Producer response to public disclosure of food-safety information

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Abstract:

Beginning in 2003, the USDA's Food Safety and Inspection Service (FSIS) embarked on a series of changes to the regulations regarding testing of chicken carcasses for Salmonella and permissible test outcomes. In particular, FSIS announced in 2003 that regulations would soon change; tightened the standard in 2006, and publicly reported the names of plants with poor performance starting in 2008. This article examines the effects of this series of regulatory changes on Salmonella test outcomes for young-chicken slaughter plants. We find that, while public disclosure of information improved Salmonella test outcomes, the effects were relatively homogeneous across well-performing and poorly-performing plants. The announcement of pending regulatory change in 2003 had a strong effect on the poorest-performing plants. We conclude that buyers' failure to fully unravel information about chicken plants and other market mechanisms (such as contractual requirements) may have driven the somewhat surprising results.

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ABSTRACT

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Introduction

Whether the monitoring and publication of information about the performance of producers or suppliers can induce change in their behavior or performance has been the subject of much economic analysis, both theoretical and empirical. As Akerlof (1970) showed, in the presence of information asymmetry, in which sellers know more about the quality of their products than buyers, moral hazard will drive an equilibrium result in which high-quality products will not be available. Holmström (1982) derived conceptual results showing that systems under which the performance of agents is evaluated and disclosed can be used to reduce the costs of moral hazard. Using plant-level administrative data, we study the response of chicken-slaughter plants to the mandatory disclosure of information about plants with poor performance on food-safety tests. In particular, from 2008 to 2017, the USDA Food Safety and Inspection Service (FSIS) published the names of plants that performed poorly on repeated tests for *Salmonella* in chicken carcasses on its public website. We find evidence that the disclosure of information about poorly-performing plants had a limited effect on plant performance on *Salmonella* tests. Instead, we find that plants' performance on tests for *Salmonella* in chicken improved markedly (a) after FSIS announced plans, in 2003, to update regulations and publish individual plants' performance results and (b) after FSIS significantly tightened the *Salmonella* standards plants had to meet to continue operation and production and, simultaneously, the performance threshold required to be met to avoid public identification as a poorly-performing plant. Our results suggest that information disclosure alone had a limited effect on buyer perception about quality and that, in this market, other factors—including stringency of regulations—played a much more important role in determining food-safety outcomes.

Dranove and Jin (2010) provide an excellent review of the literature on quality disclosure and certification and discuss the concept of "unraveling", in which buyers should be able to deduce undisclosed quality on the basis of similar products whose (good or poor) quality is disclosed. Importantly, unraveling is not always observed; there is much evidence of buyers not being able to deduce the quality of products or firms when disclosure is not mandatory, or when labels are lacking (e.g., Liaukonyte et al., 2013; McFadden and Lusk, 2017). Most of the existing empirical analysis of "seller" (i.e., scrutinized party) response to third-party quality disclosure has focused on education (see the review by Dranove and Jin, 2010) and choice of hospitals or HMOs (e.g., Dafny and Dranove, 2008; Pope, 2009; Varkevisser, van der Geest, and Schut, 2012).

Our paper is in the spirit of Jin and Leslie (2003), who found that when Los Angeles County introduced a requirement that hygiene-quality cards be placed in restaurant windows, restaurant health-inspection scores increased and the number of foodborne illness hospitalizations decreased. Furthermore, restaurants with higher posted health grades enjoyed increased revenues. In a follow-up study, Jin and Leslie (2009) found that heterogeneity in consumer responses to the posting of hygiene-quality cards was driven by the reputations of chain restaurants and also by geography, in that repeated visits and word of mouth were more important in determining consumers' behavior in certain parts of Los Angeles County. In a similar vein, Bennear and Olmstead (2008) found that the disclosure of information about health violations in community drinking water systems as the result of the 1996 Amendments to the Safe Drinking Water Act (SDWA) reduced violations in Massachusetts. Our analysis is the first to demonstrate the effects of the disclosure of food-safety information on the performance of food processors.

Many other studies have shown that consumers responded to positive or negative information about products or producers, especially in the context of health risks or food safety. Tiesl, Roe, and Hicks (2002) found that provision of positive information about canned tuna (namely, the dolphin-safe label) increased the market share of canned tuna. Graff Zivin, Neidell, and Schlenker (2011) found that bottled-water demand increased in Northern California and Nevada in response to local violations of the Safe Drinking Water Act. Product recalls for food-safety problems have adversely affected firm stock prices (Salin and Hooker, 2001; Thomsen and McKenzie, 2001; Pozo and Schroeder, 2016), futures prices (Lusk and Schroeder, 2002; Moghadam, Schmidt and Grier, 2013), and product demand (Thomsen, Shiptsova, and Hamm, 2006; Piggott and Marsh, 2004; Marsh, Schroeder, and Mintert, 2004; Arnade, Calvin and Kuchler, 2009). Perhaps negative information about food safety prompts a visceral reaction, and buyers are more likely to react to negative information than to positive information; Bovay (2017) found no evidence that wholesale buyers increased demand for fresh tomatoes from certain regions when growers in those regions collectively adopted food-safety standards.

In the following section, we provide an overview of the inspection of meat products in the United States and review recent policy changes regarding inspection of chicken for *Salmonella*. We then discuss our data and empirical strategy. Our results show that FSIS policy changes resulted in improvements in *Salmonella* test results, and that anticipation of pending regulation and disclosure of information on poorly-performing plants both affected plant-level *Salmonella* outcomes. The article concludes with a discussion of the mechanisms that may explain the observed results.

