Market Forces, Plant Technology, and the Food Safety Technology Use.*

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ABSTRACT

Economists (Ollinger and Mueller, 2003; Golan et al., 2004) have considered some of the economic forces, such as demands from major customers, that encourage plants to maintain food safety process control. Other economists, such as Roberts (2005), have identified food safety technologies that enable better control harmful pathogens. However, economists have not put the two together. The purpose of this paper is to examine the impact of economic forces, including firm effects and plant technology, customer demands, and regulation, on food safety technology use. Preliminary results suggest that customer demand has the greatest impact.

Keywords: meat and poultry food safety, food safety technologies, HACCP.

Market Forces, Plant Technology, and the Use of Food Safety Processing Innovations.

Economists have developed some keen insights of some of the economic costs that firms incur for providing inadequate food safety. Thomsen and McKenzie (2001) found that firms that voluntarily recalled contaminated meat and poultry products suffered a decline in long-run profitability, i.e. significant declines in stock prices. Additionally, Thomsen, Shiptsova, and Hamm established that sales of branded frankfurter products declined more than 20 percent after a product recall, Ollinger and Mueller (2003) report anecdotal evidence of plants that had suffered recalls incurring higher liability and process control costs, a number of studies (Piggott and Marsh, 2004; Marsh, Schroeder, and Mintert, 2004) determined that adverse food safety events led to temporary declines in meat and poultry consumption, and Hudson Meats exited its the ground beef industry after it suffered a massive recall in 1998.

The threat of these economic costs either to themselves or to their customers has encouraged some firms to increase their use of food safety technologies. Researchers (Roberts, 2005; Ollinger, Moore, and Chandran, 2004; Golan, et al., 2004; Jaffee and Masakure, 2005; Henson, Brouder, and Mitullah, 2000) provide some evidence that U.S. meat and poultry firms and African fish exporters make investments in food safety in response to demands from their large domestic and international customers. However, this research offers only anecdotal evidence of demand driving food safety technology use and provides no empirical evidence of the effects of firm size and other economic factors identified by Golan et al (2004) and others. The purpose of this paper is to fill that void by empirically examining the economic forces affecting food safety technology use in the meat and poultry industry. Understanding these forces is particularly important to government regulators because it can enable them to better target their regulatory resources at those companies with less incentive to maintain food safety on their own. We identify four factors encouraging plants to use food safety technologies: firm and plant size, a plant's market size, government process regulations, and demands from restaurants and other major domestic customers and households consuming branded products. We find that customer demand has the greatest impact.

An economic framework for analyzing the economic forces encouraging food safety technology use.

Golan et al. (2004) provide an overview of why firms may adopt or use innovations (increase technology use). They remind us that Schumpeter (1942) argued that since large firms have more marketing outlets than smaller firms, they are better able to appropriate the value of their innovations if the value of the newly adopted technologies is embedded in a firm's products. Galbraith (1952) asserted that large firms have greater financial capacity to fund risky investments due to their ability to spread risks. Later, Schnooker (1962, 1966) sidestepped the technological discussion, arguing that demand conditions play a key role in innovation.

Regulations may also play a role. Segerson (1999) pointed out that the threat of regulation can induce innovation and (Ashford, 1979) asserted that firms may divert research expenditures towards uses that satisfy regulatory requirements. Firms may also take advantage of government oversight by shifting as much effort as possible to government inspectors. Anderson et al. (1994) and Booz-Allen (1977) assert that some meat and poultry plants use food safety requirements mandated by the Food Safety Inspection Service (FSIS) and FSIS inspectors as their quality control programs and inspectors.

Equation 1 is a model expressing food safety technology use as a function of firm effects, plant technology, customer demand, regulatory oversight, and other factors.

