. Establishments that passed a set were scheduled for subsequent sets at later, varying intervals, depending in part on how many samples tested positive for *Salmonella* in the previous set. Establishments that failed to meet a *Salmonella* tolerance were carefully evaluated by the agency (FSIS, 2003) and were subsequently scheduled for a "B" set shortly after the previous set ended; if they failed again, a "C" set was assigned. Another failure led to an assignment of a "D" set and possible regulatory actions, such as temporary suspension of the FSIS Grant of Inspection.[3]

The alphabetized system was a pass or fail determination in which establishments had an incentive to meet the standard but not necessarily to surpass it because FSIS did not disclose performance on sets to the public. Buyers could not distinguish high-performing plants from those barely meeting the FSIS standard and could not demand higher performance.

FSIS replaced the alphabetical system in 2006 with a numerical ranking system that placed establishments in one of three numbered categories based on their performance on *Salmonella* tests. Establishments with fewer than 7 of 51 samples of young chicken carcasses testing positive for

[2]Certain serotypes of *Salmonella* are endemic to certain populations of chickens (Burr et al., 2005). FSIS assesses the presence of all non-typhoidal *Salmonella* serotypes because the agency considers that all *Salmonella* has the potential to be pathogenic.

[3]Grants of Inspection give an establishment authority to process meat or poultry and ship it across State lines.

Salmonella on two consecutive sets of samples were assigned to Category 1 (table 2). FSIS considered establishments in Category I to be maintaining consistent process control and good food safety performance. Establishments with 7 to 12 positive samples–that is, within 50 to 100 percent of the agency's *Salmonella* standard–were placed in Category 2 and considered to be maintaining variable process control. The Category 2 establishments were identified as either higher or lower performers. Category 2T establishments had 6 or fewer samples in the last set of 51 samples and 7 to 12 samples in the previous set that tested positive for *Salmonella*. Category 2 establishments had 7-12 positive samples in the previous set testing positive for *Salmonella*. Establishments with more than 12 positive samples, which exceeded the agency's standard for *Salmonella*, were placed in Category 3 and were considered to be maintaining highly variable process control. FSIS originally published the results as aggregated data.

Table 2
FSIS *Salmonella* performance testing categories[1]

Dates Effective	Four numerical categories after 2006			
	Category 1	Category 2T	Category 2	Category 3
2006 to June 2011	At most 6 positive samples on last 2 sample sets	6 or fewer positive samples on last set; 7 to 12 positive samples on prior sample set	7 to 12 positive samples on last sample set; at most 12 positive samples on prior sample set	13 or more positive samples on last sample set and one prior completed set.
July 2011 to present[2]	At most, 2 positive samples on last 2 sample sets.	2 or fewer positive samples on last set; 3 to 5 positive samples on prior sample set	3 to 5 positive samples on last sample set; at most 5 positive samples on prior sample set	6 or more positive samples on last sample set

FSIS = USDA, Food Safety and Inspection Service.
[1]Sample sets contain samples from 51 young chicken carcasses. The category ranking system was initially implemented in 2006. Prior to 2006, the USDA Food Safety and Inspection Service (FSIS) categorized establishment performance on *Salmonella* tests with letters A-D. It assigned letter "A" to establishments that met the standard and the letter "D" to establishments that repeatedly failed the test. Letters "B" and "C" were assigned to establishments that failed the first sample and were undergoing additional testing.
[2]FSIS no longer assesses performance based on sets comprised of 51 samples of young chickens taken at one time and then not at all until some later date. Rather, it uses moving window in which establishments are tested in a continuous fashion. This change was published in 2015; implementation was begun between March and July 2015. During the change in testing practices, the FSIS *Salmonella* tolerances did not change.
Source: USDA, Economic Research Service, based on FSIS administrative data.

On January 28, 2008, FSIS announced in the Federal Register that it would publish the names of establishments performing at the Category 2 and 3 levels (FSIS, 2008). This policy took effect on March 28, 2008. By the end of 2011, *Salmonella* levels had dropped dramatically (fig. 1). In early 2011, FSIS lowered its *Salmonella* standard for young chicken carcasses by more than half, and *Salmonella* levels continued to fall. Under this revised regulatory approach, FSIS phased out identification of Category 2 establishments on its website and cut the allowed number of samples that could test positive for *Salmonella* to no more than 5 out of 51 on consecutive sets of samples.

FSIS Process Controls and HACCP Tasks

The PR/HACCP final rule required establishments to develop, implement, and maintain written Sanitation Standard Operating Procedures (SSOPs). These SSOPs required that each establishment be operated and maintained in a manner sufficient to prevent the creation of unsanitary conditions and to ensure that product is not adulterated. The SSOP regulations (9 CFR 416) address establishment grounds and facilities; equipment and utensils; sanitary operations; employee hygiene; the development, implementation, and maintenance of sanitation standard operating procedure; corrective actions; recordkeeping requirements; and agency verification of sanitation standard operating procedures.

The PR/HACCP rule required meat and poultry establishments to develop, validate, and implement PR/HACCP process-control programs for each process used to produce products. FSIS reviews the HACCP plans, and its inspection program personnel (IPP) verify compliance of the associated HACCP regulations. (See Ollinger and Mueller (2003) for further discussion.)

Incentives for Food Safety Information

Maintaining food safety is costly because it requires effective sanitation and innovative processing techniques. Measuring food safety is also difficult because it requires time-consuming and expensive testing. Data from the Centers for Disease Control and Prevention (Painter, 2013) indicate that Federal and State health authorities detect and recall only a small share of contaminated products from the marketplace. The high measurement costs passed on to buyers, the infrequent levels of detection of foodborne illnesses by public health authorities, and the high costs of sanitation for producers give slaughter establishments for young chickens an incentive to lower their costs by reducing their effort to maintain food safety.

Occasional food safety recalls, such as those that led to bankruptcies at Topps Meat and Peanut Corporation of America and the sale of Hudson's ground beef establishment to Iowa Beef Processors, create some incentives for producers to invest in food safety. Other incentives come from large commercial buyers, such as fast food restaurants, that face the prospect of a damaged reputation for food safety if they are linked to a foodborne illness outbreak. For this reason, these buyers may impose private, enforceable standards for food safety on their suppliers. Golan et al. (2004), for example, detail a food safety system instituted by the Jack-in-the-Box restaurant chain after its near-bankruptcy due to a foodborne-illness outbreak in the early 1990s. More broadly, contract standards are being used in international commerce under the Global Food Safety Initiative (a global, industry-driven collaboration) (http://www.mygfsi.com/).

Most buyers are not as large as Jack-in-the-Box and may not have the capacity to impose a quality-control program on their suppliers. These smaller buyers may rely on publicly available food safety information in choosing their sources. FSIS has provided aggregated food safety performance data and product recall information via its website for many years. This public information has included industry performance on *Salmonella* tests and other food safety measures. However, aggregated data provides no information about individual performance, making it very difficult to assign responsibility for food safety failures to an establishment and ineffective as a tool for encouraging better performance. Holmström (1982) argued that strong incentives occur only if a failure in quality can be directly linked to its source. In the chicken slaughter industry, this means linking performance on tests for *Salmonella* to a specific establishment and disseminating that information to the public.

More publicly available information on the *Salmonella* levels of young chicken carcasses means better informed purchasing decisions. Better information would likely lead to lower profitability at establishments with poor food safety performance that would lose customers to competitors with better food safety records unless they gave price discounts.

FSIS made changes starting in the early 2000s that provided the public with better information about the food safety performance of slaughter establishments for young chickens. First, the agency created an easy-to-understand metric for food safety performance with the introduction of the Category 1, 2, and 3 ranking system for performance on *Salmonella* tests. Then it informed the industry that this information would be made publicly available. Finally, it began publishing the information in 2008. Our analysis follows the impact that these changes and the adoption of a revised *Salmonella* tolerance had on performance on *Salmonella* tests.

