Findings

In this section, we summarize and interpret results of the ERS survey in the context of our economic model. The questionnaire contains three categories of questions. One major category asked operators about their costs of complying with the PR/HACCP rule and included some subjective assessments of the benefits and costs of the regulation. Also included in this category are questions asking about food safety investments not required under PR/HACCP. More than half the questions in the questionnaire dealt with food safety technology and production practices. As described earlier, these questions deal with equipment, production practices, sanitation, testing, and dehiding. The third category of questions asks about plant characteristics, including questions about plant production volume, output and input mixes, and types of markets served by plants.

PR/HACCP Rule Costs

The expenditures required for compliance under PR/HACCP for five meat and poultry industries are shown in table 7. Costs in tables 7-10 are tabulated only for those plants responding to all cost questions. As shown, poultry plants incurred 2 times as much in variable costs and more than 50 percent more in fixed costs than the next highest cost industry. These high costs are partly due to a much larger average plant size. Raw meat processors with no slaughter operations had the lowest costs.

The data in table 7 are from the ERS questionnaire. Capital expenditures are the total of property, plant, and equipment required (Q11 of the survey) and

Table 7—The cost of compliance per plant with the PR/HACCP rule in various industries¹

	Industry Slaughter Processing			ssing	
Expenditure type	Cattle	Hog	Poultry	Cooked meat	Raw meat
		Dollar	s (thousan	nds)	
Capital expenditures: ²			•	•	
Property, plant, and equipment expenditures required to comply with PR/HACCP	281.5	251.8	630.7	376.0	259.5
HACCP planning costs	6.8	7.4	8.7	8.5	7.3
Total long-term expenditures	288.3	259.2	639.4	384.5	266.8
Variable costs due to PR/HACCP:3					
Production worker wage	61.8	44.5	141.8	48.6	37.4
Quality control (QC) worker wages	36.8	42.6	101.6	47.5	38.1
Nonlabor variable costs	111.5	31.9	259.8	62.1	41.0
Total variable costs	210.1	119.0	503.2	158.2	116.5
Number of plants	135	104	58	198	143

¹Mean values are based on the number of respondents who answered all questions.

²Capital expenditures are longrun costs, meaning that they are either one-time costs or costs that are incurred over a period longer than 1 year. Fixed costs are expenditures since the PR/HACCP rule was mandated in 1996 and are based on estimates derived from Q11, Q12, and Q13 and the methodology described above. Since we do not know precisely when these costs were incurred, they are not assigned a net present value.

³Variable costs are annual costs and are based on Q14 (nonlabor variable costs) and Q7 (labor costs). See www.ers.usda.gov/data/haccpsurvey for complete text of the questions. Source: ERS.

planning labor (Q15B) required complying with the PR/HACCP rule. Planning labor was converted to costs by multiplying the average wage rate for meat or poultry slaughter or processing industries from Census Bureau publications, divided by a 270-day work-year times the number of total planning days required to develop HACCP and sanitation plans, as reported in Q15B. Production worker costs and quality control worker costs are based on question Q7A and Q7B, average Census wages, and a 270-day work-year. Nonlabor variable costs come from Q14.

We also projected our within-survey estimates of the costs of the PR/ HACCP rule to the industry as a whole. We estimate that total meat and poultry slaughter and processing industry investment amounted to about \$570 million in HACCP-required investments and \$380 million in variable costs per year to maintain HACCP quality-control programs.

The estimates of total PR/HAACP fixed costs and PR/HACCP variable costs were made in the following way:

- For the slaughter industries, we obtained total investments by size class and industry by multiplying the total expenditures made by all of the survey respondents in a particular size class and industry times the inverse of the respondents' share of output from all plants in that group.
- For cooked and raw meat processors with no slaughter operations, we
 multiplied total investment expenditures within each size class and
 industry by the inverse of their share of cooked or raw processed products from all plants in that group.
- Industry estimates are, then, the sum of expenditures of the size classes.

Market Mechanisms' Effect on HACCP Implementation Costs

At least three types of plants are more exposed to a competitive demand for greater food safety investments: those that are subject to food safety requirements embedded in contracts; those that are exporters whose products are inspected by food safety authorities in importing countries; or those that have brand names, which require greater plant attentiveness to food safety process control. These plants would likely have made many of the investments required under PR/HACCP before it became mandatory and, thus, should have a lower cost of complying.

Plants that are subject to buyers' food safety requirements, export meat or poultry products, or sell products under their own brand names had modestly lower costs of compliance with the PR/HACCP rule (table 8). Cattle and hog slaughter facilities and cooked meat processing plants (no slaughter operations) that were subject to the same market mechanisms generally had lower fixed costs, and poultry slaughter plants subject to market mechanisms had lower variable costs.

A very sharp difference in costs between plants subject to market mechanisms and those not subject to these forces would suggest that market mechanisms impose the same kinds of requirements as those mandated under the

⁸Fixed costs for red meat are based on survey questions Q11 and Q15B and variable costs are based on questions Q7 and Q14 for red meat. The questions are identical for poultry. Questions asking about plant output markets (e.g., exports) are Q42 (exports), Q43 (local or national distribution), Q44 (buyer requirements), and Q45 (branded products).

Table 8—Plants subject to selected market mechanisms have lower fixed costs necessary for compliance with PR/HACCP¹

			Market med	chanism		
	Buye	r food			Produ	ct sold
	safety rec	juirements	Export i	market	under ov	vn brand
Plant type	No	Yes	No	Yes	No	Yes
			Dollars pe	er pound		
Cattle slaughter:						
Variable costs ²	0.021	0.022	0.021	0.021	0.018	0.023
Fixed costs ³	0.025	0.024	0.024	0.020	0.031	0.021
Number of plants	66	54	90	45	24	112
Hog slaughter:				0.004	0.040	
Variable costs	0.023	0.030	0.021	0.024	0.019	0.022
Fixed costs	0.012	0.007	0.029	0.019	0.040	0.025
Number of plants	55	32	71	33	12	91
Poultry slaughter:						
Variable costs	0.011	0.008	0.022	0.008	D	0.010
Fixed costs	0.006	0.008	0.009	0.007	D	0.008
Number of plants	18	33	9	47	3	53
•						
Cooked meat proce no slaughter:	ssing/					
Variable costs	0.016	0.019	0.016	0.014	D	0.032
Fixed costs	0.050	0.023	0.043	0.025	D	0.020
Number of plants	104	99	128	75	3	195
	. • .	50	. 20	. •	Ü	. 50
Raw meat procession no slaughter:	ng/					
Variable costs	0.012	0.015	0.017	0.007	D	0.018
Fixed costs	0.018	0.015	0.019	0.013	D	0.014
Number of plants	75	64	93	46	D	D

¹Plants are in five meat and poultry slaughter and processing industries.

Notes: Number of plants varies because all plants did not respond to all questions.

Source: ERS.

PR/HACCP rule. The very modest difference actually observed, however, indicates one of two things: (1) either the requirements imposed by market mechanisms and those mandated under the PR/HACCP rule are very different, suggesting that both plants subject to market mechanisms and those not subject to these forces had a similar number of tasks to perform to be in regulatory compliance; or (2) plants subject to market mechanisms and those not subject to these forces had a similar number of tasks to perform in order to be in compliance with PR/HACCP because the regulation requires only tasks that most plants would perform regardless of whether they were subject to market forces (like plant A in figure 1).

