Food-safety test performance and public disclosure: The value of information in encouraging improvements in food safety in the chicken-slaughter industry

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ABSTRACT

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This paper examines the impact of changes in the regulatory standards enforced by the USDA Food Safety and Inspection Service on the *Salmonella* test performance of chicken-slaughter establishments. Regulatory changes include open disclosure of establishments with poor performance on *Salmonella* tests and rigorous *Salmonella* standards. Empirical results show that public disclosure of establishments with mediocre or poor levels of performance on *Salmonella* tests led to a substantial drop in *Salmonella* levels over the 2008−2010 period, which allowed FSIS to later reduce its tolerance for acceptable levels of *Salmonella* in chicken by 50 percent.

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Salmonella spp is the second-most common cause of foodborne illness in the United States, causing 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 infected with *Salmonella* and other bacteria, over 1998−2008.

Salmonella and other foodborne pathogens cannot be directly observed. Starbird (2005) argued that food-safety sampling provides the necessary information to guide purchasing decisions. However, sampling is costly and, typically, only large commercial buyers elect to undertake it. To address this market failure, the USDA Food Safety and Inspection Service (FSIS), the Federal agency that oversees the food safety of poultry, put forth the Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP) rule in 1996 to strengthen food safety standards. This regulation had an immediate impact. Williams and Ebel (2012) found that PR/HACCP reduced chicken-related salmonellosis illnesses by 190,000 over 1996–2000. However, since 2000, there has been no evidence of further improvements.

One provision of PR/HACCP required chicken slaughter plants to meet a *Salmonella* sampling standard based on *Salmonella* levels present when PR/HACCP was promulgated in 1996. This standard did not change even as illness outbreaks persisted, prompting a call for regulatory change (Federal Register, 2003). However, FSIS initially only returned test results to establishments as they became available in the hope that establishments would voluntarily take actions to reduce *Salmonella* levels. FSIS also published summary information about all chicken test results. This modest regulatory change was later strengthened, when FSIS began publishing the names of establishments with mediocre or failing *Salmonella* sampling records on the FSIS website in 2008. In 2011, FSIS again tightened *Salmonella* standards and reduced openness by ceasing to disclose the names of mediocre establishments, but continued to report the names of the establishments with the worst performance.

This paper empirically examines the effects of the changes in regulatory regimes over 2006−2012 on *Salmonella* levels in chicken carcasses. It contributes to the existing literature in two important ways. First, it highlights a novel, market-based approach to regulation in which improvement in performance is motivated by public disclosure of an easily understood measure of quality. Second, it applies Holmström (1982)—which showed conceptually that group incentives are ineffective and that a proper incentive system, applied across agents, can overcome moral hazard—to a regulatory setting.

This paper proceeds as follows. First, we provide information about FSIS regulation. Next, we discuss buyer and seller incentives and food-safety information. Then, we provide an economic framework and empirical model. This section is followed by a detailed description of our unique data, a presentation of estimation procedures, and the results. We conclude by discussing implications for policy and directions for future research.

FSIS Regulation

FSIS and its antecedent USDA agencies have regulated the food safety of meat since 1906, when Congress mandated that establishments follow hygienic meat processing practices. Congress greatly expanded USDA's authority for regulating the safety of chicken meat under the

Wholesome Poultry Products Act (WPPA) of 1968 and subsequent regulations. FSIS further expanded its regulatory authority when it put forth the final Pathogen Reduction Hazard Analysis and Critical Control Point (PR/HACCP) rule on July 25, 1996.

The PR/HACCP rule required that establishments that slaughter livestock or process ground meat or poultry meet *Salmonella spp* performance standards. Chicken slaughter establishments had to have fewer than 13 out of 51 samples test positive for *Salmonella spp* to be in good regulatory standing.[1] Under this system, establishments meeting the standard were assigned a class "A" rating and testing stopped until the next round of testing. Establishments that failed testing were assigned a class "B" rating and were subject to additional testing. Plants that still did not meet the standard on the next tests were assigned a class "C" rating; another failed test result led to a "D" rating. Plants reaching a class "D" rating could be subject to regulatory actions.

The alphabetized system was vague in that it did not distinguish the best-performing establishments from those just meeting the standard. The ratings did distinguish poorly performing establishments from others, but this was not very meaningful to the public and commercial buyers because ratings were not publicly disclosed.

FSIS subsequently developed a numerical rating system as a means of giving more informative and meaningful information. Table 1 provides a timeline of the most relevant regulatory changes. The first change in the regulations occurred in 2006 when FSIS replaced the alphabetized categories of "A" through "D" with a numerical rating system that placed establishments in one of three categories based on their performance on *Salmonella* tests. As

[1] Certain serotypes of *Salmonella* are endemic to certain populations of chickens (Burr, 2005). Public health officials recognize that eliminating *Salmonella* from chicken meat is expensive and, perhaps, not necessary since cooking chicken to 165°F kills *Salmonella*.

shown in table 2, establishments that had fewer than 7 of 51 samples testing positive for *Salmonella* on two consecutive sets of samples were assigned to Category 1. This Category 1 designation was supposed to indicate good control over food safety performance. Plants were assigned to Category 2 if they had with *Salmonella* levels between 50-100% of the *Salmonella* tolerance. Category 3 performers had over 100% of the allowed threshold for *Salmonella* presence in the plant.

