International Food and Agribusiness Management Review
Volume 18 Special Issue A, 2015

U.S. Domestic *Salmonella* Regulations and Access to European and Other Poultry Export Markets[1]

Michael Ollinger[ⓘa] and Fawzi A.Taha[b]

[a] *Economist, Diet Safety Economics Branch, Economic Research Service, United States Department of Agriculture, 355 E Street NW, Washington DC, 20024, USA*

[b]*Economist , Food Security & Development Branch, Economic Research Service, United States Department of Agriculture, 355 E Street NW, Washington DC, 20024, USA*

Abstract

U.S. Poultry exports over the past twenty years have risen dramatically. But, concern over *Salmonella* has threatened access to some traditional export markets. This paper examines the economic forces driving recent reductions in *Salmonella* on U.S. chicken and discusses the implications of these reductions for U.S. poultry exports. Empirical results suggest that plant size and regulatory changes have contributed to a 50 percent reduction in *Salmonella* on chicken. These lower *Salmonella* levels will likely strengthen the U.S. bargaining position in trade negotiations and enhance the U.S. reputation in world trade but will not likely result in immediate export gains.

Keywords: U.S. poultry exports, Trade restrictions, *Salmonella*, food safety, regulation

[ⓘ]Corresponding author: Tel: + 1. 202.694.5454
Email: M. Ollinger: ollinger@ers.usda.gov
F. Taha: ftaha@ers.usda.gov

[1] The views expressed here are those of the authors, and may not be attributed to the Economic Research Service or the U.S. Department of Agriculture.

Introduction

The presence of *Salmonella* in poultry and other foods can cause diarrhea, fever, and abdominal cramping, and, if untreated, the infection can potentially cause death. Scallan et al. (2011) reported that outbreaks of food borne disease in the U.S. in 2011 led to an estimated 1,027,561 illnesses, 19,336 hospitalizations and 378 deaths, making it the second leading cause of food borne illness in the U.S.

Chicken is a major source of *Salmonella* (Scallan et al. 2011). Matthews et al. (2003) show that many countries have imposed *Salmonella* tolerances on chicken imports; these tolerances may protect the health of citizens, but they can also be import barriers and have been a subject of considerable debate in international trade.

Tolerances for *Salmonella* are reasonable if they are attainable and if they are the same for domestic producers and global exporters (Matthews et al. 2003). However, zero or near zero tolerances for *Salmonella* in chicken are viewed by many experts, such as Kramer (Feb 14, 2014), as unreasonable because *Salmonella* contamination naturally occurs in chicken flocks and a zero tolerance is costly to achieve. Nevertheless, Mathews et al. (2003) report that (1) Japan, Hong Kong, and Estonia reserve the right to test imports and reject shipments that test positive for *Salmonella*, (2) Russia and Ukraine have very low tolerances for *Salmonella*, and (3) the Czech Republic, El Salvador, Honduras, Slovakia, and Chile imposed zero tolerances on fresh chicken imports during the 1990s. The zero tolerances imposed by Czech Republic, El Salvador, Honduras, Slovakia, and Chile were particularly troublesome because those countries did not hold their own producers to the same standard.

What is a reasonable standard? Under the Pathogen Reduction and Hazard Analysis Critical Control Program (PR/HACCP) of 1996, the Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA) mandated that no more than 12 out of 51 chicken carcasses could test positive for *Salmonella*. This *Salmonella* tolerance was maintained until 2011. In comparison, plants in Denmark, Sweden, and some other European countries achieve a zero or near zero tolerance (European Food Safety Authority 2010).

Kramer (2014), among others, points out that a zero tolerance for U.S. producers may be too costly of a goal, yet a tolerance of 12 out of 51 positive samples may have been too high. In 2011, FSIS cut the tolerance to 5 positive samples out of 51, suggesting that U.S. *Salmonella* levels are converging toward the more stringent standards demanded by some trading partners.

The purpose of this paper is to examine the main factors driving the reduction in *Salmonella* levels at American producers and discuss the implications of the *Salmonella* reduction for U.S. poultry exports. The empirical analysis relies on a model used in an analysis of the economic forces affecting *Salmonella* levels in ground beef in school meals (Ollinger, Guthrie, and Bovay 2014). Data were compiled from FSIS and the World Trade Atlas.

The U.S. Regulatory Environment

FSIS and its antecedent USDA agencies have regulated meat food safety since 1906 and have had an expanded role since 1968 when food safety process controls were established. These process controls include Sanitation Standard Operating Procedures (SSOPs) that required plants to (1) perform knife cleaning and other food safety tasks during operations (operating tasks), (2) equipment disassembly and cleaning and other tasks at the beginning or end of a shift (pre-operating tasks), and (3) a number of regulations, such as those dealing with maintaining facilities, cooking times and temperatures, preparation of fermented, smoked, and other processed products (see Ollinger and Mueller 2003).

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. This regulation required meat and poultry slaughter and processing plants to develop and implement HACCP process control programs for each product. FSIS approves all HACCP plans and its inspectors verify that plants perform all tasks specified in their HACCP plan and do all SSOPs.

Under the PR/HACCP rule, FSIS mandated a *Salmonella* performance standard that requires plants that slaughter livestock or produce ground meat or poultry to meet *Salmonella* performance standards. FSIS conducts testing for *Salmonella* by randomly selecting plants for testing from a pool of plants that are not undergoing testing and evaluating their performance on *Salmonella spp.* tests. Under the PR/HACCP rule, chicken slaughter plants could have no more than 11 out of 51 carcasses test positive for *Salmonella spp*. Improvements in performance on these tests allowed FSIS to cut the *Salmonella* tolerance to 5 positive carcasses out 51 samples.

