Chapter 6

Relationship Between the Performance of SPCP and HACCP Tasks

Chapters 4 and 5 provide some evidence that food safety process control is costly, yet necessary for plant survival. While these findings are important, we need to know whether performance under the Wholesome Meat Act (WMA) and Wholesome Poultry Products Act (WPPA) is still applicable to performance under the Pathogen Reduction Hazard Analysis and Critical Control Point (PR/HACCP) rule in order to see whether relationships developed in the earlier analyses are applicable to current regulatory practices. In this chapter, we examined the statistical relationship between food safety process control performance under WMA and WPPA in 1992 to that which occurred under PR/HACCP in 1998. We use these 2 years because these and other necessary data are available and they represent pre- and post-PR/HACCP years.

Table 6.1 illustrates the relationship between plant performance of SPCPs and plant performance of HACCP tasks. The top row shows the percentile difference between a plant's SPCP performance rank relative to its HACCP task performance rank.[1] The first cell shows that 28 percent of all meat slaughter plants had a change in rank of less than 10 percentile in performance when the PR/HACCP rule supplanted SPCPs. To fall into this category, a plant in the 30th percentile of sanitation and process control tasks would have to fall within the 20-40th percentile of performance of HACCP tasks. Similarly, a plant in the second cell with a 30th percentile ranking for SPCPs would fall in the 10-20th or 40-50th percentile category under PR/HACCP, and a plant in the third cell with a 20th percentile ranking for SPCPs would fall in the 0-10th or 50-60th percentile under PR/HACCP. Notice that about one-half the plants realized a change of less than 20 percent in their relative performance ranking under PR/HACCP from their performance under SPCPs and that about two-thirds of plants fell within 30 percent of their former ranking.

Economic Framework

The PR/HACCP rule went beyond the regulatory framework based on the WMA/WPPA by mandating that all meat and poultry slaughter and processing plants establish a HACCP process control plan and perform the associated tasks while continuing to perform sanitation and process control tasks. As discussed in chapter 3, each plant's HACCP plan has to include critical control points, a plan of action to control those critical control points, criteria for when a process is out of compliance, and recordkeeping to gauge operating performance and prove that the plant performed specified tasks.

The PR/HACCP rule dealt only with food safety issues and increased the number of the types of tasks that inspectors monitored beyond those required under WMA/WPPA, but did not fundamentally change the nature of the public health tasks. For example, each plant has at least one critical control point (CCP) under PR/HACCP and, similarly, had to comply with process control requirements under WMA/WPPA. FSIS inspectors do monitor CCPs in order to verify that the plant completed all tasks outlined in the HACCP plan, but also monitored performance of process control tasks. Additionally, it is true that failure to comply with the HACCP plan could prompt the FSIS inspector to discuss the failure with top management, assign the equivalent of a deficiency to the plant

[1] HACCP performance is defined as HACCP tasks that are in noncompliance divided by the total performed HACCP tasks. Under PR/HACCP, inspectors can mark a task as unperformed because: (1) the plant failed to perform a necessary HACCP task, (2) the plant was producing a product that did not require the operation, or (3) the inspector had more pressing duties and did not examine the task. To avoid counting unperformed tasks that were unnecessary, we considered only tasks that were in noncompliance (these tasks are necessary but were not performed correctly) and only those tasks that were actually performed. For the denominator, we also used performed scheduled tasks and unscheduled task. Results with this measure were similar. To compute the difference in the percentile ranking from WMA/WPPA to PR/HACCP, we first ranked SPCP and HACCP performance of all plants. Next, we computed the absolute value of the change.

by assigning a noncompliance record, and, if the problem persisted, motivate a temporary withdrawal of inspection services. However, those same enforcement tools were available under WMA/WPPA. Finally, the PR/HACCP rule did require plants to take responsibility for their HACCP process control programs, but plants have always paid a price for producing off-quality products. Under either regulatory approach, a failure to meet customer demands for food safety leads to lost revenues and profits. Thus, taking responsibility for a HACCP program would likely have little effect on plant performance in the marketplace.[2]

Plants respond to market and regulatory incentives to provide process control. Plants with poorly performing process control programs may sell products in markets that require less process control effort, while plants with more stringent process controls may sell products in markets that demand more process control effort.