Analytical Framework

Various researchers (Muth et al., 2007; Ollinger and Moore, 2009; Ollinger, Guthrie, and Bovay, 2014; Ollinger et al., 2015) have expressed food safety performance (FS) as a function of establishment technology (K), buyer effects (B), labor (L), and FSIS regulation (R). We illustrate that relationship in equation 1. Other studies have examined the cost of food safety regulation (Antle, 2000; Ollinger and Mueller, 2003; Ollinger and Moore, 2009), the effectiveness of food safety regulations in controlling *Salmonella* (Ollinger and Moore, 2009), and the impact of an establishment's financial performance on FSIS *Salmonella* tests (Muth et al., 2012).

(1) $FS = FS(K, B, L, R)$

The establishment technology variables (K) are establishment size, age, slaughter of multiple species, forward integration into processing, and belonging to a multi-establishment firm. Ollinger and Moore (2009) found that establishment size positively affects food safety performance in the chicken slaughter industry. Muth et al. (2007) found that the vintage of establishment capital (establishment age) is correlated with lower *Salmonella* levels in slaughter establishments for young chickens. Establishment technology also includes whether an establishment slaughters turkeys, other fowl, or poultry in addition to young chickens because they may have more complicated slaughter operations. Similarly, establishments that forward-integrate into processing young chicken carcasses into case-ready and other processed products may have more complicated finishing operations. Greater complexity places greater time burdens on management, making failures of food safety control more likely. These establishments may also have less of an incentive to adhere to stricter standards for *Salmonella* than those required by FSIS since *Salmonella* on their chicken carcasses will be killed when the raw chicken is further processed. Finally, managers in central offices can influence decisions at the establishment level and may facilitate synergies among other establishments owned by the firm, making it important to account for establishments that are part of a multi-establishment firm in the econometric model.

The buyer-effects variables include direct effects–whether the supplier has buyer contracts–and indirect effects, including establishment food safety technology and *Salmonella* levels in young chicken inputs. The fear of bad publicity and damaged reputation due to a foodborne illness outbreak has led many large buyers of chicken and meat, such as Jack-in-the-Box Restaurant, to adopt their own testing and food safety process control programs (Golan et al., 2004). Ollinger, Moore, and Chandran (2004) report that about 60 percent of slaughter establishments for young chickens that responded to a 2001 survey had agreements with buyers, and Ollinger and Moore (2009) found that chicken slaughter establishments with buyer contracts had lower *Salmonella* levels. However, specialized food safety programs delineated in buyer contracts are costly, and only large commercial buyers, such as fast food restaurants, typically place these specialized demands on suppliers. Many large and all small commercial buyers and all consumers rely on chicken suppliers and FSIS oversight to ensure food safety.

Ollinger and Moore (2009) found that establishments that made more extensive use of food safety technologies had lower *Salmonella* levels. Establishments invest in such technologies and provide better control over *Salmonella* in live chicken inputs to meet buyer demands for lower *Salmonella* levels or Federal *Salmonella* standards. Their food safety technologies may include specialized eviscerators, carcass washes, and types of antimicrobial washes and other technologies that minimize handling and contaminants and provide better sanitation.

Bailey (2001) identified many factors that contribute to *Salmonella* in live chickens. These include chicken age, survival of the *Salmonella* through the gastric barrier, competing bacteria in the intestinal tract, the chicken's diet, health and disease status of the chicken, medication effects, the season of the year, and weather. See Russel (2012) for full discussion of *Salmonella* in chickens.

Labor devoted to sanitation and process control tasks (L) is reflected in performance on SSOPs and tasks required to maintain the effectiveness of the HACCP system. SSOPs are done both during operations and before the shift starts (pre-operational). Operating SSOPs may include tasks such as cleaning and sanitizing knives, while pre-operational SSOPs may include equipment disassembly, cleaning and sanitizing of food contact surfaces, and other tasks following a shift or after a day's production. See Ollinger and Mueller (2003) for further discussion.

All establishments have to perform SSOPs and HACCP tasks. FSIS inspection program personnel verify whether a task was performed and was in compliance with FSIS regulations. A high number of noncompliances imply less effort devoted to food safety process control.[4] Ollinger and Moore (2009) found that better performance on HACCP tasks led to lower levels of *Salmonella* in some meat and poultry industries.

The regulatory variables (R) include two variables with performances on *Salmonella* tests compatible with a Category 3 or Category 2 rating by FSIS: poor and mediocre performance. Poor performance occurs if the share of samples testing positive for *Salmonella* exceeds the FSIS tolerance. Mediocre performance occurs if the share of samples testing positive for *Salmonella* is greater than half the FSIS standard but less than the full standard.

The regulatory variables also include four regulatory periods, as discussed earlier: (1) 2000-05, before FSIS began adjusting the *Salmonella* regulatory regime; (2) 2006 and 2007, when the Category 1, 2, and 3 food safety rating system was introduced and FSIS announced its intention to publicly disclose the names of poorly performing establishments; (3) from 2008 until the end of 2010, when the identities of Category 2 and 3 establishments were made publicly available on the FSIS website; and (4) from 2011 to 2014, when performance standards (tolerances) were made more stringent and only the identities of Category 3 establishments were publicly available on the FSIS website. The year 2010 may also be important, since FSIS was preparing to adopt more stringent *Salmonella* testing requirements that year but had to delay implementation.

[4]FSIS inspectors do have some discretion over their assessment of establishment performance of SSOPs and PR/HACCP tasks, suggesting that our measure may include inspector error or variance in determining compliance.

Estimation Procedures

The available data and our economic model shape our empirical approach. We have annual data on the number of young chickens slaughtered and performance on SSOPs, HACCP verification tasks, and FSIS *Salmonella* testing. We also know the year the establishment began processing young chickens, the types of animals slaughtered, whether the establishment is owned by a firm that owns other establishments, and the types of processes used by the establishment. We do not have data on establishments' food safety technologies, whether establishments are subject to buyer standards, and the *Salmonella* levels in live chicken inputs. Fortunately, there are econometric techniques that can account for all or some of these unobserved variables.

Constant unobserved effects can be accounted for by either random-effects or fixed – effects models. Random-effects models adjust for unobserved heterogeneity that is constant over time and correlated with the independent variables. Fixed-effects models are most appropriate if (1) unobserved variables are constant over time and uncorrelated with the independent variables and (2) within-unit variation in the dependent variable is greater than cross-unit variation (Chamberlain, 1980). We use a Hausman test to determine which approach is best suited for our data.[5]

Allison (2009) reminds us that there must be at least two observations of each group, and the dependent variable must change at least once for each group member. If these criteria are not met, all observations associated with the group are dropped. The group in our data is an establishment.

Each slaughter establishment for young chickens could have up to 15 observations over 2000-14, but on average establishments had about 7.7 observations. We account for establishment-level clustering in order to avoid understating standard errors (Cameron and Miller, 2015).

Econometric Methods: Changes in Performance on Tests for *Salmonella*

We evaluate both the changes in *Salmonella* tests and the level of performance. Changes in performance on *Salmonella* tests provide the first evidence that a policy or other force is driving change; levels of change indicate aggregated effects.

One way to consider change in performance is to evaluate the probability of a decrease in the percentage of samples teting positive for *Salmonella*. A decrease, regardless of magnitude, represents a subtle change in direction and provides a measure of the first changes in response to a policy or other impetus. Larger drops (we use 2 percent) reflect the breadth of large changes in *Salmonella* percent-positives.