We suspect that one question was poorly worded and may have elicited unintended responses from plants selling products under their own brand.

²Variable costs are annual costs and are based on Q14 (nonlabor variable costs) and Q7 (labor costs. See www.ers.usda.gov/data/haccpsurvey for complete text of the questions.

³Fixed costs are expenditures since the PR/HACCP rule was mandated in 1996 and are based on estimates derived from Q11, Q12, and Q13 and the methodology described in section 8.

D: Disclosure violation, meaning information is suppressed.

Our intent for the question asking plants whether they sell products under their own name was to see if the plant produced branded products for consumers. However, it appears that plants took it to mean whether their product was shipped to a buyer with the producer's name on the product, regardless of whether it was going to consumers or a vendor to be repackaged or further processed. Given this meaning, virtually all poultry plants and processors without slaughter operations answered affirmatively and even most cattle slaughter plants, which typically produce products that are sold under store brands in grocery stores, responded positively.

Plant Characteristics Affect Expenditures for Compliance with PR/HACCP

We considered three dimensions in which the PR/HACCP rule may have differential effects. First, we examined the PR/HACCP rule and plant size. Economists, such as Thomas (1990) and Ollinger and Fernandez-Cornejo (1998), among others, found that regulation adversely affects research productivity more in small firms than in larger ones in the pharmaceutical and pesticide industries. Pashigian (1984) found that environmental regulation of production facilities favored large factories over smaller ones and capital-intensive industries over more labor-intensive ones. These size and industry effects suggest that small plants may have higher regulatory costs per pound of meat or poultry than larger ones under PR/HACCP and that differential costs may exist between poultry and red meat plants.

Second, the costs of implementing the PR/HACCP rule also could vary by the degree of sophistication of a plant's quality control program prior to PR/HACCP. Since product testing, use of a plant schematic that identifies critical control points, and periodic reviews of the schematic and production process to ensure plant process control are essential components of HACCP, plants employing these practices prior to promulgation of the PR/HACCP rule may have had lower PR/HACCP compliance costs.

Third, there are also some indirect effects of regulation. On the one hand, product quality, i.e., shelf life for meat and poultry products, may rise because of better control over pathogens. On the other hand, plants imposing a higher quality standard may have to either slow production lines, shut down lines more frequently to make adjustments necessary to meet stricter standards, or discard more products.⁹

Plant Size and the Costs of PR/HACCP

The costs of PR/HACCP per pound of meat or poultry in slaughter and processing industries for the largest and smallest plants and the entire industry are shown in table 9. The weighted cost is much lower than the average cost per pound per plant because the very largest plants have minuscule costs per pound and those plants produce most of the output. ¹⁰ If plants were of generally equal size, then average cost per pound per plant would equal the weighted cost per pound.

The table shows that unweighted variable costs were three times higher for the smallest relative to the largest cattle slaughter plants, and fixed costs ⁹Plants can attain a higher level of product quality by either modifying production processes or discarding products that do not meet the standard. If they modify their production processes, then production costs rise. If they discard products that fail to meet the new standard, then the cost of product waste rises.

¹⁰The weighted average cost is weighted by plant output. We do this by summing costs within a percentile grouping and then summing output within the same grouping. Cost per pound is then the sum of costs divided by the sum of output. The unweighted cost is the mean of cost per pound of all plants.

were more than six times larger.¹¹ Estimates show that the average costs per pound per plant were around 1.5 to 2.5 cents per pound in variable and fixed costs for cattle and hog slaughter plants. The three right columns show that the weighted cost per pound is much lower than mean cost per pound per plant. For both hogs and cattle slaughter, the weighted cost per pound was less than one-half of a cent and about one- seventh the average cost per pound per plant.

The cattle and hog slaughter industries are comprised of a few very large plants that produce most of the output and numerous smaller plants that produce a blend of commodity and niche products. In cattle slaughter, plants in the 80th to 99th percentiles produce about 90 percent of all output and most of that quintile's output was produced by a few giant plants. The giant plants, in turn,

Table 9—PR/HACCP costs of plants subject to market mechanisms¹

		weighted i	_		ustry weig cost per p	_
		Size percer	ntile	Siz	ze percen	tile
Plant type	0-19	80-99	Mean	0-19	80-99	Mean
			Dollars	s per pouna	1	
Cattle slaughter:						
Variable costs	0.023	0.008	0.022	0.010	0.003	0.0033
Fixed costs	0.055	0.009	0.022	0.020	0.004	0.0045
Number of plants	17	27	135	17	27	135
Hog slaughter:						
Variable costs	0.016	0.005	0.014	0.008	0.001	0.0020
Fixed costs	0.050	0.008	0.026	0.022	0.003	0.0043
Number of plants	23	22	96	17	22	96
Poultry slaughter:						
Variable costs	0.025	0.004	0.010	0.023	0.004	0.0037
Fixed costs	0.013	0.004	0.008	0.012	0.003	0.0047
Number of plants	14	9	58	14	11	58
Cooked meat proce	ssing /no sla	aughter:4				
Variable costs	0.018	0.005	0.016	0.015	0.005	0.007
Fixed costs	0.079	0.019	0.036	0.057	0.015	0.018
Number of plants	50	37	198	50	37	198
Raw meat processir	ng/no slaugh	nter:5				
Variable costs	0.020	0.005	0.013	0.006	0.003	0.0046
Fixed costs	0.027	0.012	0.017	0.006	0.005	0.0080
Number of plants	25	26	139	25	26	139

¹In the five meat and poultry slaughter and processing industries we left out intermediate percentiles from 20-79 because they follow a trend of higher to lower costs.

Source: ERS.

¹¹The fixed costs are the costs of compliance with the PR/HACCP rule since its inception in 1996. We do not know precisely when plants made their investments, so these costs are not all in current dollars. Despite this inaccuracy, the magnitude of the differences suggests differences in costs. Larger plants had to comply with the PR/ HACCP rule before the smallest plants; thus, their investments would have likely been made before the smaller plants, suggesting that their fixed costs may have actually been higher in current dollars than those of smaller plants.

²Plants are in five meat and poultry slaughter and processing industries.

³Many plants answered only some of the questions. We used only plants reporting all variable and fixed costs. The average costs are the average costs for that percentile category only. ⁴The weighted average cost is weighted by plant output. We do this by summing costs and then summing output. Cost per pound is then the sum of costs divided by the sum of output. The unweighted cost is the mean of cost per pound of all plants.

⁵Estimated number of plants producing cooked or raw processed meat is based on either cooked or raw meat output as a share of total output, as indicated in the survey. For example, plants with more than 50 percent of their output coming from cooked products were defined as cooked meat processors.

have very low costs of compliance with PR/HACCP, making the weighted regulatory cost per pound much lower than the average cost per pound per plant. Poultry slaughter and the processing industries have similar effects. ¹²

The substantial gap between the weighted cost per pound and average cost per pound per plant suggests heterogeneous price changes in the meat and poultry industries. The largest plants produce commodity products, like cut-up and boneless meat and poultry, and sell their products in mass markets. For these products, the largest plants drive prices and their costs, in turn, determine their prices. So, price increases would be imperceptible for commodity-like raw red-meat products. For smaller plants that produce commodity products that compete with commodity products from the giant plants, this means an erosion of profitability and a necessity to either exit the industry or shift to other products. ¹³

Plants that produce unique products or produce products in small batches that compete against other small plants might be able to recover all of their PR/HACCP costs by raising prices. These plants would typically be the very smallest plants. Thus, it is the plants in the middle between the very small plants and the very largest plants that will feel the most cost pressures due to PR/HACCP. Effects should be similar for hog and poultry slaughter industries.