Background and Regulatory Context

Food-safety problems remain a threat to public health in part because the presence of pathogens cannot be observed without considerable expense. Because of the expense of measuring food safety and the myriad ways that food may become contaminated, information about food safety can be characterized as both asymmetric and imperfect, even after food is sold and consumed. (In other words, food safety is not always an experience attribute.) The information asymmetry gives producers incentives to invest less in food safety than the socially optimal level, and less than they would if information were symmetric. This incentive may be tempered by the threat of a recall or other legal consequences for food-safety problems (see discussion above). However, recalls for known food-borne illness outbreaks account for only a small share of all food-borne illnesses (Painter et al., 2013).

To offset the incentives of suppliers to cut corners and underinvest in food safety, buyers may impose private, enforceable standards for food safety on their suppliers. Jack in the Box restaurant, for example, instituted numerous safeguards after its near-bankruptcy due to a foodborne-illness outbreak in the early 1990s (Golan et al., 2004), and the USDA Agricultural Marketing Service has imposed strict standards on ground beef suppliers to the National School Lunch Program (Ollinger and Bovay, 2017). More broadly, contract standards are being used in international commerce under the Global Food Safety Initiative (a global, industry-driven collaboration).[1]

[1] See http://www.mygfsi.com.

While some buyers elect to impose food-safety standards on their suppliers, others may judge the costs of imposing and monitoring performance standards as too high. These buyers may rely on publicly available food safety information, such as information from FSIS on plant recalls, industry performance on *Salmonella* tests, and, from 2008–2016, plant performance of *Salmonella* tests.

FSIS and its antecedent USDA agencies have regulated the safety of meat since 1890, when federal legislation enabled inspection of salted pork and bacon for export to certify that the products were trichinella-free (Olmstead and Rhode, 2015, ch. 8). In 1906, Congress mandated the antemortem and postmortem inspection of cattle, sheep, swine, and goats used for human food and the inspection of their carcasses, parts, and further-processed products under the Federal Meat Inspection Act. USDA was granted authority to regulate the safety of chicken meat under the Wholesome Poultry Products Act (WPPA) of 1968. In 1996, FSIS promulgated the Pathogen Reduction and Hazard Analysis and Critical Control Point (PR/HACCP) rule, one provision of requires slaughter establishments for young chickens to meet a *Salmonella* sampling standard based on typical *Salmonella* levels at that time. FSIS verifies through routine sampling that establishments meet this standard. However, more than twenty years after the promulgation of PR/HACCP, the safety of meat and poultry remains a serious concern for public health officials. Painter et al. (2013) estimated that poultry contaminated with *Salmonella* and other bacteria caused 650,000 illnesses per year for U.S. consumers over 1998−2008. PR/HACCP encouraged greater food safety effort, but PR/HACCP did not address the fundamental problem with food safety in that food safety is costly to provide (Antle, 2000) and buyers are unable to evaluate food safety without undertaking costly tests (Antle, 2001; Golan et al., 2004). Williams and Ebel (2012) found that PR/HACCP reduced chicken-related salmonellosis illnesses by

190,000 over 1996–2000 but had little effect afterward. Product recalls create some direct incentive for firms to provide safe food, but Centers for Disease Control and Prevention (CDC) data (Painter et al., 2013) indicate that most foodborne illnesses are not linked to a product recall and therefore suppliers are rarely held accountable unless buyers require random tests of products for pathogens and other contaminants.

PR/HACCP forced plants to implement food-safety process controls, but it did not give buyers any new information about food-safety practices or outcomes, making it useless for evaluating plant food safety and for providing incentives to improve food safety. Following full implementation of PR/HACCP in 2000, *Salmonella* test outcomes did not change markedly, as evidenced by figure 1. In 2003, FSIS began implementing a series of regulatory changes and changes to provision of information to buyers about plants' performance on *Salmonella* tests. Details are given in tables 1 and 2. The timing of this greater information disclosure coincided with a sharp drop in *Salmonella* levels, as seen in figure 1.

The PR/HACCP rule and its antecedent regulations form the basis for federal oversight of food safety of meat and poultry. Under the PR/HACCP rule, cattle-, hog-, chicken-, and turkey-slaughter plants and ground-meat and chicken-parts producers are required to establish a Hazard Analysis and Critical Control Point (HACCP) plan for each product and perform all tasks outlined in the plan, perform Sanitation Standard Operating Procedures (SSOPs),[2] and meet *Salmonella* standards. As discussed by Ollinger and Bovay (2017), FSIS inspectors monitor compliance with all SSOPs and HACCP tasks and issue noncompliance reports. FSIS can

[2] SSOPs require plants to clean knives and perform other food-safety tasks during operations and to perform equipment disassembly and cleaning and other tasks at the beginning or end of a shift.

temporarily halt a plant's production if infractions are serious and corrective actions are not taken, but these instances are rare. Most noncompliance incidents are quickly resolved with no disruption of production.

For its *Salmonella* tests, FSIS samples plants on a weighted random basis under which poorer-performing plants and larger plants are sampled more frequently. FSIS requires that all plants achieve a certain performance standard on *Salmonella* tests—these are non-zero tolerances, set by FSIS at levels most plants have historically been able to achieve. For young chickens, FSIS permitted 12 out of 51 samples to test positive for *Salmonella* from the implementation of PR/HACCP until 2011 when FSIS reduced the tolerance to no more than 5 out of 51 samples. Under the PR/HACCP rule of 1996, plants were rated an "A", "B", "C", or "D", on the basis of the number of times plants failed inspection. These ratings were not shared publicly. Plants that failed three times in a row were given a "D" rating and were subject to regulatory actions, such as suspension of the FSIS Grant of Inspection, which gives plants the right to ship products across state lines.