Discrete data are often analyzed with either a probit or logit regression. These regressions employ maximum likelihood techniques. Greene (2003) asserts that fixed-effects logit and probit models are biased if there is a large number of groups relative to the number of observations. Instead of either a simple probit or logit, we use conditional fixed-effects logit regressions because they yield unbiased estimates by conditioning the number of groups out of the likelihood function (Allison and Christakis, 2006). Logit parameter estimates can be transformed into odds ratios, which are equal

[5]Mixed-effects models include both random and fixed components. We tested this model but do not report results because they were similar to the fixed-effects model and a Hausman test had rejected random effects.

to the probability divided by 1 minus the probability of reaching a level of change, i.e., probability / (1 – probability).

The conditional-logit model uses discrete data with two observed values: 1 or 0. These data lose some information since our data are percentages of samples testing positive for *Salmonella*, which can vary from 0 to 100 percent. To take advantage of these more detailed data, we use fixed-effects, ordinary least squares regressions to evaluate changes in performance on *Salmonella* tests. Ordinary least squares (OLS) regression techniques are ideal for examining unbounded and normally distributed data, such as those that exist for changes in performance on tests for *Salmonella*.

Econometric Methods: Levels of Performance on Tests for *Salmonella*

Changes in performance on *Salmonella* tests are differences between two points in time. *Salmonella* levels are the total amounts of *Salmonella* at any given time and are equal to the sum of changes up to that point in time plus an initial amount. *Salmonella* levels are expressed as percentages and are bounded from below by zero. Tobit regressions are typically used for bounded data. However, Greene (2004) points out that, in fixed-effects tobit models, the estimated standard errors are biased downward, i.e., are too small. Other econometric approaches, such as ordered multinomial regressions that rely on maximum likelihood techniques, also cannot provide unbiased estimates. Poisson or other count data regressions also are incompatible with our data because FSIS may test 20 to 150 young chicken samples for *Salmonella* per year in any establishment, depending on establishment size and other factors. An establishment could have many positive *Salmonella* test samples because it was subjected to many tests or because it has poor performance on *Salmonella* tests.

We use a conditional logit regression because it yields unbiased estimates and allows for fixed effects. Conditional logit regressions use discrete data with two outcomes: whether the establishment meets or does not meet a threshold. We consider two thresholds: one-sixth and one-twelfth the FSIS standard that existed until 2011. Both of these measures represent large improvements in performance.

We recognize that some information is lost when threshold data are used, so we also examine the model with a fixed-effects OLS model. Greene (1993) asserts that parameter estimates are biased downward and inconsistent because the distribution of data is truncated. However, Greene indicates that parameter estimates can approximate an efficient estimate by adjusting the proportion of unbounded observations in the sample, i.e., the number of non-zero values of the share of samples testing positive for *Salmonella*.

The Empirical Model

Equation 2 is our empirical model. The right-hand variables have been discussed. The measure of food safety ($FS^*_{i,t}$) equals the percentage of young chicken samples testing positive for *Salmonella*.

$$(2) \qquad FS^*_{i,t} = \alpha_0 + \sum_h \delta_g K_{g,i,t} + \theta B_{it} + \sum_h \psi_h L_{h,i,t} + \sum_l \rho_l R_{l,i,t} + \varepsilon_{i,t}$$

A fixed-effects model accounts for the constant effects across observed and unobserved variables. We include a fixed-effects parameter (F_i) in equation 3 that can account for all unchanging effects of buyer contracts, food safety, and establishment technology, *Salmonella* levels in live chicken inputs, and other unchanging factors. If variables accounted for by the fixed-effects parameter do not change, then their effects on our model will be captured by the fixed-effects parameter. However, if these attributes change, then our results may overstate the impact of policy changes on *Salmonella* levels.

There is reason to believe that buyer standards, food safety technologies, and *Salmonella* levels on live young chickens did not change in a way that would affect our regression results. Salvage (2014) indicates that Wal-Mart first held its chicken suppliers accountable for food safety performance in 2014. Salvage quotes Dr. Gary Acuff of Texas A&M as saying that he thought Wal-Mart was the first retailer to implement this type of program. Another major buyer –the Agricultural Marketing Service, which buys ground beef and chicken for the National School Lunch Program–mandated more stringent standards for ground beef twice during the study period (in 2008 and 2011), but did not change its standards for the chicken it purchased (Ollinger et al., 2014).

There is little incentive for a firm to invest in food safety technology or attempt to better control *Salmonella* in young chicken inputs unless it is under pressure to do so from buyers or Government regulators. In the absence of market demands, there should not be much change in the use of food safety technologies. There is little evidence of changes in buyer-contracting practices over 2006-2014, and Centers for Disease Control and Prevention (CDC) data indicate that there were only 2 foodborne illness outbreaks for 10 major chicken products during that period.

We rewrite equation 2 as equation 3 below. Note that we replaced the term for buyer contracts, food safety technology, and *Salmonella* levels in live young chicken inputs with a fixed-effects term (F_i) because we assume that the effects of these factors vary across establishments but are constant within establishments.

$$(3) \qquad FS^*_{i,t} = \alpha_0 + \sum_f \gamma_f F_i + \sum_g \delta_g K_{g,i,t} + \sum_h \psi_h L_{h,i,t} + \sum_l \rho_l R_{l,i,t} + \varepsilon_{i,t}$$

Our empirical strategy is to evaluate both the changes and level of food safety performance. Changes in *Salmonella* level are the difference in *Salmonella* levels over one time period (1 year). Levels of performance equal the initial performance level plus changes in performance levels over time. Changes in performance may occur before a difference in a level food safety is apparent. Performance changes may start small and accelerate as their full impact occurs.

Model of Changes in Food Safety Performance

Equation 4 is a model of factors affecting changes in food safety performance. The change in food safety equals the change in the share of samples testing positive for *Salmonella* ($\Delta FS^{*}_{\mathrm{I,t}}$) and equals $FS^{*}_{\mathrm{i,t}} - \mathrm{FS}^{*}_{\mathrm{i,t-1}}$ or the change in *Salmonella* from the previous period to the current period:

$$(4) \qquad \Delta FS^{*}_{i,t} = \alpha_0 + \sum_f \gamma_f F_i + \sum_g \delta_g K_{g,i,t} + \sum_h \psi_h L_{h,i,t} + \sum_l \rho_l R_{l,i,t} + \varepsilon_{i,t}$$

$$(5) \qquad \Delta FS_{i,t} = 1 \text{ if } \Delta FS^{*}_{i,t} < T,$$

$$\Delta FS_{i,t} = 0 \text{ if } \Delta FS^{*}_{i,t} \geq T.$$

We consider three ways of examining changes in food safety performance: (1) we discount the amount of variance and consider all decreases as equal, i.e., a large decrease is treated the same as a small one; (2) we consider only large decreases—those with a change of less than 2 percent; and (3) we consider all variations. We represent case (1) and case (2) mathematically in equation 5. In case (1), we set $\Delta \mathrm{FS}^{*}_{\mathrm{i,t}}$ equal to 1 if T is less than zero and zero otherwise; then we run the model (equation 4) using a fixed-effects conditional econometric approach. In case (2), we set $\Delta \mathrm{FS}^{*}_{\mathrm{i,t}}$ equal to 1 if T is less than – 2 and zero otherwise; then we run the model (equation 4) using a fixed-effects conditional logit econometric approach. Finally, we provide no threshold and allow $\Delta \mathrm{FS}^{*}_{\mathrm{i,t}}$ to range freely and run the model (equation 4) using a fixed-effects OLS econometric approach.