(1) $TECH\_USE = f(F, \tau, D, R, X)$

where TECH_USE equals an index of food safety technology use valued between zero and one. Food safety technologies include equipment, sanitation practices, operating procedures, and plant modifications. Index values are monotonic in that plants with a particular type of food safety equipment have a higher index value than a plant without that equipment. Similarly, a plant that cleans more intensively is rated higher than a plant that is rated lower. The index is outlined in Ollinger, Moore, and Chandran (2004). F is firm effects, τ is a vector of plant technology variables, D is a vector of demand conditions, R is a vector of regulatory performance variables, and X is a vector of other factors that must be controlled.

Schumpeter (1942) and Galbraith (1952), and many other economists explain why firm effects must be included in the model (above discussion). Plant technology plays a role since large plants can spread the costs of a new technology over much greater output than smaller plants, making new relatively fixed-cost technologies less costly per unit of output. Capital intensity may also play a role since more capital intensive operations may require more capital intensive food safety technologies.

Many large and small firms selling meat and poultry products want to be readily identified by their customers in order to facilitate sales, but, in so doing, become subject to much more intense customer scrutiny of their products, including its food safety (Ollinger and Mueller, 2003; Golan et al., 2004; and Ollinger, Moore, and Chandran, 2004). Some of these firms are meat and poultry producers but many others are major customers of meat and poultry suppliers. These large customers include McDonalds and other restaurant chains, grocery stores, and other major buyers. Often these firms impose their own food safety standards on meat and poultry suppliers. Similarly, Jaffee and Masakure (2005) and Henson, Brouder, and Mitullah (2000) demonstrate that international markets impose strict standards and Klein and Leffler (1983) assert that branded products must offer quality or their producers will lose their reputations for quality and the resulting premium price. Thus, major customers, international markets, and the sale of branded products should encourage greater food safety technology use.

The national and local media also influence meat and poultry plant food safety reputations. Chicken slaughter plants, for example, developed and installed counter-current scalders, bird washes, chlorine rinses and other pathogen-reducing technologies after the television show 60 *Minutes* highlighted the risks of *Salmonella* contamination in chicken (Waldroup et al., 1992).

Incentives for plants serving local markets may differ from those serving national markets. Managers of plants serving local markets come into direct contact with customers, giving them a substantial depth of knowledge about local market conditions. They take advantage of this knowledge to craft products that meet particular needs. These managers also, often, directly oversee their operations. Together, these factors may lead to lower food safety technology use because (1) food safety technologies address a smaller market, discouraging investment by equipment suppliers, and (2) direct oversight of production may lead plant managers to believe that they have less of a need for food safety technologies.

Segerson (above) gives a rationale for why *Salmonella* performance standards may encourage managers to raise their levels of food safety technology use. First, note that the *Salmonella* standard is a performance standard since it (1) establishes a tolerance in terms of a *Salmonella* level that plants must meet, and (2) allows plants to use whatever means they feel is necessary to reach that *Salmonella* tolerance. Now, following Segerson, recognize that plants could make food safety investments in anticipation of *Salmonella* testing in order to avoid any penalties and production downtime.

FSIS did not mandate the use of any equipment under PR/HACCP, arguing that maintenance of SSOPs and HACCP plans was sufficient to maintain food safety process control. However, if a plant does make greater use of food safety technologies, then it could reduce its effort devoted to performing SSOPs and HACCP tasks, suggesting that food safety technology should decline with greater effort devoted to compliance with food safety tasks.

A number of other factors may also affect food safety technology use. Plants that primarily produce raw products but also make cooked meats as secondary products may have less need to control pathogens than plants producing only raw meat or poultry products. The reverse would be true for plants primarily producing cooked products that process raw products as a secondary activity. Additionally, since producers of ground meat products typically combine meat inputs from several sources and only one of these inputs needs to be contaminated with pathogens for the whole batch to be affected after mixing, ground meat processors have an incentive to make greater use of food safety technologies.

Specialization may also play a role in adopting innovative food safety technologies. Plants that slaughter different types of animals use more general technologies that are flexible enough to accommodate different animal sizes, shapes, and skins. These general technologies require more manual labor and lower throughputs, making them less amenable to some innovative food safety technologies and leading to lower food safety technology use.