The PR/HACCP rule was prompted by a public outcry over reports of foodborne illnesses and, as recognized in the 1996 *Federal Register* announcement for PR/HACCP, many plants were moving independently to adopt HACCP programs. Combined, this apparent shift in consumer demand for food safety process control and the need of plants to deliver the same relative quality control effort to their customers lead us to hypothesize that plants that performed well under the WMA/WPPA should, likewise, have a superior performance under PR/HACCP. If a plant exceeded minimum compliance under WMA/WPPA, then it would be more likely to meet or exceed minimum compliance requirements under the PR/HACCP rule. Conversely, if a plant just barely met compliance under WMA/WPPA, then it would likely just barely meet minimum compliance under PR/HACCP.

Model Linking HACCP Compliance to SPCP Compliance

We hypothesize that, since meat and poultry plants did not change their product market after FSIS implemented the PR/HACCP rule, SPCP performance should be correlated with HACCP performance. In the model below, we regress percent-deficient SPCPs and vectors of plant technology, plant product market, and company-effect variables on percent HACCP noncompliance records:

$$H = f(D, T_k, M_i, C_j), \qquad (6.1)$$

where H is HACCP noncompliance records as a share of all performed HACCP tasks relative to the industry mean value, D is percent-deficient SPCPs relative to the industry mean value, T_k is a vector of plant technology variables, M_i is a vector of markets served by the plant, and C_j is a vector of company effects variables.

It is necessary to examine plant technology effects because plant size, plant age, and other attributes related to plant technology likely affect the ability to perform HACCP tasks. For example, larger plants may be more difficult to manage and older plants more difficult to clean because they were not designed to conform to modern slaughter and processing plant technology. Additionally, product markets establish acceptable food safety standards to which suppliers must adhere to win sales. For example, meat purchased for cooking may have a lower food safety standard than ready-to-cook products for consumers. Finally, we consider company effects because companies often have company policies that affect manufacturing processes and product quality.

The dependent variable, H, is an index bounded below by zero, denoting plants for which inspectors report no HACCP noncompliance records, and bounded above by one, reflecting plants for which inspectors report only HACCP noncompliance records. Statisticians call bounded distributions such as these censored data. In our case, H has a normal distribution centered around and truncated at zero. If the distribution is not truncated, some values would be less than zero. In theory, negative values have implications in that they include plants that undertake quality control measures beyond those required by FSIS (they overcomply with HACCP standards).

Tobin (1958) was the first to consider regressions with censored dependent variables. He specified a dependent variable with a distribution centered at zero that contained a theoretically possible latent variable (y*). Greene (1993) gives the following general formulation of the censored regression model, also known as the Tobit model:

$$\begin{aligned} y_i^* &= \beta' x_i + \varepsilon_i \\ y_i &= 0 \text{ if } y_i^* \leq 0 \\ y_i &> 0 \text{ if } y_i^* > 0. \end{aligned} \qquad (6.2)$$

[2] FSIS inspectors also monitor nonfood safety regulatory requirements. These requirements did not change under the PR/HACCP rule.

Applying equation 6.2 to 6.1, the distribution for y_i* is the percent HACCP noncompliance records. Theoretically, this distribution contains both positive (HACCP noncompliance records) and negative (performed HACCP-like tasks) values. HACCP-like tasks include tasks that may not be required under the PR/HACCP rule but are performed by the company because they are deemed to be necessary. A positive coefficient on an independent variable means that the variable positively affects compliance with HACCP tasks or discourages a more extensive quality control program. Negative signs mean that the independent variable encourages quality control programs beyond what is required under PR/HACCP.