Meat Type and the Costs of PR/HACCP

The weighted cost of compliance with the PR/HACCP rule per pound of output in the poultry slaughter industry was about equal to that of cattle and twice as high as that for hog slaughter (see table 9, last column). Antle (2000) estimated cost of poultry production as about half that of beef. Combined, these imply that the percentage price increase in the cost of poultry products due to PR/HACCP is about twice that of beef.

One major difference between poultry plants and red meat plants is that poultry slaughter plants tend to be more vertically integrated into processing. Thus, it may be appropriate to compare the cattle and hog slaughter costs plus the red meat processing costs with the poultry slaughter costs. For raw products, costs due to PR/HACCP become about the same for beef and poultry, but remain lower for pork relative to poultry. Beef and pork costs plus either raw processing or cooked processing costs exceed those for poultry, suggesting that beef and pork costs may be greater than poultry in both percentage and absolute values. In either case, however, the average cost is less than 1 cent per pound.

Process Control Programs and Costs Prior to PR/HACCP

Now consider how having a more sophisticated process control program prior to PR/HACCP affected the cost of implementing the PR/HACCP rule. Process control programs prior to PR/HACCP were assumed to consist of systems that enable plant operators to identify critical control points, monitor performance at the critical control points, verify cleanliness through testing, and respond to deviations from standards. See questions Q17, Q18, and Q29 in the survey.

¹²Large-plant compliance costs with PR/HACCP may be somewhat lower than those of smaller plants because they would have been more likely to have had to comply with buyer requirements prior to PR/HACCP.

¹³Hooker et al. (1999) argue that small plants facing cost pressure in one market could shift to other products or simply stop production of their unprofitable product lines.

PR/HACCP costs of compliance for plants with process control programs prior to PR/HACCP were either lower or about the same as plants without these programs prior to PR/HACCP (table 10). Variable cost differences were quite small except for cattle and hog slaughter plants and small raw meat processing plants. Fixed costs of compliance were lower for large cattle slaughter plants and all small plants with process control programs prior to PR/HACCP. For other plants, fixed costs of compliance were comparable. These cost differences suggest that a process control program prior to PR/HACCP had many components similar to the requirements promulgated under the PR/HACCP rule and that these similarities gave plants with these programs lower costs of compliance with PR/HACCP.

Indirect Effects of the PR/HACCP Rule

Changes in food safety process controls have both positive and negative indirect impacts on production costs. Roberts and Pinner (1990), for example, found that better control of the pathogen *Listeria monocytogenes* led to an increase in product shelf life. The PR/HACCP rule appears to have had a similar effect. Survey results indicate that about 9 percent of respondents

Table 10—PR/HACCP costs for plants with pre-PR/HACCP process control program

		Plant size ¹				
		nall_		rge		
		ntrol prior to ACCP		ntrol prior to IACCP		
Plant type	No	Yes	No	Yes		
	Dollars i	per pound	Dollars	per pound		
Cattle slaughter:	20	oo. pourru	20	po. poua		
Variable costs	0.036	0.020	0.016	0.008		
Fixed costs	0.039	0.025	0.016	0.006		
Number of plants	47	10	57	21		
Hog slaughter:						
Variable costs	0.035	D	0.019	0.008		
Fixed costs	0.059	D	0.017	0.016		
Number of plants	D	D	60	12		
Poultry slaughter:						
Variable costs	0.016	D	0.005	0.004		
Fixed costs	0.011	D	0.002	0.005		
Number of plants	D	D	16	11		
Cooked meat processi	ng /no slaughter:					
Variable costs	0.020	0.020	0.012	0.009		
Fixed costs	0.058	0.020	0.024	0.022		
Number of plants	78	24	62	34		
Raw meat processing/	no slaughter:					
Variable costs	0.019	0.011	0.011	0.008		
Fixed costs	0.019	0.006	0.017	0.017		
Number of plants	55	14	52	22		

¹Large plant size is defined as any plant in the 50th or higher percentile in all industries, except for hogs, in which the cutoff for large plants was the 70th or higher percentile. The cutoff was changed in order to avoid potential confidentiality concerns.

D: suppressed due to confidentiality concerns

stated that their products' shelf lives increased by more than 1 week and 21 percent said that their products' shelf lives increased by less than 1 week. Only about 1 percent of respondents claimed a decrease in shelf life. The remainder reported no change in shelf life.

Implementing a new process control program or making an existing program more stringent can have two indirect effects on production costs:

- On the one hand, products may better satisfy buyers and result in a reduction in product recalls, an improvement in product yields, and a decline in plant downtime if the plant formerly had a poorly functioning process control program.
- On the other hand, a more stringent process control program may reject
 products that formerly would have been sold to buyers and may cause a
 plant to shut down more frequently in order to comply with new process
 control requirements.

A case study of Texas American Beef (Golan et al., 2004) indicates that Texas American Beef instituted a process control program to reduce product recalls and then successfully implemented a program that led to a competitive advantage in pathogen control technology. Thus, this privately motivated process control program generated substantial benefits to its developer. Government mandated process controls, however, differ in that no plant gains a competitive edge over its rivals because all plants must comply with the same standard. Plants can gain an advantage only if they perform at a level greater than the industry mean. Thus, companies like Texas American Beef may have a quality level comparable to that of Plant D in figure 1 while the rest of the industry would reside at the horizontal bar. If the regulatory standard becomes more stringent, then companies, such as Texas American Beef, would have to increase their food safety process control standards even further to distinguish themselves from their competitors.

The PR/HACCP rule raised regulatory stringency by raising the acceptable level of food safety and the stringency of process control requirements. ¹⁶ Plants could deal with the regulation by either removing meat that failed to meet FSIS standards as it occurred in production or increasing work effort and processing complexity to prevent the production of the off-quality meat or poultry from happening in the first place. ¹⁷ If a plant removed meat or poultry that failed to meet FSIS standards from production as it occurred, then processing yields may have declined because product that would have otherwise been sold must now be rejected. ERS survey data suggest that many plants followed this route. Only about 2 percent of the 963 plants reporting on plant yields believed that yield improved with the introduction of the PR/HACCP rule, while about 25 percent believed that yield decreased. The remainder reported no change. See question Q10 in the survey to review the survey question.

Some plants that increased processing complexity by adding a new step, such as a steam vacuum cleaner to remove fecal matter, to the production process to meet more stringent pathogen-control standards would incur the cost of greater downtime because those plants would have to shut down when the new step in the production process failed. However, if a plant that had been experiencing

¹⁴This is not to say that production costs actually dropped. Product recalls may have declined because products that would have formerly been released for sale were held and then either sold for alternative uses or discarded. Texas American Beef did reduce some of this rejected meat as it further developed its process control program but a detailed study of its costs is not available. It is clear, however, that improving its process control program gave Texas American Beef a competitive advantage at a time when buyers were becoming more discriminating in their purchasing behavior and enabled it to increase market share at the expense of its competitors.