FSIS classifies poultry plants in three food safety categories based on their performance on *Salmonella* tests. If a plant meets one-half the tolerance, then it is considered to have good process control and is put in category 1. Plants that perform at a level between one half to equal to the tolerance are placed in category 2 and plants that exceed the tolerance are placed in category 3. Plants in category 1 are tested no more than once per year but at least once every two years; plants in categories 2 and 3 are tested more often than plants in category 1.

In 2008, FSIS began publishing the names of plants in category 2 and 3 on the Worldwide Web. The names of plants not published on the Web were in category 1. Publishing the names of plants with relatively weak food safety performance can encourage buyers to require their suppliers to improve performance and adversely affects the food safety reputation of suppliers assigned to either category 2 or 3. The poultry industry responded with a dramatic performance improvement on *Salmonella* tests (Figure 1). Then, in 2011, FSIS lowered the tolerance for *Salmonella* to five positive bird carcasses out of 51 samples and stopped publishing the names of plants assigned to category 2 on the Worldwide Web.

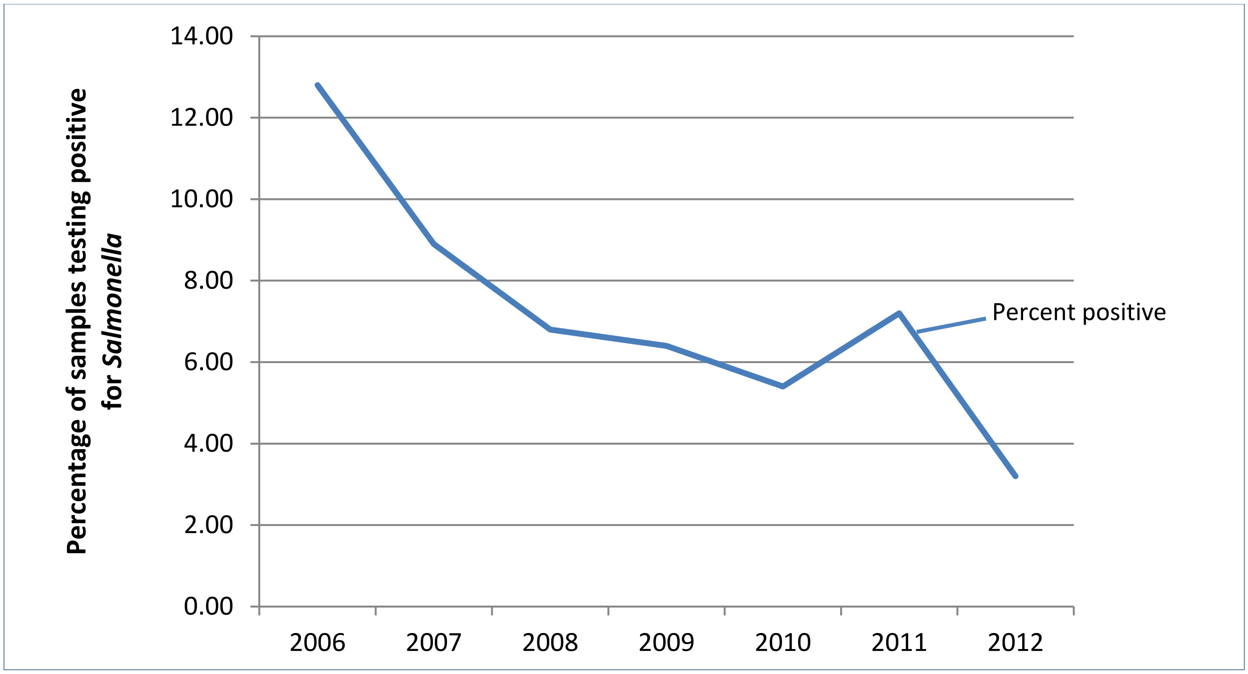

Figure 1. Percentage of Chicken Samples Testing Positive for *Salmonella* in Tests Conducted by the Food Safety Inspection Service

Source. Calculations by authors using FSIS data over 2006-2012

Economic Framework

Managers of chicken slaughter plants sell raw chicken to domestic or international buyers, depending on the profitability of each market. The costs of production are the same for all products, but the cost of food safety may vary. Products sold in the domestic markets require no extra precautions, but products sold in international markets may face very low tolerances for *Salmonella* and, in some cases, must be produced without microbial sprays and chlorine baths. These special food safety precautions raise the cost of chicken production. But, plants that are able to comply with all of these requirements at a lower cost can generate greater sales by exporting to international markets. Below, we examine a model to explain performance by chicken plants on *Salmonella spp* tests conducted by FSIS.

Muth et al. (2007), Ollinger and Moore (2008), and Ollinger, Guthrie, and Bovay (2014) examined the effectiveness of plant and food safety technologies in controlling *Salmonella* Other research has evaluated the cost of food safety regulation (Antle 2000; Ollinger and Mueller 2003; Ollinger and Moore 2009), and the impact of financial performance on *Salmonella* tests (Muth et al. 2012).