The alphabetized system was a pass-or-fail system under which plants had an incentive to meet the standard by the fourth attempt but not necessarily to surpass it. In order to incentivize plants to perform better than the standard—after all, 23% of chicken carcasses testing positive for *Salmonella* is hardly a mark of excellence for a pathogen reduction regulation—FSIS announced in April 2003 that it would be updating regulations and possibly publicize individual performance results for tests for *Salmonella* in chicken carcasses. (See table 2 for a summary of the regulatory changes.) In May 2006, FSIS replaced the alphabetical rating system with a system that categorized plants according to the results of tests for *Salmonella*. Each sample set consisted of 51 tests of young chicken carcasses, spread over a period of several weeks. Plants with fewer than 7 samples testing positive for *Salmonella* on two consecutive sample sets were designated Category 1. Plants with 7 to 12 positive samples were designated Category 2.[3] Plants with more than 12 positive samples, which exceeded the agency's tolerance level for *Salmonella*, were designated Category 3. From 2006 until early 2008, FSIS published the results as aggregated data but warned the industry that the categories of individual plants could one day be made publicly available. The introduction of the numerical category system represented a substantial change because, under the alphabetical system, a plant could be compliant with three consecutive sample sets with more than 12 positive samples, whereas under the numerical category system, a single sample set with more than 12 positive samples was unacceptable.

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, effective March 28, 2008. From 2004 to 2010, *Salmonella* levels had dropped dramatically (see figure 1). In early 2011, FSIS lowered its *Salmonella* tolerance for young chicken carcasses by more than half, and stopped publishing the names of Category 2 plants on its website. Further regulatory changes followed, but are beyond the scope of our analysis.

In the following sections, we develop a series of empirical tests to analyze the effect of regulatory change and information disclosure on *Salmonella* test outcomes.

[3] Beginning in March 2008, plants that had fewer than 7 positive samples in the most recent sample set but not both of the most recent sample sets were designated Category 2T, with the T signifying "transition", i.e., that the plant was trending toward Category 1.

Data

We created a unique data set of all plants that slaughtered young chicken and whose products were tested for *Salmonella* by FSIS over 2000–2010, based on confidential administrative data from FSIS.[4] *Salmonella* test results are not available for each plant year because FSIS conducts *Salmonella* testing based on volume of production and past performance on *Salmonella* tests. As a result, some plants may have had multiple tests per year while others may not have been tested at all. In addition, the FSIS administrative data set we analyze includes information on (a) types and numbers of animals slaughtered, (b) the date each plant began operations, (c) performance on sanitation and HACCP tasks, and (d) information from Dun & Bradstreet on the number of plant-level employees and whether the plant was part of a firm that owned more than one plant. We use the above-listed variables as controls. We retain observations only for plants that entered the industry before 2006.

During the timeframe of our study, testing was done in batches or sample sets of 51, spread out over some period of days or weeks. Thus, testing may have begun for some establishments in one year and extended into the subsequent year, leaving a partial sample set for the data we analyze.

As seen in figure 1, the yearly average plant-level *Salmonella* test results remained fairly

[4] The data made available to us by FSIS extended through 2014, but the criteria for assigning plants to categories changed in 2011, so we use data only through 2010. Also, FSIS changed its *Salmonella* testing program in 2015 to a process of continuous testing in which new samples replace older samples, giving an updated performance level based on the 51 most recent samples.

stable over 2001–2006, between 11.6 and 14.1 percent. Subsequently, positive *Salmonella* samples dropped drastically, maintaining a level between 5.0 and 7.2 percent between 2007–2010.

Figure 2 illustrates how the performance of plants on *Salmonella* tests varied from test-year to test-year. In particular, it shows the share of plants that remained at the same broad performance category or moved to a different performance category with each testing year.[5] Of special note, Tile 1 plants (the best performers) were very unlikely to become Tile 3 (the worst) throughout the period of our analysis. Following regulatory change in 2006, Tile 1 plants were even more likely to remain Tile 1, and Tile 2 plants were much more likely to move to Tile 1 the following test year. Last, we note that few plants remained Tile 3 in consecutive test years, suggesting that even before FSIS commenced increasing the stringency of regulation, Tile 3 status was an undesirable outcome, and that managers of Tile 3 plants may have taken actions to reduce *Salmonella* counts.

[5] FSIS did not begin categorizing plants using the numeric system until 2006, so to maintain consistency across all years of our analysis, we use the thresholds for categorization as they were effective in 2006–10 and analyze plants' performance on *Salmonella* tests for the entire year. After Jin and Leslie (2003), for the rest of this article, we use the following terminology: Tile 1 indicates performance on *Salmonella* tests at or better than the Category 1 standard of 6 positive samples out of a 51-sample set (11.76 percent or lower); Tile 2 indicates performance on *Salmonella* tests of greater than 6 but less than 12 positive samples out of a 51-sample set (11.77 to 23.52 percent); and Tile 3 indicate performance on *Salmonella* tests worse than the Category 2 standard (23.53 percent or higher).

Empirical Strategy

Our empirical strategy is to test whether a series of FSIS policy changes regarding the disclosure of plant FSIS disclosure of plant performance on *Salmonella* tests over 2003–08 improved the performance of plants on subsequent tests. Hence, our dependent variables in two series of regressions are (a) binary variables indicating whether plants met or surpassed one of various thresholds for *Salmonella* and (b) a continuous measure of the same outcome—the share of samples testing positive for *Salmonella*.