Model of Levels of Performance on Tests for *Salmonella*

Equation 6 represents our model of levels in food safety performance. For this model, $\mathrm{FS}^{*}_{\mathrm{it}}$ equals the share of samples testing positive for *Salmonella*:

$$(6) \qquad FS^{*}_{i,t} = \alpha_0 + \sum_f \gamma_f F_i + \sum_g \delta_g K_{g,i,t} + \sum_h \psi_h L_{h,i,t} + \sum_l \rho_l R_{l,i,t} + \varepsilon_{i,t}$$

$$(7) \qquad FS_{i,t} = 1 \text{ if } FS^{*}_{i,t} < \mathrm{T},$$

$$FS_{i,t} = 0 \text{ if } FS^{*}_{i,t} \geq T.$$

We consider three variations of equation 6. In two cases, we define the dependent variables as threshold variables representing large improvements in performance on *Salmonella* tests; in the other case, we consider all variation. We represent cases (1) and (2) mathematically in equation 7. In case 1, we set $FS^{*}_{\mathrm{i,t}}$ equal to 1 if T is less one-sixth the FSIS *Salmonella* standard that existed from 1996-2010 and zero otherwise and run the model using a fixed-effects conditional econometric approach. In case (2), we set $FS^{*}_{\mathrm{I,t}}$ equal to 1 if T is less than one-twelfth the standard for *Salmonella* and zero otherwise, and we run the model using a fixed-effects conditional logit econometric approach. Finally, we construct no thresholds and run the model (equation 6) using a fixed-effects OLS method. These OLS estimates are biased, making conditional logits the best econometric model for examining our data. Table 3 gives all the definitions, including those for the left-hand variable ($FS_{\mathrm{I,t}}$).

Table 3
Variable definitions and their mean, minimum, and maximum values

Model variable	Empirical variable	Definition	Mean	Max	Min
FS	Decrease	One if percent of samples testing positive for *Salmonella* decreases; else zero	0.457	1.0	0
FS	Decrease_02	One if percent of samples testing positive for *Salmonella* decreases by 2 percent or more; else zero	0.355	1.0	0
FS	Change Percent Positive	Percentage of samples testing positive for *Salmonella* this year minus Percentage of samples testing positive for *Salmonella* last year.	-0.010	0.51	-1.0
K_1	Chickens	Millions of young chickens	48.6	116.6	0.014
K_2	Establishment age	Current year minus year meat grant issued	26.1	56.0	1
K_3	Multi-species	One if establishment slaughters more than one animal species, else zero	0.121	1.0	0
K_4	Multi-establish-ment	One if establishment is part of a multi-establishment firm, else zero	0.507	1.0	0
K_5	Process	One if establishment cooks or otherwise further process-es chicken; else zero.	0.114	1.0	0
L_1	HACCP compliance	One if share of HACCP tasks not in compliance with FSIS regulations exceeds the industry mean share by 50 percent. The mean share equals 0.032.	0.148	1.0	0
L_2	Pre-op SSOP compliance	One if SSOP tasks performed before operations not in compliance with FSIS regulations exceeds the industry mean share by 50 percent. The mean share equals 0.112.	0.274	1.0	0
L_3	Op SSOP Compliance	One if SSOP tasks performed during operations not in compliance with FSIS regulations exceeds the industry mean share by 50 percent. The mean share equals 0.092.	0.228	1.0	0
R_1	Poor Performance	One if percent positive *Salmonella* samples exceeds the standard; else zero	0.070	1.0	0
R_2	Mediocre Performance	One if percent positive *Salmonella* samples exceeds one-half the FSIS standard; else zero	0.211	1.0	0
R_3	Year_2006	One if year is 2006 or 2007, else zero	0.122	1.0	0
R_4	Year_2008	One if year is 2008 to 2010, else zero	0.168	1.0	0
R_5	Year_2010	One if year equals 2010, else zero	0.063	1.0	0
R_6	Year_2011_2014	One if year after 2010, else zero	0.256	1.0	0
FS	One-sixth FSIS *Salmonella* stan-dard	One if share of samples testing positive for *Salmonella* is less than one-sixth 2006 FSIS standard, else zero. The standard put forth in 1996 did not change until 2011.	0.487	1.0	0
FS	One-twelfth FSIS *Salmonella* stan-dard	One if share of samples testing positive for *Salmonella* is less than one-twelfth 2006 standard, else zero. The stan-dard put forth in 1996 did not change until 2011.	0.361	1.0	0
FS	Percent Positive	Percentage of samples testing positive for *Salmonella*	0.079	0.627	0
	Observations		1,755		

HACCP = Hazard Analysis and Critical Control Point; FSIS = USDA Food Safety and Inspection Service; SSOP = Standard Sanitation Operating Procedures.
Source: USDA, Economic Research Service, based on FSIS administrative data.

Data

All of the data came from FSIS and include observations of 169 slaughter establishments for young chickens whose products were tested for *Salmonella* by FSIS over 2000–2014. Not all establishments are in the dataset each year because FSIS selects establishments for testing based on volume and past results and some may not be tested in some years, while others may be subject to numerous tests. Since we are particularly interested in changes starting in 2006, we dropped establishments that entered the chicken slaughter industry after that year. Additionally, we dropped all establishments that exited the chicken slaughter industry before 2001. After these adjustments, there were 1,755 observations available for analysis.

FSIS *Salmonella* testing results are based on a sample-set of 51 samples of young chicken carcasses from 2000 through 2014.[6] Testing may have begun for some establishments in one year and extended into the subsequent year, leaving a partial sample set. The lowest number of samples taken from any establishment in our dataset was 17 (one-third of a sample-set). Since establishments faced up to 3 sets of tests, the maximum number of samples for any establishment was 153 (3 sample sets times 51 samples per set). Most establishments (92 percent of the observations) fall in the range of 40-112 test samples.

Data on the number of young chickens and types of animals slaughtered come from FSIS data; the age of the establishments is the last year of our data (2014) minus the year in which the establishment was first awarded a poultry Grant of Inspection.[7] Dun & Bradstreet (D&B) data were used to identify the business activities at the establishment and whether the establishment was part of a firm that owned more than one establishment. The D&B data also included sales, a subsidiary indicator, a manufacturing indicator, a small business indicator, and a public/private indicator, square footage of the establishment, major industry category, line of business, a primary activity code, and some financial variables.

Information on compliance with SSOP and PR/HACCP requirements tasks and establishment characteristics came from FSIS administrative data and were available for all establishments inspected by FSIS in all years. The FSIS administrative data include types and numbers of animals slaughtered, estimates of young chicken production, name and address information, and the date each establishment began operation.

Establishment size and age varied considerably. The smallest establishments in our sample slaughtered 15,000 young chickens per year, while the largest slaughtered nearly 117,000; establishment ages varied from 1 to 56 years (table 3). Table 3 includes the means, maximums, and minimums of all variables.

[6]FSIS changed its *Salmonella* testing program in 2015 to one in which it continuously samples establishment production, rather than carrying the testing out in sets.

[7]Poultry Grants of Inspection are necessary for establishments to be able to sell products in interstate commerce and export markets.