Following Ollinger, Guthrie, and Bovay (2014), we adopt a production framework in which food safety (FS) is a function of labor devoted to food safety (L), plant capital (K), plant technology (t), plant characteristics (Z), and regulatory changes made by FSIS (R):

(1) $$\mathrm{FS} = \mathrm{FS}(\mathrm{L}, \mathrm{K}, \mathrm{t}, \mathrm{Z}, \mathrm{R})$$

Equation 1 is represented econometrically as,

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

FSIS conducts *Salmonella* testing to verify a plant's food safety process control. Variables based on the results of these *Salmonella spp* tests were used as alternative measures of food safety (FS) in equation 2. Under the FSIS *Salmonella* testing program, a plant had to meet a tolerance of 12 out of 51 samples testing positive for *Salmonella* from 1996 to 2011 and 5 out of 51 samples testing positive for *Salmonella* from mid-2011 to the end of 2012.

Tolerance levels of 5 out of 51 samples testing positive for *Salmonella* is a dramatic improvement in performance on *Salmonella* tests, but it is still too high to meet the tolerance levels demanded by some export markets. A major goal of this study is to better understand the characteristics of plants best able to meet the stricter standards demanded by some importing countries. Thus, we evaluate performance on three successively stricter tolerances in which FS^* is defined as one if a plant's performance on the FSIS *Salmonella spp* test is one-fourth, one-sixth, and one-twelfth the 1996 FSIS *Salmonella spp* tolerance and zero otherwise. These are the equivalent of 3, 2, and 1 out of 51 chicken samples testing positive for *Salmonella*.

Plants meet a tolerance or they do not meet the tolerance. Thus, we use a probit regression (equation 3).

(3) $$FS^* = \alpha_0 + \sum \beta_i L_i + \delta K + \sum_j \rho_j t_j + \sum_k \lambda_k Z + \omega R + \xi$$

$$FS^* = 1 \quad if \quad FS \le tolerance$$

$$FS^* = 0 \quad if \quad FS > tolerance$$

FSIS requires all meat and poultry plants to perform SSOPs and tasks needed to maintain a HACCP process control programs. SSOPs and HACCP tasks are monitored by FSIS inspectors that record whether a task was performed and in compliance with FSIS standards. A high number of noncompliant ratings (noncompliances) imply that less effort is devoted to food safety process control; a low number of noncompliances suggest that more effort (labor) is devoted to food safety process control.

There are pre-operational and operational SSOP tasks. Pre-operational SSOP tasks are tasks at the end or beginning of the production day; operating tasks are duties performed during production. HACCP tasks are process control tasks that are specified in the plant's HACCP plan. Ollinger and Moore (2008) found that better performance of SSOPs and HACCP tasks improved performance on *Salmonella* tests in ground beef plants.

A plant's capital equipment is captured by plant size (the number of chickens slaughtered). Muth et al. (2007) and Ollinger and Moore (2008) found that plant size had a positive impact on food safety performance in the cattle, hog, and chicken slaughter industries.

There are several plant technology variables. Muth et al. (2007) found that plant age had a significant and negative impact on *Salmonella* levels in hog and chicken slaughter and further-processing plants. Other technology variables account for the variety of animals slaughtered and whether the plant did further processing. Both operations may raise food safety costs by making the plant more complicated.

It is also necessary to identify plants that are owned by firms that own other plants because these plants may benefit from the parent company's ability to share food safety practices across units. Additionally, it is important to account for the geographic region since different types of birds with different market outlets may be processed in different regions. Finally, there is a regulatory change variable to account for the change in FSIS tolerances in 2011.

Data and Variables

The data are a pooled dataset of all chicken slaughter plants whose products were tested for *Salmonella* by FSIS over 2009-2012. After dropping observations with missing values and several very large and very small plants, our dataset includes data records for 462 chicken slaughter plants. These plants may have lucrative contracts with large restaurants and other large commercial customers that impose their own food safety standards. These private standards may be stricter than those required by FSIS. The data also include plants that sell to wholesalers, retailers, and others with no specific food safety requirements.

Salmonella data come from files at FSIS. Each year FSIS randomly selects plants for *Salmonella* testing. Selection is based on the volume of production. Not all plants are tested each year, but there was an average of about 120 plants tested each year over 2009-2012.

The SSOP and HACCP compliance data and some plant characteristics come from FSIS administrative data and are available for all plants inspected by FSIS every year. The FSIS administrative data include the type and number of animals slaughtered, types of meat or poultry processed, name and address information, and when a plant began operation.

Dunn and Bradstreet, a widely-used database of plants and firms, was used to identify business activities of the plant and whether the plant is part of firm that owns more than one plant. The Dunn and Bradstreet data include a wide array of business and financial information, including sales, square footage of the plant, major industry category, line of business, US 1987 SIC 1, US 1987 SIC 2, and US 1987 SIC 3, a primary activity code, and indicators for being a subsidiary, manufacturer, small business, public/private firm and others.

Estimation Procedures

The data are a pooled dataset with a binary choice dependent variable. Pooled data include temporal and cross-sectional components, making it necessary to consider possible autocorrelation errors and heteroskedasticity. Beck, Katz, and Tucker (1998) obtain accurate standard errors using duration dependence techniques for pooled data with a binary dependent variable that extends over 30 periods and has 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 4 periods, making a duration dependence model inappropriate and a probit model the technique of choice.

Our data has a time series component, raising the possibility of autocorrelated error. Beck, Katz, and Tucker (1998) argue that autocorrelation cannot be detected in probit models and a review of the econometric literature suggests this still is the case. Beck and Katz (1997) assert that the Huber sandwich estimator (Huber 1967) corrects most of the auto-correlated error in the standard error if there is autocorrelation and does not affect results if there is no autocorrelation. Thus, we use a Huber sandwich to adjust for autocorrelation.

We also tested our model for multiplicative heteroskedasticity in plant size since plant size varies substantially across plants. However, there was no need to make an adjustment because a log-likelihood test does not reject the null hypothesis that the model is homoscedastic.