Our observations are at the plant-year level. As discussed in the preceding section, FSIS announced its intention to release information on industry average *Salmonella* test performance in 2003; this was followed with the publication of industry average test results in 2006, and the publication of the names of poorly-performing plants on a monthly basis beginning in March 2008. Thus, our key explanatory variables are dummy variables representing the periods 2004–10, 2006–10, and 2008–10, interacted with dummies for whether individual plants' performance no the most recent set of *Salmonella* tests would have placed them into Category 2 or Category 3 under the regime in place from 2008–10. (As described above, these dummies are labeled Tile 2 and Tile 3.) This strategy focuses the analysis on the poorly performing plants, to determine whether the various FSIS policies were effective incentives for the worst performers to improve their performance. Our regressions also include a linear time trend, under the premise that technology may have allowed for an improvement in food-safety outcomes over time; and the number of *Salmonella* recalls for the chicken industry in the previous year.

In most of our regression specifications, we include several additional controls for plant-level characteristics including compliance with process controls required under PR/HACCP.

Most of these control variables have been found to affect performance on *Salmonella* tests. These include (a) number of chickens slaughtered, a well-accepted measure of plant size (Ollinger and Moore, 2009); (b) age of plant, in years (Muth et al., 2007); (c) share of slaughtered animals that were not chickens; (d) a dummy variable to indicate whether the plant cooked or in any way further processed chicken, which adds complexity to a plant's operations (Ollinger and Moore, 2008); and (e) a dummy variable to indicate whether the plant was part of a multi-plant firm, which also adds complexity. We also control for compliance rates with HACCP tasks, pre-operational SSOP tasks, and operational SSOP tasks.

Effect of information disclosure on plants' ability to meet Salmonella *performance thresholds*

In our main empirical specification, we use a fixed-effects logit regression (see Chamberlain, 1980, and Cameron and Trivedi, 2005, pp. 796–797) with plant-level fixed effects to test the effects of information disclosure and firms' anticipations about pending regulatory change on plant-level *Salmonella* test outcomes. Following Ollinger and Bovay (2017), our dependent variables, in a series of regressions, are equal to 1 if a plant met or surpassed a particular threshold for *Salmonella* content in a given year. Specifically, these thresholds are equivalent to 6 samples testing positive for *Salmonella* out of a 51-sample set, 4/51, 2/51, and 1/51, respectively. Note that from 2008 to 2010, a firm would have been designated as Category 1 if it met the least stringent of these thresholds.

In our main empirical specification, we estimate the effects of (firms' anticipation about future requirements for) information disclosure on plants' probabilities of achieving *Salmonella* levels equivalent to the standards for Category 1 and various more stringent thresholds. We use a logit regression with plant-level fixed effects, as given by equation (1),

$$(1) \qquad S_{it}^{*} = \frac{\exp\left(\beta \boldsymbol{x}_{it} + \rho \boldsymbol{r}_t + \theta \tilde{\boldsymbol{s}}_{i,t-1} + \eta y_{t-1} + \alpha \tilde{\boldsymbol{s}}_{i,t} \boldsymbol{r}_t + \gamma t + \mu_i + \varepsilon_{it}\right)}{\exp\left(1 - \left(\beta \boldsymbol{x}_{it} + \rho \boldsymbol{r}_t + \theta \tilde{\boldsymbol{s}}_{i,t-1} + \eta y_{t-1} + \alpha \tilde{\boldsymbol{s}}_{i,t} \boldsymbol{r}_t + \gamma t + \mu_i + \varepsilon_{it}\right)\right)},$$

where $S_{it}^{*} = 1$ if the share of positive *Salmonella* samples for plant i in year t are less than a threshold that varies by regression specification. In equation (1), $\boldsymbol{x}_{it}$ is a vector of plant characteristics and variables indicating compliance with process-control tasks, as discussed in the preceding section; $\boldsymbol{r}_t$ is a vector of three dummy variables indicating the FSIS regulatory actions on *Salmonella* implemented in 2003, 2006, and 2008; $\tilde{\boldsymbol{s}}_{i,t}$ is a vector of two dummy variables indicating whether the performance of plant i on the most recent yearly set of *Salmonella* tests corresponded with the thresholds for Category 2 or Category 3; y_{t-1} is the number of recalls for *Salmonella* in chicken faced by the industry in year $t-1$; t is the time trend, μ_i represents plant fixed effects, and ε_{it} is the residual.

Effect of information disclosure on share of samples testing positive for Salmonella

The fixed-effect logit regressions indicate the effects of explanatory variables on odds of attaining or surpassing a *Salmonella* threshold. Alternatively, we estimate the effects of information disclosure and regulatory change on a measure of *Salmonella* test performance, the share of samples positive. For these regressions, we use a panel Tobit model with plant-level fixed effects, after Honoré (1992), because the share of samples testing positive for *Salmonella* is bounded by [0,1]; a Tobit model is appropriate because *Salmonella* test results represent an approximation of an underlying distribution of unobservable food-safety risks. The form of the regression specification is cumbersome to reproduce in print, but uses $share_{it}$ as the dependent variable and the same regressors as in equation (1).