Empirical Model

The dependent variable (TECH_USE) is a continuous variable, making Ordinary Least Squares (OLS) appear to be an appropriate regression technique. However, the range of the dependent variable is restricted to be between zero and one, which causes OLS to break down. A more appropriate regression approach is an interval regression since it allows for a continuous, censored dependent variable between two truncated ends, i.e. one and zero in this case. Using this interval (double censored) regression technique (see Greene for a discussion), we specify an empirical model that follows from equation 1:

$$(2) \qquad TECH\_USE_i = \beta_0 + \beta_1 MULTI_i + \beta_2 SALES_i + \beta_3 CAP\_LABOR_i + \beta_4 CUSTOMER\_DEMAND_i + \beta_5 EXPORT_i + \beta_6 BRANDS_i + \beta_7 LOCAL_i + \beta_8 SSOP\_0\_NCPLY_i + \beta_9 HACCP\_NCPLY_i + \beta_{10} TEST\_9800_i + \beta_{11} COOK\_MEAT_i + \beta_{12} RAW\_MEAT_i + \beta_{13} GROUND_i + \beta_{14} INPUT\_SPECIAL_i + \beta_{15} OUTPUT\_SPECIAL_i + \xi_i$$

where TECH_USE has been defined above; the other variables follow from equation (1).

There is one firm effects variable and two plant technology variables. MULTI is a firm effects variable equal to one if the plant is part of a multi-plant firm and zero otherwise. SALES equals plant sales. CAP_LABOR is the value of machinery and buildings from Census files. If larger, more capital intensive plants make greater use of food safety technologies, then the signs on the parameters of these variables should be positive.

The vector of demand variables (D) includes CUSTOMER_DEMAND, EXPORT, and BRANDS. They deal with customer requirements, exports, and whether the plant sells branded products. CUSTOMER_DEMAND equals one if the plant's customers had contract requirements that were stricter than those imposed by FSIS and zero otherwise. EXPORT is one if the plant exports products and zero otherwise. BRANDS is one if the plant produced branded products and zero otherwise. If demand for food safety from large domestic customers, export markets, and users of branded products encourage the use of food safety technologies, then signs on the parameters of these variables should be positive.

LOCAL represents the size of a plant's market and equals one if the plant sells only in the states adjacent to the state of its domicile and zero otherwise. Since food safety technologies for more specialized equipment may be more costly than equipment for larger, national markets and managers more closely monitor food safety operations, there should be less need for a high level of food safety technology use, implying a negative sign for LOCAL.

The vector R contains regulation variables that are based on performance and process standards. The variable capturing the effect of the performance standards is TEST_9800. This variable equals one if the plant was subject to *Salmonella* testing prior to 2000 and zero otherwise. Following Segerson, if plants subjected to testing improved their food safety technology to pass FSIS testing requirements or do not anticipate ever being tested, then TEST_9800 should be positive.

Note that plants not tested for *Salmonella* by 2000 would likely be rarely selected in the future and may never be subjected to testing. Selection for testing under the *Salmonella* standard depends on a plant's volume of production and not on whether it was previously tested. It is just at likely that a plant will be selected for testing if it completed testing one month earlier as it is if it completed testing 3 years earlier. It is also much more likely that a large plant rather than a small plant will undergo testing since selection is based on production volume. Thus, not all eligible plants are tested each year and some plants may never be tested since plants are selected randomly and selections are weighted by their production volume. See Ollinger and Mueller (2003) for details.