FSIS published quarterly reports indicating performance on *Salmonella* testing from 2006 to 2008. On January 28, 2008, FSIS announced in the *Federal Register* that it would begin publishing the names of establishments performing at the Category 2 and Category 3 levels. This policy took effect on March 28, 2008 and remained in effect until the beginning of 2011.

FSIS came full circle in May of 2010 when it announced another change in policy, which took effect on July 1, 2011. Under this new regulatory approach, FSIS phased out publication of Category 2 establishments on its website and cut the allowed number of samples that could test positive for *Salmonella* by more than half – no more than 5 out of 51 samples testing positive for *Salmonella* on consecutive sets of samples to attain Category 2 status.

FSIS Process Controls and HACCP Tasks

Under the WPPA of 1968 and subsequent regulations, FSIS promulgated a number of process control actions called Sanitation Standard Operating Procedures (SSOPs). These SSOPs required establishments to perform knife cleaning and other food safety tasks during operations (operating tasks), perform equipment disassembly and cleaning and other tasks at the beginning or end of a shift (pre-operating tasks), and comply with several other regulations, including those dealing with maintaining facilities, cooking times and temperatures, and preparation of fermented, smoked, and other processed products.

The PR/HACCP rule also required meat and poultry establishments to develop and implement HACCP process control programs for each product. FSIS reviews and approves the HACCP plans and its inspectors verify performance of the associated HACCP monitoring and control tasks and all SSOPs. See Ollinger and Mueller (2003) for further discussion.

Buyer and seller incentives and food-safety information

Food safety is costly because it requires careful attention to details, frequent sanitation, and innovative processing techniques. Food safety is also difficult to measure, partly because the tests are pathogen-specific while types of contaminants and food safety risks are many. Often, the relative safety of food is uncertain until it is eaten. This difficulty in measuring food safety may give rise to moral hazard and an incentive for chicken establishments to lower their costs by reducing their food safety effort.

Buyers have an incentive to purchase chicken that meets a high food safety standard because there are substantial costs to being held responsible for a foodborne illness. Companies like Hudson Beef and Peanut Corporation of America have gone bankrupt over bacterial contamination incidents. Recalls and other food-safety problems in meat and poultry have led to temporary declines in consumption of those products (Piggott and Marsh, 2004; Marsh et al., 2004) and sharp declines in stock prices (Thomsen and McKenzie, 2001).

Buyers make purchasing decisions based on the available information, and some buyers impose private, enforceable standards for food safety and other quality attributes 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. Other buyers may not have the capacity to impose a quality program on their suppliers. These buyers, however, can use food-safety information from FSIS to make better-informed purchasing decisions. Food safety is one quality attribute, and information from FSIS testing can eliminate information asymmetries and allow buyers to make better-informed choices.

Holmström (1982) argued that group incentives are ineffective and that a proper incentive system, applied across agents (in our case, plants) can overcome moral hazard. The 2006 FSIS regulatory change introduced a quality rating system for *Salmonella*, but because *Salmonella* ratings were not publicly disclosed, it was very difficult for any consumer or commercial buyer to obtain the rating. To overcome this information asymmetry, FSIS began publishing the names of each plant performing at worse levels (Category 2 or 3) on its website. The public release of information gave establishments a strong incentive to attain the highest rating (Category 1) or risk losing sales. After 2010, FSIS stopped publishing the names of Category 2 plants and mandated much stricter tolerances based on a revised *Salmonella* baseline.

Economic Framework

Chicken plants faced four distinct regulatory regimes for *Salmonella* testing over 2005−2012. The standards introduced in the original 1996 PR/HACCP *Salmonella* standards were in effect through 2005. The second regulatory period occurred over 2006−2007, when FSIS first used its revised numerical ratings but published only aggregate performance data. The next regulatory period extended from 2008 through 2010, when FSIS published on its website the names of establishments that failed to meet a standard of no more than six of 51 samples testing positive for *Salmonella* on consecutive tests *spp*. Finally, the fourth regulatory period started in 2011, when FSIS lowered its (Category 2) tolerance to no more than five samples out of 51 testing positive for *Salmonella spp* on consecutive sets of samples to pass testing, but ceased to publish the names of Category 2 establishments on its website.

Below, we empirically examine how performance on *Salmonella* tests changed in response to different regulatory regimes. We use an approach that closely follows Muth et al. (2007), Ollinger and Moore (2008), and Ollinger, Guthrie, and Bovay (2014), who examined the effectiveness of food-safety technologies in controlling *Salmonella*. Other research has examined the cost of food-safety regulation (Antle, 2000; Ollinger and Mueller, 2003; Ollinger and Moore, 2009a), the effectiveness of food-safety regulations in controlling *Salmonella* (Ollinger and Moore, 2008), and the impact of financial performance on *Salmonella* tests (Muth, et al., 2012). Following Ollinger, Guthrie, and Bovay (2014), we model production with a framework in which food-safety test performance for establishment *i* in year *t* (FS_{it}) is a function of labor devoted to food safety, as reflected by performance on FSIS-mandated process controls (**L**), plant size (K), plant technology (**t**), a vector of plant and firm characteristics (**Z**), and regulatory variables (**R**):

(1) $$FS_{it} = FS(\mathbf{L},\ K,\ \mathbf{t},\ \mathbf{Z}, \mathbf{R})$$

Equation 1 is represented econometrically as:

