Salmonella Control in Chickens: 2000-2014

By Michael Ollinger, Kar Ho Lim, and Peter Evans

Salmonellosis from chicken accounts for more than 25,000 illnesses per year and has shown no signs of diminishing (Centers for Disease Control and Prevention). In response to this persistent public health concern, the Food Safety Inspection Service (FSIS) of USDA launched an effort to reduce Salmonellosis from chickens by 25 percent by 2030. One way FSIS uses to better control *Salmonella* is through establishment-level testing of samples of chicken carcasses for *Salmonella.* This paper examines changes in performance on *Salmonella* tests after a change in standards in 2011. It finds that *Salmonella* rates dropped only for one subgroup of establishments across the regulatory change. Other results show regulation may have contributed to a sharp narrowing of differences in *Salmonella* rates between the best and worst performing establishments on *Salmonella* tests before and after the change in standards.

Key words: broilers, food safety, FSIS regulation, *Salmonella*, *Salmonella* standard

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Introduction:

Salmonella from chicken accounts for about 310,000 infections per year and has held steady for the past several years according to the Centers for Disease Control and Prevention. In response to this public health concern, the Food Safety Inspection Service (FSIS) of USDA launched an effort to reduce Salmonellosis from chickens by 25 percent by 2030. One way it aims to reduce infections is by testing chicken carcasses for *Salmonella* and establishing a credible enforcement mechanism.

Establishment-level testing of samples of chicken carcasses for *Salmonella* has been a central feature of the FSIS food safety program since 1998. At first, the rates of chicken samples testing positive for *Salmonella* (*Salmonella* rates) and cases of Salmonellosis declined. However, progress on reductions in the *Salmonella* rate soon halted and held steady until 2006 when *Salmonella* rates dropped sharply due to public disclosure of *Salmonella* test results (Ollinger and Bovay, 2020). *Salmonella* rates for establishments performing poorly on tests dropped again after 2014 when FSIS introduced a more evenly spread out sampling protocol (Ollinger, Lim and Knott, 2024). Other important policy changes, including the reduction in the *Salmonella* standard from 12 per 51 to 5 per 51 in 2010 also may have affected *Salmonella* rates but has received little attention in the economic literature. The purpose of this paper is to fill that gap by evaluating the impact of the more stringent *Salmonella* standards mandated in 2010 on performance on *Salmonella* tests. Following Ollinger, Lim, and Knott (2024), this paper creates five food safety performance groups (FSPGs) based on historic performance on *Salmonella* tests and evaluates the impact the change in standards had on each of the FSPGs. The results show

that the change in standards affected different FSPGs differently and that the relative difference in *Salmonella* rates across FSPGs changed from before to after the change in standards..

2 Data

The data include 571 observations of 164 chicken slaughter establishments existing over 2009 to 2014. Each observation has *Salmonella* test results, number of poultry slaughtered, and ratings for the performance of sanitation and process control tasks. *Salmonella* test results are the key data because FSIS assesses establishment food safety process control based on it (*Salmonella* Verification Testing Program Monthly Posting | Food Safety and Inspection Service (usda.gov). The *Salmonella* rate is defined formally as $\frac{p_{i,t}}{N_{i,t}}$, where $p_{i,t}$ is *Salmonella* positive samples over past year; $N_{i,t}$ is number of samples tested over past year. Here and throughout the paper, the subscript *i* represents establishment identities, where i=[1,…,164]; t represents years , where [t=2009,..,2014].

FSIS assigns establishments to categories based on *Salmonella* test results. Establishments are assigned Category 1 if the number of *Salmonella* positives is less than half the standard; Category 2 if the establishment meets the standard but is not Category 1; or Category 3 if the establishment does not meet the standard. Category 1 establishments have less and Category 3 establishments have more regulatory oversight.

The reduction in the Salmonella standard meant that the threshold at categories were defined also had to be reduced. A drop by more than half in the standard (12 per 51 to 5 per 51) in 2011

implied that some establishments that were Category 1 and all establishments in categories 2 and 3 were reclassified as Category 3.

Salmonella standards are enforced by disclosing the identities of Category 2 and Category 3 establishments to the public, enabling buyers to select suppliers that best match their food safety needs. Establishments can continue production if they fail to meet the standard but they face greater oversight.