A well designed regulatory system that is faithfully implemented should minimize food safety process control lapses. The model contains two variables representing regulatory process controls: SSOP_0_NCPLY, which equals one if the plant had completed all of the tasks required by its Standard Sanitation Operating Procedures and zero otherwise, and HACCP_NCPLY, which is the number of required HACCP tasks out of compliance as a share of all HACCP tasks. Since plants that more faithfully perform regulatory tasks will have no or very few SSOPs or HACCP tasks out of compliance with standards and these plants may have less of a need for greater food safety technology use, the sign on SSOP_0_NCPLY should be negative and the sign on HACCP_NCPLY should be positive.

The vector X contains several plant scope variables. COOK_MEAT is one if a plant that slaughters animals or uses raw meat inputs produces cooked meat products and zero otherwise. RAW_MEAT is one if a plant that produces cooked products also produces raw meat products. GROUND is one if the plant produced ground meat products and zero otherwise. INPUT_SPECIAL is the number of animals that are slaughtered for use in the primary business of the plant divided by all of the animals slaughtered by the plant (e.g. cattle as a share of cattle, hogs, and other animals slaughtered by a cattle slaughter plant). OUTPUT_SPECIAL is the total value of shipments coming from the primary 5-digit SIC code business of the plant as a share of total value of shipments coming from all business of the plant.

Data: three linked data sets.

Data are a matched dataset that includes data from a survey conducted by the Economic Research Service in 2001 on the costs of the PR/HACCP rule and food safety technology, the

Enhanced Facilities Database (EFD) of FSIS for 2000, and the Longitudinal Research Database (LRD) from the Bureau of the Census.

The survey of meat and poultry slaughter and processing plants queried plant operators about the costs they attribute to food safety process controls since 1996. These costs included all costs due to compliance with the PR/HACCP rule of 1996. The survey also asked operators about their plant's food safety process control technologies. Ollinger, Moore, and Chandran (2004) summarize the responses to the survey provides the actual questions and a tabulation of responses.

The survey garnered responses from about 1,000 of the 1,720 plants in the registry of plants regulated by the Food Safety Inspection Service (FSIS) and considered to be manufacturers. FSIS regulates all establishments, including retail stores, restaurants, and manufacturing facilities, that process meat or poultry and ship products across state lines and many plants that ship strictly within state borders. The 1,720 plants selected as manufacturers and subsequently sent questionnaires include all plants slaughter plants and all other plants that produce meat or poultry and are designated as manufacturers, i.e. were assigned to SIC 2011, 2013, or 2015, and have sales exceeding $7.0 million per year or production greater than 1.0 million pounds.

The ERS data include only plants from the EFD that responded to the survey and are not nationally representative, so it may not be valid to generalize results. However, several reasons lead us to believe that the bias is small. First, the final dataset has a large number of plants, including 252 of the 407 federally inspected cattle and hog slaughter plants, 122 of the 236 federally inspected poultry slaughter plants, and 622 federally inspected cooked and raw meat processors with no slaughter operations. Second, the share of total output closely tracks the share of plants responding to the survey. Third, a regression analysis by the authors suggests that no correlation exists between plant size and survey response.

To account for remaining biases in the data, we treated it with a post-stratification adjustment (Gelman and Carlin, 2002). Under this approach, the regression is adjusted with a response weight equal to the reciprocal of the share of plants responding to the survey.

The ERS data include approximately 10 questions dealing strictly with costs and benefits of HACCP regulation, 35 on food safety technologies and practices, and 15 miscellaneous questions about plant and firm characteristics. The 35 technology questions were based on five types of food safety technologies and practices: (1) food safety equipment, such as heat treating equipment, (2) plant equipment, such as the use of positive air ventilation to prevent pathogen dispersal in the air to finished product areas, (3) cleaning and sanitation frequency and type, (4) food safety operating procedures and training, and (5) hide-removal practices (cattle slaughter only). Ollinger, Moore, and Chandran (2004) create an index for the overall technology and the technology associated with each of the five types of food safety technologies. For each index, one equals the most rigorous technology and zero is the least rigorous. We use only the overall technology index in this paper.