(2) $$FS = \alpha_0 + \sum_i \beta_i L_i + \delta K + \sum_j \rho_j t_j + \sum_k \lambda_k Z_k + \sum_l \kappa_l R_l + \xi$$

Again, the dependent variable in equation 2 is given by an establishment's performance on *Salmonella* tests administered by FSIS. We evaluated performance on three successively stricter tolerances, in which FS is defined as one if the plant performed at one-third, one-sixth, and one-twelfth the 1996 FSIS *Salmonella spp* tolerance (that is, equivalent to four of 51, two of 51, and one of 51 samples testing positive). The choice of these tolerances is arbitrary except that (1) the one-third tolerance is more stringent than the threshold for Category 1 plants in effect prior to 2011 and the (Category 2) FSIS tolerance that was established in 2011 and remains in effect today, (2) the one-sixth tolerance is more stringent than the Category 1 ranking over the entire period, and (3) a tolerance equal to one-half the 1996 FSIS *Salmonella* standard is less stringent than the FSIS tolerance of 2011 and could not be used. (Recall that Category 3 plants are considered to have failed the testing, and remain under consistent FSIS review until their performance improves.)

We now rewrite equation 2 as a binary choice model, given in equation 3:

(3) $$FS_{ey} = \alpha_0 + \sum_i \beta_i L_{iey} + \delta K_{ey} + \sum_j \rho_j t_{jey} + \sum_k \lambda_k Z_{key} + \sum_l \kappa_l R_{ley} + \xi_{ey},$$

where

$FS_{ey} = 1$ if $FS^*_{ey} \leq$ tolerance, and

$FS_{ey} = 0$ if $FS^*_{ey} >$ tolerance.

The subscripts *e* and *y* represent observations at the establishment-year level. The variables are described below. Detailed definitions of the following variables and their summary statistics are provided in table 3.

Labor devoted to food safety (*L*) is reflected in the performance on SSOPs and the tasks needed to implement HACCP process control programs. SSOPs and HACCP tasks are monitored by FSIS inspectors who record whether a task was performed and in compliance with FSIS standards. A high number of noncompliances implies less effort devoted to food-safety process control. FSIS inspectors do have some discretion over their assessment of establishment performance of SSOPs and HACCP tasks, suggesting that our measure included inspector error.

There are two types of SSOPs—pre-operational and operational SSOP tasks. Pre-operational SSOP tasks are those at the end or beginning of the production day; operational tasks are those duties performed during production. HACCP tasks are process control tasks that are specified in the establishment's HACCP plan. Ollinger and Moore (2008) found that greater compliance with SSOPs and HACCP tasks improved performance on *Salmonella spp* tests.

Establishment size (measured by the number of chickens slaughtered) is used as a proxy for capital (*K*). Muth et al. (2007) and Ollinger and Moore (2008) found that establishment size positively affects food-safety performance in the cattle-, hog-, and chicken-slaughter industries.

There are two plant technology variables. Muth et al. (2007) found that establishment age is correlated with reduced *Salmonella spp* levels in hog and chicken slaughter. The other technology variable accounts for establishments that slaughter more than one type of animal. These establishments have more complicated operations than single-species establishments, making food safety more costly for them to maintain.

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 control for establishments that are part of a multi-establishment firm. We also used regional dummy variables for chickens since the types of chickens processed in some regions can vary. For example, Iowa and some other Midwestern states may have a large share of egg-laying hens, western states are geographically distinct from the rest of the U.S. with a variety of bird-types, northeastern states may have more niche-type birds, while most commercial chicken production is done in the south and southwestern states.

As described earlier, there were three regulatory changes and four regulatory periods from 2005 through 2012. We use three dummy variables to reflect these regulatory periods, and the effects of these regulatory changes on *Salmonella* test results is the central focus of this paper.

Data

The data include observations on all chicken slaughter establishments whose products were tested for *Salmonella spp* by FSIS over 2006–2012. Sets of chicken samples typically include 51 test samples. However, testing may have begun for some establishments in one year and extended into the subsequent year. As a result, some establishments may have fewer than test 51 samples in a given year. The fewest number samples taken from any establishment in our dataset was 17 test samples. Establishments may be tested more than once per year. No establishment was tested more than twice in one year, making the maximum number of test samples equal to 102. Thus the range of chicken test samples was 18-102; 91 percent of the observations fall in the range of 40-60 test samples.

After dropping observations with missing values, our data included 841 observations. FSIS randomly selects the establishments it tests for *Salmonella spp* from a pool of establishments based on the volume of production. Thus, some establishments are selected more often for testing than others, with some being selected at least once in a year and others less frequently. Our sample of chicken slaughter establishments is, therefore, representative of the volume of production but does not include all chicken slaughter establishments every year.

SSOP and HACCP compliance data 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 chicken production, name and address information, and the date each establishment began operation.

Dun & Bradstreet data were used to identify the number of employees at the establishment level, business activities at the establishment, and whether the establishment was part of a firm that owned more than one establishment. The data also included sales, a subsidiary indicator, a manufacturing indicator, a small business indicator, a public/private indicator, square footage of the establishment, major industry category, line of business, a primary activity code, and some financial variables.