Fig. 1 illustrates better- and worse-performing. Following Ollinger, Lim, and Knott (2024), FSPGs were created by ranking establishments by their mean *Salmonella* share over 2007-2011 and creating five FSPGs. We used the 2007-2011 period because these years are after introduction of disclosure policy in 2006 and before implementation of the revised *Salmonella* standards in 2011. We created five FSPGs (FSPG_0_19, … ,FSPG_80_99) out of the 164 available establishments so that each group includes at least 30 establishments. Figure 1 shows that mean *Salmonella* shares range from the worst FSPG at 0.11 in the 0-19th percentile (FSPG_0_19) to the best at 0.02 for 80-99th percentile (FSPG_80_99).

Models

Two panel-data models and one cross-sectional model are used to examine changes in *Salmonella* rates and *Salmonella* Categories after implementation of revised standards. A third model uses cross sectional data to show differences in the average *Salmonella* rate and average *Salmonella* category across FSPGs before and after the change in standards.

Changes in Salmonella rates

Equation (1) examines changes in *Salmonella* rates ($S_{i,t}$) after the change in *Salmonella* standards. Formally,

$$(1) \qquad S_{it} = \rho \boldsymbol{r}_t + \boldsymbol{\beta FSPG}_i' \boldsymbol{r}_t + \eta \boldsymbol{y}_t + \theta S_{it-1} + \beta \boldsymbol{x}_{it} + \mu_i + \varepsilon_{it}$$

The vector $\boldsymbol{r_t}$ = [Announcement, Implement]$_t$ accounts for the impacts of both when the policy is proposed and when it is implemented. The vector FSPG contains five dummy variables-one for each FSPG. Each FSPG represents twenty percentiles of establishments ranked by performance on *Salmonella* tests and is nested within the vector **FSPG**. See table 2 for a description of all variables and their summary statistics.

The coefficients of interest are ρ, which captures changes in the standards affecting the entire industry; and $\boldsymbol{\beta}$**,** which measures how the effects of changes in standards varies across FSPGs. The model also includes (1) control variables embedded in the vector $\mathbf{y_t}$ that account for the lag of mean rate of *Salmonella* shares of all chicken slaughter establishments, a two-year moving average of recalls of chicken products, and a time trend, (2) the lagged *Salmonella* rate, as shocks from one period may spillover to the next, and (3) a vector of establishment characteristics ($\mathbf{x_{i,t}}$) that control for the number of chickens slaughtered, share of poultry slaughtered that are chickens, noncompliant pre-operational sanitation tasks, operational sanitation tasks, and HACCP tasks. μ_i represents establishments' fixed effects.

Establishment-level food safety technology, locations, and other unique factors can affect *Salmonella* shares; thus, we specify fixed effects (FE) and use an Arrellano-Bond (AB) estimator to adjust for dynamic panel bias .

Changes in Salmonella categories

Equation 2 is used to investigate how categories changed for each FSPG.

$$(2) \qquad C_{it} = \rho \boldsymbol{r}_t + \boldsymbol{\beta FSPG_i' r_t} + \eta \boldsymbol{y}_t + \theta C_{it-1} + \beta \boldsymbol{x}_{it} + \mu_i + \varepsilon_{it}$$

where $C_{i,t}$ is the *Salmonella* category; Other variables are the same as in equation 1. A FE model with an AB estimator is used to evaluate the regression.

Differences in Mean Salmonella rates and categories before and after Implementation of the revised Salmonella standard

The revised standards gave different incentives for change for different FSPGs. Most establishments in the 40-99th percentiles had *Salmonella* rates below one-half the new standard (figure 1) and all establishments except those in the 0-19th FSPG met the standard. Equation 3 is cross sectional regression that is used to examine either mean *Salmonella* rates or categories before (2008-2009) and after (2012-2014) implementation of the new standard. The aim is to

compare the relative standing of establishments in terms of *Salmonella* rates and categories before and after the change in standards.

(3)) $\overline{S_i} = \boldsymbol{\beta FSG_i'} + \beta \boldsymbol{x}_i + \varepsilon_{it}$

where $\overline{S_i}$ is the mean establishment *Salmonella* rate over either 2008-2009 or 2012-2014.