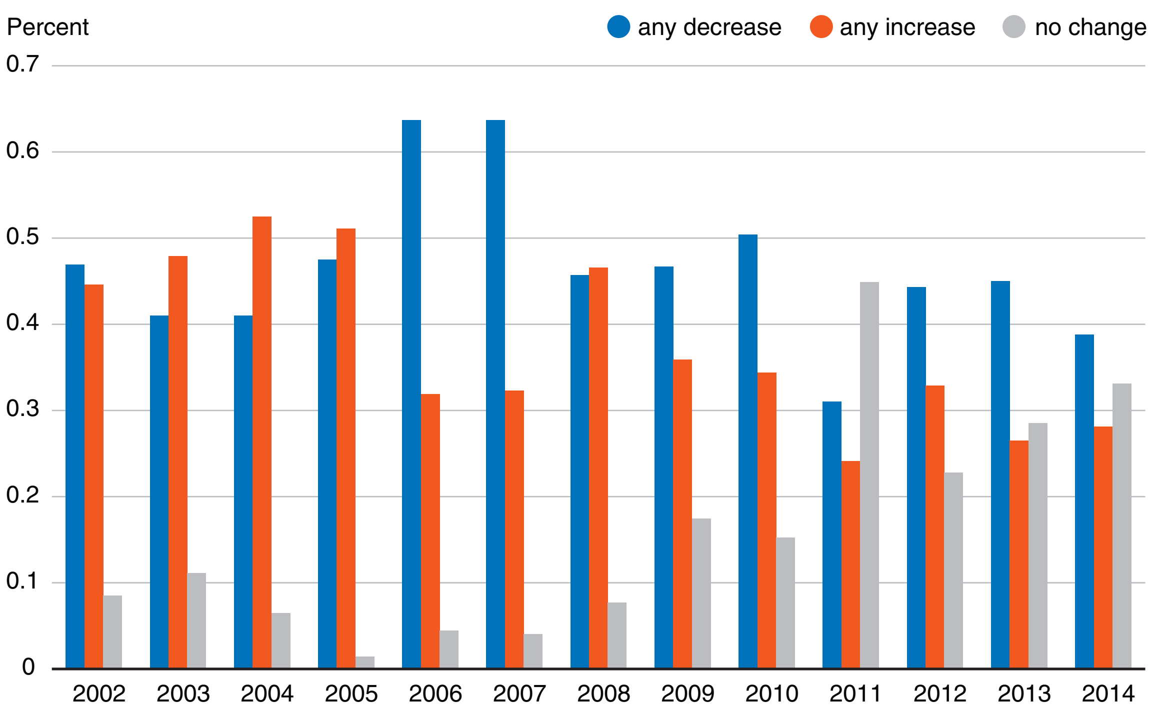
Results

Figure 1 (p. 2) showed that the share of samples testing positive for *Salmonella* dropped sharply from 2005 to 2007 and then declined modestly. The decline in *Salmonella* coincides with important initiatives put forth by FSIS (table 1). Below, we examine the impact of changes in the regulatory environment on the performance on *Salmonella* tests of establishments that slaughter young chickens. First, we consider the impact of regulatory changes on performance on *Salmonella* tests; then we examine the impact of regulatory changes on the level of performance on these tests.

Changes in Performance on Salmonella Tests

Changes in *Salmonella* levels show the path these levels take over time and the breadth of change within the industry. If there are more increases than decreases, there is evidence of an upward trend in *Salmonella* levels and of a downward trend if there are more decreases. If there are many more decreases than increases, there is evidence of broad-based declines in *Salmonella* levels. Figure 2 gives the percentage of establishments with increases, decreases, or no changes in their shares of samples testing positive for *Salmonella*. The figure shows that increases exceeded decreases until 2006, when there was a sharp reversal within which decreases exceeded increases. The large difference in 2006 narrowed over time but persisted until 2014.

Figure 2
Changes in percentage of samples testing positive for *Salmonella*



Source: U.S. Department of Agriculture, Economic Research Service estimates using *Salmonella* test data from USDA, Food Safety and Inspection Service.

Figures 1 and 2 provide evidence that changes in food safety policy had an impact on performance on *Salmonella* tests. However, establishment size, performance on food safety tasks, technology, and other attributes have been shown to affect *Salmonella* levels and need to be evaluated in the context of the changes in the shares of samples testing positive for *Salmonella*. We consider three slightly different definitions of changes (table 3). First, we examine the impact of regulatory changes on shares of test samples with decreases of zero percent or more in *Salmonella* (Decrease). Next, we determine whether regulatory changes encouraged larger decreases of *Salmonella* of 2 percent or more (Decrease_02). Finally, we consider regulatory change in the context of any changes in performance on *Salmonella* tests (Change Percent Positive). The first two regressions of *Salmonella* thresholds rely on a fixed-effects conditional logit regression and the last regression on a fixed-effects ordinary least squares regression. Definitions of all variables are given in table 3.

Columns 4 and 5 of table 4 have fixed-effects conditional logit regression results for dependent variables equal to 1 for any decrease (column 4) or any decrease of 2 percent or more (column 5), and zero otherwise. The R-square values are 0.22 and 0.289, respectively. Results show that four of the six regulatory variables and further processing ("process") are significant. Other variables are not significant.

The parameters for decrease and decrease of 2 percent or more are defined as an odds ratio (probability/(1-probability)). An odds ratio equal to one-half means there is only a 33-percent chance of a decrease; an odds ratio of 1 means a 50-percent chance of a decrease, and an odds ratio of 10 means there is about a 90-percent chance of a decrease. Results in table 4 show that parameter values for mediocre or poor performance on *Salmonella* tests were 7 and 48.3, respectively, for any decrease (col. 4) and 10 and 81, respectively, for any decrease and 2-percent decrease (col. 5) in *Salmonella* levels. These results make sense; slaughter establishments with poor performance are likely facing greater scrutiny from regulatory authorities, leading to better performance.

There are also high odds of a decrease in the share of samples testing positive for *Salmonella* from 2006-2010 when FSIS undertook a program of publicly disclosing the identities of establishments with poor or mediocre performance on tests for *Salmonella*. The strongest increase in the odds of a decrease occurred over 2006-2007, ranging from 2.7 to 3.2 (about 3 to 1). The odds for a decrease over 2008-10 were about 2.5 to 1, and the odds after 2011 were about 1.25 to 1.

The variables shown in table 4 (K1-K5) other than Process are not significantly related to changes in *Salmonella* levels. The low odds for Process are as expected because the chickens are processed at a high-enough temperature to kill *Salmonella*, leading to the assumption that it is less necessary to control *Salmonella* at chicken slaughter. Processing establishments also slaughter chickens, making food safety efforts more complex than in slaughter-only establishments and more taxing of management's time. Other effects are not significant with respect to changes in *Salmonella* levels. It may be that these effects are constant over time and are captured as fixed effects. For example, SSOPs and HACCP tasks are important for overall process control and do help control the spread of *Salmonella*, but performance does not change much over time. Ollinger and Moore (2009), for example, found no significant effect of SSOPs and HACCP tasks on *Salmonella* levels in chicken carcasses.

Results from the logit regression give the odds of change at a certain threshold but do not indicate the amount of change that may occur. Moreover, threshold variables lose some information by not capturing all the variance in the share of samples testing positive for *Salmonella*.

Table 4

Sources of change in the number of samples testing positive for *Salmonella* on FSIS sampling tests over 2000-14[1]

Model variable	Empirical variable	Units	Decrease percent positive	Decrease 2-percent positive or more	Change percent positive
			Odds Ratio		OLS Estimate
K_1	Millions of chickens	1 million chickens	1.007 (0.009)	1.008 (0.008)	-0.0004 (0.0003)
K_2	Establishment age	Year	1.013 (0.022)	1.013 (0.024)	-0.001 (0.0008)
K_3	Multi-species	Multi-species facility	0.820 (0.181)	0.750 (0.169)	0.013* (0.008)
K_4	Multi-establishment firm	Multi-establishment	0.912 (0.163)	0.971 (0.176)	-0.006 (0.007)
K_5	Process	Processes chicken.	-0.600* (0.165)	0.501** (0.163)	0.043** (0.018)
L_1	HACCP compliance	Noncompliance is 150 percent of mean.	1.337 (0.285)	1.323 (0.310)	0.006 (0.008)
L_2	Pre-op SSOP compliance	Noncompliance is 150 percent of mean.	1.115 (0.187)	1.040 (0.196)	-0.006 (0.006)
L_3	Op SSOP Compliance	Noncompliance is 150 percent of mean.	1.034 (0.184)	0.981 (0.196)	0.005 (0.007)
R_1	Poor Performance	Poor performance.	48.28*** (14.07)	81.05*** (25.16)	-0.267*** (0.016)
R_2	Mediocre Performance	Mediocre performance	7.432*** (1.088)	10.180*** (1.666)	-0.071*** (0.007)
R_3	Year_2006_2007	2006-07 vs. 2000-05	2.708*** (0.632)	3.210*** (0.748)	-0.044*** (0.009)
R_4	Year_2008_2010	2008-10 vs. 2000-05	2.250*** (0.504)	2.948*** (0.756)	-0.045*** (0.011)
R_5	Year_2010	2010 vs. 2008-10	1.263 (0.324)	0.893 (0.242)	-0.004 (0.009)
R_6	Year_2011_2014	2011-14 vs. 2000-05	1.293 (0.301)	1.123 (0.299)	-0.028*** (0.011)
	R^2		0.220	0.289	0.317
	Observations		1,636	1,636	1,636

[1]Establishments entered the chicken slaughter industry before 2006 and exited after 2001.
HACCP = Hazard Analysis and Critical Control Point; FSIS = USDA, Food Safety and Inspection Service;
SSOP = Standard Sanitation Operating Procedures.
*, **, *** = 0.10, 0.05, and 0.01 levels of significance. Clustered standard errors in parentheses.