Estimation Procedures

The data include temporal and cross-sectional components, which makes it necessary to consider possible autocorrelation errors and heteroskedasticity. Beck and Katz. (1997) obtained accurate standard errors using duration dependence techniques for pooled data with a binary dependent variable that extended over 30 periods and had little or no change in the dependent variable. Our data are also panel data with a binary dependent variable, but the maximum duration of the temporal component is 7 periods, making a duration dependence model inappropriate. Instead, we used a probit regression.

Beck et al. (1998) showed that autocorrelation cannot be detected in probit models. Yet, our data is grouped by establishment with a time series component. These data are not correlated across plants but may be correlated over time. Cameron and Miller (2015) demonstrated that analyses of these types of data can understate the standard errors and overstate the *t*-statistics. Thus, we use a Huber-White heteroskedasticity-consistent estimator to adjust for possible autocorrelation and data clustering.

We also tested our model for multiplicative heteroskedasticity in the number of chickens slaughtered because establishment size varies substantially across establishments. A Wald test did not reject the null hypothesis that the model is homoskedastic, making it unnecessary to adjust for multiplicative heteroskedasticity.

Results

Chicken slaughter plants responded in a dramatic fashion to the regulatory changes occurring over 2005−2012. Figure 1 shows the change in *Salmonella* levels at federally inspected plants and figure 2 shows a sharp increase in the number of establishments meeting the one-third, one-sixth, and one-twelfth FSIS tolerances.

Table 4 presents the econometric results for the model given by equation 3. The dependent variable in the three regressions is whether the establishments met one-third, one-sixth, or one-twelfth of the 2006 FSIS *Salmonella spp* tolerance, respectively. All models are highly statistically significant (see the χ^2statistics in third row from the bottom of table 4). Wald tests for multiplicative heteroskedasticity (see the last row of table 4) are not statistically significant.

We focus on the effects of the policy-change variables on performance on *Salmonella* tests. After FSIS introduced the category rating system (reflected in our *Year_2006_2012* variable), plants were about 15 percent more likely to meet one-third the FSIS tolerance. Publishing the names of mediocre and poorly performing plants on the FSIS website (*Year_2008_2010*) had a positive and statistically significant effect on all measures of performance. The improvement was about 20 percent for the one-third and one-sixth tolerances and 13 percent for the one-twelfth tolerance. The overall effect of introducing the category rating system and publishing the names of Category 2 and 3 plants on the FSIS website was about a 30 percent improvement in reaching the one-third tolerance and 20 and 13 percent improvements in reaching the one-sixth and one-twelfth tolerances, respectively. The third regulatory period brought improvements of between 38 and 45 percent, depending on the tolerance level considered. Compared with the 2005 *Salmonella* test outcomes, establishments' performance was 38 to 54 percent in 2011 and 2012, after the FSIS standards had been tightened and after a period during which the names of mediocre and poorly performing plants had been published online.

The adoption of the three-category system in 2006 led to some improvement in food safety performance because large buyers could demand that their suppliers have a superior level of food safety, e.g., Category 1, without any cost to the buyer. This regulatory approach gave only a modest incentive to improve *Salmonella* performance because consumers and others not a party to a contract could not observe plant food safety. After FSIS began to publicly disclose the names of establishments that had more than 6 of 51 samples testing positive for *Salmonella*, food-safety performance improved dramatically.

We also note that larger establishments—as measured by the number of chickens slaughtered—were more likely to meet the most stringent hypothetical tolerance levels. The results were consistent with previous research on establishment size and *Salmonella* levels by Muth et al. (2007) and Ollinger and Moore (2008). Almost all other coefficients were statistically insignificant in more than one regression specification.

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 HACCP tasks on food safety performance is consistent with Ollinger and Moore (2008) and Ollinger, Guthrie, and Bovay (2014). This last result makes sense because chicken plants are highly automated with a strong reliance on the use of automation, chemicals, and heat to control harmful pathogens. Cleaning and sanitation constitutes a smaller share of the pathogen control system.

We interpret our results for the regulatory changes in the following way. The adoption of the three-category system in 2006 led to some improvement in food safety performance because large buyers could demand that their suppliers have a superior level of food safety, e.g., Category

1, without any cost to the buyer. This regulatory approach gave only a modest incentive to improve *Salmonella* performance because consumers and others not a party to a contract could not observe plant food safety. Food-safety performance, subsequently, improved dramatically and was highly statistically significant after FSIS began to publicly disclose the names of establishments performing below one-half the *Salmonella* standard.

FSIS sets tolerances based on a baseline of current *Salmonella* levels. Since public disclosure of establishments with poor or mediocre performance on *Salmonella* tests led to a drop in the baseline level, FSIS could set a new tolerance much lower than previously promulgated. This lower tolerance encouraged further improvement in performance on *Salmonella* tests.

As noted in the 2006 Federal Register announcement, FSIS establishes a baseline at a *Salmonella* level at which there is an 80 percent chance that a plant operating at this level would pass. Tolerances are set such that all establishments can pass the standard, meaning the baseline must be adjusted by 25 percent such that all establishments can meet the tolerance. 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 could test positive for samples. The standard was therefore set at 5 samples out of 51 testing positive for *Salmonella*.