The same model with $\overline{C_i}$replacing $\overline{S_i}$is used to examine average categories.

Results:

Table 3 gives changes in *Salmonella* shares after the announcement of a change in standards in 2010 and implementation in 2011. Results (columns 1 and 2) indicate that only establishments in 20-39th percentile had a decline in the *Salmonella* rate. These results are consistent with data presented in Figure 1 showing that establishments in the three highest rated FSPGs were already performing at a category 1 *Salmonella* rate under the new standard and may have had little incentive to change after the revised standards were introduced . More puzzling are results for the 0-19th percentile – there was no change yet the *Salmonella* rate for the establishments over 2007-2011 was substantially higher than the new standard.

Table 3 gives results for the change in category. Column 3 shows that on average there was a 0.363 increase in category rating after 2011; column 4 indicates that all significant changes were confined to the 0-59th percentile establishments. This increase was offset by a downward trend

and by 2014 the shift up in category rating occurring after revised standards were introduced had disappeared, suggesting that establishments were meeting the new standard.

Table 4 gives a comparison of *Salmonella* rates and categories across FSPGs before and after the change in the *Salmonella* standard. Results show that before the change differences in *Salmonella* rates between FSPG_0-19 and FSPG_80-99 were 0.133 and differences were 0.052 between FSPG_20-39 and FSPG_80_99. After the change in standards, there was an 0.028 difference in *Salmonella* rates between FSPG_0_19 and FSPG_80-99 and a maximum of 0.01 difference in *Salmonella* rates between FSPG_80_99th percentiles and other FSPGs. There was little change in *Salmonella* categories across FSPGs.

Discussion

Results show that the change in standards encouraged establishments in the 20-39th percentile improve their performance on tests for *Salmonella* but no other significant changes. We attribute the lack of change for establishments in the 40-99th percentile as due to their low *Salmonella* rates before the change in standards. Establishments in 0-19th percentile did not change, however. One plausible reason is that FSIS has no formal mechanism to penalize establishments for not meeting its standard, and it could be that the direct cost of increased food safety measures were greater than the cost of noncompliance or that the establishment served customers that preferred noncompliance to the use of anti-bacterial rinses and other interventions commonly used to control pathogens.

Results from the cross sectional model and Ollinger and Bovay (2020) point to the complementary nature of regulation under standards and regulations under disclosure. FSIS began implementing a policy of disclosing *Salmonella* test results in 2006 and had a formal introduction in 2008. The change led to a sharp drop in *Salmonella* rates but a substantial difference in rates across establishments as the motivation for change appeared to differ across establishments . This paper shows that the more stringent standard of 2010 mainly affected establishments that were less motivated to change due to disclosure. Combined, the two findings suggest that market driven policies, such as disclosure, can drive down *Salmonella* rates in aggregate while more oversight-based policies, such as more stringent standards, lead to narrower differences in *performance* on *Salmonella* test between better and worse performing establishments on *Salmonella* tests.

References

Ollinger, M., and John Bovay. (2020). "Producer Response to Public Disclosure of Food Safety Information." *American Journal of Agricultural Economics,* 102, no. 1, 186-201.

Ollinger, M., and Kar Ho Lim, and Tabitha Knott. (2024). Incentives for *Salmonella* control in chicken broilers: Why the sampling protocol matters." *Food Control,* 155, 1, 1-8.

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 establishments permitted 12 carcasses out of 51 to test positive for *Salmonella* spp. Slaughter establishments also required to test for generic *E. coli*. Also mandates that each establishment must have and maintain a PR/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* spp. 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* spp. Publish names of establishments in Category 3 in last set.
Fed. Reg. Notice[5]	07-01-2011	Policy Effective Date of 2010 revised *Salmonella* standards (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.(pps 27288-27294)

[5] Federal register 80 FR 3940: https://www.federalregister.gov/documents/2011/03/21/2011-6585/new-performance-standards-for-*salmonella*-and-campylobacter-in-young-chicken-and-turkey-slaughter