The last column of table 4 has the fixed-effects ordinary least squares regression results of the impact of model variables on changes in the share of samples testing positive for *Salmonella*. Results are similar to the other regressions. Being a further chicken processor or establishment that slaughters multiple species encourages higher shares of *Salmonella*. All of the regulatory variables are associated with a reduction in the share of samples testing positive for *Salmonella*. The strongest response comes from establishments with poor or mediocre performance. The regulatory periods also have large, significant negative effects on the change in the shares of chicken carcass samples testing positive for *Salmonella*.

Overall, the results show that regulatory actions are associated with changes in performance. The variables for poor and mediocre performance correspond to Category 3 and 2 ratings from FSIS. Results suggest that these classifications may have encouraged reductions in samples testing positive for S*almonella*. Results also show that the 2006-10 period was a time of improvements on *Salmonella* tests after 6 years of a horizontal trend. The period after 2010 exhibited less change; this was a time of stringent, but constant, standards that gave establishments less incentive to improve performance beyond the new standard of 5 positive samples per 51 test samples, but also gave them strong incentives to do no worse than the standard.

Results shown in figure 2 and table 4 provide some evidence that greater disclosure policies adopted over 2006-2010 may have encouraged a reduction in *Salmonella* in young chicken carcasses. Results do not show the impact of our model on *Salmonella* levels. Next, we examine levels.

Levels of Performance on *Salmonella* Tests

A performance level is the accumulation of changes over time. Figure 2 shows that changes over 2006-14 were in the direction of stronger performance. Below, we directly examine performance levels in terms of hypothetical tolerances that are fractions of the FSIS standard that existed in 2006. The tolerances are one-sixth and one-twelfth the FSIS standard that existed over 1996-2010 and are equivalent to 2 and 1 samples out of 51 samples testing positive for *Salmonella.* All tolerances are more stringent than the 5-of-51-samples FSIS standard that was established in 2011 and remains in effect today; the one-sixth tolerance is more stringent than the Category 1 threshold over the entire period. We also consider a regression in which the dependent variable, percent of samples testing positive for *Salmonella*, varies freely.

Figure 3 shows that by 2014, nearly 80 percent of slaughter establishments for young chickens met a *Salmonella* performance level of one-twelfth the tolerance that existed in 2005 and almost all establishments met the one-third tolerance. By contrast, only about 15 percent of establishments met the one-twelfth and 40 percent met the one-third *Salmonella* performance criterion in 2005.

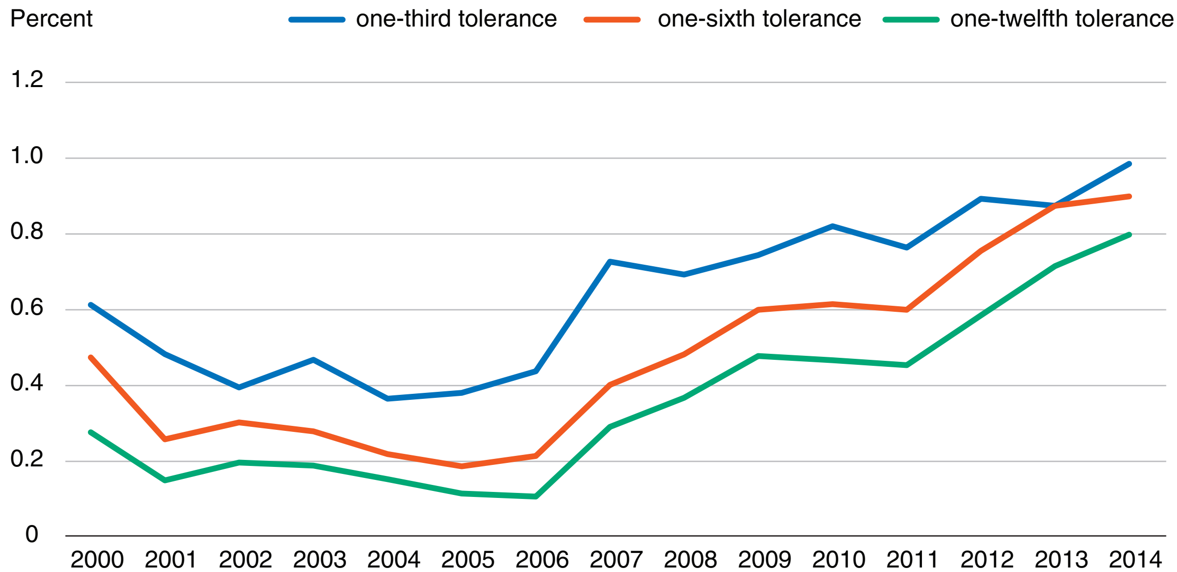
Figure 4 shows how achievement of Category 1, 2, and 3 ratings changed over time. There is a sharp increase in Category 1 establishments after 2005 when FSIS created its category rating system and declared its intention to disclose the identities of establishments with poor or mediocre performance on *Salmonella* tests. There was a modest increase after 2008 when FSIS began disclosing the identities of establishments with mediocre or poor performance, followed by a dip in 2011. Category 2 had a reverse pattern, while Category 3 establishments had a modest decline. This figure suggests that the number of establishments rated at a Category 2 level of performance changed the most over 2006-14.

We next examine the impact of regulatory changes on performance on *Salmonella* tests using a fixed-effects conditional logit model. A Hausman test supports our choice of a fixed-effects model, significantly rejecting the hypothesis that there are no fixed effects.[8]

[8]Recall that Hausman tests are used to determine whether a random-effects or fixed-effects econometric model is appropriate. Fixed-effects models are appropriate if (1) unobserved variables are constant over time and uncorrelated with the independent variables, and (2) within-unit variation in the dependent variable is greater than cross-unit variation (Chamberlain, 1980).