¹⁵For example, automobiles produced by American companies have improved in quality over the past 30 years; yet many Japanese automobiles sell at a premium because they have even higher quality. The important point is that relative quality matters.

¹⁶Regulatory stringency increased in two ways. First, in production, slaughter plants now have to conduct a test for E. coli and comply with a generic E. coli standard, and slaughter and ground meat plants must adhere to a Salmonella standard. Neither type of testing was required prior to PR/HACCP. Additionally, plants must keep records on and adhere to their SSOP and HACCP practices. Second, in the marketplace, FSIS increased the number and sensitivity of tests for harmful pathogens. This increased diligence has led to a sharp spike in product recalls. See "Weighing Incentives for Food Safety in Meat and Poultry" in the April 2003 issue of Amber Waves for further discussion about the nature of the recalls.

¹⁷The PR/HACCP rule specifies two process standards—SSOPs and HACCP plan implementation—that require plants to perform specified functions. There are also two performance standards—E. coli and Salmonella testing that indicate a failure in the food safety system. Plants could avoid such failures by either improving their food safety system or testing animals and meat for E. coli and Salmonella and discarding those that are not acceptable. Either approach can achieve a safe food supply. The last option—test and discard—is very costly, however.

frequent shutdowns due to poor processing practices introduced an improved process control program, then production downtime may have been reduced. ERS survey data (Q9 in the survey) suggest that many more plants realized an increase than a decrease in production downtime.

Now consider the four components of the PR/HACCP rule—compliance with the HACCP plan, SSOPs, the zero fecal matter/generic E. coli standard, and the Salmonella standard—and changes in annual downtime. About 12 percent of all plants said they had more than 24 hours of annual downtime due to HACCP compliance and 46 percent said they had between 0 and 24 hours of additional downtime. Only 4 percent indicated a reduction in production downtime. Plants gave a similar report for SSOPs, but had a more positive experience with the zero fecal matter standard and Salmonella testing. For the fecal matter standard, 18 percent of all plants said the requirement reduced downtime while only 7 percent said that downtime rose by more than 24 hours; 29 percent indicated a rise in downtime of less than 24 hours. Similarly, 15 percent of all plants said the Salmonella standard reduced downtime while only 2 percent said that downtime rose more than 24 hours; 20 percent indicated a rise in downtime of less than 24 hours. Overall, 54 percent of all plants said that they suffered downtime due to one of the four components of PR/HACCP with no offsetting downtime reductions in another component. Only 6 percent of all plants said that downtime declined in at least one of the components and did not change in the others. About 13 percent of all plants realized reductions in downtime due to one component but then had offsetting increases in downtime due to other components. The remainder of the plants had no changes in downtime due to PR/HACCP.

Food Safety Investment

Total fixed capital investment in food safety includes the expenditures required for compliance with regulation and the private investment motivated by market conditions. The cost of government regulation includes costs that firms otherwise may not incur. Privately motivated investments, on the other hand, are those expenditures that plants are not required to make in order to comply with regulation and for which the discounted net return to the firm is greater than or equal to the cost of the initial amortized expenditure. This independent private investment includes the cost of installation, the price of the equipment, lost downtime during installation, and transportation costs. Improvements in firm profitability come from cost savings due to reductions in labor costs and material usage, a longer shelf life, and higher prices accruing to a higher quality product. For food safety, a reduction in business risk is an important motivating factor. New technologies and more frequent use of existing practices increase the likelihood of adhering to FSIS standards and make it less likely that a plant will be either subject to a product recall or identified as the source of a foodborne illness.

Table 11 shows the estimated mean level of independent private investments and capital expenditures required for compliance under PR/HACCP for five meat and poultry industries. For the 136 cattle slaughter plants responding to all investment questions, the mean level of independent private investment was about \$181,500 per plant and total capital expenditures and HACCP planning costs required for compliance with PR/HACCP

Table 11—Mean privately motivated capital expenditures and capital expenditures required for compliance with PR/HACCP¹

		Industry				
		Slaughte	r	Proce	ssing	
Expenditure type	Cattle	Hog	Poultry	Cooked meat	Raw meat	
Capital expenditures: Expenditures required to comply with PR/HACCP	281.5	Dollars per 251.8	plant (thou	<i>376.0</i>	259.5	
Privately motivated investment, not needed to comply with PR/HACCP	181.5	227.6	501.7	298.2	130.9	
HACCP planning costs Total long-term expenditures	6.8 469.8	7.4 486.8	8.7 1141.1	8.5 682.7	7.3 397.9	
Number of plants	136	104	56	203	143	

Note: Mean values are based on the number of respondents who answered all questions.

In the meat and poultry slaughter and processing industries.

Source: ERS.

amounted to about \$288,000. Of the five industries, poultry slaughter had the highest level of private investment (\$500,000 per plant) while raw meat processing had the lowest level of private investment at about \$130,900 per plant. See Q11 in the survey for the precise wording of the question soliciting information.

Private plant investment estimates are based on the expenditures required to comply with the PR/HACCP rule. We assumed that plants made private investments only if their survey response indicated that they made food safety process control investments beyond those mandated under PR/HACCP (Q12 in the survey). If plants did and they responded affirmatively to another question asking whether their private investment exceeded their PR/HACCP-required investment (Q13 in the survey), we make a lower bound estimate by assuming that private investment equaled PR/HACCP expenditures. For plants indicating that they made investments in addition to those mandated under PR/HACCP but also responding that this investment did not exceed their PR/HACCP costs, we assumed that private investment was one-half the PR/HACCP investment. Finally, we assumed that private investment equaled zero if the plant indicated that it made only PR/HACCPrequired investments. Total respondent investment per industry, the sum of investments across all respondents, was then adjusted as outlined in section 6 to obtain private industry investment. We acknowledge that these are rough, but we believe that they do provide a general feel for the amount of investment put forth by meat and poultry slaughter and processing plants.

The Paths Plants Took To Comply With the PR/HACCP Rule

The components of the PR/HACCP rule that deliver the most benefits in terms of food safety process control are of major importance to policymakers. To meat and poultry processors, the lowest cost way to comply with PR/HACCP is of primary importance. Economists, on the other hand, believe that additional process control should be added up to the point at which the cost of process control equals the benefits of improved public health. This balance of process control costs and public health outcomes may or may not be equal to the level of food safety process control achieved through compliance with PR/HACCP regulation.

Two types of regulatory standards—performance and process standards—exist to achieve regulatory goals. Performance standards allow plants to use any means necessary to reach an established goal that is linked to a public good, such as improved health. Process standards mandate specific processes that manufacturers must achieve in order to comply with the regulation. HACCP contains elements of both: generic *E. coli* and *Salmonella* performance standards and SSOP and HACCP process standards.

Economists generally believe that process standards are more costly than performance standards because some required tasks may not be necessary to reach desirable outcomes. However, process standards do reduce the uncertainty of regulatory compliance because as long as the plant executes the necessary tasks it is in compliance, whereas performance standards require a plant to first investigate a quality breakdown and then develop a solution. Determining the solution and then implementing ways to carry it out can be both costly and time-consuming and require repeated approaches to problem solving. We consider the aspects of the PR/HACCP rule that plants felt were most beneficial and most costly, as follows.