Marginal effects for this theoretical distribution, a normal distribution, are written as in equation 6.3 and indicate how much changes in the independent variable affect failure to perform HACCP and HACCP-like tasks:

$$\partial E[y_i^* | x_i] / \partial x_i = \beta. \qquad (6.3)$$

The marginal effect of adhering to HACCP standards requires a slightly different specification than equation 6.3 because HACCP tasks occur only in the positive portion of the distribution. A positive coefficient on an independent variable means that the variable positively affects performance of HACCP tasks, i.e., discourages a plant from complying with HACCP regulation and vice versa for negative signs. The coefficient indicates how great the change is. Greene's (1993) derivation of the marginal effects follows:

$$E[y_i | x_i] = \Phi(\beta' x_i / \sigma)(\beta' x_i + \sigma\lambda_i), \qquad (6.4)$$

where

$$\lambda_i = \phi(\beta' x_i / \sigma) / \Phi(\beta' x_i / \sigma), \qquad (6.5)$$

and the marginal effect of the independent variables on y_i is:

$$\partial E[y_i | x_i] / \partial x_i = \beta\Phi(\beta' x_i / \sigma). \qquad (6.6)$$

Note, σ is the standard deviation, ϕ is the probability density function of the standard normal distribution, and Φ is the cumulative density function of the standard normal distribution.

The empirical representation of equation 6.2 is based on equation 6.1, where x_i equals a group of variables including D (percent-deficient SPCPs), T_k (technology variables in addition to percent-deficient SPCPs), M_i (markets served), and C_j (company effects) is:

$$H_i = \alpha_0 + \beta_1 D_i + \sum_{m=1}^{n} \varphi_{m,i} T_{m,i} + \sum_{k=1}^{p} \gamma_{k,i} C_{k,i} + \sum_{j=1}^{n} \delta_{j,i} M_{j,i} + \varepsilon_i, \qquad (6.7)$$

where

H_i (share of HACCP noncompliance records) $= 0$, if $H_i^* \le 0$,

H_i (share of HACCP noncompliance records) > 0, if $H_i^* > 0$.

Note that the mean of H_i*, a theoretically normally distributed dependent variable, is less than the mean of H_i because H_i cannot be less than zero. Plants that fall in the negative portion of the distribution for H_i* are plants that believe that the market they serve demands more quality control effort than required under PR/HACCP.

Variable Definitions and Data

H_i, the observed dependent variable, is defined as noncompliance records (HACCP tasks inspected and determined to be not in compliance by the FSIS inspector) as a percentage of all performed HACCP tasks divided by the mean percentage of HACCP noncompliance records. We divided by the industry mean to control for differences in scales between percentage of HACCP noncompliance records and percent-deficient SPCPs.

The variable D (equation 6.1) is denoted as DEFICIENCY in table 6.2 and is defined as the percent-deficient SPCPs divided by the mean percent-deficient SPCPs. As with HACCP noncompliance records, we divide by the mean percent-deficient SPCPs to control for scale effects. Plants with lower percent-deficient SPCPs devote more effort to SPCPs and plants with higher percent-deficient SPCPs expend less effort. We hypothesize that less effort devoted to SPCPs should mean less effort under PR/HACCP (higher percentage of HACCP noncompliance records). Statistically, we expect a positive relationship.

The technology variables include the log of plant sales (OUTPUT), the log of plant age (PLANTAGE), a dummy variable (PROCESSES) set at one for slaughter plants that also have further-processing operations and set at zero otherwise, and slaughter meat output divided by plant sales (SHSLAUTER). PLANTAGE is defined as 2000 minus the year in which FSIS awarded a meat or poultry grant to the plant.[3]

Larger plants, plants with more than one process, and plants that slaughter animals have more complex operations than other plants. Williamson (1985) argues that this complexity can lead to bureaucratic breakdowns. Thus, we posit that plant size (OUTPUT), number of plant processes (PROCESSES), and share of slaughter (SHSLAUTER) positively affect the percentage of HACCP noncompliance records.

Older plants may have older equipment and facilities not designed to be compatible with modern cleanliness standards. These plants may require a greater level of maintenance and other servicing than younger plants, resulting in a greater likelihood of not performing some tasks, so PLANTAGE should positively affect the percentage of HACCP noncompliance records. However, Dunn et al. (1988) suggest that young plants have higher exit rates than older plants because they underestimate the capital requirements needed to compete in industries. This inexperience could lead to an increase in the percentage of HACCP noncompliance records. Thus, we cannot, *a priori*, project the proper sign for plant age.