Results

Tables 3 and 4 present the results of fixed-effects logit regressions, as odds ratios, with plant-level clustered standard errors reported in parentheses.[6] These results demonstrate that plants were substantially more likely to meet or surpass various *Salmonella* performance standards following reforms in 2006 and 2008, while the typical plant was somewhat less likely to meet the strictest standards following the announcement of pending regulatory change in 2003. In addition, plants that were Tile 2 or Tile 3 based on the most recent year's test results were less likely to meet or surpass these more stringent *Salmonella* thresholds, which suggests that plants' performance on *Salmonella* tests was relatively stable from year to year. More important for the evaluation of policy and design of future policy, the coefficients on the interaction terms suggest that the worst-performing plants—those in Tiles 2 and 3—improved their performance after the announcement in 2003 of plans to revise the regulatory framework. However, the actual publication of the names of Category 2 and 3 plants, in 2008, did not have a strong effect on the likelihood of Tile 2 and 3 plants improving their *Salmonella* performance and meeting stricter performance standards the next test cycle. In other words, the publication of information about *Salmonella* levels in chicken plants improved overall industry performance but did not serve as a sufficient deterrent for the poorest-performing plants to improve their operations. Last, the

[6] Odds ratios greater than 1 indicate greater likelihood of meeting the various thresholds that serve as our dependent variables.

results in tables 3 and 4 suggest that the industry improved its *Salmonella* test performance in years following recalls.

Table 5 presents a second set of results for our panel Tobit regression models, with plants' share of samples positive for *Salmonella* each year as the dependent variable in each regression. These results corroborate the findings in tables 3 and 4. In particular, the regulatory reforms of 2006 and 2008 brought *Salmonella* levels down, while the 2003 announcement about pending FSIS regulation improved *Salmonella* test results for the worst-performing plants (those in Tile 3). The coefficients estimates suggest that Tile 3 firms had similar rates of positive *Salmonella* samples the following test cycle as Tile 1 firms; while Tile 2 firms had higher rates of *Salmonella* samples the following test cycle than Tile 1 firms. This suggests that plants' status as Tile 3 (or Category 3) may have been idiosyncratic and not reflecting repeated outcomes, whereas plants in Tile 2 (or Category 2) were more likely to maintain this poor-but-compliant *Salmonella* test performance from year to year. Finally, the results in table 5 show a rise in the rate of positive *Salmonella* samples over time (ceteris paribus) and support the findings in tables 3 and 4 that *Salmonella* test performance improved in years following recalls.

Discussion, Conclusions and Synthesis

This article investigated the effects of information disclosure on the results of tests for *Salmonella* in chicken carcasses. In 2003, the USDA Food Safety and Inspection Service announced plans to update *Salmonella* testing regulations and possibly to publish information about plants' performance on tests for *Salmonella*. Updates to the regulations followed in 2006 and 2008; the first regulatory change penalized the worst performers (Category 3 plants), while the second change made public the names of both Category 2 and Category 3 plants. Our findings suggest that the typical plant responded to the regulatory changes in 2006 and 2008. However, the information disclosure policy is not shown to have had a special effect on the plants whose names were most likely to have been disclosed as having poor performance on tests for *Salmonella*. We now explore several potential explanations for this finding.

First, the results of tests for *Salmonella* in chicken carcasses may be of limited importance to buyers, as compared with other product or firm attributes such as price, brand, and intended use (such as processing). Furthermore, chicken is almost always cooked to a temperature that kills *Salmonella*, and a reduction in the probability that a piece of raw chicken contains *Salmonella* from 14% to 12% (as implied by the difference between Category 2 and Category 1) should not substantively change buyer or consumer attitudes toward risk and chicken consumption.

Lack of salience of the published information may also have dampened the response of the producers most directly affected by it. Food recalls often (but do not always) generate headlines, and perhaps grocers and other buyers avoid buying food from producers that have recently faced recalls because consumers are more likely to be aware of recalls and buyers' reputations are more likely to be at stake. Furthermore, contracts between buyers and producers may require private food-safety standards like GFSI be met, and these private standards may take precedent over potentially less-stringent and less-frequent government testing results.[7]

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[7] Executives from a major chicken company revealed in a private conversation in October 2017 that they were uncertain about whether FSIS still reported the names of underperforming plants.

We found that plants with positive *Salmonella* samples higher than the regulatory threshold—Tile 3 plants—were not especially affected by the *Salmonella* disclosure requirement. Because Category 3 plants were required to take remedial action to ensure improved performance, it is not surprising that the disclosure requirement had limited effects on the performance of firms that had been Tile 3 based on previous test results. However, the raw data show that the number of Tile 3 plants, as a share of all plants, declined to 8.0% in 2006 after peaking at 14.1% the prior year; from 2007 to 2010, Tile 3 plants never constituted more than 7.8% of all plants.

We suggest that the limited effects of *Salmonella* disclosure on *Salmonella* outcomes for the poorest-performing plants may have been a consequence of buyers' limited ability to unravel or infer that plants not on the list had better *Salmonella* performance. That is, the competitive advantage to be gained by moving from Category 2 or Category 3 status to Category 1 status may have been limited because buyers were unable to perfectly unravel. For a limited time—from May to November 2016—FSIS addressed this possible shortcoming in its information-provision policy by publishing the category status of all poultry-slaughter plants. Unfortunately, we lack data to compare the effects of limited disclosure and unraveling with the effects of fully symmetric information disclosure, as Jin and Leslie (2003) were able to do.

In conclusion, we suggest that the anticipation of unknown policy changes after the 2003 FSIS announcement was sufficient to motivate improved *Salmonella* test outcomes for the worst-performing plants. The regulatory change in 2006 that tightened the regulatory standard by moving from a four-strikes policy to a one-strike policy was substantially more effective than the publication of information about the worst-performing firms, even for those firms that were most likely to face public scrutiny as a result of the information-disclosure policy. As we discuss, perhaps restoring a fully symmetric disclosure of information about *Salmonella* test results would improve *Salmonella* test outcomes by eliminating the need for buyers to unravel.