Figure 3

Share of slaughter establishments for young chickens at 1/3, 1/6, and 1/12 the FSIS *Salmonella* tolerance from 2000-2014[1]

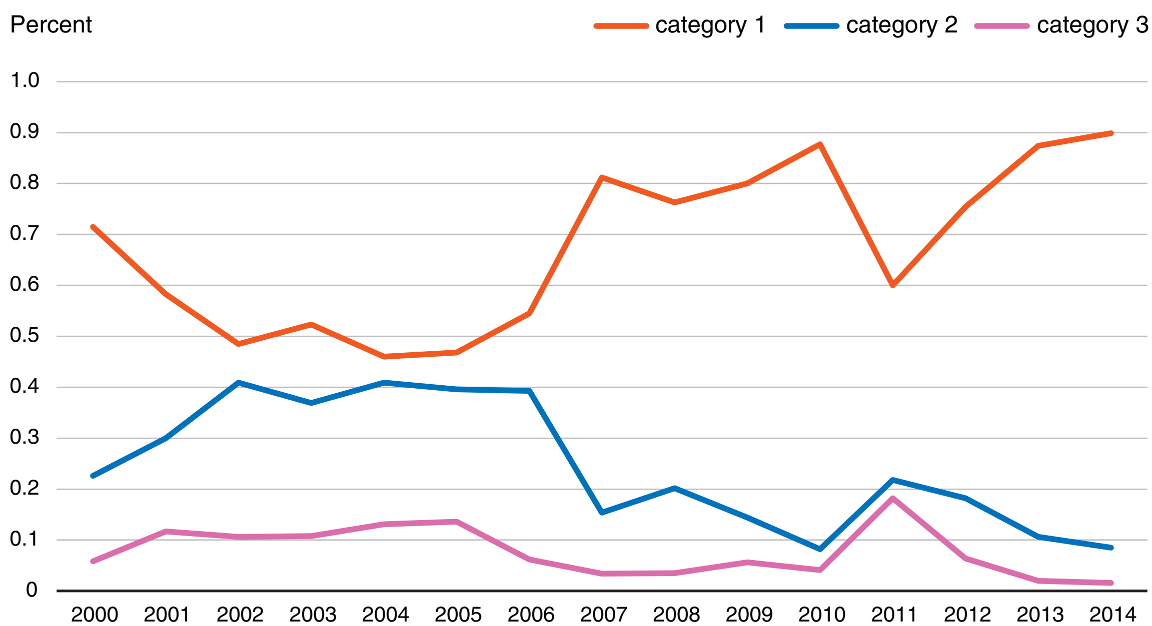


[1]The performance levels are based on the FSIS standard in effect before 2011. That tolerance allows no more than 12 samples out of 51 to test positive for *Salmonella*. The 1/3 performance level is still less than the more stringent standard of allowing no more than 5 samples out of 51 to test positive for *Salmonella* that was established in 2011.

Source: U.S. Department of Agriculture, Economic Research Service estimates using *Salmonella* test data from USDA, Food Safety and Inspection Service.

Figure 4

Estimated share of slaughter establishments for young chickens at three FSIS categories based on 2005 FSIS standards[1]



[1]Categories are based on ERS estimates of the category ranking of establishments based on yearly *Salmonella* results.

Source: U.S. Department of Agriculture, Economic Research Service estimates using *Salmonella* test data from USDA, Food Safety and Inspection Service.

Table 5 gives regression results with the dependent variable equal to 1 if the share of samples testing positive for *Salmonella* is less than or equal to one-sixth or one-twelfth of the 1996-2010 FSIS *Salmonella* standard. The R^2 values are .254 and .230. The dataset has 1,755 observations. There are more observations in this regression than in the earlier regressions because the earlier regressions were of changes in performance, which causes some leading observations to drop out.[9]

Results show that the number of chickens slaughtered, being part of a multi-establishment firm, having mediocre performance on tests for *Salmonella*, and the dummy variables representing the 2008-10 and 2011-14 periods significantly affect the odds of having a performance level equal to one-sixth or one-twelfth the FSIS standard of 2005. The odds of improving performance rose by 1.1 and 1.6 percent for each additional million chickens produced. In contrast, the odds of achieving these standards were 25 to 30 percent lower for establishments owned by multi-establishment firms and 52 to 44 percent lower for establishments with mediocre performance. There was no statistically significant relationship between an establishment with poor performance in one year and meeting a one-sixth or stricter tolerance in the subsequent year. Mediocre-performing establishments had lower odds than other establishments of meeting a one-sixth or stricter tolerance the subsequent year.

Table 5 shows that the regulatory-period dummy variables of R_4 and R_6 are associated with a dramatic increase in the odds of performing substantially better on *Salmonella* tests. The odds of having a performance level of one-sixth or one-twelfth the *Salmonella* standard was about three to one over 2008-10. From 2011 to 2014, the odds of meeting a performance level equal to one-sixth or one-twelfth the FSIS standard of 2005 were about 13.5 to 1 and 9.5 to 1 for the period. The regulatory regime dummy variable for 2010 was included to see if performance changed in anticipation of more stringent standards imposed in 2011. Results show that the odds did not change.

Threshold variables do not capture all of the variation in the shares of samples testing positive for *Salmonella*. The third column of table 5 gives the results of a fixed-effect OLS model. The parameter values are biased downward, as discussed above. Results show that slaughtering multiple species, a high level of noncompliance on SSOPs, and mediocre performance were associated with higher levels of *Salmonella*. Poor performance the previous year on *Salmonella* tests and all of the regulatory periods (R_3 to R_6) encouraged lower *Salmonella* levels. Notice that size of change for the regulatory periods (R_3, R_4, and R_5) increased over time (-0.035 for 2006-07, – 0.052 for 2008-10, and – 0.092 for 2011-14). These suggest a drop of the *Salmonella* levels of 3.5 percent over the first period, 5.2 percent over the first two periods, and 9.2 percent over the entire 2006-2014 period. By contrast, there was no change in *Salmonella* levels over 2000-2005 (fig. 1).

[9]Observations are lost because some observations do not have a lagged term for the first year.

Table 5
Economic Forces affecting performance on *Salmonella* tests over 2000-14[1]

Model variable	Empirical variable	Units	1/6th *Salmonella* standard	1/12th *Salmonella* standard	Percent positive
			Odds Ratio		OLS Estimate
K_1	Millions of chickens	1 million chickens	1.011 (0.009)	1.016* (0.010)	-0.0003 (0.0003)
K_2	Establishment age	Year	0.993 (0.019)	0.990 (0.018)	-0.0002 (0.0009)
K_3	Multi-species	Multi-species facility	0.739 (0.201)	0.749 (0.169)	0.013** (0.007)
K_4	Multi-establishment firm	Multi-establishment	0.748* (0.135)	0.707* (0.133)	-0.003 (0.008)
K_5	Process	Processes chicken	0.830 (0.484)	0.845 (0.414)	0.030 (0.021)
L_1	HACCP compliance	Noncompliance is 150 percent of mean.	1.116 (0.261)	1.269 (0.274)	0.002 (0.007)
L_2	Pre-op SSOP compliance	Noncompliance is 150 percent of mean.	1.057 (0.204)	1.013 (0.192)	-0.006 (0.005)
L_3	Op SSOP Compliance	Noncompliance is 150 percent of mean.	0.728 (0.154)	0.795 (0.176)	0.012* (0.006)
R_1	Poor Performance	Poor performance.	1.321 (0.235)	1.100 (0.211)	-0.012* (0.007)
R_2	Mediocre Performance	Mediocre performance	0.476*** (0.074)	0.555*** (0.089)	0.031*** (0.006)
R_3	Year_2006_2007	2006-07 vs. 2000-05	1.257 (0.297)	1.238 (0.279)	-0.035*** (0.009)
R_4	Year_2008_2010	2008-10 vs. 2000-05	2.912*** (0.790)	3.092*** (0.843)	-0.052*** (0.012)
R_5	Year_2010	2010 vs. 2008-10	1.369 (0.372)	1.236 (0.319)	-0.013* (0.007)
R_6	Year_2011_2014	2011-14 vs. 2000-05	13.639*** (3.945)	9.583*** (2.410)	-0.092*** (0.013)
	R^2		0.254	0.230	0.250
	Observations		1,755	1,755	1,755

[1]Establishments entered the chicken slaughter industry before 2006 and exited after 2001.
HACCP = Hazard Analysis and Critical Control Point; FSIS = USDA Food Safety and Inspection Service; SSOP = Standard Sanitation Operating Procedures. *, **, *** = 0.10, 0.05, and 0.01 levels of significance. Clustered standard errors in parentheses.