Conclusion and Synthesis

This paper examines the performance on *Salmonella* tests of chicken slaughter establishments under four regulatory regimes. Our empirical results show that the performance on *Salmonella* tests progressively improved as regulatory changes were made. There were three important changes in the regulatory regime. First, FSIS created a rating system under which plants were rated as having high, mediocre, or poor performance on *Salmonella* tests. FSIS initially provided the public with aggregated results on a quarterly basis. This yielded some but not much improvement in performance on *Salmonella* tests. FSIS then increased the pressure to improve performance by publishing the names of plants that performed at mediocre or poor levels. A large improvement in performance followed, and in 2011, FSIS made the criterion for each performance category more stringent, resulting in still further gains.

The research presented in this paper illustrates the importance of releasing clear measures of food safety quality that buyers can use to make informed decisions. 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, without publishing the names of poorly-performing firms on the FSIS website, establishments' incentives to improve performance were only limited. Publishing the rankings on the FSIS website gave the public a meaningful measure of food safety quality and prompted a dramatic improvement in food safety. After *Salmonella* levels reached a level deemed more acceptable to FSIS, the agency mandated much stricter standard (but stopped publishing the names of establishments performing at a mediocre level on the FSIS website).

A limitation of this study is insufficient data prior to 2006, when the changes in ranking system were taking place and FSIS was already hinting at the possibility of naming individual firms on the website. This analysis will be stronger when data from the early 2000s can be used in the analysis. As it stands now, our findings likely understate the impact of regulatory change on poultry-slaughter plants' performance on *Salmonella* tests.

References

Antle, J.M. 2000. “No Such Thing as a Free Safe Lunch: The Cost of Food Safety Regulation in the Meat Industry.” American Journal of Agricultural Economics 82:310–322.

Beck, N., and J.N. Katz. 1997. “The Analysis of Binary Time-Series Cross-Section Data and/or Democratic Peace.” Presented at the annual meeting of the Political Methodology Group, Columbus, Ohio.

Beck, N., J.N. Katz, and R. Tucker. October 4, 1998. “Taking Time Seriously: Time-Series-Cross-Section Analysis with a Binary Dependent Variable,” *American Journal of Political Science* 42(4): 1260-1288.

Burr, R., P. Effler, R. Kanenaka, M. Nakata, B. Holland, F.J. Angulo. 2005. “Emergence of *Salmonella* serotype Enteritidis phage type 4 in Hawaii traced to locally-produced eggs.” *International Journal of Infectious Diseases*, 9(6):340−346.

Cameron, A. Colin and Douglas L. Miller. 2015. “A Practitioner’s Guide to Cluster-Robust Inference.” Forthcoming, *Journal of Human Resources*.

Golan, E., T. Roberts, E. Salay, J. Caswell, M. Ollinger, and D. Moore. 2004. *Food Safety Innovation in the United States: Evidence from the Meat Industry*. Agricultural Economic Report 831. Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Holmström, B. 1982. "Moral Hazard in Teams." *Bell Journal of Economics* 13 (2):324-340.

Marsh, T. L., T. C. Schroeder, and J. Mintert. 2004. “Impacts of Meat Recalls on Consumer Demand in the USA.” *Applied Economics* 36(9):897−909.

Muth, M., M. Fahimi, S.A. Karns, and Y. Li. 2007. *Analysis of Food Safety Performance in Meat and Poultry Establishments Revised Final Report Contract No. 53-3A94- 3-12, Task Order 18.* Prepared for Flo Tsui and Jim Wilkus of Food Safety and Inspection Service by RTI International: Triangle Park, North Carolina.

Muth, M., D.V. Creel, and J. Wilkus. 2012. “Analysis of the relationship between economic measures and *Salmonella* testing results in young chicken slaughter establishments.” *Journal of Food Protection* March; 75(3):449-55.

Ollinger, M., J. Guthrie, and J. Bovay. 2014. *The Food Safety Performance of Ground Beef Suppliers to the National School Lunch Program.* ERR-180, USDA, Economic Research Service. http://ers.usda.gov/media/1728363/err180.pdf.

Ollinger, M., and D. Moore. 2009a. “The Direct and Indirect Costs of Food Safety Regulation.” *Review of Agricultural Economics*, Summer, 31 (2):247−65.

Ollinger, M., and D. Moore. 2008. “The Economic Forces Driving Food Safety Quality in Meat and Poultry.” *Review of Agricultural Economics,* 30-2: 289−310.

Ollinger, M., and V. Mueller. 2003. *Managing for Safer Food: The Economics of Sanitation and Process Controls in Meat and Poultry Plants.* AER-817. USDA, Economic Research Service. http://www.ers.usda.gov/media/532628/aer817.pdf.

Painter J.A., R.M. Hoekstra, T. Ayers, R.V. Tauxe, C.R. Braden, F.J. Angulo, and P.M. Griffin. 2013. Attribution of foodborne illnesses, hospitalizations, and deaths to food commodities by using outbreak data, United States, 1998–2008. *Emerging Infectious Diseases*. http://dx.doi.org/10.3201/eid1903.111866

Piggott, N.E., and T.L. Marsh. 2004. “Does Food Safety Information Impact U.S. Meat Demand?” *American Journal of Agricultural Economics.* 86:154−74.

Salin, V., and N.H. Hooker. 2001. “Stock Market Reactions to Food Recalls.” *Review of Agricultural Economics* 23(1):33−46.