Questions 1-3 of the survey asked plant operators how they perceived the costs and benefits of the PR/HACCP rule. Tables 12a-13b indicate the perceived benefits and costs associated with aspects of the PR/HACCP rule. First, consider the SSOPs and HACCP plans. The tables show that managers in all industries except poultry slaughter believed that SSOPs delivered the most benefits for pathogen control, yet far fewer plants said it was the most costly component of the PR/HACCP rule. A substantial number of plants also thought that HACCP plans were the most important component for pathogen control, but a much larger number claimed it was the most costly way to achieve it. Small plants incurred sharply higher relative costs of creating and implementing HACCP plans. Nearly twice as many of the smallest slaughter plants relative to the largest ones believed that compliance with HACCP plans was the most costly aspect of the PR/HACCP rule.

Operator frustration over the costliness of HACCP plan development implementation account for the overwhelming majority of written comments on the HACCP plan. One operator was particularly expressive, saying:

"Our plant is small (18 employees) but has a very complex product mix, from fresh beef and pork cuts all the way to finished, ready-to-eat products.

Table 12a—Slaughter plants' rating of part of PR/HACCP rule considered most beneficial for pathogen control¹

	Size p	ercentile	All plants	
Plant type	0-19	80-99		
	Sh	are of plants	saying	
		onent most l		
Cattle slaughter:				
SSOPs	41.0	32.0	36.0	
HACCP plan	16.0	25.0	23.0	
E. coli testing, zero fecal requirement	37.0	36.0	36.0	
Salmonella testing	0.0	0.0	1.0	
Other	6.0	7.0	4.0	
Number of plants	48	49	255	
Hog slaughter:				
SSOPs	36.0	49.0	40.0	
HACCP plan	25.0	16.0	23.0	
E. coli testing/zero fecal requirement	32.0	26.0	30.0	
Salmonella testing	0.0	9.0	3.0	
Other	7.0	0.0	4.0	
Number of plants	42	47	210	
ramoor or plante		.,	2.0	
Poultry slaughter:				
SSOPs	37.0	21.0	24.0	
HACCP plan	33.0	37.0	29.0	
E. coli testing/zero fecal requirement	26.0	32.0	28.0	
Salmonella testing	4.0	5.0	16.0	
Other	0.0	5.0	3.0	
Number of plants	33	24	124	

¹Responses are based on Q2 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

Table 12b—Processing plants' rating of part of PR/HACCP rule considered most beneficial for pathogen control¹

	Size percentile		All plants
Plant type	0-19	80-99	
	Sh	are of plants	saying
	component most beneficial		
Cooked meat processing, no slaughter:			
SSOPs	44.0	49.0	45.0
HACCP plan	36.0	35.0	37.0
E. coli testing/zero fecal requirement	14.0	11.0	13.0
Salmonella testing	4.0	0.0	1.0
Other	2.0	5.0	4.0
Number of plants	68	73	368
Raw meat processing, no slaughter:			
SSOPs	48.0	45.0	44.0
HACCP plan	36.0	34.0	36.0
E. coli testing/zero fecal requirement	12.0	17.0	14.0
Salmonella testing	2.0	2.0	2.0
Other	2.0	2.0	4.0
Number of plants ²	65	58	327

¹Responses are based on Q2 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

²Two raw meat processing plants have missing rank data.

Table 13a—Slaughter plants' rating of parts of PR/HACCP rule considered most costly¹

	Size pe	ercentile	All plants
Plant type	0-19	80-99	•
	Share of	f plants sayin	g PR/HACCP
	со	mponent mo	st costly
Cattle slaughter:			
SSOPs	7.0	2.0	6.0
HACCP plan	48.0	37.0	43.0
E. coli testing/zero fecal requirement	41.0	49.0	43.0
Salmonella testing	4.0	4.0	4.0
Other	0.0	8.0	4.0
Number of plants	48	49	255
Hog slaughter:			
SSOPs	12.0	15.0	11.0
HACCP plan	53.0	28.0	45.0
E. coli testing/zero fecal requirement	30.0	31.0	34.0
Salmonella testing	5.0	26.0	8.0
Other	0.0	0.0	2.0
Number of plants	42	47	210
Poultry slaughter:			
SSOPs	9.0	4.0	5.0
HACCP plan	41.0	21.0	26.0
E. coli testing/zero fecal requirement	34.0	63.0	50.0
Salmonella testing	16.0	8.0	16.0
Other	0.0	4.0	3.0
Number of plants ²	33	24	124

¹Responses are based on Q3 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

Table 13b—Processing plant rating of components of the PR/HACCP rule that is most costly varies by plant size¹

	Size percer		All plants
Plant type	0-19	80-99	
	Share of	plants saying	g PR/HACCP
	COI	mponent mos	st costly
Cooked meat processing, no slaughter:			
SSOPs	12.0	17.0	14.0
HACCP plan	55.0	47.0	58.0
E. coli testing/zero fecal requirement	16.0	28.0	18.0
Salmonella testing	9.0	4.0	4.0
Other	8.0	4.0	6.0
Number of plants	68	73	368
Raw meat processing, no slaughter:			
SSOPs	10.0	11.0	10.0
HACCP plan	62.0	51.0	59.0
E. coli testing/zero fecal requirement	13.0	28.0	21.0
Salmonella testing	8.0	7.0	6.0
Other	7.0	3.0	4.0
Number of plants ²	65	58	327

¹Responses are based on Q3 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

²Twenty-four poultry plants have missing rank data.

²Two raw meat processing plants have missing rank data.

To cover our many types of products, we had to develop and implement 19 separate HACCP plans, plus the SSOP procedures. Needless to say, this took a huge amount of time and resources. Our HACCP team of 9 individuals (half the plant [employees]) met for 1 to 2 hours on a weekly, sometimes biweekly, basis for 14 months. Additionally, one person worked half-time for two and a half years. Our direct labor cost for HACCP and SSOP plan development was well over \$100,000. During this process, there were several false starts, as the 'rule' seemed to be constantly changing, a moving target if you will. Our plant has four certified people. Each of us attended separate HACCP certification training courses (3-day sessions required by law) and each of us brought back new or different requirements."

Now consider the perceived costs and benefits of *E. coli* testing and the zero fecal matter standard. As shown in the tables, a similar number of meat plant respondents regarded these two as most beneficial and most costly. However, the attitudes of managers of poultry plants differed sharply: half the plant managers viewed *E. coli* testing and the zero fecal standard as most costly while about only one-fourth of plant managers viewed it as most beneficial. This sentiment was most pronounced for the managers of large plants. More than 60 percent of these plant managers thought the *E. coli* testing and the zero fecal matter standard was most costly while only about 30 percent believed that it was most beneficial.

The Paths Plants Would Prefer To Take To Best Control Pathogens

It is one matter to ask a plant about compliance and another to ask plants the practices they might use to best control pathogens independent of any regulation. Ideally, the two would match. Questions 4, 5, and 6 ask plant operators about their preferred approach to control pathogens and the costliness of that method.

Tables 14a and 14b demonstrate clearly that plant size and, to a lesser degree, animal species and type of product have strong influences on how plants choose to control pathogens. Table 14a shows that the smallest cattle and hog slaughter plants prefer to concentrate on changes in product flow while their larger, more capital-intensive competitors and most poultry plants focused much more on equipment. A large number of plants in all categories except large poultry plants viewed frequency of cleaning as the best way to control pathogens.