Table 2: Summary statistics

Variable	Lavel	Definition	Mean	Range	S.D.
$s_{i,t}$	*Salmonella* rate	$s = \frac{positive\ sample}{total\ sample}$ establishment *i* *=1,2,…at t=2009, ..2014*	0.036	0.0-0.49	0.060
$c_{i,t}$	*Salmonella* Category	c = if *Salmonella* rate < 0.049; = 2 if *Salmonella* rate ≥ 0.049 and ≤ 0.098; = 3 *Salmonella* rate > 0.098	1.338	1-3	0.657
r_t	*Announcement*	r_t = 1 if year = 2010; else zero	0.186	0-1	0.389
r_t	*Implement*	r_t = 1 if year > 2011; else zero	0.676	0-1	0.468
f	*FSPG_80_99*	*f=0 if Salmonella rate in 80-99th percentile ;else zero*	0.192	0-1	0.389
	FSPG_60_79	*f=1 if Salmonella rate in 60-79th percentile ;else zero*	0.241	0-1	0.428
	FSPG_40-59	*f=2 if Salmonella rate in 40-59th percentile ;else zero*	0.170	0-1	0.378
	FSPG_20-39	*f=0 if Salmonella rate in 20-39th percentile ;else zero*	0.224	0-1	0.418
	FSPG_0_19	*f=0 if Salmonella rate in 0-19th percentile ;else zero*	0.171	0-1	0.376
$\overline{s_t}$	*Lag of Mean Salmonella Share*	$\overline{s_{t-1}} = \sum_{i=1}^{I} \frac{s_{i,t-1}}{I}$ establishment *i* *=1,2, t=2009,…2014*	0.036	0.0-0.49	0.060

$y_{1,t}$	*Moving average of Number of Recalls*	Moving average over two years of all poultry recalls	10.51	6.0-13.5	2.81
$y_{2,t}$	*Trend*	Year -2000	11.70	9.0-14.0	1.70
$s_{i,t-1}$	Lag of *Salmonella* share	$S_{i,t-1}$	0.036	0.0-0.49	0.060
$x_{1,i,t}$	Log chicken slaughtered	Ln(chickens)	17.49	10.4-18.7	1.12
$x_{2,i,t}$	Chickens Slaughtered as share of poultry	Chickens/poultry	0.997	0.12-1.00	0.036
$x_{3,i,t}$	Share Pre-Operation SSOPs Not Compliant.	Noncompliant pre-op tasks/ all pre-op tasks	0.132	0.00-0.89	0.127
$x_{4,i,t}$	Share Operation SSOPs Not Compliant	Noncompliant operating tasks/ all operating tasks	0.079	0.00-0.63	0.081
$x_{5,i,t}$	Share HACCP Tasks Not Compliant.	Noncompliant HACCP tasks/ all HACCP tasks.	0.025	0.00-0.20	0.030

Table 3: The effect of revised *Salmonella* standards promulgated in 2010 on samples testing positive for *Salmonella* using yearly data over 2009-2014

(cluster-robust standard errors in parentheses)

	Model Variations Using Fixed Effects			
Dependent Variable	***Salmonella* Rate**		**Category**	
Variable	**(1)**	**(2)**	**(3)**	**(4)**
Announcement	-0.002	0.013	0.082	0.097*
	(0.011)	(0.012)	(0.054)	(0.055)
Implement	-0.0008	-0.027	0.375**	0.150
	(0.023)	(0.031)	(0.150)	(0.141)
*FSPG_80_99*implement*		-	-	-
*FSPG_60_79 *implement*	-	0.005	-	0.105
		(0.013)		(0.084)
*FSPG_40-59 *implement*	-	0.018	-	0.387***
		(0.023)		(0.144)
*FSPG_20-39 *implement*	-	-0.036*	-	0.305***
		(0.021)		(0.114)
*FSPG_0_19 *implement*	-	0.018	-	0.411**
		(0.055)		(0.196)
Lag of Mean Salmonella Share	Insignificant	Insignificant	n.a.	n.a.
Moving average of Number of Recalls	Insignificant	Insignificant	insignificant	Insignificant