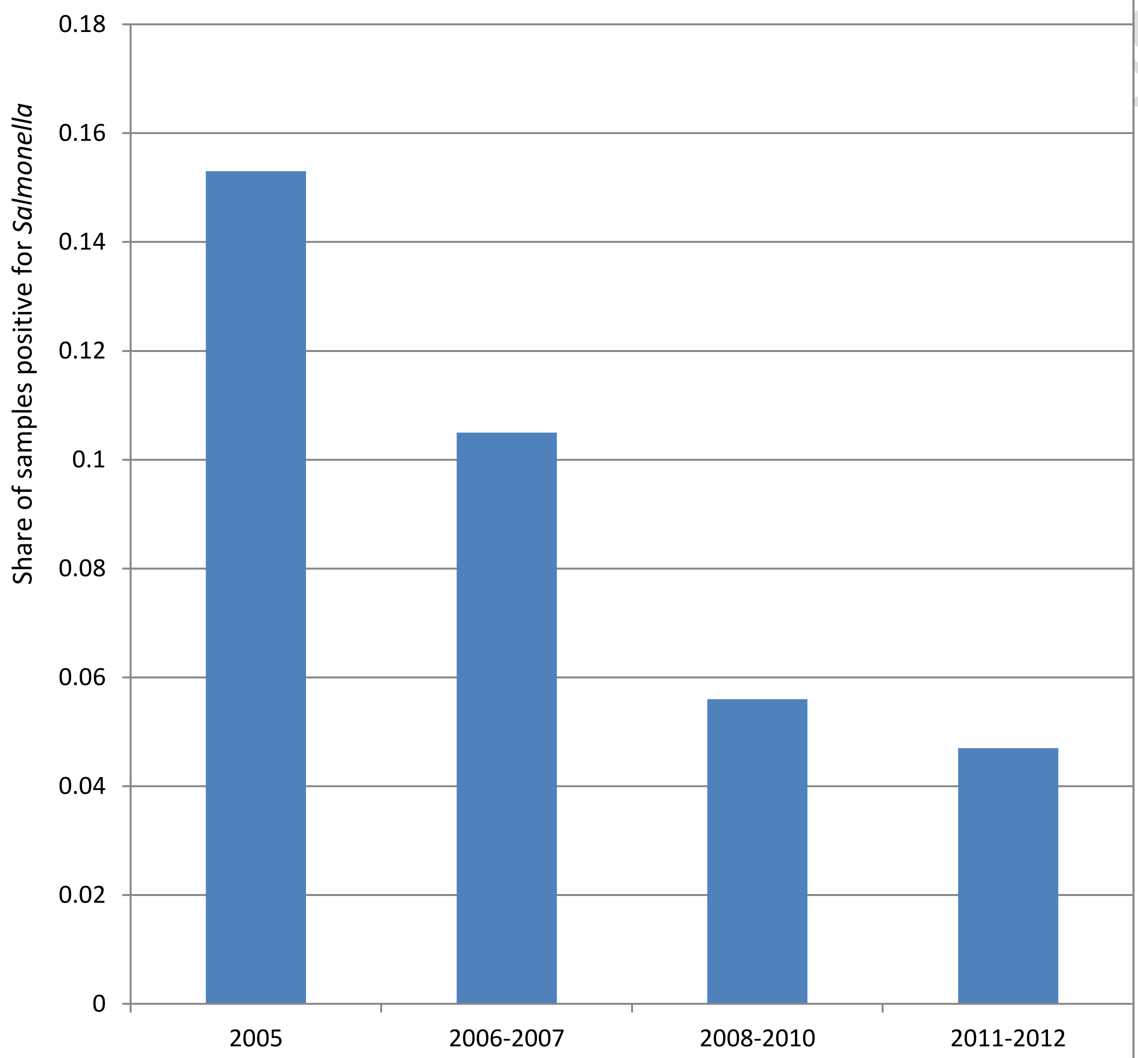
Scallan, E., R.M. Hoekstra, F.J. Angulo, R.V. Tauxe, M.-A. Widdowson, S.L. Roy, J.L. Jones, and P.M. Griffin. 2011. “Foodborne Illness Acquired in the United States-Major Pathogens,” *Emerging Infectious Diseases* 17 (1): 7–22.

Starbird, S.A. 2005. “Moral Hazard, Inspection Policy, and Food Safety." *American Journal of Agricultural Economics* 87: 15−27.

Thomsen, M.R., and A. M. McKenzie. 2001. “Market Incentives for Safe Foods: An Examination of Shareholder Losses from Meat and Poultry Recalls.” *American Journal of Agricultural Economics* 83(3): 526−538.

Williams, M.S. and E.D. Ebel. 2012. “Estimating changes in public health following implementation of hazard analysis and critical control point in the United States broiler slaughter industry.” *Foodborne Pathogen Diseases* 9(1):59-67. http://www.ncbi.nlm.nih.gov/pubmed/22091640

Figure 1:
Share of samples testing positive for *Salmonella* for different regulatory periods over 2005-2012