Table 14b shows that product flow and frequency of cleaning are important to processing plants of all sizes, whereas equipment was viewed as much less useful for pathogen control than it was in slaughter plants. It is also important to note that proportionately more raw meat processors regarded relationships with suppliers as the best way to control pathogens, probably because the PR/HACCP rule places responsibility for compliance with the *Salmonella* standard with grinders. Yet, plants that grind meat and poultry must rely on their suppliers to provide pathogen-free meat and poultry because, unlike slaughter plants, they have no means of reducing pathogens in meat supplies after their products are contaminated.

¹⁸Changes in product flow are adjustments to the production flow to enhance food safety. For example, a travel route for a bin of raw/unprocessed meat may be redirected from one route passing through a finished product area to another route that avoids this area, thereby reducing the potential for cross-contamination.

Table 14a—Slaughter plants' rating of food safety operation considered most beneficial for pathogen control¹

	Size p	ercentile	All plants
Plant type	0-19	80-99	
	S	Share of plants	saying
	plani	operation mos	st effective
Cattle slaughter:			
Grower practices	11.0	0.0	11.0
Product flow	30.0	7.0	24.0
Product rework	3.0	3.0	3.0
Frequency of cleaning	32.0	26.0	26.0
New equipment	14.0	45.0	22.0
Facilities improvement	5.0	17.0	12.0
Other	5.0	2.0	2.0
Number of plants	48	49	255
Hog slaughter:			
Grower practices	22.0	7.0	12.0
Product flow	28.0	12.0	29.0
Product rework	0.0	5.0	3.0
Frequency of cleaning	28.0	21.0	19.0
New equipment	10.0	43.0	23.0
Facilities improvement	6.0	12.0	11.0
Other	6.0	0.0	3.0
Number of plants	42	47	210
Poultry slaughter:			
Grower practices	0.0	23.0	10.0
Product flow	18.0	9.0	12.0
Product rework	4.0	5.0	2.0
Frequency of cleaning	25.0	9.0	12.0
New equipment	39.0	41.0	51.0
Facilities improvement	7.0	14.0	9.0
Other	7.0	0.0	4.0
Number of plants	33	24	124

¹Responses are based on Q4 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

Taken together, tables 14a and 14b indicate an interaction between the tools required to control pathogens and plant production technology and product mix. Large, high-speed slaughter facilities must process animals quickly in order to be profitable and so rely on high-speed equipment as much as possible to control pathogens. Small, more labor-intensive slaughter operations, by contrast, can control pathogens by ensuring a smooth product flow and intensive cleaning. Intermediate sized plants may use some equipment to control pathogens, but must still rely substantially on manual means of control. Large poultry slaughter plants, perhaps the most automated of all plants, rely almost exclusively on equipment to best control pathogens. Processing plants, in contrast, have few mechanical means of controlling pathogens; thus, they must rely on cleaning and product flows, and, for raw-meat processors, assurance from suppliers that their inputs are pathogen-free.

Tables 15a and 15b indicate plant operators' perceptions of the costliness of various operational changes. Except for small plants in two categories, managers regarded equipment as the most costly way to control pathogens while

Table 14b—Processing plants' rating of food safety operation considered most beneficial for pathogen control¹

	Size pe	ercentile	All plants
Plant type	0-19	80-99	-
	Si	hare of plants	saying
	plant	operation mo	st effective
Cooked meat processing, no slaughter:			
Grower practices	4.0	9.0	11.0
Product flow	27.0	17.0	22.0
Product rework	2.0	6.0	4.0
Frequency of cleaning	39.0	28.0	29.0
New equipment	16.0	16.0	15.0
Facilities improvement	12.0	22.0	16.0
Other	0.0	2.0	3.0
Number of plants	68	73	368
Raw meat processing, no slaughter:			
Grower practices	17.0	21.0	15.0
Product flow	27.0	11.0	23.0
Product rework	2.0	13.0	6.0
Frequency of cleaning	29.0	17.0	26.0
New equipment	15.0	17.0	14.0
Facilities improvement	10.0	17.0	14.0
Other	0.0	4.0	2.0
Number of plants ²	65	58	327

¹Responses are based on Q4 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

only the managers of large plants believed that equipment is most useful for pathogen control. Small plants claimed that the frequency of cleaning is effective and less costly than equipment, but still costly. A substantial number of plant managers also viewed product flow as useful, but a much lower number regarded it as most costly. A sizeable number also regarded facilities improvement as quite costly. Overall, large plants appeared to favor equipment-based process control approaches, while smaller plants preferred either the frequency of cleaning or product flow process control programs.

Construction of a Food Safety Technology Index

The ERS survey contained approximately 35 questions dealing with food safety technology and practices covering five broad categories: food safety equipment, testing, plant operations, sanitation, and dehiding (cattle slaughter only). These questions queried plant managers about how their plants controlled pathogens. Examples of each type of question include the use of equipment to heat carcasses, amount of pathogen testing, quantity of worker training, frequency of sanitation practices, and use of negative air pressure around the carcass in the dehiding area. We have included all of the questions and frequency of responses in the survey. In the meat questionnaire, questions Q19-Q40 and Q52-Q65 deal with food safety technologies. The poultry food safety technology questions are Q20-Q41 and Q53-Q65.

A practice adhered to by quality control managers in meat and poultry plants is to consider food safety technology as a system in which a plant

²Two plants have missing rank data.

Table 15a—Slaughter plant rating of food safety operation that is most costly¹

	Size p	ercentile	All plants	
Plant type	0-19	80-99	·	
	S	hare of plants	saying	
	plan	nt operation me	ost costly	
Cattle slaughter:	•	•	•	
Grower practices	0.0	0.0	3.0	
Product flow	5.0	9.0	11.0	
Product rework	5.0	2.0	4.0	
Frequency of cleaning	29.0	13.0	16.0	
New equipment	37.0	42.0	35.0	
Facilities' improvement	22.0	29.0	27.0	
Other	2.0	5.0	4.0	
Number of plants	48	49	255	
Hog slaughter:				
Grower practices	0.0	2.0	3.0	
Product flow	5.0	0.0	11.0	
Product rework	3.0	4.0	4.0	
Frequency of cleaning	20.0	7.0	12.0	
New equipment	36.0	55.0	39.0	
Facilities' improvement	28.0	30.0	27.0	
Other	3.0	2.0	4.0	
Number of plants	42	47	210	
Poultry slaughter:				
Grower practices	0.0	4.0	3.0	
Product flow	13.0	4.0	6.0	
Product rework	13.0	4.0	8.0	
Frequency of cleaning	17.0	13.0	11.0	
New equipment	43.0	58.0	58.0	
Facilities' improvement	10.0	13.0	10.0	
Other	4.0	4.0	4.0	
Number of plants	33	24	124	

¹Responses are based on Q5 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

marshals several different types of equipment or practices to control food safety. ¹⁹ In this vein, we consider the overall system of food safety. However, it is more precise to compare similar technologies and production practices, e.g., equipment of one plant to equipment of another rather than a mixture of technologies and practices, such as equipment and sanitation because plants may use similar equipment but have different sanitation, making the two plants appear to have much different technologies than actually occurs. As a result, we created five food safety technology indexes—food safety plant operations, testing, sanitation, equipment, and dehiding (cattle slaughter)—that correspond with the five different types of food safety technology questions in the survey.