The EFD has data on plant production and animal inputs and covers about 9,000 manufacturing and other establishments monitored by FSIS and state food safety agencies. These establishments include all meat and poultry manufacturing plants and other establishments that process meat or poultry as a minor business, e.g. some grocery stores. The EFD provides very little production data for plants monitored by state agencies but data for plants inspected by FSIS include counts of the number of slaughtered animals, estimated sales and employment, types of processing operations (e.g. animal carcasses or ready-to-eat products), and some other data on establishment characteristics.

The LRD includes information on all meat and poultry manufacturers from its survey of Manufacturers taken at five year intervals. The most recent survey was taken in 2002. The LRD also has data on a subset of larger plants and a sampling of smaller plants for the inter-Census years. Data in the LRD are highly detailed plant-level cost and production data. Data include value of shipments, number of workers, production hours, wages, end of period value of buildings, end of period value of machinery, etc.

It is inevitable that some plants cannot be linked across data sets due to missing observations. It is also necessary to delete observations that do not include all of the necessary data. After deleting these observations, the data used for the analysis included 170 of 261 cattle slaughter, 166 of 301 hog slaughter, and 129 of 238 poultry slaughter plants noted by Census and 623 cooked and raw meat processors with no slaughter operations. Sales of these plants as shares of their industries are proportional to the share of plants responding to survey and regressions showed no relation between missing variables and plant size and other variables. Nonetheless, plants were not randomly selected, so the data may not be representative.

RESULTS

The linkage between plant size and customer requirements and food safety technology intensity.

Tables 1 and 2, taken from Ollinger, Moore, and Chandran (2004), show how food safety technology use varies by plant size and customer demands. Notice that the overall technology index and most of the five specific technology indexes are much higher for large plants and plants subject to customer, international, and branding demands in five meat and poultry slaughter and processing industries. Note, the specific technology indexes for major customer, international, and brand demands are available at http://www.ers.usda.gov/Publications/TB1911//.

The evidence provided in tables 1 and 2 are compelling but there is considerable uncertainty as to the true impact of plant size and customer demands. For example, a large plant may also have extensive customer demands, export products, sell branded goods, and have other factors that may affect their use of more sophisticated food safety technology. Thus, we turn to regression analysis to evaluate the roles of plant technology and market forces on food safety technology use.

Marginal Effects of the impact of economic forces on food safety technology use.

Marginal effects are reported in table 3. The chi-square statistic is highly significant in all cases. Preliminary results indicate that firm effects and plant size – MULTI and SALES -- are positive in 9 of 10 cases but significant in only 4, suggesting modest firm and plant size effects. There is no relation between capital intensity and food safety technology use. Demand characteristics have a much stronger impact on food safety technology sue than firm effects and plant technology. CUSTOMER_DEMAND, EXPORT, and BRANDS are positive in 14 of 15 cases and significant in 11 of those cases. Additionally, LOCAL is negative in all cases and significant in two of those.

Food safety performance regulations, i.e. the *Salmonella* standard -- as captured by TEST_9800 – neither encouraged nor discouraged plants to increase food safety technology use.

However, compliance with process regulations, as measured by SSOP_0_NCPLY and HACCP_NCPLY, did have a modestly negative impact on the use of more sophisticated food safety technology. Recall that SSOP_0_NCPLY should be negative and HACCP_NCPLY should be positive if compliance with process regulations discourages the use of food safety technologies. Seven of ten results are consistent with these expectations but only three are significant.

Now consider the impact of a 10 percent change in some of the independent variables. The formula for making the estimate is 0.10*β*(MEAN of independent variable)/ (MEAN of TECH_USE). The mean values are given in table 4. Note that the he mean values of the dummy variables (table 4) equal the means of all of the one and zero responses.