We designate market effects variables (M) for both slaughter and processing industries. These variables serve as control variables because different markets likely have different food safety process control needs and thus different performance ratings. For each slaughter plant, market variables are set to one if the plant slaughters the animal and are set to zero otherwise. In particular, we assign a one to BEEF if the plant slaughters cattle and assign a zero to it if it does not. Similarly, we set PORK to one if the plant slaughters hogs and set it to zero if it does not slaughter hogs. We use this same convention for chicken slaughter with the dummy variable CHICKEN and for turkey slaughter with the dummy variable TURKEY. Additionally, we assign a one to OTHER if the plant slaughters goats and other noncattle and nonhog hoofed animals and assign a zero to it if it does not. Finally, we set GROUND at one for slaughter plants that also grind meat and set it to zero otherwise.

For meat-processing plants, the vector M includes several variables representing different markets. If a plant produced fully cooked, not shelf-stable products, such as bologna, then we set FULCUKNSS to one and set it to zero otherwise. Similarly, we designated HETTRETNSS as one if the plant produced heat-treated, not shelf-stable products, such as chicken nuggets, and designated it as zero otherwise. Likewise, we set SECINHNSS to one if the plant produced not shelf-stable products with secondary inhibitors, such as bacon, and set it as zero otherwise. Additionally, we denoted NOHETTRETSS as one if the plant produced shelf-stable, not heat-treated products, such as pepperoni, and denoted it as zero otherwise. Finally, we set HETTRETSS to one if the plant produced heat-treated, shelf-stable products, such as beef jerky.

[3] U.S. law requires meat and poultry plants to have grants (licenses) to sell meat or poultry in interstate commerce.

The vector of company effects (C) includes a dummy variable set at one for plants owned by firms with more than one meat or poultry plant and set at zero otherwise (MULTFOOD). Another company effects variable is set at one for plants owned by firms with more than one plant in that plant's four-digit SIC code industry and set at zero otherwise (MULTIND).

Data on HACCP noncompliance records and performed HACCP tasks came from a 1998 FSIS dataset obtained in a personal communication with an FSIS representative. Since the very small plants had not yet changed to HACCP by 1998, these data do not include plants with fewer than five employees or less than $2.5 million in revenues. The percent-deficiency data are the 1992 data obtained from an FSIS representative and were discussed earlier. Data on plant technology, company effects, and markets served come from the 1999 Enhanced Facilities Database and were discussed in chapter 4. We separate the data into slaughter and processing plants. Slaughter plants are FSIS-inspected plants that slaughter hoofed animals or poultry, while meat processors are plants that do not slaughter animals but operate in SIC 2013.

Results

Tables 6.2 and 6.3 contain the parameter estimates for the slaughter and meat processing industries from the Tobit regression described in equation 6.2. The parameters are estimates of the effect of a percent-deficient SPCPs and variables for plant technology and market and company effects on HACCP noncompliance records for hoofed animal slaughter, poultry slaughter, and the processing industries. All models were adjusted for multiplicative heteroskedasticity with the following specification: $\sigma_i{}^2 = \sigma^2 \exp(\gamma' Z)$ where Z is a vector of variables that affect the disturbance term, σ_i.

In our case, Z = Log of OUTPUT and $\gamma = [\ln \sigma^2, \beta]$. A likelihood test shows that the heteroskedastic correction is significant for each model.

Regression results of equation 6.2 show that the joint likelihood of the entire model is significant for each model. A Wald test indicates that the joint likelihood of plant technology is significant in all industries, but market variables are not significant, and company effects variables are significant only for poultry slaughter and meat processing. Note, we consider percent-deficient SPCPs a plant technology variable because process control is a component of plant technology.

The likelihood effects show whether an independent variable affects the percentage of HACCP noncompliance records. Percent-deficient SPCPs and output are significant and positive in all three industries. The parameter estimate for plant age is negative and significant in the hoofed animal slaughter model, but is positive and insignificant in the poultry slaughter and meat processing models. The number of processes is negative but insignificant in models for both slaughter industries. The share of slaughter products is positive in both slaughter industries but significant only in poultry slaughter. The market variables BEEF and FULCUKNSS are the only significant market variables. The dummy variable for plants owned by firms that own more than one meat or poultry plant is significant and positive in models for the poultry slaughter and meat processing industries.