Empirical Results from the Model

Table 1 gives the variable definitions and names and their mean values. The mean of chickens slaughtered equaled about 12.8 million chickens per year. The number slaughtered varied from about 10,000 to 120 million per year. The mean plant age is 17.6 years and varied from 1 to 93 years old. The data also shows that about one half of all plants had food safety performance levels equal to one-sixth the tolerance for Salmonella in 2008, i.e. no more than 2 out of 51 samples testing positive for *Salmonella*. The mean percentage of samples testing positive was about 5.5 percent (equivalent to 2.8 samples per 51 samples).

Figures 1 and 2 show the trends in performance on *Salmonella* tests over 2006-2012. Figure 1 shows that the percent of samples testing positive for *Salmonella* dropped from around 13 percent in 2006 (6.6 per 51 samples) to about 3 percent in 2012 (1.5 per 51 samples). Figure 2 shows that by 2012 about 85 percent of the chicken plants reached levels of performance on *Salmonella* tests equal to one-fourth the tolerance that existed prior to 2011 and that no samples tested positive for *Salmonella* in about 35 percent of all plants. By contrast, less than 30 percent of chicken slaughter plants had a level of performance on *Salmonella* tests equal to one-fourth the tolerance that existed prior to 2011 and less than 10 percent of chicken slaughter plants had no samples testing positive for *Salmonella* in 2006. These recent changes demonstrate a level of performance on *Salmonella* tests that is compatible with the strict standards mandated by many U.S. trading partners. Moreover, about 35 percent of all plants could meet the zero tolerance levels imposed by some countries.

Table 1. Mean Values of Selected Economic Variables of Chicken Slaughter Plants

Variable	Variable Label	Definition	Mean
-	Percent positive *Salmonella spp* Samples	Share of samples testing positive for *Salmonella spp* in FSIS testing	0.056
FS	One-Fourth *Salmonella spp* Standard	One if share of samples testing positive for *Salmonella* less than one-third FSIS standard, else zero	0.677
FS	One-Sixth *Salmonella spp* Standard	One if share of samples testing positive for *Salmonella* less than one-sixth FSIS standard, else zero	0.513
FS	One-Twelfth *Salmonella spp* Standard	One if share of samples testing positive for *Salmonella* is less than one-twelfth FSIS standard, else zero.	0.328
L	PCENT_HACCP_PASS	Percent of HACCP tasks not in compliance with HACCP plan	0.983
L	PCENT_SSOP_P_PASS	Percent of pre-operational SSOPs complying with standard	0.891
L	PCENT_SSOP_O_PASS	Percent of pre-operational SSOPs complying with standard	0.937
K	Chicken	Millions of chickens slaughtered per year	12.800
T	Plant age	Current year minus year poultry grant issued, else zero	17.600
T	Multi-species	One if slaughter more than one animals species, else zero	0.225
T	Share other animals slaughtered	Number of animals other than chickens slaughtered as a share of all animals slaughtered	0.009
T	Does further processing	One if further processes some meat, else zero	0.120
Z	Multiplant firm	One if plant is part of a multi-plant firm, else zero	0.116
Z	Atlantic	One if in Delaware, Maryland, Virginia, West Virginia	0.081
Z	Midwest	One if in Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Ohio, Wisconsin, else zero.	0.063
Z	Northeast	One if in N. Jersey, N. York, Pennsylvania, Vermont, else zero	0.066
Z	Southeast	One if in Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, N. Carolina, S. Carolina, else zero	0.450
Z	West	One if in California, Colorado, Hawaii, Washington, else zero	0.044
Z	West South	One if in Arkansas, Missouri, Oklahoma, Tennessee, Texas, else zero	0.225
R	Year_2011_12	One if started Salmonella testing after July 1, 2011, zero otherwise	0.345
	Observations		464.000

Source. Estimates by Authors using FSIS Data.