We adhered to three principles in creating the food safety technology index. First, the rating system should be monotonic because more intensive operations should yield greater food safety protection than less intensive ones. By monotonic, we mean that plants with more intensive cleaning or with a specific piece of food safety equipment have higher scores than plants with less

¹⁹A multiple-hurdle system in a high-volume cattle slaughter plant may involve a battery of steam vacuum units, a carcass pasteurizer, organic sprays, and other related equipment. Each type of equipment reduces pathogen levels but none completely eliminates them.

Table 15b—Plant operation processing plants believe is most effective way to control pathogens¹

	Size pe	All plants			
Plant type	0-19	80-99	·		
	Share of plants saying				
	plant operation most costly				
Cooked meat processing, no slaughter:					
Grower practices	7.0	3.0	4.0		
Product flow	7.0	13.0	9.0		
Product rework	6.0	7.0	11.0		
Frequency of cleaning	28.0	12.0	19.0		
New equipment	19.0	32.0	25.0		
Facilities' improvement	28.0	32.0	29.0		
Other	5.0	1.0	3.0		
Number of plants	68	73	368		
Raw meat processing, no slaughter:					
Grower practices	13.0	9.0	7.0		
Product flow	7.0	9.0	8.0		
Product rework	7.0	11.0	7.0		
Frequency of cleaning	27.0	7.0	20.0		
New equipment	20.0	35.0	28.0		
Facilities improvement	20.0	25.0	26.0		
Other	6.0	4.0	3.0		
Number of plants ²	65	58	327		

¹In terms of share of plants by plant size. Responses are based on Q5 in the survey. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

intensive cleaning or without the same piece of equipment. Second, one should be able to make food safety technology comparisons on the basis of similar technology types since some types of technology, such as plant operations, may have different purposes and long- and short-term effects than other technologies, such as equipment. Thus, the relevant comparisons are the equipment rating of one plant versus that of another and sanitation of one plant versus that of another, etc.

Third, since food safety quality control requires a systematic approach, we considered a variety of technology components within each technology type. For example, steam vacuum units, carcass pasteurizers, and other food safety equipment are equipment technologies. More precisely, we used questions Q21, Q24, Q25, Q30-Q35, and Q51 to construct a plant's operations technology index, Q26-Q28 for the testing technology index, Q36-Q40 for sanitation for the sanitation technology index, Q19, Q20, Q22, Q23, Q52-56 for the equipment technology index, and Q51 and Q58-Q65 for the dehiding technology index. ²⁰ For poultry slaughter, the questions for each category are Q22, Q25, Q26, Q31-Q36, Q53, and Q54 for the plant operations index, Q27-Q29 for the testing index, Q37-Q41 for the sanitation index, and Q20, Q21, Q23, Q24, and Q55-62 for the equipment technology index.

Following the three underlying principles, the indexes were constructed as follows. First, we grouped similar technologies and practices into one of the five types of food safety practices and technologies described above, such as

²⁰Dehiding refers to all the manufacturing operations, equipment, facilities, and sanitation practices associated with hide removal. It is a very important operation because, if done correctly, animal carcasses will not be exposed to harmful pathogens even if they are present in the animal's feces or on its hide.

²Two plants have missing rank data.

testing. Second, we valued all questions equally with a maximum value of "1" and a minimum value of "0." Third, we assigned the most intensive operation within each question a value of 1 and the least intensive a value of 0. For example, equipment usage questions and similar questions had just two possible responses: 1 or 0. Many sanitation and plant operations questions, however, had multiple answers. For these questions, we assigned a 1 to the operation that generates the most food safety, a 0 to the operation generating the least food safety, and an intermediate value between 0 and 1 for operations providing intermediate food safety performance. Finally, we created a technology index for each technology category by summing the values of the responses for each of the questions within that category—plant equipment, testing procedures, plant operations, sanitation, and dehiding—and dividing by the number of questions, yielding an index value between 0 and 1. For the overall technology category, we divided the total of all technology questions by the total number of food safety technology questions.

Consider the following example. Suppose that a sanitation question asks whether a plant cleans its processing line once per week, less than daily but more than weekly, or daily. Using our approach, the plant would be assigned 0 points for weekly cleaning, 0.5 point for less than daily but more than weekly cleaning, and 1 point for daily cleaning. Suppose also that there are five questions under the sanitation category. The maximum number of points a plant could achieve would be 5 and the minimum would be 0. Since the index value equals the number of points (5 or fewer) divided by the number of questions (5) the index value ranges from 0 to 1.

There are many other ways to create food safety indexes. For our index, we assumed that all pathogen-control activities within a category were of equal importance. For example, sanitizing knives is of equal importance to washing hands. However, it may be that sanitizing knives is more important than washing hands, in which case knife sanitation should have a heavier weight than handwashing in the sanitation index. Alternatively, we assumed a linear scale between the least and most stringent measure within a question. For example, if there were three possible responses for product cooling, the end points garnered 0 or 1 point while the intermediate response generated 0.5 point. Yet, a log or other scale could have also been used and would have, likewise, been monotonic. Finally, the five categories may not be of equal importance. For example, it may be that sanitation and cleaning is more important than equipment. To partially accommodate this concern, we emphasize the categorical, e.g., index of pathogen-control equipment, rather than the overall pathogen-control plant rating in our discussion.

Large Plants Have Much Higher Equipment and Pathogen-testing Technology Index Values

Table 16a compares the food safety technology index of the largest plants with the smallest plants in three slaughter industries. The table shows that the smallest plants had much lower technology index values overall. Most of the difference is due to a substantial variation in equipment and testing for all three industries and dehiding for cattle slaughter. Sanitation and operating procedures were nearly the same. The greatest difference in sanitation is

Table 16a—Technology index for slaughter plants for five types of food safety technologies¹

	Size p	All plants			
Plant type	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 ²	26	27	148		

¹Index values derived from Q19-65 in the meat survey and Q20-62 in the poultry survey. See the text for how the index was determined. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

the eight points separating the smallest and largest cattle slaughter plants. The operations' difference ranged from 4 to 11 points.

The differences in index values between small plants and large ones make sense. In cattle slaughter, equipment that raises carcass temperature to 160 degrees Fahrenheit or more to control pathogens can cost more than \$1 million. Yet, the smallest cattle slaughter plants butchered an average of less than one cattle per day (table 2), and even plants in the second largest size grouping (80th percentile), slaughtered only about 60 cattle per day. By contrast, plants in the largest size category processed more than 100 cattle per hour. If we assume that equipment has a useful life of 5 years, then the cost is more than \$1,200 per head of cattle for the smallest plant and about \$1 per head for the largest plant. Of course, some equipment is cost-effective for small plants and they do adopt these technologies. If they did not, their ratings would be 0. Nonetheless, their equipment index value is naturally going to be a lot lower than that of large plants.

The costs of product testing are also higher for smaller plants because large plants have sufficient needs to create in-house quality control operations that can perform microbiological testing at a lower cost than that which is available on the market and to small plants.

²Twenty-four poultry plants have missing rank data.

It may be that large plants have to test much more frequently than smaller plants. Large plants are exposed to much greater risk of being found responsible for a foodborne illness outbreak. For example, a plant slaughtering 100 head of cattle per hour on 2 shifts would produce about 960,000 pounds of beef per day while the smaller plant would produce only 600 pounds, suggesting that the larger plant has a much, much greater chance of being subject to a product recall.