Marginal effects show how small changes in independent variables affect percentage of HACCP noncompliance records. The marginal effect of output is significant and positive in all cases. A 10-percent increase in plant size increases percentage of HACCP noncompliance records by 2 percent in red meat animal slaughter, 0.0002 percent in poultry slaughter, and 0.0085 percent in meat processing. Percent-deficient SPCPs is also positive and small in all industries, but statistically significant only in poultry slaughter. A 10-percent increase in percent-deficient SPCPs results in about a 0.05-percent increase in percentage of HACCP noncompliance records in hoofed animal slaughter and a 0.001 and 0.003 percent increase in poultry slaughter and meat processing. Of the other variables, only PROCESSES, log (SHSLAUTER), and MULTFOOD for poultry are statistically significant.

Overall, likelihood and marginal effects results suggest that large plants and those plants with a high percent-deficient SPCPs will be more likely to be in noncompliance with necessary HACCP tasks. Conversely, small plants with a low percent-deficient SPCPs will be less likely to be in noncompliance with HACCP-like or HACCP tasks. This makes sense, large plants are more complex, on average, and likely have high transaction costs that raise overhead costs (Williamson, 1985). So, large plants may have a relatively greater cost of complying with quality standards than small plants. However, large plants can spread the costs of new technologies, such as carcass cleaning technologies that kill harmful pathogens, over more product volume, enabling them to have lower technological costs. Thus, large plants may be turning to new pathogen control technologies, as indicated by anecdotal evidence, because they have a comparative advantage in the use of new mechanical technologies and small plants have a comparative advantage in the performance of manual tasks.

Conclusion

In chapter 3, we argued that regulation under the PR/HACCP rule and that which existed under the WMA and WPPA were related in the types of tasks performed and oversight. In this chapter, we hypothesized that plant performance of food safety tasks under the regulatory regime associated with the WMA/WPPA should be correlated with performance under the PR/HACCP rule. Results show a correlation of performance of SPCPs with plant technology variables and the performance of HACCP tasks.

The effect of technology variables, particularly the positive effect of plant size, on percentage of HACCP noncompliance records is not surprising. Williamson (1985) asserts that, as plant size rises, so does plant complexity, making effective management more costly. Since plant management must drive quality control, greater complexity positively affects percentage of HACCP noncompliance records.

The positive effect of percent-deficient SPCPs on percentage of HACCP noncompliance records means, for example, a plant with a high percentage of deficient SPCPs would likely have a high percentage of HACCP noncompliance records. Similarly, plants with a low percentage of deficient SPCPs would likely have a low percentage of HACCP noncompliance records. These results support the argument that regulation under WMA and WPPA is closely related to regulation under the PR/HACCP rule.

Table 6.1—Percentage of plants and their change in food safety performance under PR/HACCP and WMA and WPPA in meat and poultry slaughter and processing

Plant type	Change in performance: Absolute value of difference between percentile of relative percent HACCP noncompliance records and percentile of relative percent-deficient SPCPs						
	Change in relative performance rank[1]						
	0-10	10-20	20-30	30-40	40-50	50-100	Total plants
	Percentage of plants						
Meat slaughter	28.0	23.4	19.3	5.9	10.4	13.0	239
Meat processing	27.7	18.7	20.1	5.4	11.5	16.6	1,350
Poultry slaughter and processing	39.2	16.5	19.6	5.1	9.3	10.3	97

[1] Change in relative performance rank captures the change in performance ranking from SPCP ranking to HACCP ranking. The 0-10 means that the rank under PR/HACCP is within 10 percentiles of plant rank of SPCPs; 10-20 mean rank under PR/HACCP is within 20 percentiles of SPCP rank but more than 10 percentile; and other categories are similar.

Table 6.2—Effect of percent-deficient SPCPs on the percentage of HACCP noncompliance records in meat and poultry slaughter