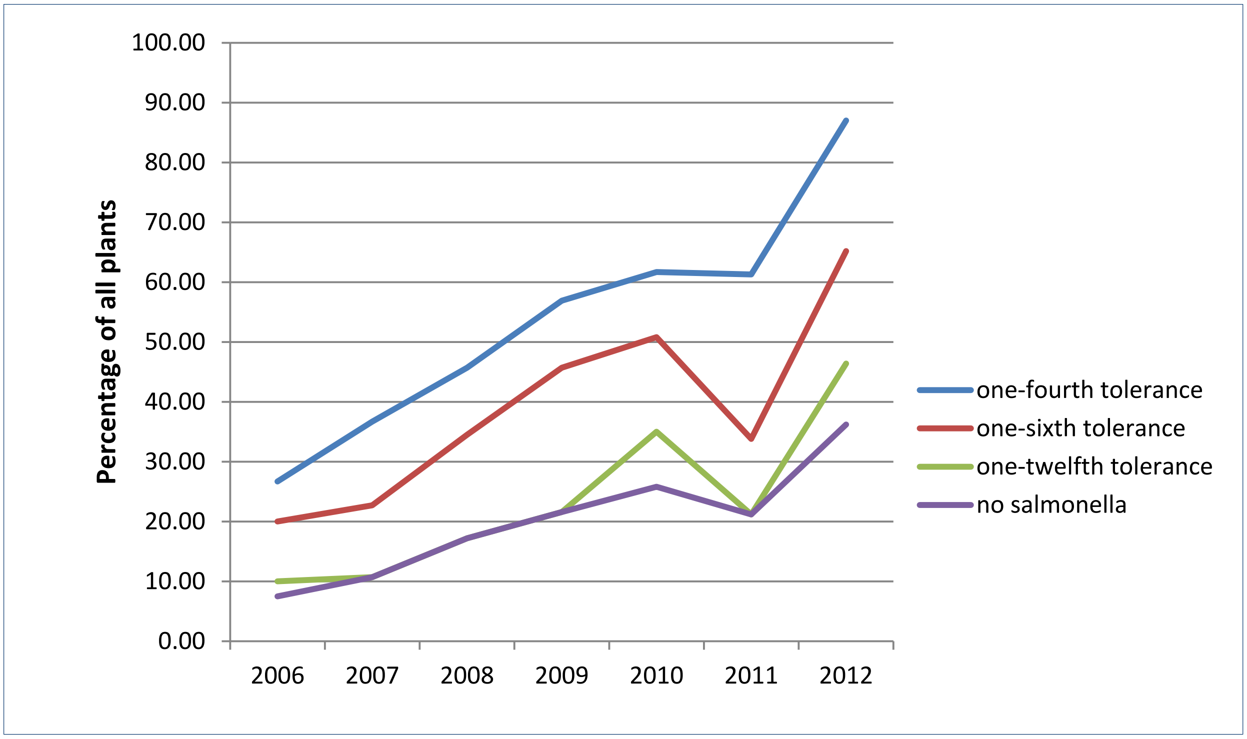

Figure 2. Chicken Plant Performance on *Salmonella* Tests Conducted by the Food Safety and Inspection Service

Note. The FSIS tolerance was 12 out of 51 samples could test positive for Salmonella from 2006-2011 and was assumed to remain the same for 2012.
Source. Authors estimates based on FSIS data.

Table 2 gives the results of three versions of our model in which the dependent variable is defined as one-fourth, one-sixth, and one-twelfth of the initial *Salmonella* tolerance. This is identical to saying that 3, 2, or 1 sample tested positive for *Salmonella* out of 51 samples taken.

The number of chickens slaughtered, whether the plant further processed chickens, and the food safety regulation of 2011 had statistically significant and positive effect on food safety performance. Model results suggest that, compared to other plants, further processors were about 17 percent more likely to have a food safety performance equal to one-fourth the FSIS *Salmonella* tolerance, 15 percent more likely to have a food safety performance equal to one-sixth the FSIS *Salmonella* tolerance, but no more likely to have a one-twelfth the *Salmonella* tolerance. Similarly, a ten percent change in the log of chickens leads to a 0.6 percent improvement in performance on the one-sixth FSIS tolerance for samples testing positive for *Salmonella* and a 0.5 percent improvement in performance on the one-twelfth FSIS tolerance for samples testing positive for *Salmonella*.

The regulatory change of mid-2011 had a major impact on food safety performance. Plants responded by improving their performance on tests of the number of samples testing positive for *Salmonella* at one-fourth, one-sixth, and one-twelfth of the FSIS tolerance, by 29.6, 17.6 and 18.1 percent, respectively.

Table 2. Marginal Effects of Food Safety Performance of U.S. Chicken Slaughter Plants

Variable	**One-Fourth Tolerance for *Salmonella spp*[1]**		**One-Sixth Tolerance for *Salmonella spp*[1]**		**One-Twelfth Tolerance for *Salmonella spp*[1]**	
HACCP_PASS0,	1.736		1.423		1.170	
	(1.352)		(1.419)		(1.425)	
SSOP_P_PASS0	0.156		-0.129		-0.242	
	(0.296)		(0.298)		(0.290)	
SSOP_O_PASS0	0.265		0.537		0.888	*
	(0.505)		(0.517)		(0.554)	
Log (Chickens)	0.009		0.061	**	0.052	**
	(0.031)		(0.027)		(0.020)	
Plant age	-0.0019		-0.0025	*	-0.0011	
	(0.0015)		(0.0015)		(0.001)	
Multi-species	-0.102		0.023		0.032	
	(0.078)		(0.080)		(0.083)	
Share other animals slaughtered	0.088	*	-0.556		0.007	
	(0.518)		(1.065)		(0.635)	
Further processing	0.170	***	0.154	**	0.061	
	(0.065)		(0.069)		(0.072)	
Multiplant firm	0.092		0.049		-0.046	
	(0.081)		(0.094)		(0.072)	
Atlantic	-0.023		0.087		0.092	
	(0.144)		(0.130)		(0.140)	
Midwest	-0.423	***	-0.171		-0.136	
	(0.132)		(0.145)		(0.104)	
Northeast	-0.403	***	-0.193		-0.225	**
	(0.136)		(0.181)		(0.097)	
Southeast	-0.097		0.039		0.047	
	(0.086)		(0.095)		(0.088)	
West	-0.128		0.140		0.193	
	(0.182)		(0.159)		(0.153)	
Year_2011_12	0.296	***	0.176	**	0.181	***
	(0.051)		(0.071)		(0.067)	
X^2	43.4	***	42.8	***	47.8	***
Observations	462		462		462	
X^2 of Likelihood of Heteroskedasticity	0.00		0.61		0.05	

Note. * Denotes 0.10 significance level, ** 0.05 level, and *** 0.01 significance level. Instead of the line above.
[1] Tolerances were reduced from 12 out of 51 samples could test positive for before the middle of 2011 to 5 out of 51 samples could test positive for *Salmonella* after the middle of 2011.