Table 5 shows that being a local plant has the biggest individual parameter impact on cattle slaughter and cooked/other processed meat plants, SALES (plant size) has the largest impact on hog and chicken slaughter plants, and export markets have the greatest influence on raw meat processors. To see which types (firm/plant effects, demand, local markets, and regulation) of independent variables have the greatest impact on technology use, we added up all of the individual contributing factors to arrive at a "collective effect". For example, the "collective effect" for demand factors is the parameter value for customer demands plus the parameter for exports plus the parameter for brands. Demand has, by far, the biggest impact on technology use in cattle and hog slaughter and cooked/other processed meats and raw meat products. Firm and plant size effects have the greatest influence in chicken slaughter.

Results provide no evidence that the *Salmonella* standard affects technology use. This does not mean that plants did not install new equipment or take other measures to improve food safety technology if they were subjected to the *Salmonella* test. Rather, it means that the plants most likely to undergo *Salmonella* testing added little or no more equipment than plants that had not been subject to it.

There is some support for the view that plants substitute effort devoted to compliance with regulatory process standards, such as SSOPs and HACCP tasks, for greater food safety technology use. This makes sense since a firm seeking a level of food safety could either (1) perform exceptional levels of cleaning with little or no technology, (2) high technology use but low levels of task performance, or (3) medium numbers of tasks and some technology use.

Concluding Comments

This paper examined the impact of firm effects and plant size, demand factors, and regulation on food safety technology use. The results indicate that demand factors have a much larger impact on encouraging greater food safety technology use in four industries – cattle and hog slaughter and cooked and other processed and raw meat processed products. Firm effects and plant size had the greatest impact in the chicken slaughter industry. Additionally, we found that larger markets encourage the use of food safety technology and better performance of regulatory tasks discourages food safety technology use. However, our measure of performance regulation under the *Salmonella* standard indicates that it had no effect on technology use.

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Table 1—Large meat and poultry plants have higher overall and specific technology index values [1]

	Size percentile		All plants
	0-19	80-99	
	Technology index		
Cattle slaughter			
Overall tech/methods	0.43	0.62	0.50
Equipment	0.32	0.55	0.39
Testing	0.34	0.75	0.51
Dehiding	0.26	0.45	0.36
Sanitation	0.51	0.59	0.56
Operations	0.59	0.70	0.62
Number of plants	48	49	255
Hog slaughter			
Overall tech/methods	0.42	0.57	0.49
Equipment	0.35	0.46	0.38
Testing	0.27	0.70	0.49
Sanitation	0.50	0.55	0.55
Operations	0.58	0.62	0.60
Number of plants	42	47	210
Poultry slaughter			
Overall tech/methods	0.50	0.67	0.61
Equipment	0.48	0.74	0.65
Testing	0.38	0.75	0.65
Sanitation	0.54	0.55	0.55
Operations	0.59	0.63	0.61
Number of plants[3]	26	27	148
Cooked meat processing, no slaughter			
Overall tech/methods	0.53	0.64	0.57
Equipment	0.46	0.64	0.55
Testing	0.46	0.74	0.51
Sanitation	0.55	0.55	0.61
Operations	0.61	0.69	0.62
Number of plants	68	73	368
Raw meat processing, no slaughter			
Overall tech/methods	0.52	0.64	0.55
Equipment	0.51	0.66	0.55
Testing	0.36	0.75	0.55
Sanitation	0.51	0.51	0.51
Operations	0.61	0.68	0.63
Number of plants[3]	65	58	327

[1] Index values derived from Q19-65 in an ERS food safety meat survey and Q20-62 in the ERS food safety poultry survey. See Ollinger, Moore, and Chandran (2004) to for a description of the index. Intermediate percentiles not included because they follow a trend from the smallest to largest plants. The surveys are available at http://www.ers.usda.gov/Data/haccpsurvey/.

[2] Twenty-four poultry plants have missing rank data.

[3] Two raw meat processing plants have missing rank data.

Source: ERS.