Variable	Cattle and hog slaughter			Poultry slaughter and processing		
	Likelihood effect	Marginal effect	Mean	Likelihood effect	Marginal effect	Mean
INTERCEPT	-4.900	-0.003		-3.395***	-0.0003***	
	(3.454)	(0.005)		(1.151)	(0.0001)	
Plant technology joint likelihood		χ^2 (5) = 36**			χ^2 (5) = 38***	
DEFICIENCY	0.250***	0.005	1.00	0.099**	0.10*10-4**	1.00
	(0.074)	(0.010)		(0.048)	(0.47*10-5)	
Log OUTPUT	0.451***	0.200***	16.83	0.221***	0.22*10-4**	17.97
	(0.168)	(0.031)		(0.066)	(0.66*10-5)	
Log PLANTAGE	-0.010**	-0.0002	2.81	0.009	0.87*10-6	
	(0.004)	(0.0007)		(0.074)	(0.74*10-5)	2.632
PROCESSES	-0.022	-0.0004	0.51	-0.127	0.13*10-5*	0.24
	(0.393)	(0.006)		(0.154)	(0.75*10-6)	
Log (SHSLAUTER)	0.243	0.005	-0.96	0.156***	0.15*10-4**	0.22
	(0.247)	(0.009)		(0.054)	(0.54*10-5)	
Markets joint likelihood		χ^2 (4) = 6.6			χ^2 (3) = 1.0	
BEEF	-1.209	-0.023	0.67			
	(0.770)	(6.158)				
PORK	-0.798	-0.015	0.65			
	(0.850)	(0.030)				
OTHER	-0.998	-0.019	0.04			
	(1.806)	(0.037)				
CHICKEN				0.082	0.82*10-5	0.76
				(0.242)	(0.24*10-4)	
TURKEY				-0.056	-0.56*10-5	0.29
				(0.267)	(0.53*10-4)	
GROUND	-0.150	-0.003	0.69	-0.057	0.57*10-5	0.31
	(0.309)	(0.005)		(0.167)	(0.17*10-4)	
Company joint likelihood		χ^2 (2) = 2.8			χ^2 (2) = 8.2**	
MULTFOOD	-0.708	-0.014	0.21	0.344**	0.34*10-4**	0.60
	(0.625)	(0.025)		(0.178)	(0.18*10-6)	
MULTIND	0.253	0.005	0.13	-0.023	-0.23*10-5	0.44
	(0.538)	(0.012)		(0.165)	(0.16*10-4)	
σ		108.6***				0.002
Model likelihood	χ^2 (11) = 144***			χ^2 (10)=70***		
Observations	239			97		

Notes: Numbers in parentheses are standard errors.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.

Table 6.3—Effect of percent-deficient SPCPs on the percentage of HACCP noncompliance records in meat processing

Variable	Likelihood effect	Marginal effect	Mean
INTERCEPT	-5.940***	$-0.79*10^{-3}$	
	(0.787)	$(0.14*10^{-2})$	
Plant technology joint likelihood		χ^2 (3) = 153.6***	
DEFICIENCY	0.233***	$0.31*10^{-4}$	1.00
	(0.030)	$(0.94*10^{-3})$	
Log OUTPUT	0.373***	$0.85*10^{-3}$***	16.73
	(0.045)	$(0.76*10^{-4})$	
Log PLANTAGE	0.008	$0.10*10^{-5}$	2.79
	(0.059)	$(0.10*10^{-4})$	
Markets joint likelihood		χ^2 (5) = 6.8	
FULCUKNSS	0.253***	$0.33*10^{-4}$	0.54
	(0.097)	$(0.62*10^{-4})$	
HETTRETNSS	-0.031	$-0.41*10^{-5}$	0.19
	(0.118)	$(0.60*10^{-3})$	
SECINHNSS	-0.429	$-0.56*10^{-4}$	0.05
	(0.305)	$(0.11*10^{-3})$	
NOHETTRETSS	0.328	$0.43*10^{-4}$	0.04
	(0.231)	$(0.84*10^{-2})$	
HETTRETSS	0.082	$-0.11*10^{-4}$	0.12
	(0.178)	$(0.55*10^{-2})$	
Company joint likelihood		χ^2 (2) = 5.8*	
MULTFOOD	0.307**	$0.41*10^{-4}$	0.16
	(0.127)	$(0.76*10^{-4})$	
MULTIND	-0.484	$-0.64*10^{-4}$	0.01
	(0.481)	$(0.14*10^{-3})$	
σ	3.06***		
Model likelihood	χ^2 (10)=212***		
Observations	1,350		

Notes: Numbers in parentheses are standard errors.
*Significant at the 90% level; ** significant at the 95% level; *** significant at the 99% level.