We do not know the food safety technology used to improve performance on *Salmonella* tests because this measure is a performance standard in which FSIS established a tolerance (a maximum of five positive test results per 51 samples) that plants can meet in any manner they choose. Plants in the U.S. frequently use antimicrobial sprays because this is effective and approved for use in the U.S. (Laury et al. 2009). EU countries and some others ban imports of products processed with anti-bacterial products, making this a trade issue.

Do *Salmonella* Reductions Matter for U.S. Exports?

Matthews et al. (2003) point out that the presence of *Salmonella* on poultry is a justified reason for restricting trade if it is excessive but it often used as way to prevent imports. These motivations make it important to define what an excessive level of *Salmonella* is. Moliterno-Duarte et al. (2009) found a 9.6 percent prevalence rate in Brazilian chicken and report that other researchers found levels, ranging from 5.9 percent to 42 percent in chicken carcasses in other Brazilian states. Moliterno-Duarte (2009) also reported that other researchers found *Salmonella* levels of 13% in Poland (Mikolajczyk 2002), 29.3% in Belgium (Uyttendaele et al. 1998), 29.7% in UK (Plummer et al. 1995), and 35.8% in Spain (Dominguez et al. 2002). More recently, The European Union Food Safety Authority (2010) reported that *Salmonella* levels in European countries varied from 0.0 to 26.6 percent.

Given the 66 percent reduction in *Salmonella* levels in U.S. broilers since 2006 (Figure 1) and the relatively high levels of *Salmonella* detected in poultry in other countries (preceding discussion), it would seem that U.S. exporters are well-positioned for growth in export markets. However, exports have remained relatively steady since 2010 after a sharp increase in sales from 1990 to 2010. Table 3 shows that U.S. poultry exports rose about 400 percent between 1990 and 2000 and another 25 percent from 2000 to 2010. Most of the growth in the early years was due to exports to major trading partners, including Russia, Hong Kong, Mexico, Canada, and Central-EU-13. That growth leveled off after 2000, but exports to the rest of the world then expanded until about 2010. Since 2010, U.S. poultry shipments have been rising to Mexico and China, but these gains have been offset by declining sales to Russia and Central-EU-13 (Table 3). Note, the European Union had a major expansion in membership when it reached 25 members in 2004 after 10 new countries joined. Currently, there are 28 member countries.

Poultry exports to Europe have been limited by food safety regulations. Changes in exports to the Central-EU-13 countries, which joined the EU after 2004, show the effect of these requirements. Exports to the Central-EU-13 countries dropped from 278,000 metric tons in 2000 to about 71,000 in 2013 (Table 3). Similarly, EU imports of US poultry dropped from 32,000 tons in 1999 to about 125 tons in 2013 (World Atlas). Note, the difference between EU imports and U.S. exports may be due to transshipments (Johnson 2012). For example, 90 percent of U.S. exports to the EU went to Lithuania—one of the smallest countries in Europe.

Table 3. U.S. Exports of Poultry Meat in Metric Tons, 1990-2013

Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**
Mexico	51.7	149.0	275.9	413.6	565.2	622.9	731.7	818.2
China	2.6	40.7	81.8	166.7	137.1	137.1	286.3	324.4
Russia	-	696.2	691.5	784.7	321.8	212.6	267.7	274.6
Hong Kong	85.4	466.5	675.4	127.7	446.7	557.6	302.4	175.2
Canada	39.3	45.7	90.7	97.9	125.0	133.9	159.6	150.5
Taiwan	0.3	2.2	24.1	88.2	104.9	103.4	141.6	132.9
EU-28	38.6	165.3	329.4	226.1	161.0	140.0	106.5	77.7
EU-15	26.5	38.0	51.1	17.7	11.2	10.6	7.8	7.1
Central-EU-13[1]	12.1	127.3	278.3	208.3	149.9	129.4	98.8	70.6
Philippines	0.2	0.4	15.6	12.1	52.7	66.2	79.1	73.7
Major Partners	217.9	1,566.1	2,184.4	1,917.0	1,914.6	1,973.6	2,075.0	2,027.2
Rest of World	353.1	383.2	631.4	782.3	1,623.7	1,767.4	1,856.2	1,796.7
World Total	571.1	1,949.3	2,815.8	2,752.3	3,538.3	3,741.5	3,931.2	3,868.9

Note. Central EU-13 is countries that joined the EU after 2004
Source. World Trade Atlas, 2014

The EU now maintains a zero tolerance for *Salmonella.* All European countries do not meet this zero tolerance (European Union Food Safety Authority 2010), while some U.S. plants are producing broilers with nondetectable levels of *Salmonella,* suggesting potential for U.S. exports to the EU. Exports by these U.S. companies, however, appear unlikely because *Salmonella* reductions were likely achieved with the use of antimicrobial washes (Laury et al. 2009) and the EU limits the use of antibiotics, vaccines and antimicrobial washes.

Access to Russian markets has been denied several times when Russian authorities claimed exporters violated the Russian *Salmonella* standard. A major dispute in 1995 occurred when Russia threatened to embargo poultry imports from the U.S. unless the U.S. exporters could certify their poultry was *Salmonella*-free. That disagreement was quickly resolved, but another interruption in 2002 had more serious consequences, leading to a 35 percent decline in U.S. exports to Russia (Orden et al. 2002, 162).