Source: Authors' calculations based on FSIS *Salmonella* spp data

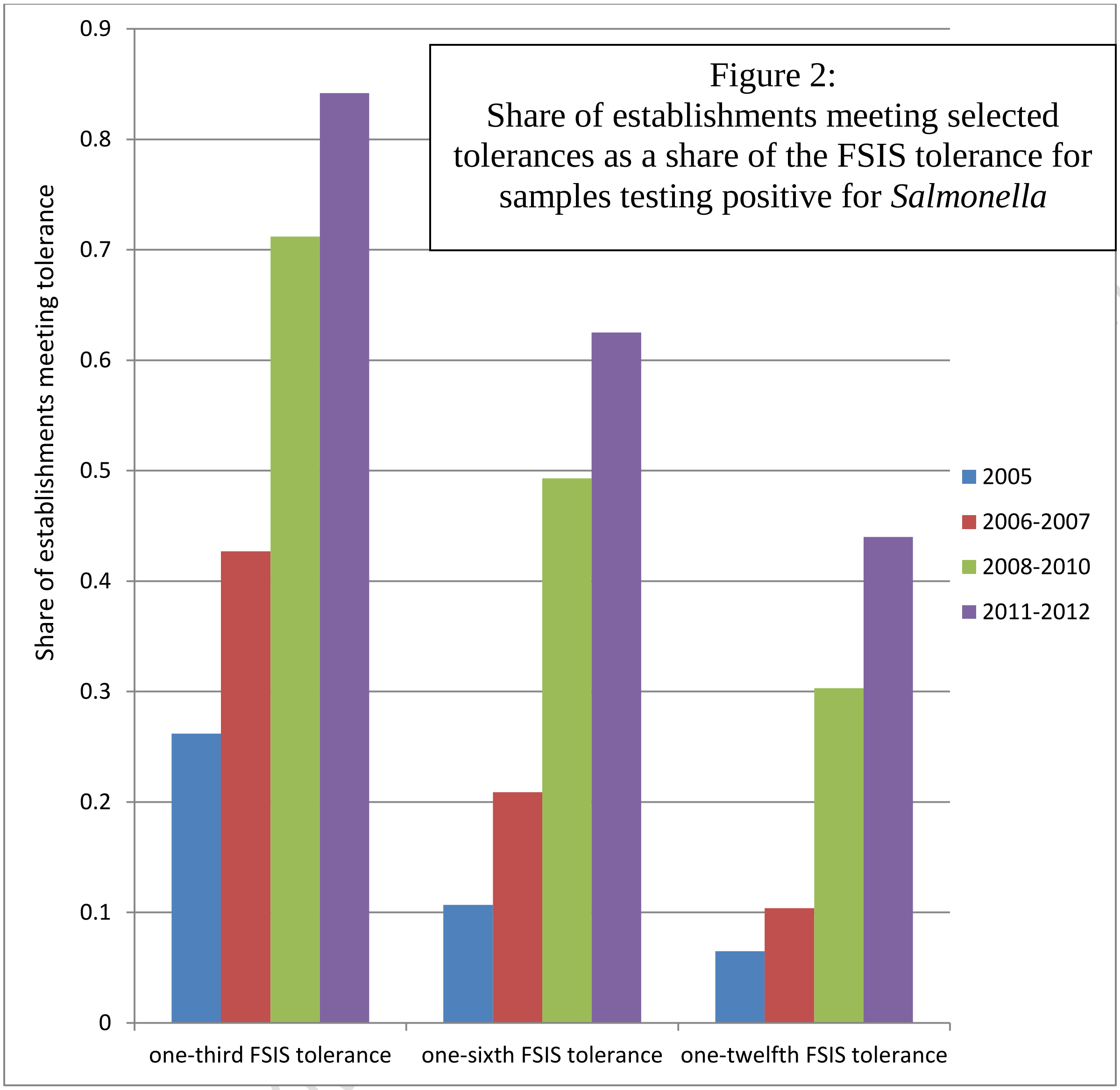


Figure 2:
Share of establishments meeting selected tolerances as a share of the FSIS tolerance for samples testing positive for *Salmonella*

Source: Authors' calculations based on FSIS *Salmonella* spp data

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

Regulation	Date	Policy changes
PR/HACCP	07-25-1996	FSIS mandates first performance standards. Chicken-slaughter plants permitted 12 carcasses out of 51 to test positive for *Salmonella*. Slaughter plants also required to test for generic *E. coli*. Also mandates that each establishment must have and maintain a HACCP plan. There are other requirements. Phased in by 2000.
Fed Reg Notice[1]	04-16-2003	Announced intent to update regulations, asked for public comments to inform the policy. Indicated future possibility of publicizing individual performance results.
Fed Reg Notice[2]	02-27-2006	Announced plan to publish aggregate industry performance records quarterly and provide establishments with individual sample results as soon as they are available. It phases out the A-B-C-D system for the Category 1, 2, or 3 ranking system. The numerical category identifies establishment performance on *Salmonella* tests.
	05-30-2006	Policy Effective Date
Fed Reg Notice[3]	01-28-2008	Announced amendment to publishing—will publish establishment names of mediocre and poorly performing establishments (Categories 2 & 3) online monthly.
	03-28-2008	Policy Effective Date: first document published (for month of March) with individual underperformers, first use of 2T categorization.
Fed Reg Notice[4]	05-14-2010	Establishments were required to have no more than 5 out of 51 chicken carcasses test positive for *Salmonella*. No longer published the names of establishments with mediocre performance (Category 2).
	07-01-2011	Policy Effective Date (took place a year later than planned)

1. Federal Register, April 16, 2003, http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/01-040N.htm.
2. Federal Register, February 27, 2006, http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/04-026N.htm.
3. Federal Register, January 28, 2008, http://www.fsis.usda.gov/OPPDE/rdad/FRPubs/2006-0034.htm.
4. Federal Register, May 14, 2010, http://www.gpo.gov/fdsys/pkg/FR-2010-05-14/html/2010-11545.htm.