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Table 1. Important regulatory changes affecting the chicken-slaughter industry over 1996−2016

Regulation	Date	Policy name and details
61 FR 38806	07/25/1996	*Pathogen Reduction; Hazard Analysis and Critical Control Point (PR/HACCP)* FSIS mandates performance standards for tests for *Salmonella* in animal carcasses and ground meat and poultry. All slaughter plants had to test for generic *E. coli*, and all plants had to have and maintain a PR/HACCP plan, along with. Phased in by 2000.
68 FR 18593	04/16/2003	*Announcement of and Request for Comment on FSIS' Tentative Determinations on the Availability of Salmonella Test Results* FSIS announced its intent to update regulations and asked for public comments. FSIS indicated a future possibility of publicizing individual performance results on tests for *Salmonella* in chicken carcasses.
71 FR 9772	02/27/2006	*Salmonella Verification Sample Result Reporting: Agency Policy and Use in Public Health Protection* FSIS announced it would publish aggregate industry performance records quarterly and give plants their test results as they became available; FSIS adopted a Category 1, 2, or 3 ranking system that identifies plant performance on *Salmonella* tests, on the basis of 51-sample sets, effective May 30, 2006.
73 FR 4767	01/28/2008	*Salmonella Verification Sampling Program: Response to Comments and New Agency Policies* FSIS announced that it would publish the names of plants with mediocre or poor performance on tests for *Salmonella* (Categories 2 & 3) online monthly.
	03/28/2008	The names of underperformers first published. FSIS began using the Category 2T categorization to indicate better-performing Category 2 plants.
75 FR 27288	05/14/2010	*New Performance Standards for Salmonella and Campylobacter in Young Chicken and Turkey Slaughter Establishments; New Compliance Guides* FSIS announced plan to tighten regulatory standard so that plants could have no more than 5 out of 51 chicken carcasses test positive for *Salmonella*. Definitions of Categories 1 and 2 would also be changed, effective July 1, 2011.
76 FR 15282	03/21/2011	*New Performance Standards for Salmonella and Campylobacter in Young Chicken and Turkey Slaughter Establishments: Response to Comments and Announcement of Implementation Schedule* Category 2 plants' names would no longer be published on the FSIS website, effective July 1, 2011.
80 FR 3940	01/26/2015	*Changes to the Salmonella and Campylobacter Verification Testing Program: Proposed Performance Standards for Salmonella and Campylobacter in Not-Ready-to-Eat Comminuted Chicken and Turkey Products and Raw Chicken Parts and*

		Related Agency Verification Procedures and Other Changes to Agency Sampling FSIS announced plans to replace sample-set framework with moving-average framework for *Salmonella* and *Campylobacter* sampling, effective March 2015.
81 FR 7285	02/11/2016	*New Performance Standards for Salmonella and Campylobacter in Not-Ready-to-Eat Comminuted Chicken and Turkey Products and Raw Chicken Parts and Changes to Related Agency Verification Procedures: Response to Comments and Announcement of Implementation Schedule* FSIS announced that it would post the names and categories of all plants on its website, effective May 11, 2016.
	11/18/2016	FSIS ceased posting individual plant-level *Salmonella* and *Campylobacter* categories on its website (FSIS, 2016b)

Table 2: FSIS *Salmonella* performance testing categories

Dates effective	Category 1	Category 2T	Category 2	Category 3
May 30, 2006 to March 27, 2008	At most 6 positive samples on last sample set	Not yet created	7 to 12 positive samples on last sample set	13 or more positive samples on last sample set
March 28, 2008 to June 30, 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	13 or more positive samples on last sample set
July 1, 2011 to May 11, 2016	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	6 or more positive samples on last sample set

Notes: Sample sets contained samples from 51 young chicken carcasses. The category ranking system was initially implemented in 2006. Prior to 2006, 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.
Sources: 71 FR 9772, 73 FR 4767, 75 FR 27288, 81 FR 7285.

Table 3. Effects of Past Performance and Regulations on Performance of Young-Chicken Slaughter Plants on Tests for *Salmonella* (Meeting or Surpassing Thresholds), 2000–2010