The most serious poultry trade breach with Russia occurred in 2010. At that time, Russia was the largest export market for U.S. poultry, averaging more than 786,000 tons (26 percent of all exports) over 2000-2009, which was about equal to Mexico (11.7 percent), China (10.8 percent), and Canada (3.4 percent) combined. Then, U.S. shipments dropped by nearly half to 322,000 tons in 2010 after Russia abruptly banned U.S. imports. National Journal (Koren 2014) reported that Russian authorities justified the restriction over concern of the use of chlorine solution as a means of controlling *Salmonella* in chicken. U.S. chicken plants had been using chlorine baths for many years prior to the ban and Russia accepted the product. National Journal noted that this trade restriction, like earlier interruptions, coincided with rising political tensions between the U.S. and Russia. After some negotiations, U.S. chicken exports to Russia resumed.

The dramatic drop in U.S. poultry meat exports to Russia illustrated in Figure 3, shows that exports dropped from 80 million kg in October 2009 to about zero in February through August 2010 and then a rebounded to previous levels. Russia was able to partially offset the sharp drop in U.S. poultry shipments with increased purchases from Brazil and Germany (Table 4). It is ironic to note that, during this time period, U.S. poultry meat prices, on average, remained below the World average price and always below that of Brazil. Moreover, U.S. *Salmonella* levels were below those for Brazil, as reported by Moliterno-Duarte et al. (2009).

Table 4. Russian Poultry Meat Imports, 2009-2013

	2009	2010	2011	2012	2013
Million Kg					
Total Volume	948	650	404	470	528
United States	700	295	240	265	266
Brazil	69	143	71	70	54
France	49	32	28	30	18
Germany	92	102	30	6	2
Average price US Dollars/Kg					
World Average	1.12	1.33	1.42	1.51	1.61
United States	1.05	1.15	1.28	1.28	1.27
Brazil	1.91	1.81	2.12	2.24	2.72
France	1.21	1.28	1.12	1.18	1.25
Germany	1.06	1.22	1.06	1.73	1.78

Source. World Trade Atlas 2014

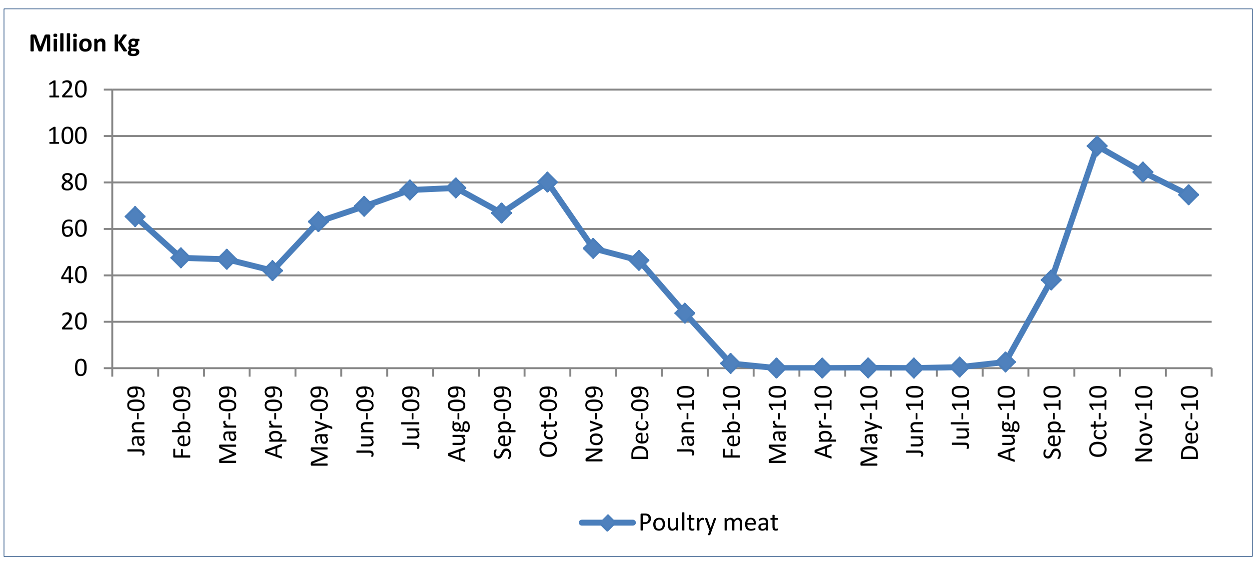

Figure 3. U.S. Poultry Exports to Russia, Jan. 2009 – Dec. 2010.
Source. World Trade Atlas 2014

Conclusion

This paper examined some of the economic forces encouraging lower *Salmonella* levels in U.S. poultry production and discussed the importance of lower *Salmonella* for encouraging exports to global markets. The paper showed that larger poultry plant size, whether a plant further processed poultry, and lower tolerances for *Salmonella* mandated by FSIS resulted in much lower levels of *Salmonella* in U.S. poultry. This reduction in *Salmonella* would seem to encourage poultry exports. Yet, as *Salmonella* levels dropped over the 2008-2012 period, growth in U.S. poultry exports stagnated as Russia and the EU reduced their poultry purchases. Neither were satisfied with U.S. reductions in *Salmonella* in poultry -- Russia insisted on a zero-*Salmonella* level and the EU-28 had concerns about *Salmonella*, the use of antibiotics in animal husbandry, and the use of anti-microbial washes in chicken processing.

The decline in exports to Russia and the EU-28 over 2008-2012 was offset by increases in exports to two NAFTA trade partners – Mexico and Canada. Herein may lay the benefit of reductions in *Salmonella* for chicken exporters. Much trade occurs through trade agreements with individual or groups of countries, such as Mexico and Canada. These trade agreements often encompass a broad array of products including agricultural outputs and cover a number of issues, including food safety. Reductions in *Salmonella* levels provide U.S. exporters a strong reputation for food safety, giving U.S. trade negotiators a better bargaining position and more flexibility in reaching valuable trade agreements that can benefit the U.S. poultry industry. All other things being equal, including prices, importing countries will most likely buy products that are less likely to have *Salmonella* in order to protect the health and safety of their citizens.