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

Dates Effective				
	One Category: Category A			
1996-2006	12 or fewer positive samples on last sample set			
	Four Numerical Categories			
	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
July 2011 to present .	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

n.a. not applicable

[1]Sample sets contain samples from 51 chicken carcasses.

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

Model variable	Empirical variable	Definition	Mean	Maximum	Minimum
	Share of samples testing positive for *Salmonella*	Share of samples testing positive for *Salmonella spp*	0.084	0.833	0
S	One-third FSIS *Salmonella spp* standard	One if share of samples testing positive for *Salmonella spp* less than one-third 2006 FSIS standard, otherwise zero	0.568	1	0
S	One-sixth FSIS *Salmonella spp* standard	One if share of samples testing positive for *Salmonella spp* less than one-sixth 2006 FSIS standard, otherwise zero	0.354	1	0
S	One-twelfth FSIS *Salmonella spp* standard	One if share of samples testing positive for *Salmonella spp* is less than one-twelfth 2006 FSIS standard, otherwise zero	0.212	1	0
N	Chickens	Millions of chickens	51.0	151.0	0.03
L_1	Share HACCP tasks compliant	Share of HACCP tasks in compliance with FSIS regulations	0.889	0.111	0
L_2	Share Pre-operating SSOPs compliant	Share of SSOP tasks performed prior to the operating shift in compliance with FSIS regulations	0.887	1.00	0.434
L_3	Share operating SSOPs compliant	Share of SSOP tasks performed during the operating shift in compliance with FSIS regulations	0.922	1.00	0.566
Z_1	Plant age	Current year minus year meat grant issued	13.0	93.0	1
Z_2	Multi-species	One if plant slaughters more than one animal species, otherwise zero	0.109	1	0
Z_3	Multi-plant	One if plant is part of a multi-plant firm, otherwise zero	0.084	1	0
Z_4	Atlantic	One if in Delaware, Maryland, Virginia, West Virginia, otherwise zero	0.088	1	0
Z_5	Midwest	One if in Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Ohio, Wisconsin, otherwise zero	0.054	1	0
Z_6	Northeast	One if in New Jersey, New York, Pennsylvania, Vermont, otherwise zero	0.066	1	0
Z_7	Southeast	One if in Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, N. Carolina, S. Carolina, otherwise zero	0.473	1	0
Z_8	West	One if in California, Colorado, Hawaii, Washington, otherwise zero	0.054	1	0
Z_9	West South	One if in Arkansas, Missouri, Oklahoma, Tennessee, Texas, otherwise zero	0.259	1	0
R_1	Year_2006_2012	One if year is 2006 to 2012, otherwise zero	0.850	1	0
R_2	Year_2008_2010	One if year is 2008 to 2010, otherwise zero	0.559	1	0
R_3	Year_2011_2012	One if year after 2010, otherwise zero	0.210	1	0
	Observations			841	

Table 4: Marginal Effects of Performance on *Salmonella* Tests over 2005-2012

Model Variable	Empirical Variable	One-third the *Salmonella* standard	One-sixth the *Salmonella* standard	One-twelfth the *Salmonella* standard
N	Log (chickens)	0.052**	0.037*	0.018
		(0.025)	(0.021)	(0.019)
L_1	Share HACCP compliant	1.449	0.787	0.372
		(1.31)	(1.331)	(1.023)
L_2	Share pre-op SSOP Compliant	0.306*	0.071	-0.037
		(0.229)	(0.214)	(0.152)
L_3	Share op SSOP Compliant	0.194	0.545	0.474*
		(0.347)	(0.356)	(0.275)
Z_1	Log (plant age)	0.005	0.012	-0.008
		(0.017)	(0.017)	(0.013)
Z_2	Multi-species	-0.056	-0.003	-0.006
		(0.067)	(0.067)	(0.055)
Z_3	Multi-plant firm	-0.030	0.035	0.069
		(0.078)	(0.071)	(0.059)
Z_4	Atlantic	-0.066	0.002	0.060
		(0.089)	(0.068)	(0.066)
Z_5	Midwest	-0.283***	-0.171***	-0.080*
		(0.086)	(0.060)	(0.049)
Z_6	Northeast	-0.170**	-0.187**	-0.116*
		(0.089)	(0.076)	(0.063)
Z_7	Southeast	-0.038	0.045	0.078**
		(0.047)	(0.048)	(0.039)
Z_8	West	0.021	0.122	0.165**
		(0.091)	(0.093)	(0.078)
R_1	Year_2006_2012	0.145**	0.075	-0.001
		(0.081)	(0.077)	(0.063)
R_2	Year_2008_2010	0.204***	0.223***	0.126***
		(0.038)	(0.049)	(0.040)
R_3	Year_2011_2012	0.401***	0.453***	0.384***
		(0.040)	(0.050)	(0.055)
	χ^2	130.9***	130.1***	114.5***
	Observations	841	841	841
	χ^2 of likelihood of heteroskedsasticity	0.31	0.44	0.29

*, **, *** = 0.10, 0.05, and 0.01 levels of significance.