	Tile 1			4 or fewer positive samples		
	(1)	(2)	(3)	(4)	(5)	(6)
68 FR 18593 (Post-2003)	0.625 (0.205)	0.652 (0.218)	0.652 (0.218)	0.620 (0.195)	0.667 (0.210)	0.650 (0.207)
71 FR 9772 (Post-2005)	7.74*** (3.26)	6.50*** (2.70)	5.94*** (2.56)	5.90*** (2.40)	4.75*** (1.985)	4.20*** (1.86)
73 FR 4767 (Post-2007)	1.92** (0.730)	1.97* (0.769)	1.83 (0.718)	1.71 (0.587)	1.78 (0.664)	1.70 (0.615)
Tile 2 in previous period	0.464*** (0.116)	0.479*** (0.120)	0.488*** (0.122)	0.372*** (0.103)	0.392*** (0.109)	0.396*** (0.111)
Tile 3 in previous period	0.870 (0.280)	0.946 (0 .303)	0.977 (0.310)	0.494** (0.163)	0.534* (0.178)	0.545* (0.182)
Tile 2 in previous period × Post-2003	2.66*** (0.871)	2.65*** (0.877)	2.65*** (0.866)	1.69 (0.694)	1.62 (0.662)	1.66 (0.676)
Tile 2 in previous period × Post-2005	0.477 (0.228)	0.536 (0.258)	0.516 (0.256)	0.937 (0.460)	1.06 (0.529)	1.01 (0.514)
Tile 2 in previous period × Post-2007	1.25 (0.659)	1.18 (0.626)	1.18 (0.632)	0.904 (0.514)	0.852 (0.481)	0.868 (0.493)
Tile 3 in previous period × Post-2003	2.98** (1.49)	3.05** (1.57)	2.83** (1.45)	4.59*** (2.40)	4.48*** (2.39)	4.38*** (2.33)
Tile 3 in previous period × Post-2005	0.452 (0.303)	0.473 (0.333)	0.514 (0.366)	0.468 (0.313)	0.507 (0.355)	0.518 (0.363)
Tile 3 in previous period × Post-2007	0.347 (0.417)	0.244 (0.330)	0.230 (0.293)	0.242 (0.262)	0.148 (0.188)	0.146 (0.185)
Lag number of *Salmonella* recalls	1.17** (0.0800)	1.17** (0.0831)	1.20** (0.0861)	1.20*** (0.0781)	1.21*** (0.0813)	1.22*** (0.0843)
Trend	0.897 (0.0642)	0.880 (0.0701)	0.904 (0.0746)	0.937 (0.0714)	0.917 (0.0736)	0.935 (0.0780)
Plant characteristic controls	No	Yes	Yes	No	Yes	Yes
Process-control controls	No	No	Yes	No	No	Yes
Observations	1,238	1,238	1,238	1,260	1,260	1,260
Wald χ^2	113.99***a	141.75***b	141.91***c	131.81***a	146.56***b	150.96***c
Pseudo R^2	0.1215	0.1382	0.1415	0.1351	0.1507	0.1522

Notes: Dependent variable in columns 4–6: whether plant had the equivalent of 4 or fewer positive samples out of 51, i.e., whether plant had no more than 7.84 percent of samples testing positive for *Salmonella*. Plant-level cluster-robust standard errors in parentheses. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.

[a] Wald $\chi^2(13)$

[b] Wald $\chi^2(18)$

[c] Wald $\chi^2(21)$

Table 4. Effects of Past Performance and Regulations on Performance of Young-Chicken Slaughter Plants on Tests for *Salmonella* (Meeting or Surpassing Thresholds), 2000–2010

	2 or fewer positive samples			1 or fewer positive samples	
	(7)	(8)	(9)	(10)	(11)
68 FR 18593 (Post-2003)	0.404***	0.423**	0.396***	0.373**	0.404**
	(0.135)	(0.142)	(0.134)	(0.152)	(0.164)
71 FR 9772 (Post-2005)	3.62***	3.01***	2.76**	2.83**	2.14*
	(1.42)	(1.24)	(1.21)	(1.24)	(0.974)
73 FR 4767 (Post-2007)	2.806***	2.88***	2.79***	2.03**	2.03**
	(0.921)	(0.967)	(0.960)	(0.710)	(0.729)
Tile 2 in previous period	0.260***	0.274***	0.272***	0.364**	0.382**
	(0.102)	(0.108)	(0.108)	(0.165)	(0.174)
Tile 3 in previous period	0.425**	0.471*	0.473*	0.485	0.530
	(0.171)	(0.189)	(0.189)	(0.251)	(0.264)
Tile 2 in previous period × Post-2003	2.85*	2.78*	2.87*	1.46	1.39
	(1.62)	(1.57)	(1.62)	(1.02)	(0.966)
Tile 2 in previous period × Post-2005	0.691	0.779	0.754	0.864	1.04
	(0.379)	(0.432)	(0.426)	(0.600)	(0.727)
Tile 2 in previous period × Post-2007	0.900	0.829	0.844	1.53	1.39
	(0.678)	(0.530)	(0.541)	(1.05)	(0.930)
Tile 3 in previous period × Post-2003	4.42**	4.15*	4.16*	5.45**	5.12**
	(3.15)	(3.04)	(3.07)	(4.11)	(3.84)
Tile 3 in previous period × Post-2005	1.20	1.30	1.29	0.253	0.301
	(0.938)	(1.05)	(1.06)	(0.224)	(0.283)
Tile 3 in previous period × Post-2007	0.0741*	0.0464**	0.0474**	0.573	0.325
	(0.106)	(0.0671)	(0.0691)	(0.777)	(0.452)
Trend	0.952	0.948	0.957	1.05	1.04
	(0.0719)	(0.0771)	(0.0821)	(0.106)	(0.109)
Lag number of *Salmonella* recalls	1.09	1.09	1.10	1.03	1.04
	(0.0673)	(0.0688)	(0.0706)	(0.0699)	(0.0727)
Plant characteristic controls	No	Yes	Yes	No	Yes
Process-control controls	No	No	Yes	No	No
Observations	1,208	1,208	1,208	1,091	1,091
Wald χ^2	115.35***a	119.84***b	122.25***c	85.16***a	87.61***b
Pseudo R^2	0.1392	0.1495	0.1506	0.1342	0.1445

Notes: Dependent variable in columns 7–9: whether plant had the equivalent of 2 or fewer positive samples out of 51, i.e., whether plant had no more than 3.92 percent of samples testing positive for *Salmonella*. Dependent variable in columns 10–11: whether plant had the equivalent of 1 or fewer positive samples out of 51, i.e., whether plant had no more than 1.96 percent of samples testing positive for *Salmonella*. Plant-level cluster-robust standard errors in parentheses. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.