Sanitation and operating procedures can be more easily adjusted to accommodate plant size than can equipment because they are proportional to volume. For example, a superior sanitation practice, such as cleaning and sanitizing a cutting utensil after each carcass or cut of meat, has similar costs per cut of meat regardless of plant size. Nonetheless, these procedures still tend to favor large plants. Cleaning drains, for example, is a fixed cost over a period of time, so it has a cost that is more easily spread across many units, i.e., by large plants.

The dehiding process represents an intermediate case in which some costs are fixed, such as maintaining negative air pressure in the dehiding area, and other costs, such as cleaning knives and hands after each carcass, are more variable. Thus, food safety process control index values for small plants are lower than for larger plants but the difference is not as great as for equipment and testing or as modest as for sanitation and operating procedures.

Table 16b shows the food safety, process control index for processing plants with no slaughter operations. Notice that the overall index differential narrows

Table 16b—Technology index for processing plants for five types of food safety technologies¹

	Size percentile		All plants	
Plant type	0-19	80-99		
		Technology in	dex	
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 ²	65	58	327	

¹Index values derived from Q19-65 in the meat survey and Q20-62 in the poultry survey. See the text for how the index was determined. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

²Two raw meat processing plants have missing rank data.

considerably from the slaughter industry. This is mainly due to fewer equipment options available for controlling pathogens. It is also important to observe the sizeable jump in the testing index value as plants grow in size. This rise again illustrates that large plants place a greater reliance on testing.

Market Mechanisms Encourage the Use of a More Extensive Food Safety Technology

Market mechanisms, such as buyer requirements, export inspections, and product brands, have emerged as ways for buyers to better control seller incentives to underinvest in food safety. In each case, sellers reveal their identities, making themselves subject to greater scrutiny for food safety performance, in exchange for greater revenues per pound of meat or poultry or a secure market for their output. Empirically, we should observe a higher food safety technology index rating for plants that are subject to market mechanisms.

Table 17a shows the food safety process control index values for food safety equipment, testing, dehiding (cattle slaughter only), sanitation, and plant operations for three slaughter industries under three market mechanisms. Index values for equipment, testing and dehiding (cattle slaughter only) were nearly twice as high for cattle and hog slaughter plants subject to buyer food safety requirements or engaged in export markets than for plants not subject to these market mechanisms. In contrast to the differences for plant size, sanitation and operations were also distinctly higher for cattle slaughter. Selling products under one's own brand name appeared to have no impact on the food safety technology index. We attribute this to a poorly worded question (discussed earlier). Poultry slaughter plants exhibit similar but more muted differences between plants subject to market mechanisms and those not subject to them.

Meat and poultry processors subject to market mechanisms (table 17b) also have higher food safety technology index values, but differences are restricted to equipment and testing. Index values for sanitation and operating procedures are nearly the same. We attribute this difference from the slaughter industries to the product mix of meat processors. Lawrence et al. (2001) provide evidence showing that most processing plants sell products under brand names or can otherwise be linked to a product purchased by a consumer. So, virtually all of the plants are subject to market mechanisms. Equipment and testing index values may differ because of variations in size rather than because of greater market pressure.

Now consider how these food safety technology ratings square with the results for compliance costs with PR/HACCP. Recall that plants subject to market mechanisms had PR/HACCP compliance costs that were only modestly lower than the costs of plants not subject to market mechanisms. Combining that information with results concerning the food safety process control technology indexes provides evidence that market mechanisms encouraged plants to have process control systems that exceed the PR/HACCP standards. These data also suggest that FSIS required many tasks under the PR/HACCP rule that were different from those prompted by market mechanisms (otherwise plants subject to market mechanisms would have much lower compliance costs with the PR/HACCP rule).

Table 17a—Technology index for slaughter plants for five types of food safety technologies¹

	Market mechanism					
	Buyer	food			Product	sold under
Process control	safety requ	uirements	Export	market	plant's o	wn brand ²
method	No	Yes	No	Yes	No	Yes
	Technology index					
Cattle slaughter:						
Overall tech/methods	0.43	0.63	0.43	0.64	0.52	0.50
Equipment	0.30	0.56	0.28	0.62	0.42	0.38
Testing	0.35	0.77	0.36	0.79	0.57	0.50
Dehiding	0.28	0.48	0.28	0.51	0.41	0.35
Sanitation	0.51	0.61	0.54	0.60	0.60	0.55
Operations	0.58	0.68	0.59	0.68	0.62	0.62
Number of plants ³	128	98	169	84	43	210
Hog slaughter:						
Overall tech/methods	0.44	0.60	0.44	0.59	0.44	0.50
Equipment	0.32	0.53	0.29	0.56	0.34	0.39
Testing	0.34	0.74	0.36	0.73	0.40	0.50
Sanitation	0.55	0.57	0.56	0.53	0.59	0.55
Operations	0.59	0.64	0.58	0.63	0.52	0.61
Number of plants ⁴	106	66	138	68	25	180
Poultry slaughter:						
Overall tech/methods	0.55	0.64	0.49	0.64	0.59	0.62
Equipment	0.57	0.68	0.45	0.68	0.60	0.65
Testing	0.51	0.70	0.39	0.69	0.53	0.65
Sanitation	0.53	0.56	0.49	0.57	0.65	0.55
Operations	0.57	0.61	0.62	0.61	0.61	0.61
Number of plants ⁵	29	65	16	94	12	99
1				<u> </u>		

¹Index values derived from Q19-65 in the meat survey and Q20-62 in the poultry survey. See the text for how the index was determined. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

²Products 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.

³Twenty-nine plants did not indicate customer requirements; 2 plants did not indicate exports; 2 plants did not indicate products under own brand.

⁴Thirty-eight plants did not indicate customer requirements; 4 plants did not indicate exports; 5 plants did not indicate products under own brand.

⁵Fifty-four plants did not indicate customer requirements; 38 plants did not indicate exports; 37 plants did not indicate products under own brand.

Table 17b—Technology index for processing plants for five types of food safety technologies¹

	Market mechanism					
	Buye	r food			Product s	sold under
Process control	safety requirements		Export market		plant's own brand2	
method	No	Yes	No	Yes	No	Yes
	Technology index					
Cooked meat processing no slaughter:	g,					
Overall tech/methods	0.51	0.64	0.53	0.63	0.55	0.57
Equipment	0.46	0.65	0.49	0.65	0.51	0.55
Testing	0.47	0.78	0.51	0.78	0.67	0.61
Sanitation	0.55	0.57	0.56	0.56	0.53	0.56
Operations	0.60	0.66	0.61	0.65	0.61	0.63
Number of plants	202	166	230	138	12	356
Raw meat processing, no slaughter:						
Overall tech/methods	0.49	0.62	0.52	0.61	0.56	0.55
Equipment	0.45	0.67	0.51	0.64	0.55	0.55
Testing	0.40	0.72	0.45	0.73	0.55	0.54
Sanitation	0.50	0.53	0.50	0.52	0.47	0.51
Operations	0.61	0.66	0.63	0.64	0.67	0.62
Number of plants	179	148	215	112	30	297

¹Index values derived from Q19-65 in the meat survey and Q20-62 in the poultry survey. See the text for how the index was determined. Intermediate percentiles not included because they follow a trend established by the highest and lowest rated plants.

²Products 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.