Trend (starting in 2009)	insignificant	insignificant	-0.095***	-0.094***
			(0.029)	(0.029)
Lag of dependent variable	Insignificant	insignificant	Insignificant	insignificant
Controls for establishment characteristics	insignificant	insignificant	Insignificant	insignificant
Control for SSOPs and HACCP tasks.	insignificant	insignificant	Insignificant	insignificant
Observations	571	568	571	568
Establishments	164	163	164	163
AB1 statistic	0.144	-1.46	-1.11	-0.82
AB2 statistic	0.83	0.47	-0.81	-1.06
Hanson test for over identification.	11.74	6.88	3.58	3.44

Note: Percentile variables are incorporated in the fixed effects as establishment effects, fixed effects also account for location, plant technology, and other effects.

n.a. is not applicable

Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1%

Table 4: Differences in Mean *Salmonella* rates and categories relative to establishments in the 0-19th percentile before (2008-2009) and after (2012-2014) the Change in Standards.

(cluster-robust standard errors in parentheses)

Variable	**Models Using Cross Sectional Regressions.**			
Dependent Variable:	Mean *Salmonella* Rate		Mean Category	
	2008-09	2012-14	2008-09	2012-14
FSPG_80_99	-0.133***	-0.028**	-0.767***	-0.727***
	(0.019)	(0.009)	(0.086)	(0.058)
FSPG_60_79	-0.121***	-0.026**	-0.777***	-0.738***
	(0.019)	(0.011)	(0.086)	(0.054)
FSPG_40-59	-0.103***	-0.018*	-0.681***	-0.654***
	(0.020)	(0.011)	(0.091)	(0.059)
FSPG_20-39	-0.081***	-0.023***	-0.517***	-0.474***
	(0.019)	(0.009)	(0.092)	(0.057)
FSPG_0_19	-	-	-	-
Log chickens	-0.014	-0.019**	-0.008	0.034*
	(0.008)	(0.009)	(0.037)	(0.019)
Chicken share of poultry	-0.272***	Insignificant	-1.282***	Insignificant
slaughtered	(0.054)		(0.300)	
Pre-operation SSOP	Insignificant	Insignificant	Insignificant	Insignificant
Operation SSOP	Insignificant	Insignificant	Insignificant	Insignificant
HACCP Tasks	Insignificant	Insignificant	Insignificant	Insignificant

Observations	143	160	143	160
F-statistic	141.8^{***}	2.34^{***}	88.1^{***}	39.1^{***}
R^2	0.658	0.391	0.712	0.683

Note: Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1%

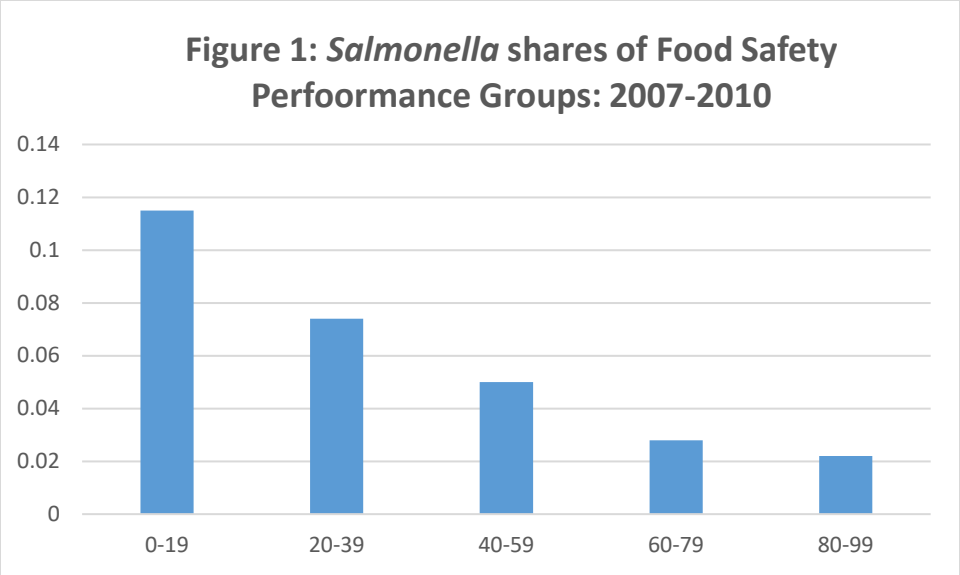
Figure 1: *Salmonella* shares of Food Safety Perfoormance Groups: 2007-2010
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0-19
20-39
40-59
60-79
80-99