[a] Wald $\chi^2(13)$

[b] Wald $\chi^2(18)$

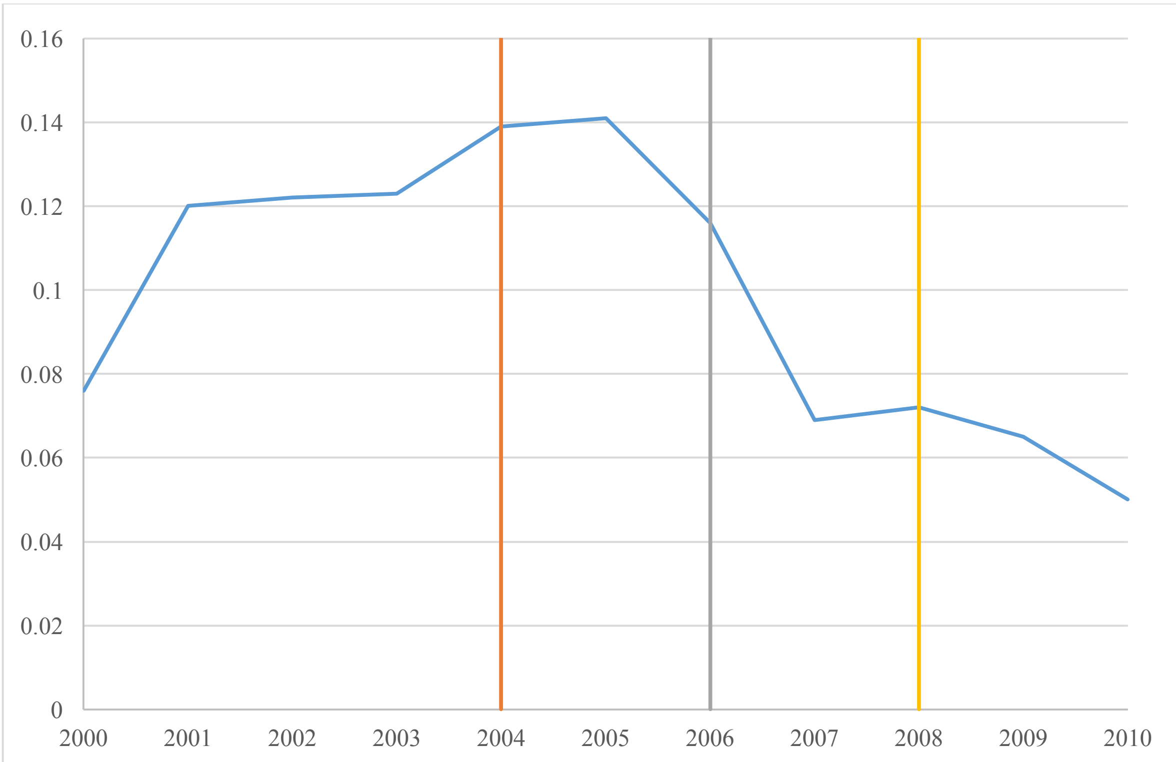
[c] Wald $\chi^2(21)$

Table 5. Effects of Past Performance and Regulations on Performance of Young-Chicken Slaughter Plants on Tests for *Salmonella* (Share of Samples Positive), 2000–2010

	(1)	(2)	(3)
68 FR 18593 (Post-2003)	0.0143	0.0134	0.0162
	(0.0128)	(0.0128)	(0.0132)
71 FR 9772 (Post-2005)	–0.0808***	–0.0759***	–0.0774***
	(0.0153)	(0.0162)	(0.0168)
73 FR 4767 (Post-2007)	–0.0316***	–0.0331***	–0.0315**
	(0.0122)	(0.0124)	(0.0128)
Tile 2 in previous period	0.0496***	0.0490***	0.0484***
	(0.0135)	(0.0135)	(0.0134)
Tile 3 in previous period	0.00862	0.00953	0.00813
	(0.0162)	(0.0167)	(0.0166)
Tile 2 in previous period × Post-2003	–0.0269	–0.0268	–0.0262
	(0.0175)	(0.0174)	(0.0173)
Tile 2 in previous period × Post-2005	–0.00863	–0.0118***	–0.0119
	(0.0188)	(0.0192)	(0.0191)
Tile 2 in previous period × Post-2007	0.0191	0.0193	0.0205
	(0.0212)	(0.0207)	(0.0210)
Tile 3 in previous period × Post-2003	–0.0556**	–0.0573**	–0.0543**
	(0.0238)	(0.0241)	(0.0237)
Tile 3 in previous period × Post-2005	0.0151	0.0118	0.0105
	(0.0292)	(0.0313)	(0.0312)
Tile 3 in previous period × Post-2007	0.0644	0.0650	0.0653
	(0.0525)	(0.0541)	(0.0513)
Lag number of *Salmonella* recalls	–0.00663***	–0.00680***	–0.00736***
	(0.00255)	(0.00263)	(0.00264)
Trend	0.00506*	0.00662**	0.00610*
	(0.00293)	(0.00309)	(0.00324)
Plant characteristic controls	No	Yes	Yes
Process-control controls	No	No	Yes
Observations	1,380	1,380	1,380
χ^2	178.76	223.28	231.84
Share of Observations Uncensored	0.89	0.89	0.89

Notes: Plant-level cluster-robust standard errors in parentheses. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.

Figure 1. Mean plant-level *Salmonella* test results by year, 2000–2010



Notes: Share of chicken carcass samples testing positive for *Salmonella*, mean of plant-level annual averages. Vertical lines represent FSIS policy changes.
Source: FSIS administrative data.

Figure 2. Changes in plant classification by *Salmonella* tiers, 1999–2010