Table 2—Technology indexes for meat and poultry plants subject to customer, export, and brand demands. [1]

Process control method	-------------------------Demand type------------------					
	Customer food safety requirements		Export Market		Product sold under plant's own brand[2]	
	No	Yes	No	Yes	No	Yes
Cattle slaughter						
Technology Index	0.43	0.63	0.43	0.64	0.52	0.50
Number of plants[3]	128	98	169	84	43	210
Hog slaughter						
Technology Index	0.44	0.60	0.44	0.59	0.44	0.50
Number of plants[4]	106	66	138	68	25	180
Poultry slaughter						
Technology Index	0.55	0.64	0.49	0.64	0.59	0.62
Number of plants[5]	29	65	16	94	12	99
Cooked meat processing, no slaughter						
Technology Index	0.51	0.64	0.53	0.63	0.55	0.57
Number of plants	202	166	230	138	12	356
Raw meat processing, No slaughter						
Technology Index	0.49	0.62	0.52	0.61	0.56	0.55
Number of plants	179	148	215	112	30	297

[1] Index values derived from Q19-65 in an ERS food safety meat survey and Q20-62 in the ERS food safety poultry survey. See Ollinger, Moore, and Chandran (2004) to for a description of the index. Intermediate percentiles not included because they follow a trend from the smallest to largest plants. The surveys are available at http://www.ers.usda.gov/Data/haccpsurvey/.
[2] Products may or may not be sold to consumers. Selling a product under one's own name could be shipping a labeled product to further processor that repackages the meat or poultry under its own name and resells it.
[3] Twenty-nine plants did not indicate customer requirements; 2 plants did not indicate exports; 2 plants did not indicate products under own brand.
[4] Thirty-eight plants did not indicate customer requirements; 4 plants did not indicate exports; 5 plants did not indicate products under own brand.
[5] Fifty-four plants did not indicate customer requirements; 38 plants do not indicate exports; 37 plants did not indicate products under own brand.
Source: ERS.

Table 3: The marginal effects of plant and firm characteristics, customer types, and food safety regulation on technology use in the meat and poultry industries.

Variable	--------------Slaughter-------------			--------Processing------	
	Cattle	Hog	Chicken	Cooked/Other	Raw
MULTI	0.039 (1.07)	0.009 (0.25)	0.069** (2.25)	0.036** (1.97)	0.002 (0.01)
SALES	0.026+ (1.59)	0.049+ (1.39)	0.026 (0.68)	-0.101** (-2.46)	0.014 (0.28)
CAP_LABOR	-0.001 (-0.78)	-0.0002 (-0.26)	0.001+ (1.52)	0.0003 (0.73)	-0.001+ (-1.25)
CUSTOMER_DEMAND	0.098*** (3.04)	0.099*** (3.48)	0.018 (0.75)	0.088*** (4.57)	0.027+ (1.34)
EXPORT	0.104*** (2.95)	0.085** (2.35)	0.028 (0.72)	0.041** (2.19)	0.147*** (5.15)
BRANDS	0.046* (1.75)	0.050** (2.12)	-0.017 (-0.62)	0.026 (1.13)	0.024 (0.99)
LOCAL	-0.064** (-1.97)	-0.015 (-0.47)	-0.019 (-0.80)	-0.077*** (-4.10)	-0.01 (-0.76)
TEST_9800	0.037+ (1.58)	0.001 (0.04)	0.010 (0.22)	-0.007 (-0.19)	-0.030+ (1.24)
SSOP_0_NCPLY	-0.037 (-1.16)	-0.033 (-0.98)	-0.088 (-1.01)	0.005 (0.22)	-0.068*** (-2.12)
HACCP_NCPLY	0.461 (1.08)	0.830+ (1.55)	0.375+ (1.43)	-0.015 (-0.38)	-0.199* (-1.87)
COOK_MEAT	-0.005 (-0.57)	0.008+ (1.39)	0.035 (0.98)	-	-0.003 (-0.14)
RAW_MEAT	-	-	-	0.003* (0.34)	-
INPUT_SPECIAL[1] (e.g. Share cattle)	-0.038 (-1.15)	-0.054+ (-1.60)	0.011 (0.24)	-	-
OUTPUT_SPECIAL	0.0001 (0.24)	0.001** (1.98)	-0.001+ (-1.29)	-0.001 (-1.16)	0.001 (1.10)
GROUND	-0.019 (-0.81)	-0.032+ (-1.35)	-0.025 (-0.89)	-0.025+ (-1.41)	0.012 (0.73)
Chi Square	312***	129***	37.4***	147.2***	105.4***
Observations	170	166	129	352	271