There are three important implications of this research. First, large poultry processing plants are best able to meet the very strict tolerances for *Salmonella* demanded by international markets. Second, FSIS regulations helped reduce the *Salmonella* levels of U.S. poultry plants, making poultry from all U.S. poultry plants more competitive on the basis of food safety in international markets. As food safety technology improves, further reductions in *Salmonella* tolerances is possible, enabling greater U.S. competitiveness in international markets. Third, reductions in *Salmonella* may have little direct immediate impact on poultry exports, but will likely provide a stronger U.S. bargaining position in global markets and trade negotiations.

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(2): 310–322.

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

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

Dominguez, C., I. Gómez,, and J. Zumalacárregui. 2002. Prevalence of *Salmonella* and *Campylobacte*r in retail chicken meat in Spain. *Int. J. Food Microbiology* 72:165-168.

European Commission. 2005. Ban on antibiotics as growth promoters in animal feed enters into effect. IP/05/1687/Brussels. http://europa.eu/rapid/press-release_IP-05-1687_en.htm.

European Food Safety Authority Journal. 2010. Analysis of the baseline survey on the prevalence of *Campylobacter* in broiler batches and of *Campylobacter* and *Salmonella* on broiler carcasses in the EU, 2008: Part A: *Campylobacter* and *Salmonella* prevalence estimates. *European Food Safety Authority* (*EFSA) Journal* 8(3):1503.

Huber, P. J. 1967. The Behavior of Maximum Likelihood Estimates under Nonstandard Conditions. *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*. Vol. I: 221–33.

Johnson, R. 2012. U.S.-EU Poultry Dispute on the Use of Pathogen Reduction Treatments (PRTs). *Congressional Research Service* 7-5700 R40199.

Koren, Marina. 2014. Irked by Sanctions, Russia Is Going after America's Chickens. *The National Journal*, August 5. http://www.nationaljournal.com/economy/irked-by-sanctions-russia-is-going-after-america-s-chickens-20140805.[Accessed July 10, 2015].

Kramer, M. 2014. Raw Poultry: Legal History, Public Policy, and Consumer Behavior. *Food Safety News*, February 14. http://www.foodsafetynews.com/2014/02/raw-poultry-the-legal-history-public-policy-and-consumer-behavior/#.VaXQMvlViko.

Laury, A.M., M.V. Alvarado, G. Nace, C.Z. Alvarado, J.C. Brooks, A. Echeverry, and M.M. Brashears. 2009. Validation of Lactic Acid-Citric Acid-Based Antimicrobial Product for the Reduction of *Escherichia coli* O157:H7 and *Salmonella* on Beef Tips and Whole Chickens. *Journal of Food Protection* 72(10): 2208-2211.

Mathews, K., Jr., Bernstein, J., and J.C. Buzby. 2003. International Trade of Meat/Poultry Products and Food Safety Issues. In *International Trade and Food Safety: Economic Theory and Case Studies,* edited by J. Buzby, 48-73. AER-828. United States Department of Agriculture, Economic Research Service.

Mikolajczyk, A. and M. Radkowski. 2002. *Salmonella* spp. on chicken carcasses in processing plants in Poland. *Journal of Food Protection* 65: 1475-1479.

Moliterno-Duarte, D. Angélica, A. Ribeiro, A. Vasconcelos, S. Barros Santos, J. Silva, P.L.A. de Andrade, and L. S. de Arruda Falcão. 2009. Occurrence of *Salmonella* spp. in broiler chicken carcasses and their susceptibility to antimicrobial agents. *Brazilian Journal of Microbiology* 40(3): 569-73.

Muth, M., M. Fahimi, S. 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 F. Tsui and J. Wilkus of Food Safety and Inspection Service by RTI International: Triangle Park, North Carolina.

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

Ollinger, M., J. Guthrie, and J. Bovay. 2014. *Pass or Fail: The Performance of Ground Beef Suppliers to the National School Lunch Program on a Food Safety Test,* ERR-180. U.S. Department of Agriculture, Economic Research Service.

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 D. Moore. 2009. The Direct and Indirect Costs of Food Safety Regulation. *Applied Economic Perspectives and Policy* 31(2): 247-265.

Ollinger, M., and V. Mueller. 2003. *Managing for Safer Food: The Economics of Sanitation and Process Controls in Meat and Poultry Plants*, AER-817. U.S. Department of Agriculture, Economic Research Service.

Orden, D., T. Josling, and D. Roberts. 2002. Product Differentiation, Sanitary Barriers, and Arbitrage in World Poultry Markets. In *Global Food Trade and Consumer Demand for Quality*, edited by Krissof, 147-164. New York, NY: Kluwer Academic/Plenum Publishers.

Plummer, R.A., S.J. Blissett, and C.R. Dodd. 1995. S*almonella* contamination of retails chicken products sold in the UK. *Journal of Food Protection* 58: 843-846.

Scallan, E., R. M. Hoekstra, F. J. Angulo, R. V. Tauxe, M. 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.

Uyttendaele, M.R., J.M. Debevere, R.M. Lips, and K.D. Neyts. 1998. Prevalence of *Salmonella* in poultry carcasses and their products in Belgium. *International Journal of Microbiology* 40:1-8.

World Trade Atlas. 2014. Online global trade information system, [accessed September 2014]. www.gtis.com/gta/usda.