Conclusions and Synthesis

This study examined the effects of public disclosure of the performance of chicken slaughter establishments on tests for *Salmonella* on young chicken carcasses across four regulatory periods. The four periods include:

1. The time before public disclosure of the identities of establishments with mediocre or poor performance on *Salmonella* tests (2000-2005);
2. The period 2006-07, when FSIS began publishing aggregate industry performance records quarterly, established a 1, 2, or 3 Category ranking system that identifies establishment performance on *Salmonella* tests, and announced its intention to monitor performance and make changes when it sees them as necessary[10];
3. The period 2008-10, when the identities of Category 2 and 3 establishments were disclosed; and
4. The period 2011-14, when FSIS promulgated new performance standards and stopped disclosing the identities of Category 2 establishments.

The empirical model accounted for the number of chickens an establishment slaughtered per year (a measure of size) and whether the establishment slaughtered more than one species of animal, was owned by a firm also owning other establishments, and did further chicken processing, and whether the establishment had a high number of noncompliances on sanitation and food safety process-control requirements.

Results show that the share of samples testing positive for *Salmonella* dropped by 4.4 percent over 2006-07 and 4.5 percent over 2008-10; there was a weaker, but still significant, negative change over 2011-14. The odds of a decrease in *Salmonella* levels were about 3 to 1 over 2006-07 and 2 to 1 over 2008-10. The odds were much smaller in the 2011-14 period. Overall, results show that there was a 9.2-percent drop in *Salmonella* levels over the period of regulatory change (2006-14).

The analysis did not specifically control for buyer contracts, product-recall policies and technologies, food safety technology, or *Salmonella* on live chicken inputs.[11] Some of the impact of these missing variables is accounted for through a fixed-effects parameter incorporated into the econometric model. The technique controls for attributes that are unique to establishments and do not change over time. This econometric approach, however, cannot account for changes over the study period.[12]

[10]Poor performance (Category 3) is defined as a level in which the share of samples testing positive for *Salmonella* exceeds the FSIS standard; mediocre performance (Category 2) is a level that meets the FSIS standard but is greater than one-half the FSIS standard; good performance (Category 1) is less than one-half the FSIS standard.

[11]Food safety technologies and the reduction of *Salmonella* on live chicken inputs require investment in facilities or equipment. Establishments have an incentive to make these investments only if it is profitable to do so. Pressure from a buyer, the threat of a recall, or FSIS food safety standards may give that incentive, suggesting there is no need to consider these forces separately.

[12]Many chicken buyers had already established standards as early as 2001 (Ollinger et al., 2004), and these contracts influenced establishment *Salmonella* levels (Ollinger and Moore, 2009). It is likely that some of these buyers with contracts and some establishments' own marketing plans include a policy of achieving a level of performance on *Salmonella* tests that exceeds industry standards. Improvements in industry performance on *Salmonella* tests after 2006 may, therefore, encourage them to improve their performance on *Salmonella* tests even though they may already meet the highest rating available from FSIS.

It appears unlikely that uncontrolled factors accounted for most or all of the change in *Salmonella* levels. For those factors to account for the change, they would have to be strongly correlated with the timing of reductions. Moreover, about 60 percent of all chicken slaughter establishments had buyer contract requirements in 2001 (Ollinger et al., 2004). It is likely that other establishments had buyer contracts by 2014. Buyers could have changed contract terms, but, many establishments likely faced no—or weakly binding—contracts. Salvage (2014) indicates that Wal-Mart undertook its first comprehensive food safety program for chicken in 2014 and quotes Dr. Gary Acuff of Texas A&M as saying that he thought Wal-Mart was the first retailer to implement this type of program. It is also notable that the USDA Agricultural Marketing Service, which buys ground beef and raw chicken for the National School Lunch Program, raised standards for the ground beef it purchases for the program over the 2005-11 period but not for chicken (Ollinger et al., 2014).

The threat of a recall and a subsequent liability cost can create a strong incentive for an establishment to improve food safety performance in general. There have been improvements in DNA-typing and other techniques that can more accurately link a pathogen found in foods to its source. However, recalls of raw chicken products are infrequent, and most recalls of chicken are for processed products and not the whole chicken carcasses.[13] Data from the Centers for Disease Prevention and Control (CDC) indicate that over 1998-2004, there were 10 recalls due to *Salmonella* of 10 commonly consumed chicken products.[14] These recalls caused 408 illnesses, 33 hospitalizations, and no deaths. Over 2005-2014, there were only 2 recalls, 125 illnesses, and 22 hospitalizations for those same 10 products.

Overall, this report has empirically shown a correlation of the timing of improvements in performance on FSIS *Salmonella* tests with FSIS regulatory changes in which the identities of chicken slaughter establishments with poor or mediocre performance on *Salmonella* tests were publicly disclosed. The analysis could not rule out pressure from chicken buyers or improvements in recall technologies as forces driving this change. We conclude that regulatory changes, buyer group effects, and changes in recall policy all contributed to a drop from 0.14 to 0.02 in the share of chicken samples testing positive for *Salmonella* over 2006-14. This change contrasts sharply with the flat trend in the data over 2001-05 (fig. 1).

Notwithstanding the caveats of missing variables, the analysis provides evidence of the importance of releasing clear measures of food safety quality that buyers can use to make informed decisions. In the case documented here, changing from an alphabetical pass/fail system to a simple binding numerical system that ranks establishments as good (Category 1), mediocre (Category 2), or poor (Category 3) provided a more precise measure of the establishment's food safety performance. However, establishment incentives to improve performance are strengthened if the information is made publicly available. Publishing the category ratings on the FSIS website gave the public a meaningful measure of food safety quality and likely prompted an improvement in performance on *Salmonella* tests. Changes in performance began when the new policy became apparent over the 2006-07 period. They continued through 2010 when FSIS stopped disclosing the names of establish-

[13]FSIS recall data identifies eight recalls for *Salmonella* in chicken over 2000-14; only three recalls were of raw products.

[14]The 10 products were chosen because they were generally uncooked and commonly consumed. They are: chicken nuggets/fingers, raw chicken, chicken for tacos, chicken tenders, diced chicken, shredded chicken, chicken hamburger, ground chicken, chicken strips, and breaded chicken cutlets.

ments performing at a Category 2 level on its website and promulgated new standards that allowed less than half the number of positive *Salmonella* samples permitted under the older standards.[15]

The research also reveals a new tool for encouraging compliance with food safety and other quality measures. Traditionally, regulators have mandated the performance of sanitation tasks and other process controls and have established standards for pathogens and other harmful agents. Both of these tools require costly regulatory oversight and labor devoted to compliance. Moreover, regulators rather than buyers determine the appropriate level of food safety and costs.

The results were consistent with previous research on establishment size and *Salmonella* levels by Muth et al. (2007) and Ollinger and Moore (2008), and the modest impact of compliance with SSOPs and PR/HACCP tasks on food safety performance is consistent with findings by Ollinger and Moore (2008) and Ollinger, et al. (2014), who found little impact of SSOPs and PR/HACCP tasks on *Salmonella* levels on chicken carcasses. This last result makes sense because slaughter establishments for young chickens rely strongly on the use of automation, chemicals, and heat to control harmful pathogens. Cleaning and sanitation is useful for limiting exposure to a wide variety of pathogens, not only *Salmonella*.

[15]FSIS based the 2011 and earlier standards on a baseline of *Salmonella* levels. As noted in the 2006 Federal Register announcement, FSIS established a baseline at a *Salmonella* level at which an establishment would have an 80-percent chance of passing. Since standards are set so that all establishments can pass the standard, the baseline was adjusted by 25 percent to establish the standard. In 1996, this methodology implied a standard of a maximum of 12 of 51 samples testing positive. By 2011, performance on *Salmonella* tests had improved to such a degree that the revised baseline was at a 7.5-percent prevalence, i.e., 4 samples out of 51 samples could test positive. The standard was then set at a tolerance of 5 samples out of 51 testing positive for *Salmonella*.

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