+, *, **, *** significant at 20, 10, 5, and 1 percent levels
Dependent variable: an index of the intensity of plant food safety technology use. One is highest rating and zero is the least. See Ollinger, Moore, and Chandran (2004) for a description.
[1]INPUT_SPECIAL is cattle inputs as a share of all animal inputs for cattle slaughter, hog inputs as a share of all animal inputs for hogs, and chicken inputs as a share of all bird inputs.

Table 4: The Mean Values of Selected Variables

	-----------------Slaughter---------------			--------Processing------	
Variables	Cattle	Hog	Chicken	Cooked/Other	Raw
Dependent variable:					
TECH_USE	0.50	0.48	0.61	0.56	0.55
Independent Variables:					
MULTI	0.11	0.18	0.70	0.31	0.24
Sales (in millions)	81.8	97.6	200.2	56.0	44.0
CUSTOMER_DEMAND	0.35	0.29	0.57	0.47	0.45
EXPORT	0.31	0.29	0.83	0.39	0.37
BRANDS	0.87	0.89	0.90	0.89	0.87
LOCAL	0.72	0.68	0.30	0.57	0.58
TEST_9800	0.66	0.62	0.83	0.12	0.26
SSOP_0_NCPLY	0.18	0.17	0.036	0.16	0.16
HACCP_NCPLY	0.01	0.009	0.057	0.008	0.008
COOK_MEAT	0.45	0.58	0.13	1.00	0.68
RAW_MEAT	0.98	0.99	1.00	0.70	1.00
INPUT_SPECIAL[1]	0.50	0.69	0.89	-	-
GROUND	0.59	0.58	0.21	0.39	0.45

[1] cattle as a share of all animals, hogs as a share of all animals, and chickens as a share of all animals for the cattle, hog, and chicken slaughter industries respectively.

Table 5: Percent Changes in technology index with 10 percent changes in selected variables.

	----------------Slaughter--------------			--------Processing------	
Variables	Cattle	Hog	Chicken	Cooked/Other	Raw
Firm Effects and Plant Size					
MULTI	0.086	0.034	0.79	0.20	0.009
Sales	0.425	0.99	0.853	-0.912	0.112
Total Firm and Plant Size	**0.511**	**1.024**	**1.643**	**-0.712**	**0.121**
Demand					
CUSTOMER_DEMAND	0.68	0.60	0.17	0.74	0.23
EXPORT	0.64	0.59	0.38	0.16	1.00
BRANDS	0.80	0.92	-0.25	0.41	0.38
Total Demand	**2.12**	**2.11**	**0.55**	**1.31**	**1.61**
Market Size					
LOCAL	-0.92	-0.21	-0.09	-0.78	-0.11
Total Market Size	**-0.92**	**-0.21**	**-0.09**	**-0.78**	**-0.11**
***Salmonella* Standard**					
TEST_9800	0.49	0.13	0.14	-0.015	-0.14
Total *Salmonella* Standard	**0.49**	**0.13**	**0.14**	**-0.015**	**-0.14**
Regulatory Tasks					
SSOP_0_NCPLY (used a 10% drop since declines raise technology index)	0.13	0.12	0.052	-0.014	0.20
HACCP_NCPLY	0.092	0.16	0.35	-0.0021	-0.029
Total Regulatory Tasks	**0.22**	**0.28**	**0.402**	**-0.0161**	**0.171**